

# **EFFECT OF OIL TEMPERATURE ON GS-2 TERRY TURBINE BEARING PERFORMANCE AND CONDITION**

A Thesis

by

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Submitted to the Office of Graduate and Professional Studies of  
Texas A&M University  
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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December 2020

Major Subject: Nuclear Engineering

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## ABSTRACT

The 2011 Fukushima Daiichi nuclear accident led to the destruction of three BWR cores and containment buildings. Despite the negative outcomes of this incident, the RCIC system for both Unit 2 and Unit 3 operated in harsher conditions, and for longer durations, than previously believed possible. The Terry Steam Turbine, which powers the RCIC system, is believed to have operated with oil temperatures higher than currently accepted limits spurning an investigation into bearing durability. Initial work in this collaboration demonstrated how Mobil DTE-732 Light Turbine Oil could withstand higher temperatures than the commercial nuclear power industry limits (71.1 °C, 160 °F), and did not significantly alter the performance or condition of ZS-1 Terry Turbine bearings when heated during operation. This thesis investigates how the full-scale G-series Terry Turbines, with softer Babbitt bearings, would behave based on oil temperature, while also simulating operation conditions experienced by the RCIC system in commercial nuclear power applications. Tests were conducted on the bearings of a GS-2 Terry Turbine to quantitatively record changes in physical parameters during operation based on lubricating oil temperature, while also qualitatively inspecting the bearings for damage. Results showed an increase in bearing temperature and decrease in shaft torque as oil temperature increased but did not significantly alter the operation of the turbine. Additionally, minor wear was observed on the bottom bearings of both sides of the turbine, but it is believed to be independent of oil temperature.

## **ACKNOWLEDGEMENTS**

First, I would like to thank Dr. Karen Kirkland for offering me the opportunity to conduct this research and her professional guidance throughout the process. Second, I send my deepest gratitude to all members of the NHTS Laboratory who helped me conduct this research, including: Dr. Matthew Solom, Gage Green, Benjamin Leer, Dallin Keesling, and Ashraf Alfandi. Their support, both technical and personal, was a vital part of the completion of this project. Third, the members of the NESC machine shop, Jim Reynolds and Mike Kerstetter, need to be thanked for their assistance with metal work and welding. Last, and most importantly, I would like to thank my girlfriend, Danielle, and family: Mom, Dad, Grandma, Michael, James, Jean, Erik, Luke, Bridget, Brooklyn, and Kayla. Their unending love, encouragement, motivation, and spiritual support gave me the foundation I needed to succeed.

## **CONTRIBUTORS AND FUNDING SOURCES**

### **Contributors**

This thesis was supported by a thesis committee consisting of Dr. Karen Kirkland and Dr. John Ford of the Department of Nuclear Engineering, and Dr. Adolfo Delgado of the Department of Mechanical Engineering. Equipment for testing was supplied by Clinton Power Station, owned by Exelon Corporation, and was refurbished by Revak Keene Turbomachinery Services.

### **Funding Sources**

This work was funded by the Institute of Applied Energy (Japan), Battelle Energy Alliance, LLC/Idaho National Laboratories, and the Pooled Equipment Inventory Company (US nuclear industry partner). Refurbishment of equipment was paid for by Sandia National Laboratories.

## NOMENCLATURE

AC	Alternating Current
BWR	Boiling Water Reactor
BWROG	Boiling Water Reactor Owners Group
CST	Condensate Storage Tank
DC	Direct Current
DAQ	Data Acquisition System
LWR	Light Water Reactor
RCIC	Reactor Core Isolation Cooling
SBO	Station Blackout
TDAFWS	Turbine-Driven Auxiliary Feedwater Systems
TTE <sub>x</sub> OB	Terry Turbine Extended Operating Band
PWR	Pressurized Water Reactor
VFD	Variable Frequency Drive

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# 1. INTRODUCTION

## 1.1 Reactor Core Isolation Cooling System in Boiling Water Reactors

Current Boiling Water Reactor (BWR) designs have a multitude of systems used to inject cooling water into the reactor core. One example is the Reactor Core Isolation Cooling (RCIC) system. The driving force of RCIC is a Terry Turbine which utilizes steam, produced within the reactor core, to create mechanical power. This mechanical power rotates an attached pump which sends cooling water into the reactor core. In the case of a Mark I BWR containment, steam, after expanding within the turbine, is sent to the “torus” suppression pool where it condenses into water. The aforementioned pump draws water first from the condensate storage tank (CST), but can also pull from the suppression pool should water levels in the CST be depleted.

The rate at which RCIC pumps water into the reactor core is governed by the flow rate of steam into the Terry Turbine. To control this, an electronic control valve is attached on the steam inlet line of the turbine. This allows for throttling, or complete closure, of the steam flow rate into the turbine. During normal operation of RCIC the control valve is powered via off-site Alternating Current (AC) power supplied to the facility. Should operation of RCIC be needed, and AC power is not available, the control valve is then controlled by Direct Current (DC) power supplied by on-site batteries. DC power is dependent upon the battery lifetime which varies between specific BWR power plant sites. The minimum lifetime of the batteries is generally assumed to be 4 hours, and lifetime can be extended by reducing the load placed on the batteries.<sup>[1]</sup> Should a plant lose both AC and DC power operators are to assume RCIC is no longer operable.

## **1.2. RCIC Performance in Fukushima and Subsequent Response**

The Great East Japan Earthquake in 2011 caused the infamous Fukushima Daiichi nuclear disaster. The earthquake, and subsequent tsunami, led to the meltdown of 3 BWR units and destruction of 3 Mark I BWR containment buildings. Radionuclides from the reactor cores were released into the atmosphere and endangered public health and safety.<sup>[1]</sup> However, despite the negative outcomes of the event, a positive point of interest was found in the operation of RCIC during the accident. RCIC was activated in Fukushima Daiichi Unit 2 and 3, and in Unit 2 operated in complete station blackout (SBO) conditions (no AC or DC power) for almost 70 hours before finally failing.<sup>[1]</sup> The cause of RCIC's ultimate failure is still unknown, and inspection of the system is impossible due to radiation related safety hazards. However, it is known the system operated in conditions much harsher, and for durations much longer, than previously thought possible.

The performance of RCIC during the Fukushima Daiichi nuclear accident spurred a research collaboration between United States and Japanese governments and industries to evaluate the RCIC system. Specifically, lubricating oil within the Terry Turbine bearings was investigated to see if it could handle the hypothesized conditions or was the eventual source of system failure. This led to testing including thermal degradation of Mobil DTE-732 Light Turbine Oil, and observations of the performance of ZS-1 Terry Turbine bearings with thermally degraded oil at elevated temperatures. Testing found Mobil DTE-732 Light Turbine Oil could chemically withstand thermal degradation, and the performance and condition of the brass ZS-1 Terry Turbine bearings were minimally affected by prior lubricating oil thermal degradation or operating temperature.<sup>[2,3]</sup> These results have increased optimism in the commercial nuclear power industry that Terry Turbines can operate under a wider range of conditions than currently accepted.



### **1.3 Project Motivation and Significance**

Due to the results of tests on the small-scale ZS-1 Terry Turbine bearings, a need has arisen to conduct similar testing on the full-scale G Series Terry Turbines used in the commercial nuclear power industry. Z series Terry Turbines utilize brass bearings and an 18-inch wheel while the G series uses softer babbitted bearings and a 24-inch wheel. The increase in rotating mass combined with the softer bearing material means there may be a greater chance for a catastrophic failure between the bearings and turbine shaft. Additionally, previous testing was conducted at constant speeds and did not mimic the alternating speed of Terry Turbines in RCIC seen during traditional operation. This work is significant as it will provide an investigation into how lubricating oil temperature affects the performance and condition of GS-2 Terry Turbine bearings. By simulating characteristics of Terry Turbines in normal RCIC operation, the research also hopes to provide data to the commercial nuclear power industry to aid in plant operations. There are currently approximately 25 BWR facilities in the United States with a RCIC system similar to that of Fukushima, and Terry Turbines are also used in the Turbine-Driven Auxiliary Feedwater Systems (TDAFWS) of many Pressurized Water Reactors (PWR). Because of this, the effect of oil temperature on the bearing performance and condition of the GS-2 turbines will be of significance to the entire operating reactor fleet. Positive results of this research would indicate Terry Turbines can play a larger role in plant safety than previously thought possible.

## 2. LITERATURE REVIEW

### 2.1. Terry Turbine Design

Terry Turbines have over a 100-year operational history in industrial applications, originally built and designed by the Terry Steam Turbine Company they are currently marketed by Dresser-Rand.<sup>[4]</sup> They are a wheel-type impulse steam turbine with a low efficiency but high operational reliability.<sup>[3]</sup> Mechanical power is generated by steam injecting via nozzles into semicircular buckets on the periphery of the turbine wheel. Reversing chambers allow for expansion of the steam and interaction with multiple buckets during injection.<sup>[4]</sup> The wheel is attached to the center of a long cylindrical shaft which is supported by journal bearings on both sides. Lubricating oil is applied to the journal bearings to reduce friction of the system and protect from metal-on-metal contact of rotating parts. The turbine is typically operated with an overspeed trip mechanism to prevent operating above a predetermined setpoint. Historical data on Terry Turbine operational characteristics is sparse with the majority of knowledge being passed orally via operators.<sup>[2]</sup> Work completed in earlier stages of this research collaboration successfully acquired data on the Z series Terry Turbine operational characteristics.<sup>[3,5]</sup>

### 2.2. Journal Bearings

Terry Turbines utilize journal bearings to support the shaft and apply lubrication. Journal bearings are a cylindrical shell which wrap around the cylindrical shaft of a rotating piece of equipment. In the case of Terry Turbines, they are a split bushing design meaning the bearing has two parts which are radially attached via screws around the shaft. The bearings contain rings, known as slinger rings, loosely wrapped around the shaft which hang down into the oil well below the bearing.

During operation, the rings rotate around the shaft pulling oil into the bearing from the oil well below.<sup>[2]</sup> The lubricating oil pulled into the bearing creates a film which surrounds the rotating shaft and prevents microscopic ridges, known as asperities, on the surfaces of the shaft and bearing from making contact and creating unwanted resistance and friction.<sup>[7]</sup> Given the lubrication film provides a sufficient thickness, the shaft will “float” within the bearing creating a near frictionless rotating environment.<sup>[6]</sup> Journal bearings are a conformal design meaning the rotating shaft and bearing surfaces are curved in the same direction and the bearing encloses the shaft.<sup>[7]</sup>

### **2.3. Bearing Lubrication**

Three forms of lubrication exist when operating a journal bearing: boundary lubrication, mixed-film lubrication, and thick-film lubrication.<sup>[6,7]</sup> In boundary lubrication the fluid film between the shaft and bearing is of insufficient thickness to fully separate the shaft and bearing asperities.<sup>[7]</sup> In this case the friction coefficient of the bearing is dependent entirely upon the roughness of the shaft and bearing surfaces. For Terry Turbines this has the highest probability of occurring when the shaft first begins rotating from a total rest. In mixed-film lubrication the shaft has reached a speed which can pull enough oil into the bearing to create a film thickness capable of removing contact for the shaft and bearing for brief periods of time.<sup>[7,8]</sup> This is often seen at intermediate speeds of a system.<sup>[6,8]</sup> During mixed-film lubrication the friction coefficient is dependent upon both the fluid properties of the lubricating oil and the heights of the highest asperities of the two surfaces.<sup>[7]</sup> Finally, thick-film lubrication occurs when the lubricating oil reaches a thickness which sufficiently removes contact between the shaft and bearing.<sup>[7]</sup> This thickness must be able to support the pressure generated from the load of the system which in this case is the turbine shaft. During thick-film lubrication the friction coefficient is strictly a function of the lubricating fluid’s

parameters and is independent of the roughness of the bearing and shaft.<sup>[7]</sup> Typically, high speed operation is required to achieve full-film hydrodynamic lubrication.

Oil temperature plays a key role in maintaining a sufficient oil film thickness. To determine what type of lubrication is occurring the Bearing Parameter is used, as shown in Equation 2.1 below.<sup>[6]</sup>

$$\text{Bearing Parameter} = \frac{\mu N}{P} \quad (2.1)$$

In Equation 2.1  $\mu$  is the oil viscosity (Pas),  $N$  is the shaft speed (rpm), and  $P$  is the load capacity ( $\text{N m}^{-2}$ ).<sup>[6]</sup> As temperature of the lubricating oil increases the viscosity decreases thus lowering the bearing parameter.

#### **2.4. Heated Oil in Terry Turbines**

Experimentation has been conducted at the Laboratory for Nuclear Heat Transfer Systems at Texas A&M University to observe how ZS-1 Terry Turbines operate with heated lubricating oil. Tests were conducted to thermally degrade Mobil DTE-732 Light Turbine Oil for 72 hours at a temperature of 121 °C. <sup>[3]</sup> While a color change of the oil was denoted after the thermal degradation, no change was detected in the viscosity-temperature profile of the oil before and after degradation. <sup>[3]</sup> The change in color indicates there was a chemical change in the oil due to heating, but due to the unchanged viscosity it was determined there was no significant chemical change. <sup>[3]</sup> Though the viscosity-temperature profile did not change between the fresh and degraded oils, the viscosity did decrease while the oil was actively heated as expected.

To determine if the thermal degradation of the oil would affect the operational characteristics of a ZS-1 Terry Turbine, the turbine was operated via a coupled electric motor using fresh and degraded oil. During testing the turbine shaft speed, torque, oil temperature, and system vibrations were recorded while the turbine operated at constant speeds of 1000 RPM and 3000 RPM.<sup>[3]</sup> Tests were repeated using both fresh and degraded oil, and the recorded metrics were compared between the two. Minor scoring of the brass bearings did occur, but it was believed the damage was superficial.<sup>[3]</sup> Oil composition did affect the shaft torque during operation, but the effects were minor and only observed with the turbine operating in the forward direction.<sup>[3]</sup>

## **3. FACILITY**

### **3.1. GS-2 Bearing Facility**

The GS-2 Bearing Facility was designed and assembled at The Laboratory for Nuclear Heat Transfer Systems at Texas A&M University in College Station, TX. This facility served as the location of all testing and experimentation discussed in this thesis.

#### ***3.1.1. Equipment***

##### ***3.1.1.1. GS-2 Turbine***

The GS-2 Bearing Facility was designed and assembled around a GS-2 Terry Turbine supplied to the laboratory by the Clinton Power Station owned by Exelon Corporation. The turbine was received after a refurbishment was completed by Reevak Keene and was secured to a steel pallet. Because this equipment was on loan, and not to become a permanent fixture of the laboratory, the turbine was left on the pallet for the duration of testing. Similar to all GS-2 Terry Turbines, this turbine contained a 24-inch diameter Terry Turbine wheel with a corresponding 2-inch cylindrical shaft. Babbitted bearings encase the shaft on both sides of the turbine wheel, and the entire assembly fits inside of a pressure rated steel casing. Two oil wells are located on either side of the turbine wheel, one for each journal bearing. To provide a non-permanent working base necessary for securing experimental equipment, the turbine and pallet were placed on top of a 7 ft x 6 ft x 0.5 in steel plate resting on the floor of the laboratory. Figure 3.1 on the following page shows the turbine and pallet resting on the steel plate.



**Figure 3.1:** Photograph of the Clinton Power Station GS-2 Terry Turbine bolted to a steel pallet and resting on top of the steel working base.

### ***3.1.1.2. Motor Stand***

Supplied to the facility from Reevak Keene, along with the GS-2 Terry Turbine, was a stand to support an electric motor. Measurements taken at the laboratory showed the stand was too tall, and a height modification was made. Once reduced to the proper height, 16 threaded rods were welded to the steel base plate (unfortunately two broke during installation), and the stand was then placed such that the threaded rods penetrated through holes on the base of the stand and were secured via steel nuts. Figure 3.2 on the following page shows the motor stand secured to the plate as described.



**Figure 3.2:** Picture of the motor stand secured to base plate by threaded steel rods and nuts.

### ***3.1.1.3. Motor***

To physically rotate the GS-2 Terry Turbine, a coupled electric motor was used. A 3-phase 7.5 hp Baldor Reliance motor (model number CEM3709T) was selected. The motor operated with 460 V at 9 amps and a synchronous speed of 3520 RPM. Figure 3.2 above shows the motor secured to the motor stand and coupled to the GS-2 Terry Turbine.

### ***3.1.1.4. Variable Frequency Drive***

A variable frequency drive (VFD) was used to operate the motor. A Galt G300 series VFD (model number G34000185UL01) was selected and installed in the laboratory. The purpose of the VFD



was to control the direction and speed of the motor. On the VFD is a detachable control panel which can be moved to the desired location of operation. An ethernet cable was used to connect the control panel to the VFD so operation could be conducted at a different location in the laboratory. The VFD and control panel is shown in Figure 3.3 below.



**Figure 3.3:** Variable frequency drive as installed in the laboratory.

### ***3.1.1.5. Safety Coupling***

To attach the motor to the turbine a series of couplings were used. Of most significance was the safety coupling which provided a disconnect of the system should torque values exceed a

prescribed limit. The SK2 Torque Limiter coupling from R+W was selected for the facility. The safety coupling was coupled to the torque meter on one end and turbine shaft adapter on the other, and had a set disconnect torque value of 40 Nm. Should torque of the shaft reach 40 Nm, an internal locking mechanism in the coupling would disconnect allowing for the turbine to rotate freely from the rest of the system and safely coast to a stop. The safety coupling is shown in Figure 3.4 below.



**Figure 3.4:** SK2 safety coupling used to attach torque meter to Terry Turbine.

### ***3.1.1.6. Torque Meter***

To measure torque of the system during operation, an in-line torque meter was used. An HBM Torque Transducer (model number T21WN/20NM) was coupled between the motor and turbine. The torque meter had a maximum readable torque of 20 Nm with a maximum physical torque limit of 40 Nm. The torque meter has a freely rotatable shaft which was coupled in-line to the rotating system. Strain gauges within the torque meter produce an electrical signal based on the applied

torque which can then be measured. All measurements contain an error of  $\pm 0.2\%$ , and the torque meter could operate at speeds less than or equal to 20,000 RPM.

#### ***3.1.1.7. Heaters***

To heat the oil during testing, immersed electric heaters were placed in the oil wells. Watlow  $\frac{3}{4}$  in Firerod Cartridge Heaters (model number 2080-2071) were placed into the oil wells by penetrating through the oil well cover via drilled holes. The heaters were stainless steel cylindrical rods containing resistor heating elements and a k-type thermocouple inside. The electric heaters operated at 120 V and produced a power output of 800 W. One heater was placed in each oil well.

#### ***3.1.1.8. Heater Control Console***

To operate the immersed heaters in the oil wells, a custom control console was used. The control console was produced by Valin (model number VTS-110-2-1-120-K). Both immersed heaters were plugged into the controller and operated via Bluetooth connection to the Watlow EZ-Link mobile app. Two k-type thermocouples were plugged into the controller as well to externally monitor heater temperature in both oil wells (discussed further in section 3.1.1.11). Figure 3.5 on the following page shows the control box with power supplied.



**Figure 3.5:** Valin Heater Control Console with power supplied connecting to Bluetooth connection.

### ***3.1.1.9. Accelerometers***

Four PCB Piezoelectric High Temperature ICP Accelerometers (model number 320C33) were attached to the system for vibration measurement. The accelerometers have a frequency range of 1 Hz – 4000 Hz, range of  $\pm 50$  g pk, sensitivity of 100 mV/g ( $\pm 10\%$ ), and a maximum amplitude uncertainty of  $\pm 2\%$ . To secure the accelerometers to the turbine the accelerometer caps, containing threaded holes for the accelerometers to screw into, were adhered to the turbine using JB Weld. Since the accelerometers read in the direction normal to the surface they are attached, two accelerometers were placed on top of the turbine facing downwards, while the other two were attached to the sides of the turbine.

For data analysis the maximum frequency of the accelerometers was reduced to 2000 Hz outputting 64 bins with a size of 31.25 Hz per bin. This reduction was necessary for the data acquisition system to handle the large output files of the accelerometers while maintaining an acceptable frequency resolution. Vibrational data was recorded continuously throughout the duration of each test. Figure 3.6 below shows the accelerometers attached to the turbine.



**Figure 3.6:** The four accelerometers attached to the GS-2 Terry Turbine.

#### ***3.1.1.10. Tachometer***

A Monarch Remote Optical Laser Sensor-W (model number 6180-030) was used to measure the turbine speed during operation. The sensor has a recordable range of 1 RPM – 250,000 RPM and an error of  $\pm 0.01\%$ . To record the shaft speed a piece of black electrical tape was wrapped around

the motor shaft, and a smaller piece of white electrical tape was placed over the black tape. The tachometer laser was pointed at the tape and was able to detect the change in tape color as the shaft rotated and output the shaft speed. Unfortunately grooves on the shaft caused errors at low speeds, however this only affected the speed reading for a brief period of time during start up of the turbine. The tachometer is shown in its operation position in Figure 3.7 below.



**Figure 3.7:** Tachometer used to measure turbine speed during operation shown in its operational position during testing.

### ***3.1.1.11. Thermocouples***

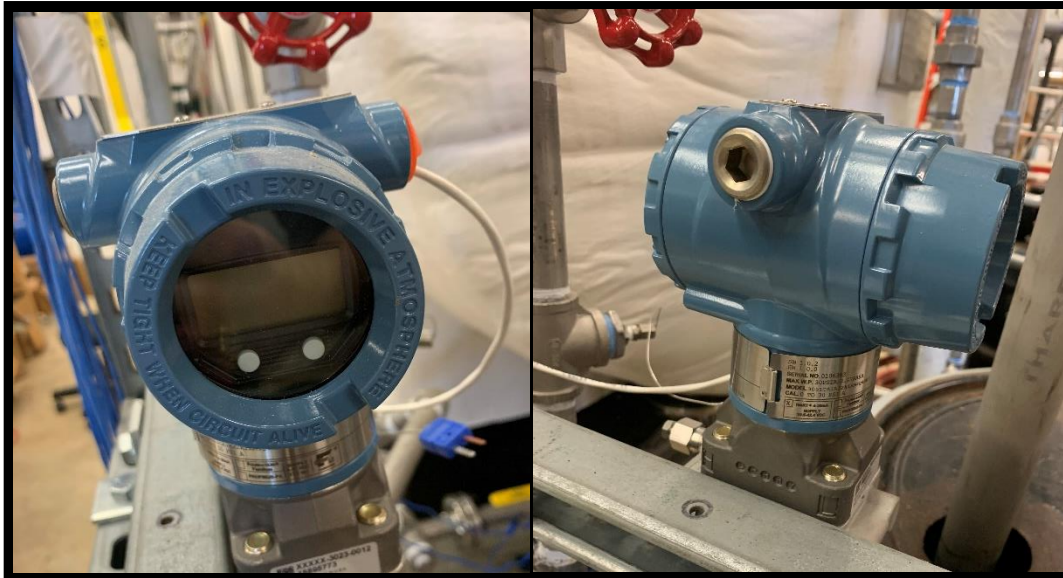
Thermocouples were used at points of interest in the experiment to measure temperatures during testing. All data recording thermocouples were Omega T-type thermocouples made of 316 stainless steel with a temperature range of -250 °C – 400 °C and uncertainty of  $\pm 0.5$  °C. All thermocouples used had a sheath diameter of 0.062 in and ranged in length from 6 in – 18 in. Quick disconnect ends were used to attach the thermocouples to the data acquisition system via T-type thermocouple extension wire. A total of 16 T-type thermocouples were used.

K-type thermocouples were required for the heater control console to monitor temperature outside of the heating elements. Two 7 in K-type thermocouples were used, one placed in each oil well and attached to the heater via K-type extension wire. The thermocouples had 316 stainless steel sheaths with a diameter of 0.062 in and were electrically grounded. As previously stated, these thermocouples were used to record experimental data rather to aid the heater control console in temperature management and power output.

### ***3.1.1.12. Barometer and Hygrometer***

Atmospheric conditions within the laboratory were recorded during each test to ensure proper documentation of any conditions that may have affected testing. The barometer measured the laboratory pressure while the hygrometer measured the temperature and humidity. A Rosemount 3051 Coplanar Pressure Transmitter (model number 3051Ca1A22A1AM4W4HR7) was used for the barometer and had a maximum readable pressure of 207 kPa. The hygrometer was a Vaisala Humidity and Temperature Transmitter (model number HMT334) which had an operable

temperature range of  $-70\text{ }^{\circ}\text{C}$  –  $180\text{ }^{\circ}\text{C}$  and pressure range of  $0\text{ MPa}$  –  $10\text{ MPa}$ . The barometer is shown below in Figure 3.8 and the hygrometer in Figure 3.9 on the following page.



**Figure 3.8:** Barometer installed in The Laboratory for Nuclear Heat Transfer Systems.

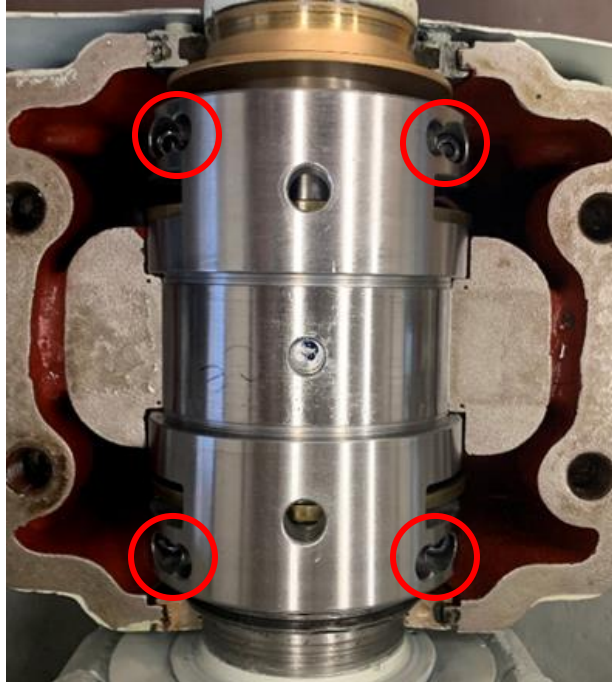




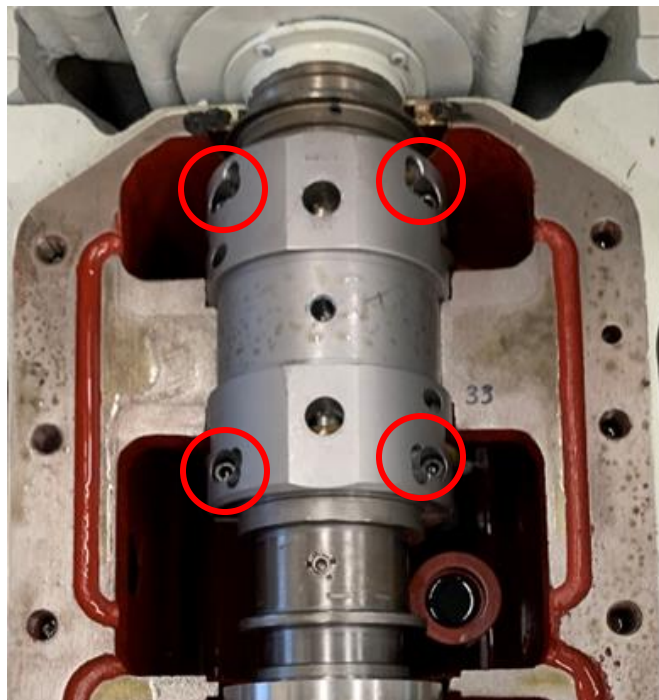
**Figure 3.9:** Hygrometer with power supplied showing atmospheric conditions of the Laboratory for Nuclear Heat Transfer Systems.

### ***3.1.1.13. Bearings***

Custom bearings were supplied with the GS-2 Terry Turbine from Revak Keene. The bearings are split-bushing journal bearings made of stainless steel coated with babbitt. Babbitt is an alloy consisting of tin, antimony, and copper and it covers the inside of the bearing which is exposed to the turbine shaft. Two bearings were used in the turbine, one on each side of the turbine wheel. Four ports were drilled into the top bearings allowing for the placement of thermocouples as close to the oil wedge in the bearing as possible. Figures 3.10 and 3.11 on the following page shows the top bearings on both sides of the turbine with red circles highlighting the location of the custom drilled thermocouple ports.



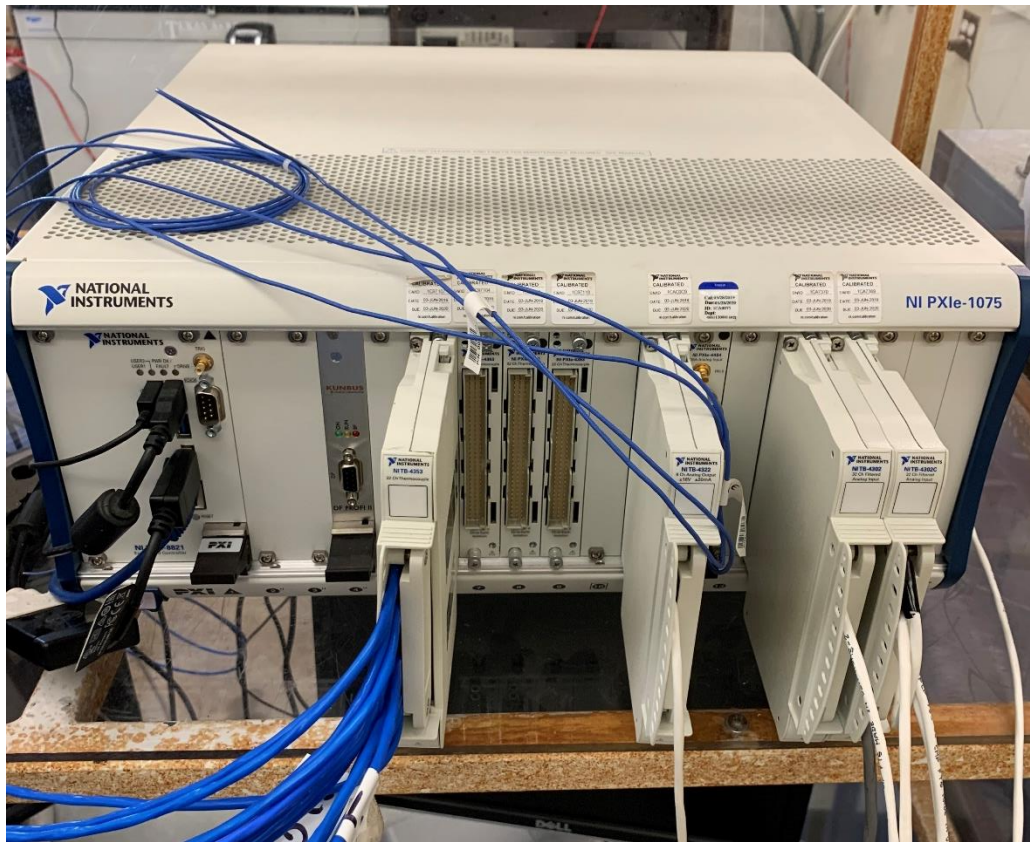
**Figure 3.10:** Motor Side top bearing as installed in turbine. Red circles indicate location of custom drilled thermocouple ports.



**Figure 3.11:** Governor Side top bearing as installed in the turbine. Red Circles indicate location of custom drilled thermocouple ports.

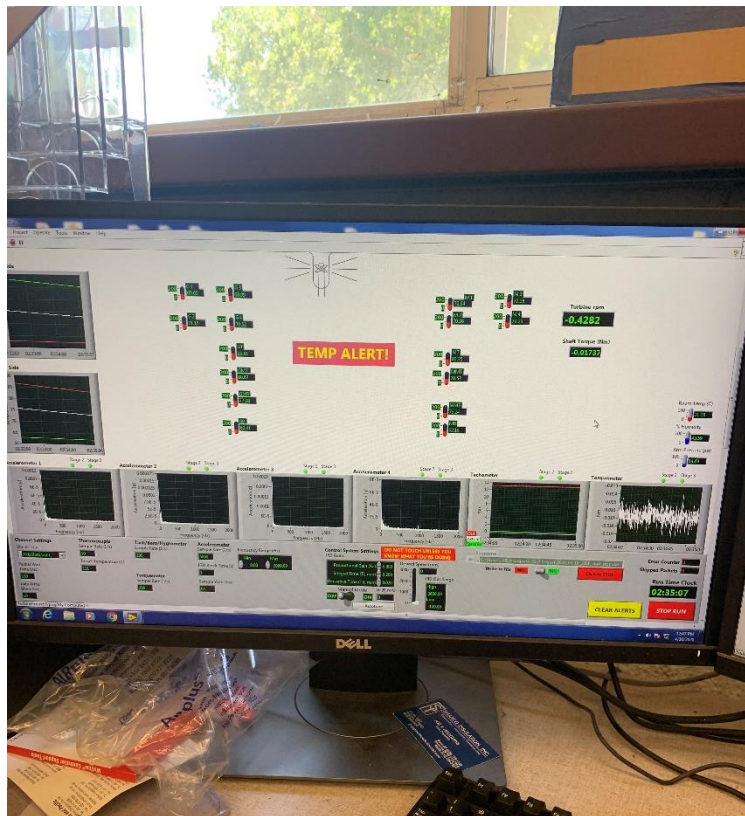
### 3.1.1.14. Data Acquisition System

The Data Acquisition System (DAQ) was the computer guided system which recorded and saved all experimental data during tests. The workhorse of the DAQ was the National Instruments PXIe-1075 chassis which used 5 modules: TB-4302, TB-4302C, TB-4322, TB-4353, and PXIe-4464, and a PCIe-6341 data acquisition card. The entire DAQ is shown in Figure 3.12 below with all instrumentation wired to the system as used during testing.



**Figure 3.12:** PXIe-1075 chassis with five modules and instrumentation attached.

The chassis was controlled and interfaced to a computer using the LabVIEW 2018 program. This allowed for control of data acquisition by the operator and provided a visual interface for the user to ensure all equipment was operating properly. Figure 3.13 below shows the LabVIEW2018 program while being operated on the control computer. The Temp Alert in Figure 3.13 is because the turbine and heaters were not operating, and the temperatures were below prescribed limits.



**Figure 3.13:** LabVIEW 2018 program for the GS-2 Bearing Facility. Note: Temp Alert is due to low temperature because heaters were not operating when photograph was taken.

### ***3.1.1.15. Turbine Oil***

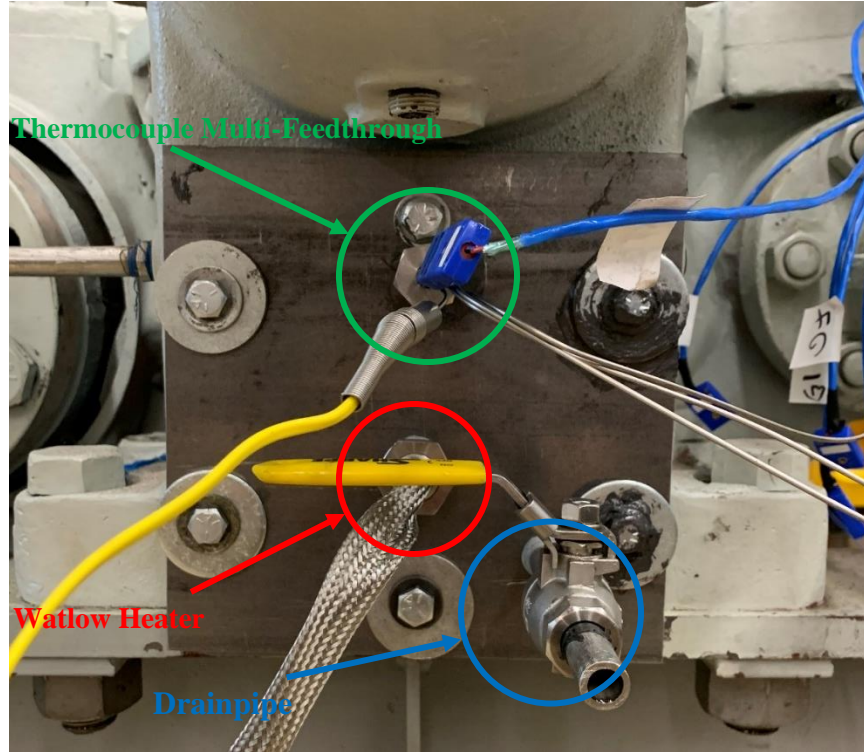
Mobil DTE 732 Light Turbine Oil was used for all testing conducted. A single 55-gallon drum of the oil was purchased and kept in the laboratory. Fresh oil was used in each test and never reused.

### ***3.1.2. Layout***

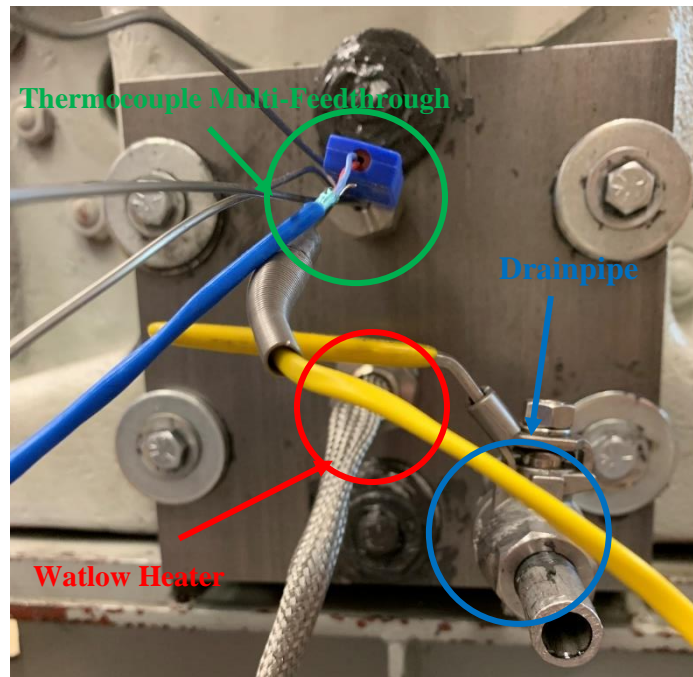
#### ***3.1.2.1. Oil Wells***

To keep the instrumentation organized the turbine was labeled in two sections, the Governor Side and Motor Side. The Governor Side refers to the oil well and bearing located on the side of the turbine in which a governor valve would traditionally be attached. The Motor Side refers to the oil well and bearing which were closest to the motor rotating the system. Each side required its own oil well cover, Watlow heater, drainpipe, and 5 oil well thermocouples.

Because the GS-2 Terry Turbine supplied to the lab was on loan from Exelon Corporation, no permanent physical changes could be made to the turbine. This meant custom oil well covers needed to be made to accommodate holes to be drilled for instrumentation. Two covers were made, one for each oil well, using  $\frac{3}{4}$  in carbon steel which was measured, cut, and drilled at the laboratory. Threaded holes for a thermocouple multi-feedthrough, the Watlow heater, and a drainpipe were drilled. Figure 3.14 and Figure 3.15 on the following page show the Governor Side and Motor Side oil well covers, respectively. The green circle shows the thermocouple multi-feedthrough, the red circle highlights the Watlow heater, and the blue circle shows the added drainpipe. The oil well covers were bolted to the turbine through threaded holes which were previously drilled into the turbine to accommodate the original oil well covers.

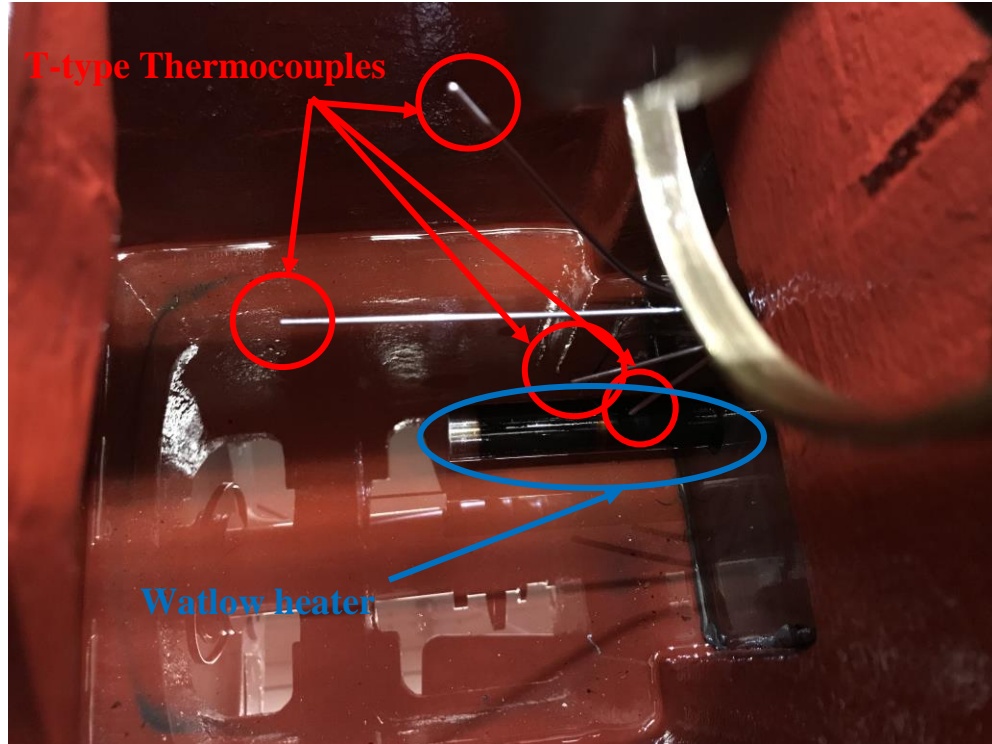


**Figure 3.14:** Governor Side oil well cover with labeled instrumentation.



**Figure 3.15:** Motor Side oil well cover with labeled instrumentation.

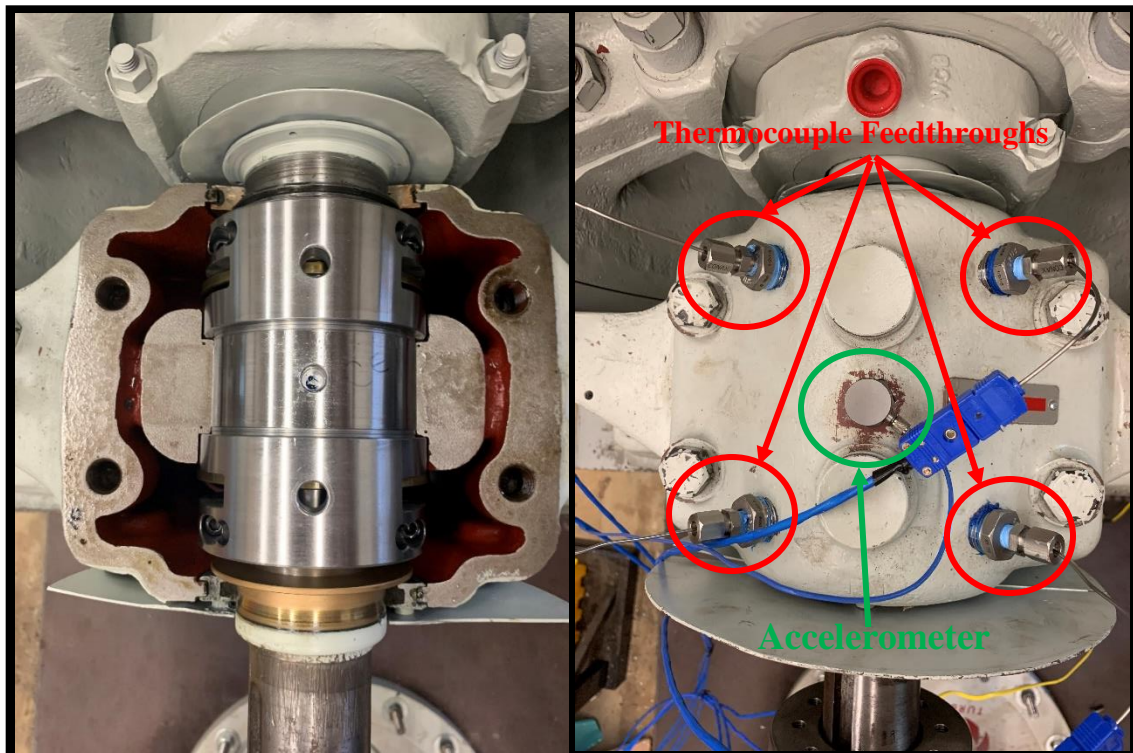
Inside the oil wells the four T-type thermocouples were placed at four increasing elevations to observe any thermal stratification of the oil due to heating. The K-type thermocouple was angled straight down and the sensor end placed as close to the Watlow heater as possible. The Watlow heater was placed near the bottom of the oil well so it would heat the cooler oil at the bottom of the oil well which would rise to the top of the oil well where the slinger rings would pull it into the bearing. Figure 3.16 shows the inside of the Governor Side oil well. Red circles indicate the sensor ends of the T-type thermocouples, and the blue circle shows the Watlow heater. Photographs of the Motor Side oil well were not taken due to the lack of lighting and space inside the oil well.



**Figure 3.16:** Inside view of the Governor Side oil well with labeled instrumentation.

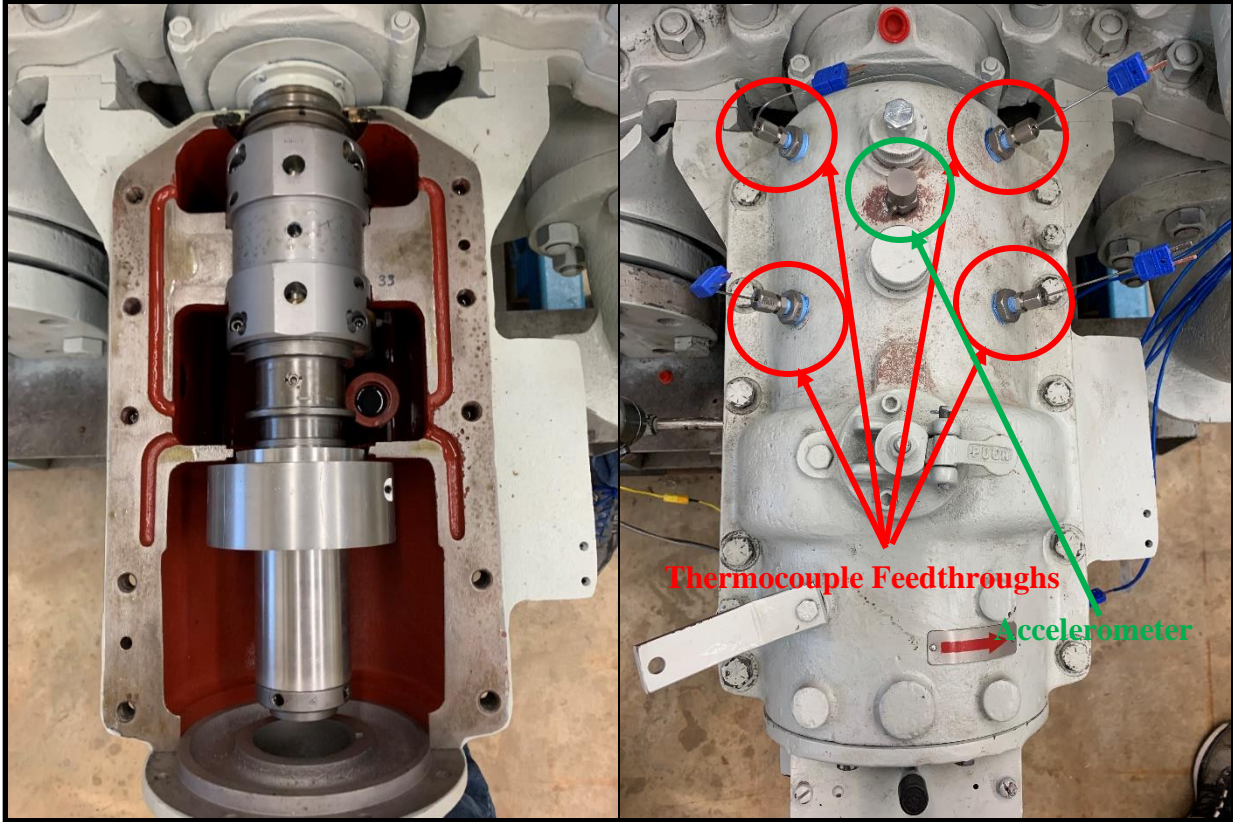
### 3.1.2.2. Bearing and Housing Instrumentation

Special ports drilled into the turbine bearings by Revak Keene were discussed in section 3.1.1.13. To allow for thermocouples to reach the bearing ports, threaded holes were drilled in the outer turbine casing to accommodate threaded thermocouple feedthroughs. Once again, the turbine was organized and labeled using the previously mentioned Governor Side and Motor Side descriptions. Four T-type thermocouples were placed in the bearing ports on each side of the turbine. Additionally, two accelerometers were placed on each side of the turbine. One was placed on top of the bearing housing facing down, and the other placed on the side of the oil well facing horizontally. Figure 3.17 below shows the Motor Side bearing with and without its housing with labeled instrumentation. Figure 3.18 on the following page shows the same for the Governor Side.



**Figure 3.17:** Motor Side bearing housing with labeled instrumentation.



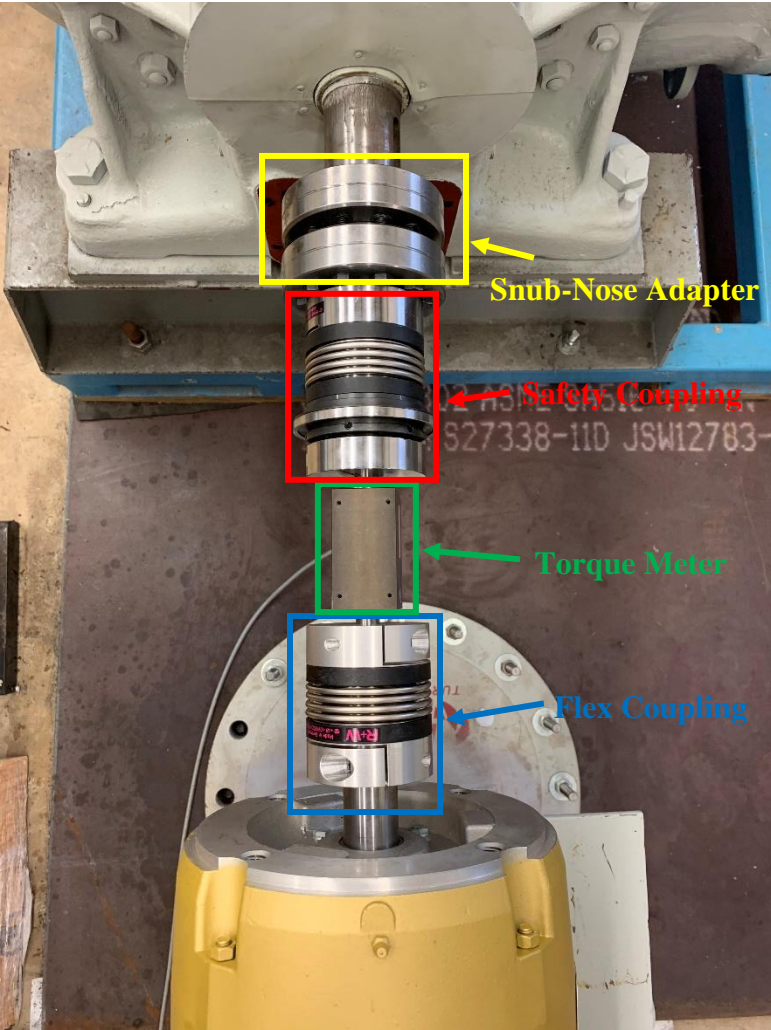


**Figure 3.18:** Governor Side bearing housing with labeled instrumentation.

**3.1.2.3. Torque Meter and Shaft Assembly**

As previously mentioned in section 3.1.1.6, a torque meter was used to record the in-line torque of the system. This required coupling the torque meter to both the motor and the turbine and allowing the torque and rotation of the motor to pass through the torque meter on its way to the turbine. Due to the varying sizes and lengths of each shaft a series of couplings had to be used. The motor had a cylindrical 1 3/8 in shaft, the torque meter had a 16 mm shaft, and the turbine had a 2 in shaft. To accommodate for these differences, a flex coupling with bores to match the motor and torque meter was used to couple the two together. A snub-nose adapter was placed on the turbine to reduce the shaft diameter from 2 in to 1 3/8 in. The safety coupling described in section

3.1.1.5. was then used to couple the torque meter to the snub-nose adapter thus completing the assembly from motor to turbine. A blast guard was placed over the shaft system to protect the operator from potential projectiles should the couplings break and come apart. Figure 3.19 shows the full shaft system below.



**Figure 3.19:** Shaft assembly with labeled pieces without blast guard (NOTE: This image shows torque meter oriented downward, during testing it was vertically oriented).

#### 3.1.2.4. Facility as Tested

The final test facility had insulation placed over each oil well to help limit heat loss from the oil to the environment. Also, the torque meter cable was run through the motor eye hook to keep the torque meter in a vertical orientation during operation as needed. The heater control console was placed on the steel pallet where it rested during operation. Figure 3.20, 3.21, and 3.22 show the final facility as it was used during testing.



**Figure 3.20:** Whole turbine test facility with heater control console and shaft blast guard.



**Figure 3.21:** View of the Governor Side of the turbine with insulation on oil well and all instrumentation attached.



**Figure 3.22:** View down the facility shaft with torque meter in vertical orientation as tested.

## 4. TESTING

### 4.1. Constant Speed Bearing Tests

During the constant speed bearing tests, the lubricating oil was heated to a desired temperature, and the turbine was then brought to its maximum speed which was maintained for a duration of 1-2 hours. The purpose of these tests was to determine how the turbine and bearings performed with varying oil temperatures, and to observe any damage or wear which may have occurred to the bearings. Bearing inspections were conducted before and after each test.

#### 4.1.1. Procedure

Before testing began an inspection of the bearings was conducted. This included removing the bearings from the turbine, wiping them clean with lint free cloths, and visually observing and documenting any notable damage, wear, or markings. Photographs were taken of the bearings to keep a record of documentation. The bearings were then reinstalled into the turbine and the oil wells filled. At this point a check of the DAQ and corresponding components was conducted to ensure operation of all electronic equipment and recording systems. If all components were functional then the test was cleared to begin.

For tests requiring oil heating the immersed heaters in the oil well were turned on and the system remained at rest while the oil heated to the desired temperature. Once the oil was sufficiently heated the turbine was brought to its maximum speed in 45 seconds and maintained for 2 hours. After the desired operation time the turbine was returned to a rest in 3.5 minutes, the immersed heaters were turned off, data files were saved, and the test was deemed complete.

Once the equipment had cooled to room temperature the oil wells were drained and a post-test inspection of the bearings was conducted. Once again, this included cleaning the bearings with a lint free cloth and visually checking for damage or markings. Photographs were taken to ensure documentation of bearing condition. If no obvious signs of damage or wear were noted, the bearings were installed back in the turbine, and this inspection would also serve as the pre-test inspection for the following test to be conducted. Detailed instructions and procedures for the constant speed tests can be seen in Appendix C.

## **4.2. Start-Stop Bearing Tests**

Due to the operational conditions of Terry Turbines in RCIC, start-stop bearing tests were conducted with heated oil to see how the turbine and bearings would respond. This involved operating the turbine for 10-minute intervals with 10-minute intervals of rest in between. The oil was heated to desired temperatures for the tests to see its effect on the performance of the turbine and condition of the bearings. These tests aimed to mimic the Terry Turbine operation in RCIC at power plants.

### ***4.2.1 Procedure***

An inspection of the bearings was conducted prior to the test. The inspection included removing the bearings from the turbine and visually inspecting them for damage or wear. Photographs were taken to document the bearing condition. The bearings were reinstalled into the turbine and the oil wells were filled. A test of the DAQ and related instruments was conducted to ensure their operability. If the DAQ was shown to be working the test was cleared to begin. If the test required oil heating then the immersed heaters in the oil well were turned on and the oil was heated to the

desired temperature. Temperature of the oil was maintained throughout the duration of the test. When the oil was at the proper temperature then the turbine was started. The turbine was brought to speed in 45 seconds and remained at a constant speed for 10 minutes. Next, the turbine was brought to a rest in 3.5 minutes and remained at rest for a 10-minute interval. This start-stop process was repeated 3 times.

After the third start-stop interval was finished the test was deemed completed and all instrumentation was turned off. The turbine was allowed to cool to ambient room temperature. At this time the oil wells were drained, and a bearing inspection was conducted. The bearings were removed from the turbine and visually inspected for damage, wear, or markings. Photographs were taken to keep documentation of the bearing condition. If no significant damage or wear was observed this inspection counted as the pre-test inspection for any following tests and the bearings were reinstalled in the turbine. Detailed instructions and procedures for the constant speed tests can be seen in Appendix C.

#### **4.3. Test Matrix**

Testing was conducted at varying oil temperatures as shown in Table 4.1 on the following page. This test matrix was determined after discussions with members of the Terry Turbine Extended Operating Band (TTEXOB). Oil temperatures were manually maintained throughout the duration of the tests by the operator. Due to fictional heat added into the system during operation, the temperature was only able to be held in a range of  $\pm 5$  °C. Similarly, variations in the viscosity of the oil affected the capability of the VFD to maintain speed during operation and the turbine speed was held to  $\pm 5$  RPM of the desired speed. Temperatures, speeds, and test parameters were chosen



at the direction of the Boiling Water Reactor Owners Group (BWROG), a part of the TTEXOB, due to their significance in relation to RCIC operation at BWR power plants.

TABLE 4.1  
Testing Matrix for GS-2 Terry Turbine Bearing Tests

Oil Temperature (°C/°F)	Turbine Speed (RPM)	Test Type
Unheated	3595	Constant Speed
71.1/160	3595	Constant Speed
82.2/180	3595	Constant Speed
93.3/200	3595	Constant Speed
Unheated	3595	Start-Stop
71.1/160	3595	Start-Stop
82.2/180	3595	Start-Stop
93.3/200	3595	Start-Stop

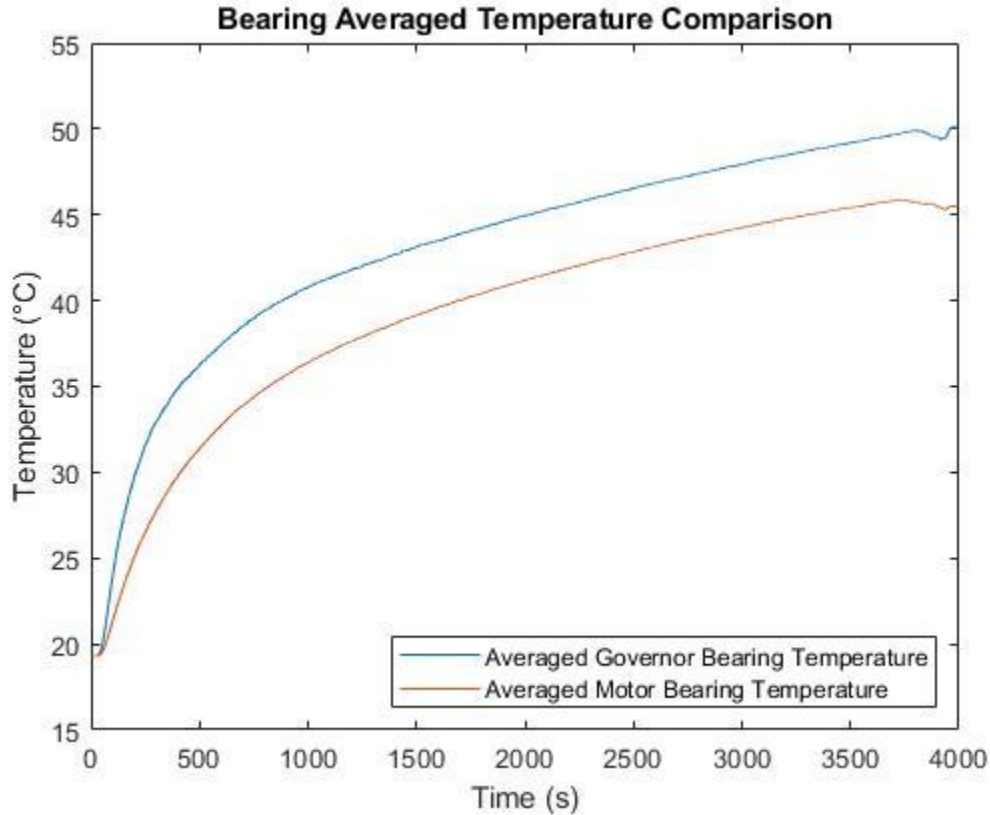
## 5. RESULTS

### 5.1. Constant Speed Tests

#### *5.1.1. Unheated Constant Speed Test*

The first test conducted was the unheated constant speed test which was started and completed on April 10<sup>th</sup>, 2020. This test was to serve as the benchmark, or “standard”, for operation of the test facility, and used for comparison to later tests. The turbine was brought to speed in 45 seconds and operated for 1 hour at a constant speed of 3595 RPM with no heating of the oil wells. Data was successfully recorded for the duration of the test and saved.

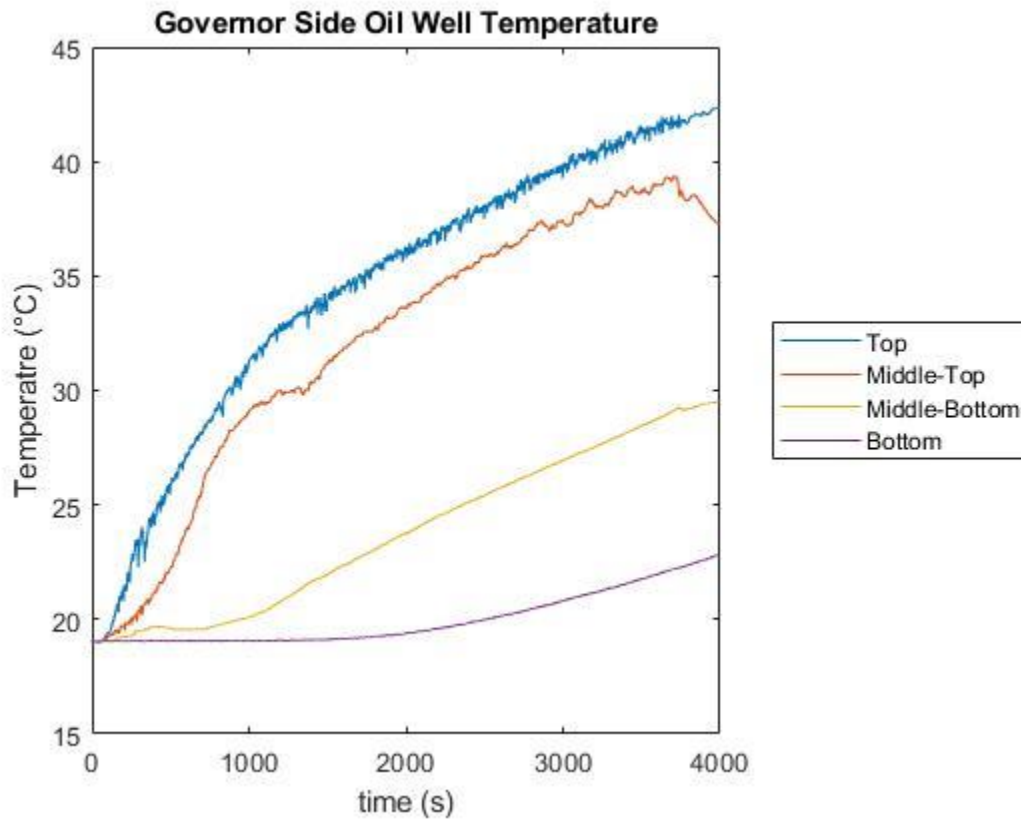
When operation of the turbine began, frictional heat from the shaft’s rotation began dissipating into its surroundings. This included the oil, bearings, and the outer steel casing of the turbine. The temperature increase of the bearings loosely resembled a logarithmic curve with a quick increase in temperature at the beginning of the test, but the increase slowed to a linear increase as the test went on. To visualize this phenomenon, the Governor Side bearing and Motor Side bearing average temperatures were plotted with respect to time. These temperatures are averages of the 4 thermocouples placed in special drilled ports of the bearings as discussed in section 3.1.1.13. Figure 5.1 on the following page shows the temperature vs. time plot. Throughout the duration of the test, the average temperature of the Governor Side bearing was higher than the Motor Side bearing, but both bearings followed the same trend.



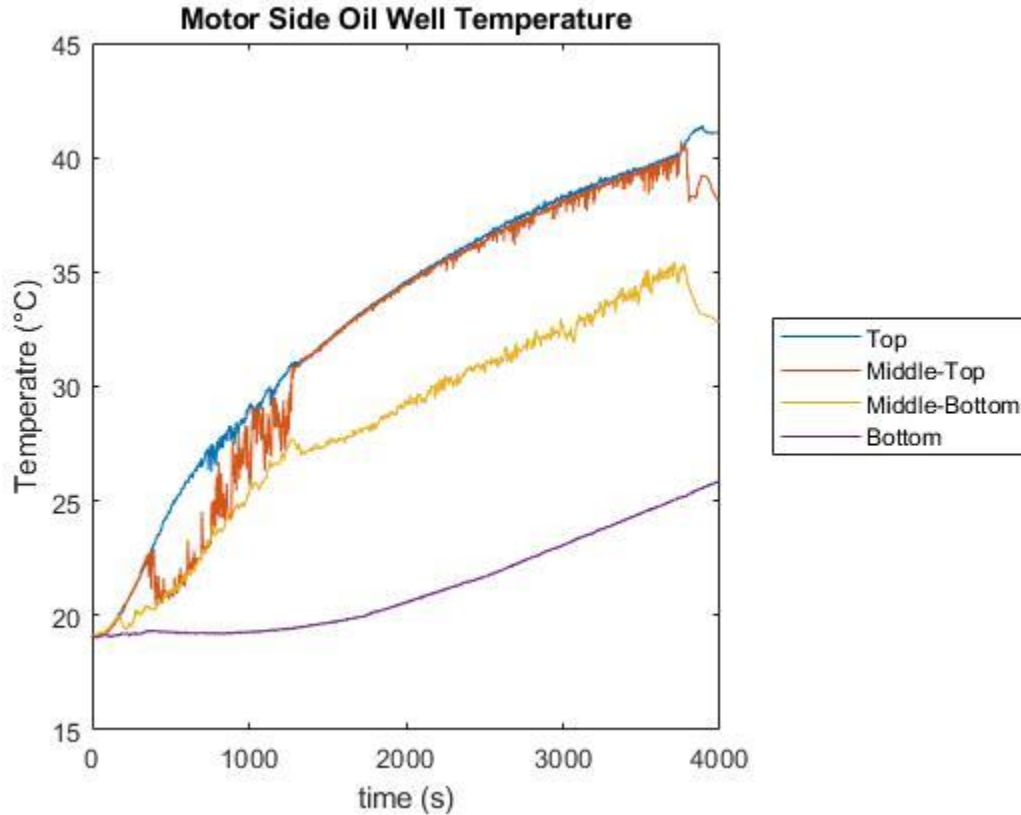
**Figure 5.1:** Comparison of the average Motor Side bearing temperature and Governor Side bearing temperature with respect to time.

As the turbine operated, frictional heat from the shaft’s rotation also reached the oil within the turbine oil wells. Oil was pulled into the bearing by the bearing slinger rings and then fell back into the oil well via gravity and acceleration after making contact with the rotating shaft. This led to oil being heated by the bearing, dropping back into the top of the oil well, and pulled into the bearing again where more frictional heat was added. Combined with the stratification due to natural convection of a heated fluid, this effect led to a temperature difference across the height of the oil well. The temperature of the oil was measured by 4 thermocouples vertically stratified within the oil well. These thermocouples were labeled as Bottom, Middle-Bottom, Middle-Top,

and Top, where Middle-Bottom refers to the 2<sup>nd</sup> thermocouple from the bottom of the oil well, and Middle-Top refers to the 3<sup>rd</sup> thermocouple from the bottom of the oil well. The temperature distribution with respect to time is for the Governor Side oil well is shown below in Figure 5.2, and the Motor Side oil well temperature distribution is shown in Figure 5.3 on the following page.



**Figure 5.2:** Temperature with respect to time of thermocouples in the Governor Side oil well.

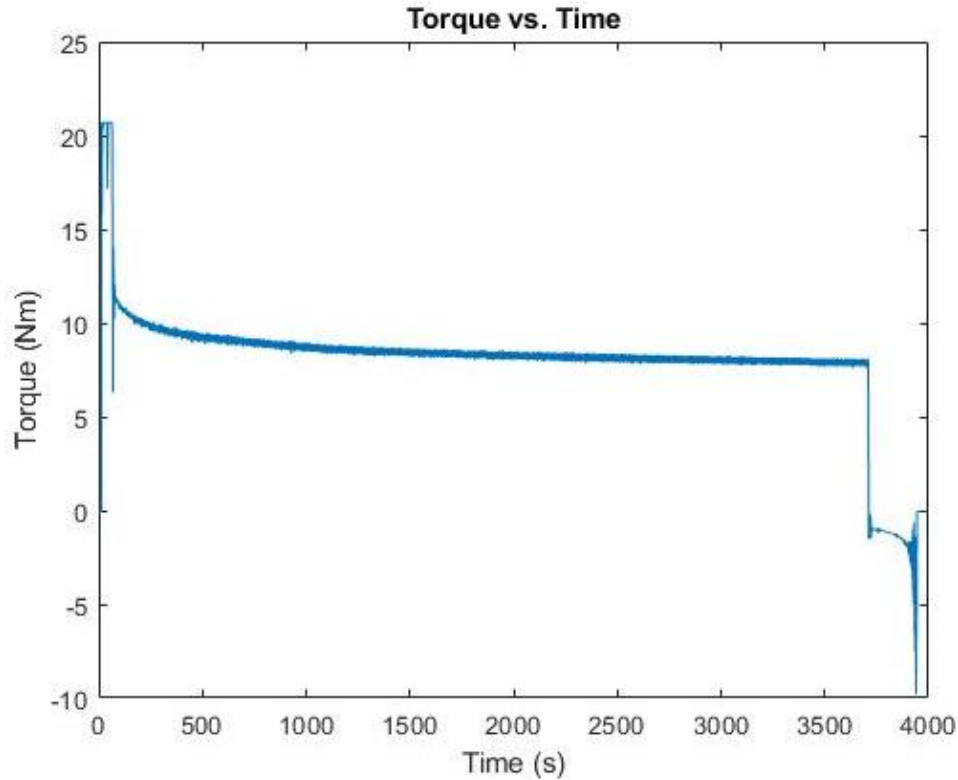


**Figure 5.3:** Temperature with respect to time of thermocouples in the Motor Side oil well.

When comparing Figures 5.2 and 5.3, a difference is noted in that the top three thermocouples of the Motor Side oil well are grouped closer together than in the Governor Side oil well. This is believed to have occurred due to the smaller volume of the Motor Side oil well. The lowest thermocouple of the Motor Side oil well also reached a higher temperature than the lowest thermocouple of the Governor Side oil well. Heat from the bearing eventually conducted through the steel casing and began heating the bottom of the oil well on both sides. This phenomenon was more pronounced on the Motor Side because of the smaller volume.

Torque of the system was recorded throughout the duration of the test. At initial startup there was a large spike in torque as the motor began moving the system from rest. Unfortunately, this maximum torque value was greater than the readable limit of the torque meter, and the torque meter output its maximum torque of 20 Nm during this time. As the system approached its steady state speed the torque rapidly dropped to an initial steady state value of approximately 12 Nm. The torque began decreasing corresponding to the increase in oil temperature resulting in a decrease of the oil's viscosity. A decrease in the steady state torque continued throughout the duration of the test as the temperature of the oil continued to increase. At the time of shut down the torque had reached approximately 8 Nm. When the test was concluded, a shutdown signal was sent to the VFD which slowed the motor and system to a rest by applying a negative torque to the system to ensure it would stop within 3.5 minutes. At the final moments of the ramp down, the torque reached a minimum value slightly greater than -10 Nm. Figure 5.4 on the following page shows the torque with respect to time of the test.

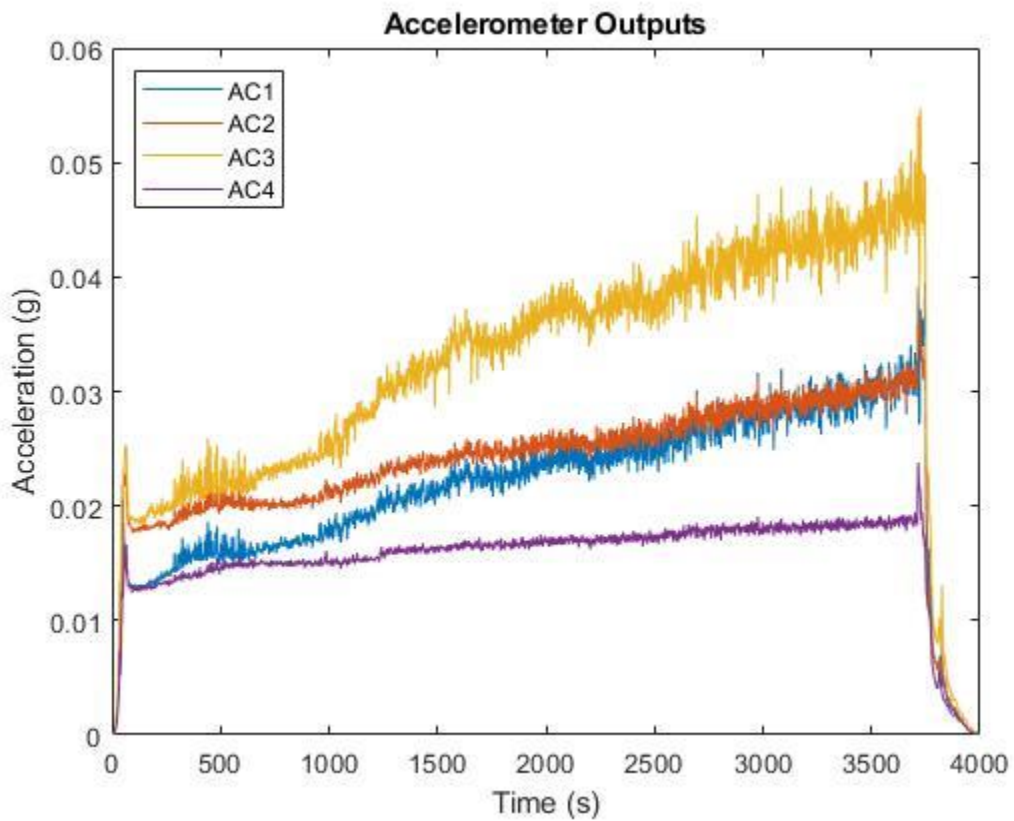
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**Figure 5.4:** Torque with respect to time of the unheated constant speed test.

Vibrational data from the accelerometers was also recorded during the test to observe the baseline vibration profile of the system. During operation minor vibrations were noticed due to operators stepping on or near the steel working base of the system. Once this phenomenon was observed, operators avoided stepping on the steel working base to avoid the collection of any erroneous vibrational data. Of note, the acceleration recorded by all 4 accelerometers increased throughout the duration of the test. This was likely caused by the increase of oil temperature and its subsequent decrease in viscosity leading to a less stable rotating system. Accelerometers 1 and 3 were the vertically aligned accelerometers, accelerometer 1 on the Governor Side and accelerometer 3 on the Motor Side, and both had higher readings than the horizontal accelerometers on their

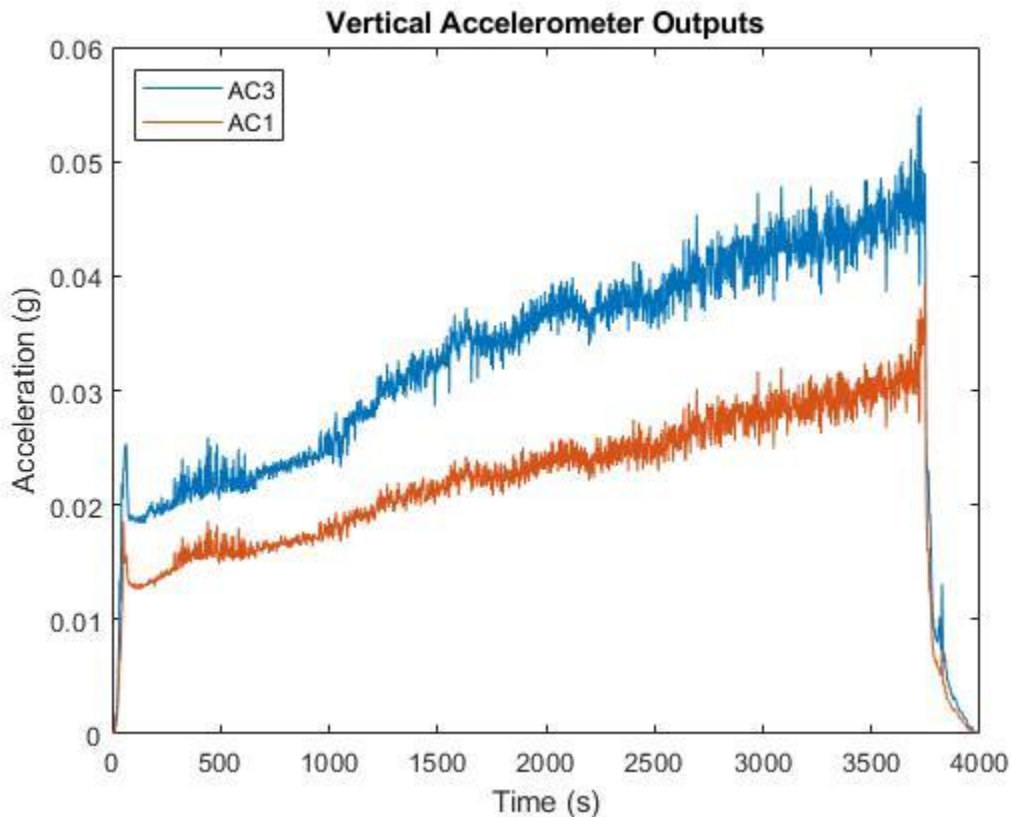
corresponding side. This is believed to have occurred because the vertically oriented accelerometers were adhered to the top removable casing which was attached to the main turbine casing. Because these were separate smaller pieces than the main turbine casing, they had a smaller mass and higher probability of rattling. Figure 5.5 below shows the acceleration with respect to time of all 4 accelerometers.



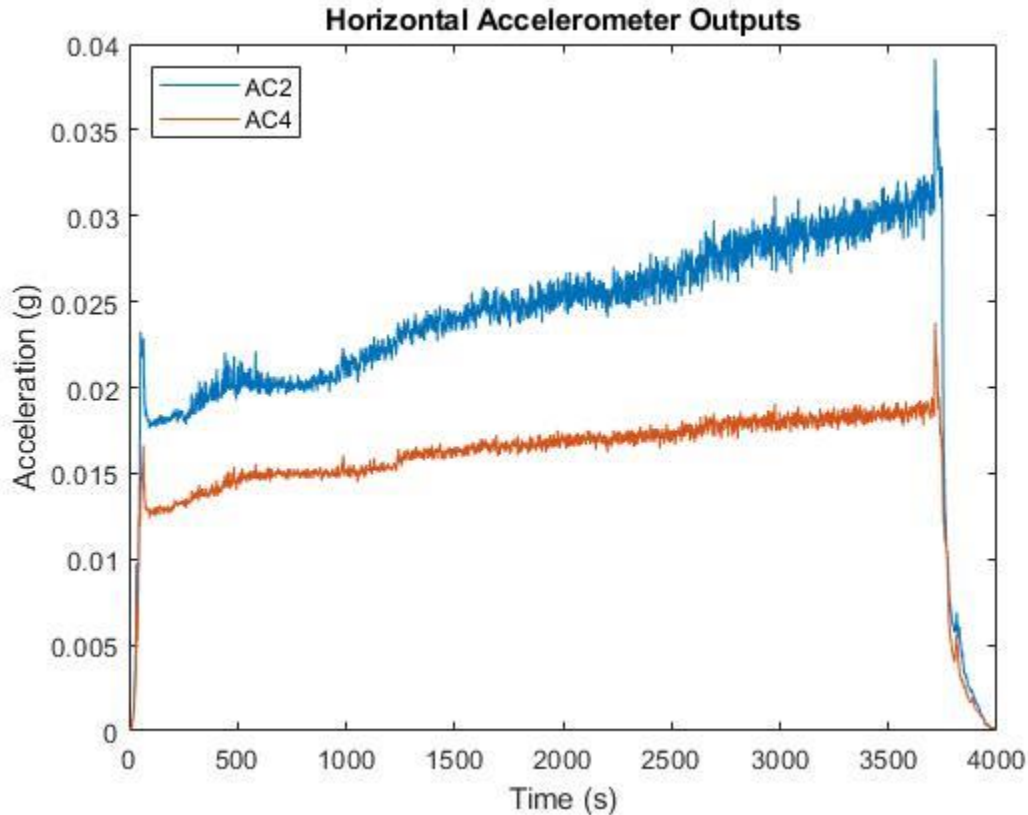
**Figure 5.5:** Output acceleration of all four accelerometers with respect to time.



Accelerometers of the same orientation followed the same general trend during operation. Figure 5.6 below shows the two vertically oriented accelerometers while Figure 5.7 on the following page shows the two horizontal accelerometers. Of note, accelerometer 3, located on the top casing of the Motor Side bearing, recorded the highest acceleration throughout the entire test. This is believed to have occurred because it was attached to the smallest attachable piece of metal to the system which had the lowest ability to dampen vibrations. Also, it was located closest to where the turbine shaft penetrated into the turbine casing.



**Figure 5.6:** Output acceleration of the vertically oriented accelerometers with respect to time.

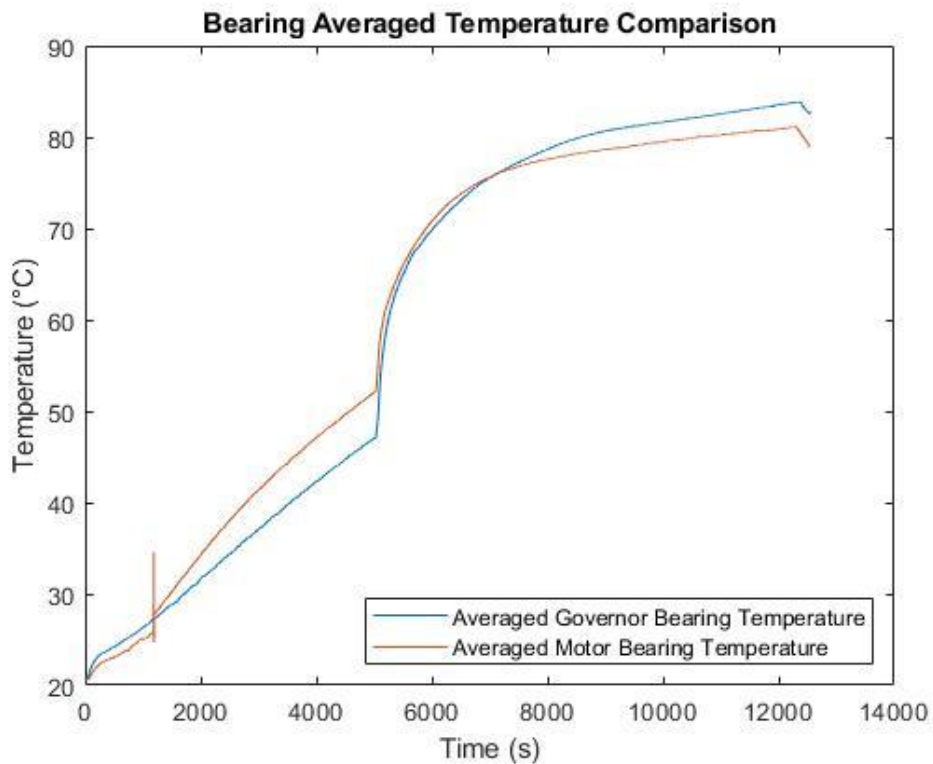


**Figure 5.7:** Output acceleration of the horizontally oriented accelerometers with respect to time.

### ***5.1.2. 93.3 °C Constant Speed Test***

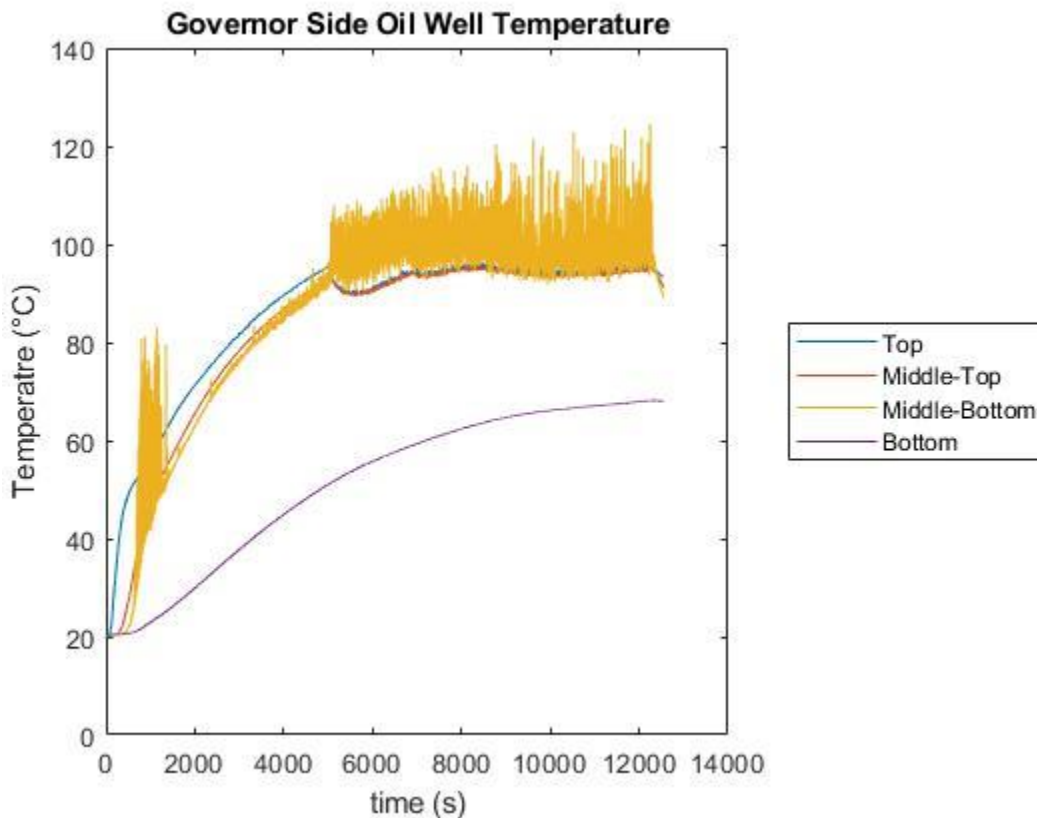
Chronologically, the 93.3 °C constant speed test was the next constant speed test conducted on April 21<sup>st</sup>, 2020. Following the test process described in section 4.1, the test involved a heat up time while the oil temperature was increased to 93.3°C followed by 2 hours of operation at 3595 RPM. Operators maintained the outputs of the immersed oil well heaters to maintain the oil temperature throughout the duration of operation. The main goal was to ensure oil temperature at the top of the oil well did not fall below 93.3°C for a significant period of time during the test.

Analysis of the bearing temperatures showed during the oil heat up period, heat from the immersed heaters conducted through the oil to the slinger rings and turbine casing into the bearings. This led to a linear increase of the overall temperature in both bearings. When operation began the temperature profile of the bearings resembled that of the unheated constant speed test with a loosely logarithmic curve. As the initial hot oil was pulled into the bearing a rapid increase in bearing temperature occurred, and then frictional heat in the system continued to heat the bearing throughout the test. Figure 5.8 below shows the bearing average temperature comparison. There was a brief discrepancy in the Motor Side bearing temperature due to failure of a thermocouple which was quickly addressed by the operators leading to a brief spike in the average temperature at approximately 1000 s.

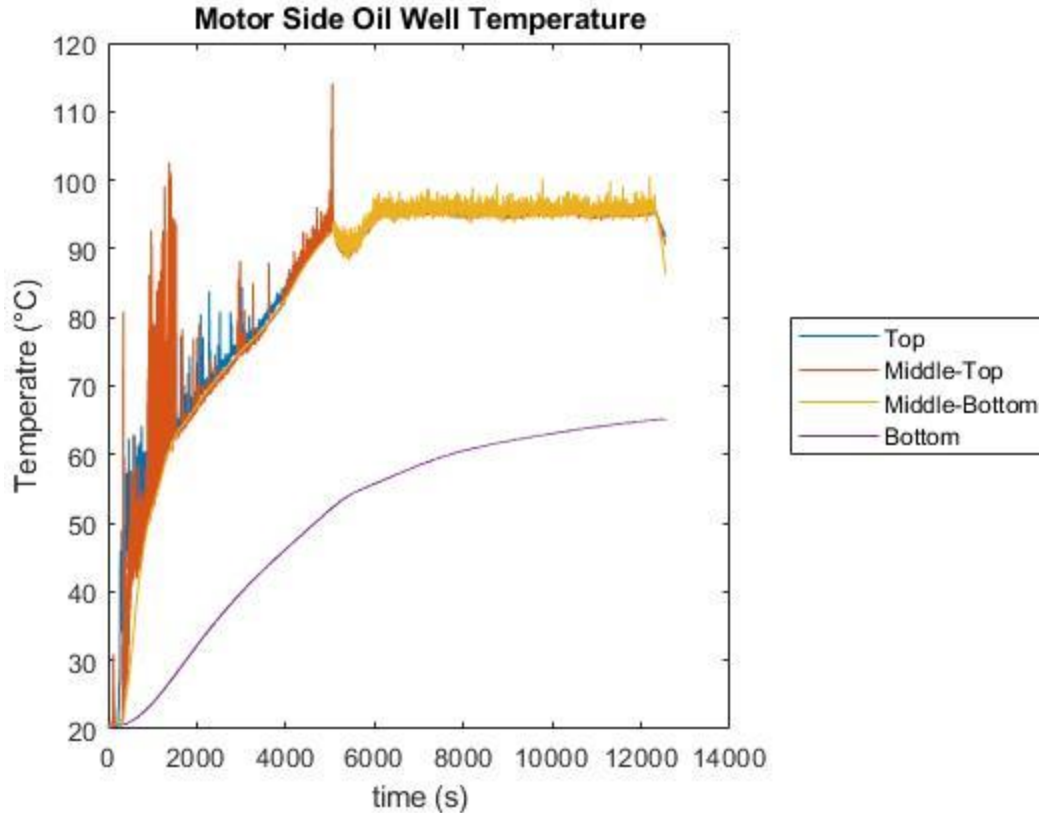


**Figure 5.8:** Comparison of the average Motor Side bearing temperature and Governor Side bearing temperature with respect to time.

Heating of the oil produced a different stratification profile of the oil well temperature than the unheated test. The immersed heaters were located at the bottom of the oil well so natural convection of the fluid would carry heated oil to as large a portion of the oil well as possible. In practice, this led to oil interacting with the hot heater surface, and rapidly ascending to the top of the oil well. As this oil rose to the surface, it passed over multiple thermocouples leading to them outputting increases in temperature and then decreasing back to its original temperature after the plume of hot oil had passed over it. This phenomenon can be observed in the Governor Side oil well in Figure 5.9 below, and in the Motor Side oil well in Figure 5.10 on the following page.



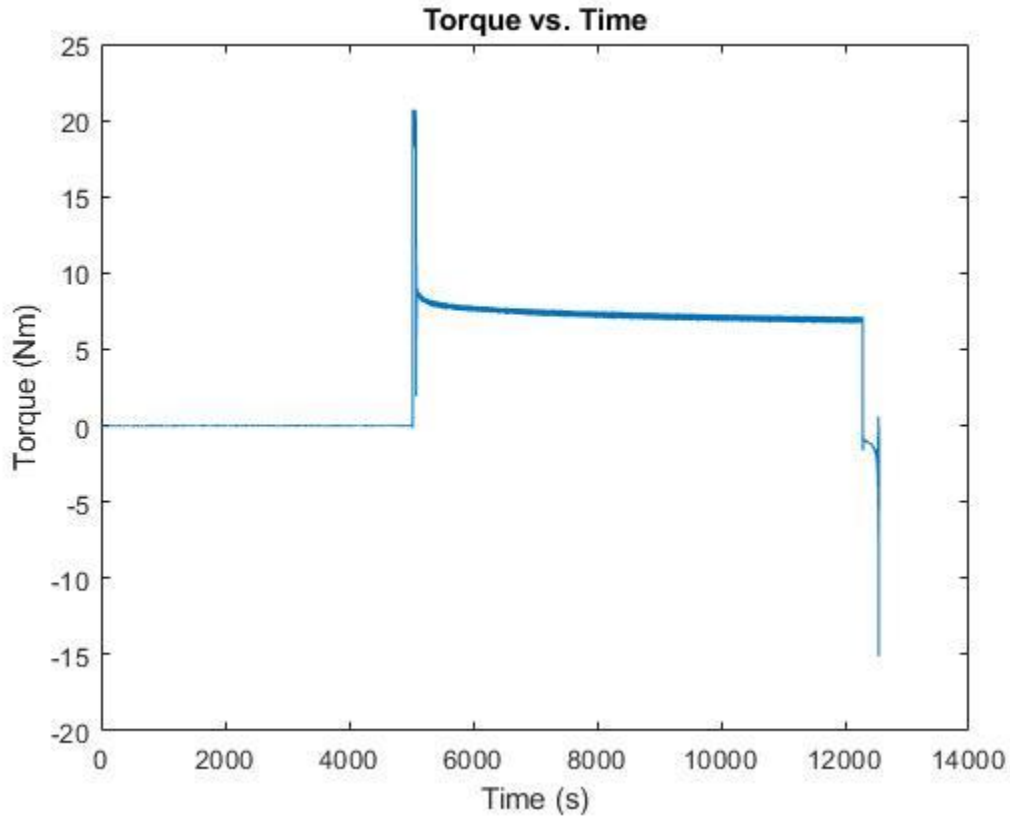
**Figure 5.9:** Governor Side oil well temperature profile with respect to time.



**Figure 5.10:** Motor Side oil well temperature profile with respect to time.

The torque of the system followed the same profile as the unheated test. Initial start-up of the turbine caused a torque value greater than the 20 Nm readable limit of the torque meter. Once the system began to approach its steady state speed of 3595 RPM, the torque reached an initial steady state value of approximately 8 Nm and dropped as frictional heat was added into the bearing. The torque decreased during the test and reached approximately 7 Nm before shutdown began. Both of the steady state values were lower than the unheated test as the increased oil temperature led to a decrease in the oil viscosity. Shut down included a negative torque sent by the VFD and motor system which reached a higher magnitude torque value than the unheated test. The final negative torque sent to the system was below -15 Nm because the decrease in oil viscosity required more

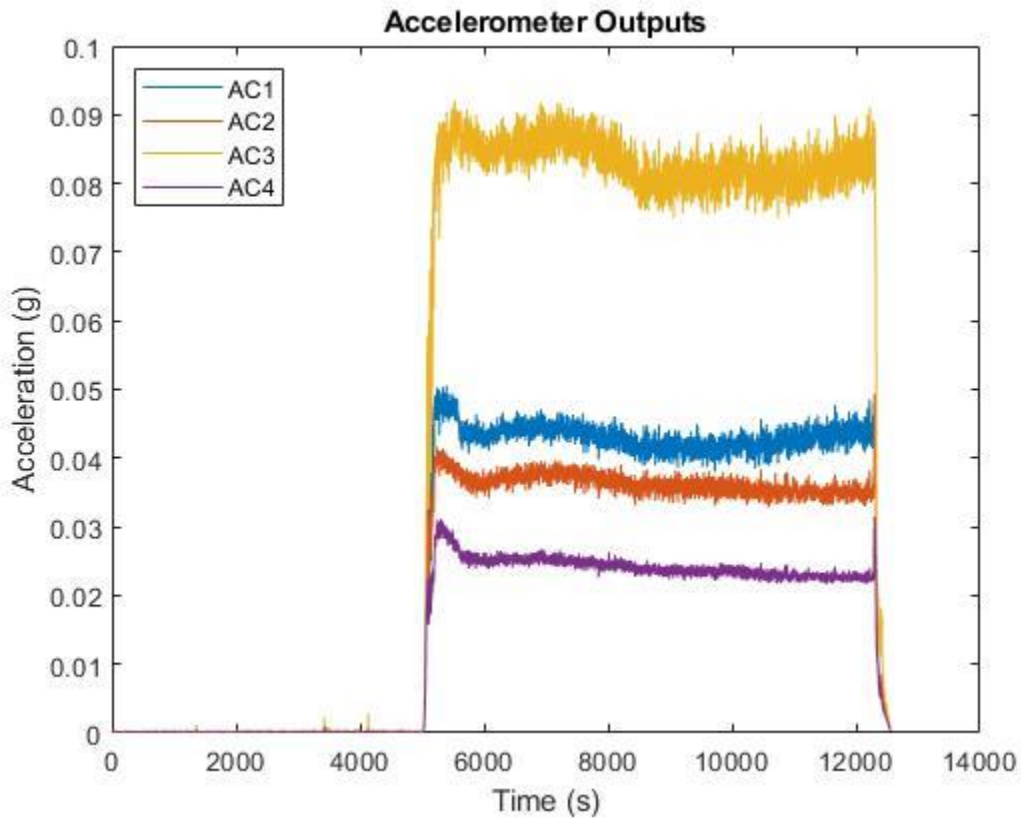
work from the motor and VFD to stop the system. Figure 5.11 below shows the torque profile. The initial 0 Nm torque is due to the heat up period of the test in which the turbine was not operating.



**Figure 5.11:** Torque with respect to time of the 93.3°C constant speed test.

Vibrational analysis was conducted to see how oil temperature affected the stability of the system. As seen in the unheated test, the vibrations for the vertically oriented accelerometers, accelerometers 1 and 3, were greater than the vibrations seen in accelerometers 2 and 4 with horizontal orientations. Accelerometer 3, located on the top casing of the Motor Side bearing,

experienced the highest acceleration as it did in the unheated test. The trend of the recorded accelerations was different for this test as they remained flat and did not show a linear increase as seen in the unheated test. This is believed to have occurred due to the constant oil temperature which was maintained by the heaters, while in the unheated test frictional heat was increasing the oil temperature. Figure 5.12 below shows the outputs of all 4 accelerometers.

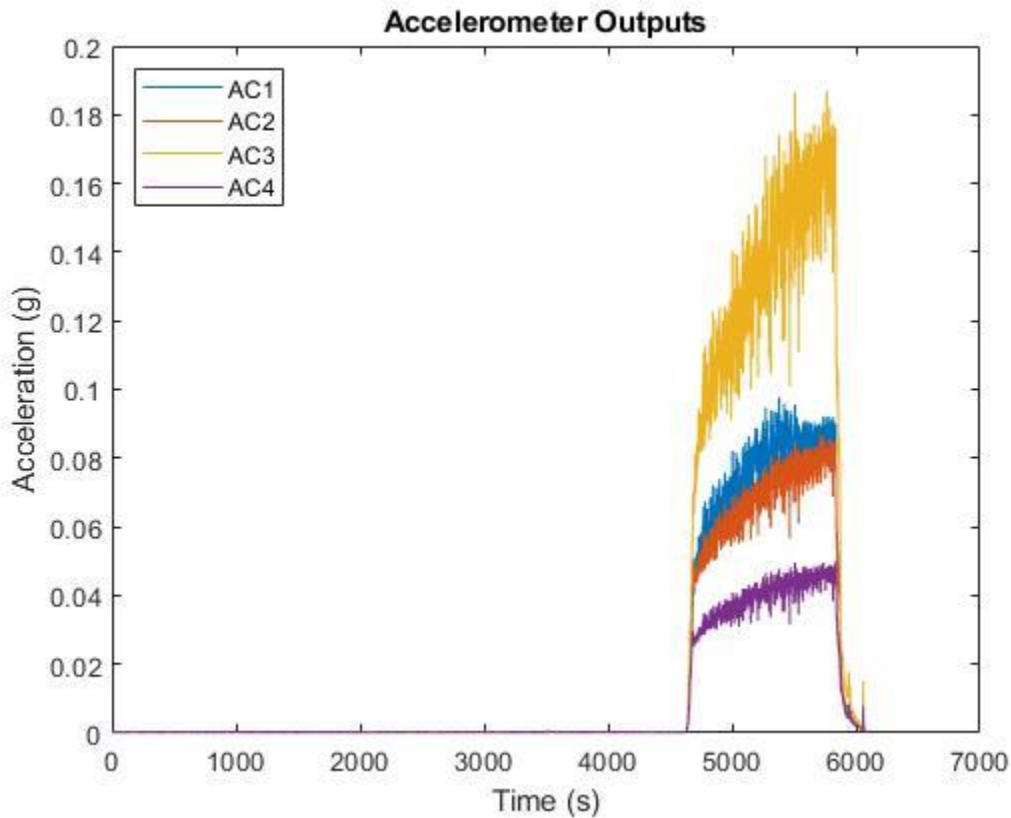


**Figure 5.12:** Output acceleration of all four accelerometers with respect to time.

### ***5.1.3. 82.2 °C Constant Speed Test***

The next constant speed test conducted was the 82.2 °C test on April 22<sup>nd</sup>, 2020. Unfortunately, equipment failure led to the termination of the test prior to completion. The coupling system used

to couple the motor, torque meter, and turbine shaft began to fail due to higher than expected torques experienced at start-up of the turbine. These torques led to the system coming unaligned during operation and leading to excessive vibrations deemed unsafe by the equipment operators. Figure 5.13 below shows the increase in vibrations as the equipment came unaligned and the subsequent termination of the test.



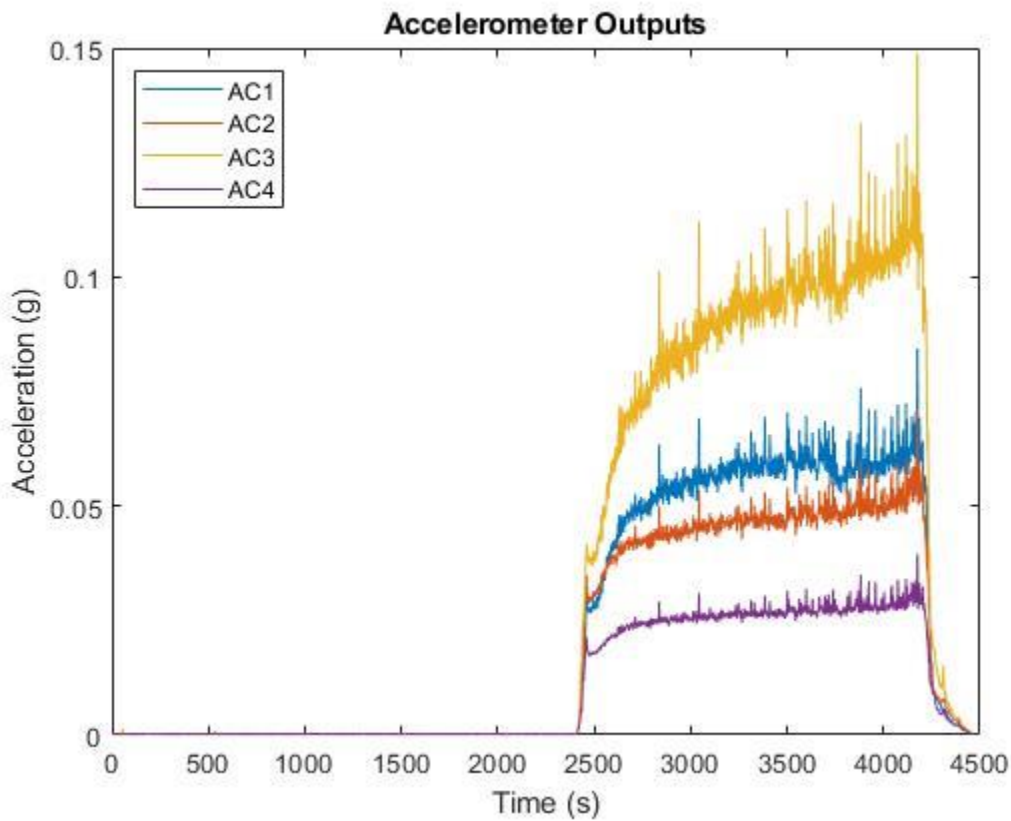
**Figure 5.13:** Output acceleration of all four accelerometers with respect to time.

#### ***5.1.4. 71.1 °C Constant Speed Test***

The final constant speed test, and the final of all tests, was the 71.1 °C constant speed test conducted on April 23<sup>rd</sup>, 2020. After the failure of the 82.2 °C constant speed test, an alignment of



the shaft system was conducted to try and fix the previously experienced issues. The desire was to change the oil temperature to the lower testing temperature and see if the newly aligned system would be able to survive the test. Unfortunately, vibrations were worse than before and the test was prematurely terminated. Damage to the couplings was found to be permanent after disassembly of the system. This phenomenon can clearly be seen at the end of the test where the Accelerometer 3, located above the Motor Side bearing, reached a peak acceleration of 0.15 g. Figure 5.14 below shows the vibrations of all 4 accelerometers during operation and the subsequent point of test termination.



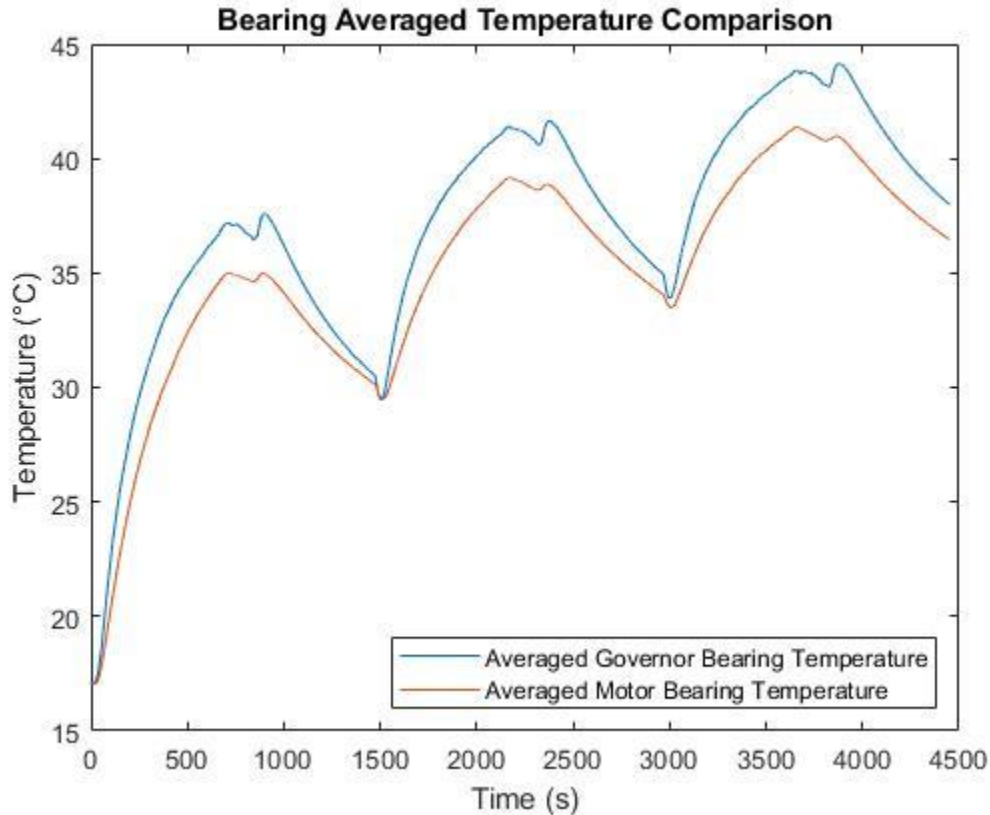
**Figure 5.14:** Output acceleration of all four accelerometers with respect to time.

## **5.2. Start-Stop Tests**

### ***5.2.1. Unheated Start-Stop Test***

In a similar fashion as the constant speed tests, the first start-stop test conducted was the unheated test to serve as a basis for comparison. The test was successfully conducted on April 13<sup>th</sup>, 2020. Operation of the system followed the test outline and procedure discussed in section 4.2 which involved 3 operating periods lasting 10 minutes each.

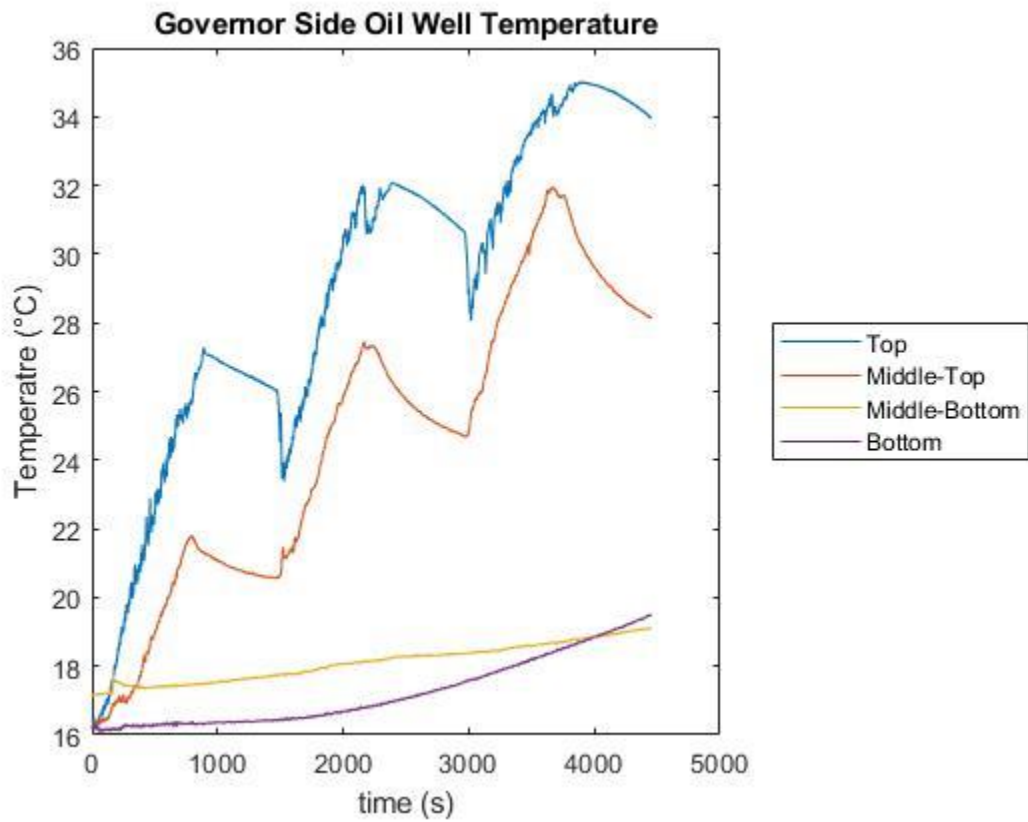
The average temperature of the bearings was analyzed to see how frictional heat was added into the system. At the beginning of the first run period, frictional heat from the shaft's rotation was added into the lubricating oil and bearing causing a drastic increase in temperature. However, unlike the constant speed test, the turbine was returned to a rest and heat in the bearing from friction dissipated into the atmosphere. When the second run cycle began there was again an increase in bearing temperature, but the increase was less pronounced as there was still residual heat in the oil from the first run period. Similarly, the third run cycle showed a less pronounced increase in temperature due to the residual heat from the three runs before it. Figure 5.15 on the following page shows the average temperatures of both the Motor Side and Governor Side bearings during operation.



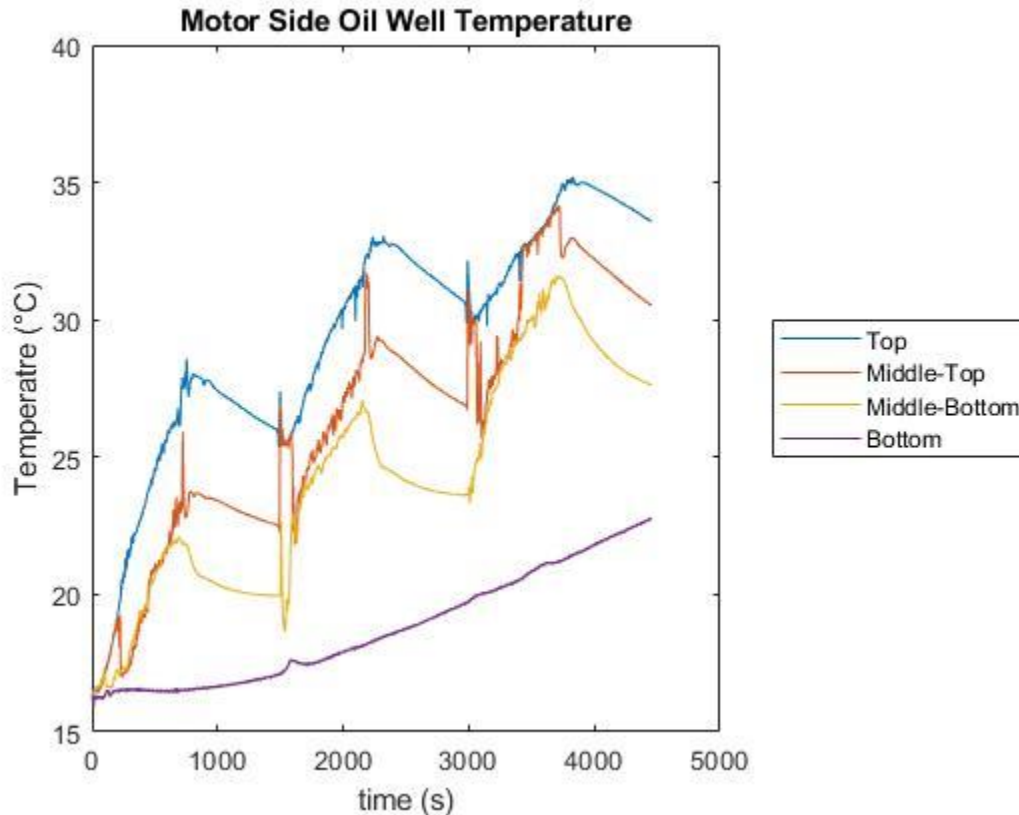
**Figure 5.15:** Comparison of the average Motor Side bearing temperature and Governor Side bearing temperature with respect to time.

Similar to the bearing temperature profile, the oil well thermocouples showed a cyclical increase in temperature throughout the duration of the test. As operation began, oil from the top of the oil well was pulled into the bearing and heated via friction. This oil then dropped down into the oil well only to be picked up again by the bearing slinger rings. When the turbine was brought to a rest following the first run time period, the oil cooled as it slowly mixed with the cooler oil below it. When the turbine was again operated for 10 minutes, another corresponding increase in temperature was noted, and this repeated for the third operational cycle as well. Unfortunately, the Middle-Bottom thermocouple of the Governor Side oil well encountered a failure and did not

record accurate data during the test. Figures 5.16 and 5.17 show the Governor Side and Motor Side oil well temperature profiles below and on the following page.

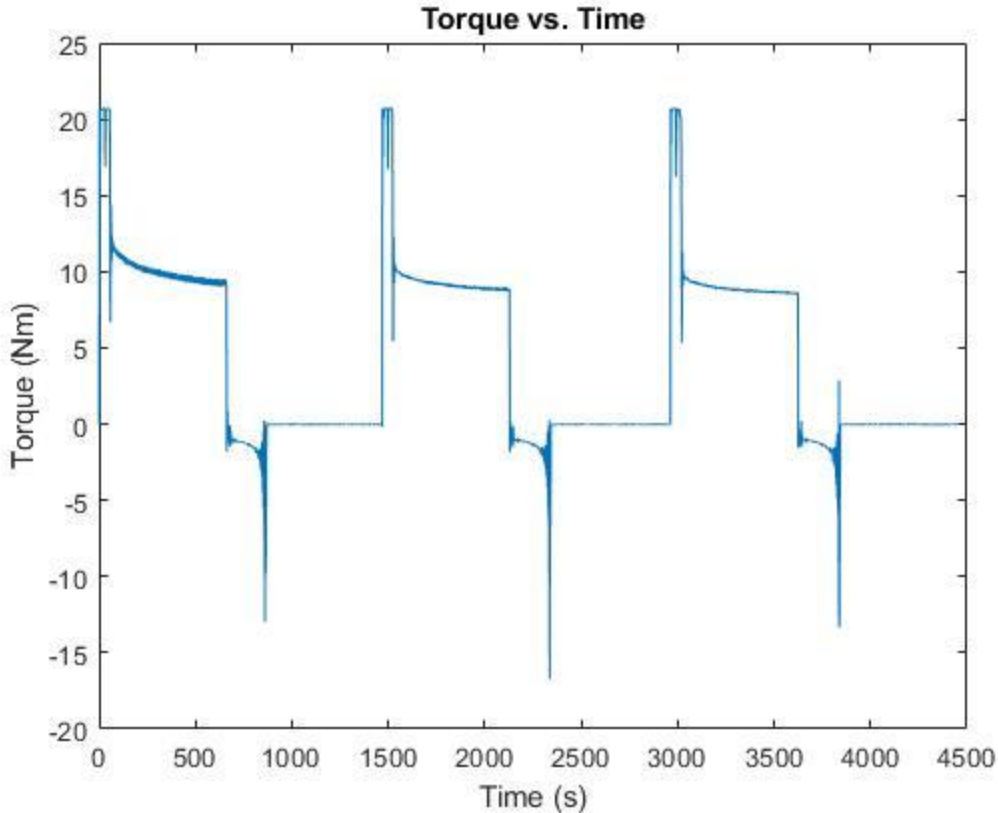


**Figure 5.16:** Governor Side oil well temperature profile with respect to time.



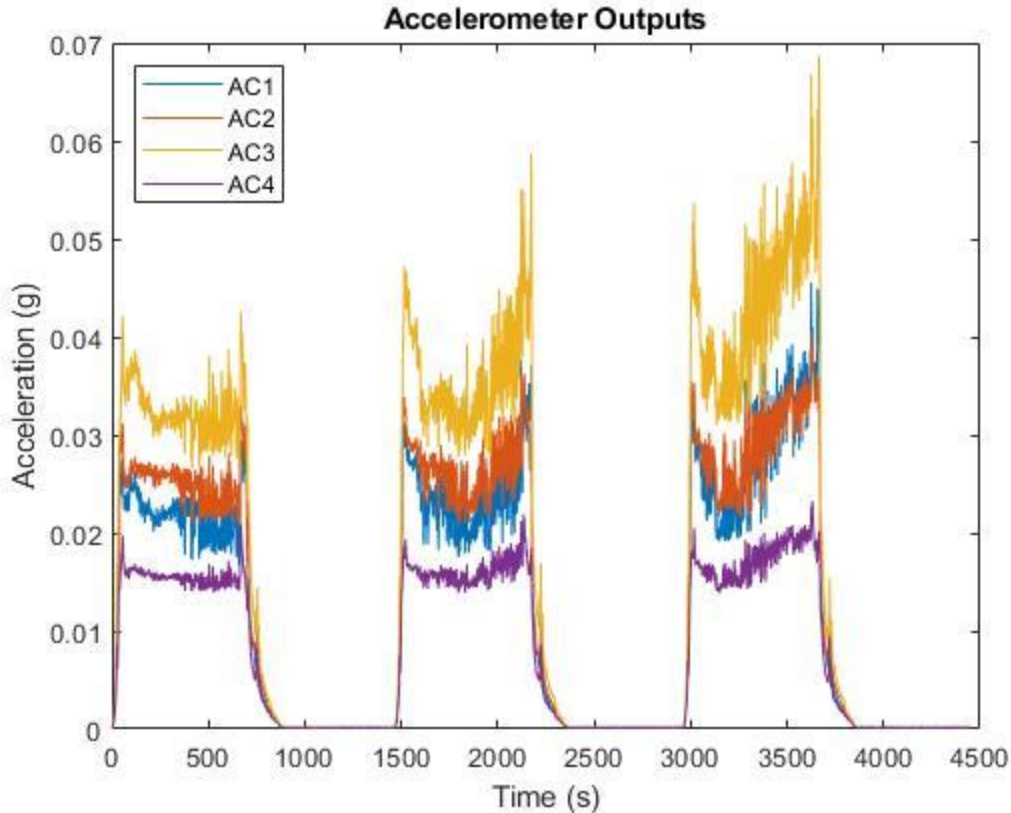
**Figure 5.17:** Motor Side oil well temperature profile with respect to time.

The torque of the system showed a similar profile to those seen in the constant speed tests; however, the profile was repeated three times, one for each operational period of the turbine. As before, the initial start-up torque was higher than the maximum readable limit of the torque meter, 20 Nm. Initial steady state torque was approximately 12 Nm which is higher than what was observed at initial startup of the unheated constant speed test. This was caused by a cold front which entered the College Station, TX area and cooled the stored oil used before the test began. As operation of the turbine continued, and the oil was heated by friction, the initial steady state torque value decreased with each start-up. Eventually, the final steady state torque dropped just below 9 Nm. Figure 5.18 on the following page shows the torque profile with respect to time.



**Figure 5.18:** Torque profile of the system with respect to time.

Vibrations of the system show how the system handled the start-stop exercise. With each run period there was an increase in vibrations of the system. This is believed to have been caused by the increase in oil temperature as was observed during the unheated constant speed test. Also, the variance of the acceleration, especially for accelerometer 3, increased with each subsequent run sequence. Additionally, by the end of testing an audible sound coming from the system could be heard by operators at the facility. The sound and increase in vibrations are believed to be the beginning signs of failure of the couplings. Figure 5.19 on the following page shows the acceleration recorded by each accelerometer throughout the duration of the test.

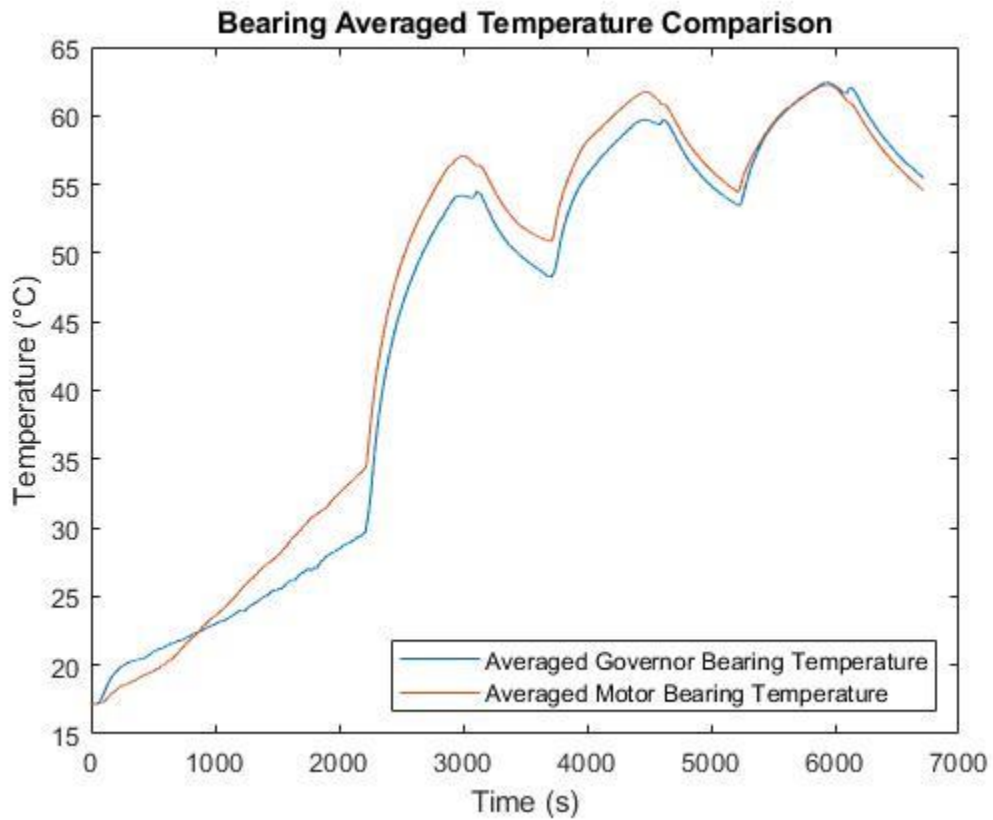


**Figure 5.19:** Output acceleration of all four accelerometers with respect to time.

### 5.2.2. 71.1 °C Start-Stop Test

The next start-stop test chronologically completed was the 71.1 °C test completed on April 14<sup>th</sup>, 2020. The bearing temperature profile followed that of the unheated test, but there was an initial heat up period as the oil was heated to the desired testing temperature. Heat from the immersed heater was transferred to the oil which then conducted into the slinger rings and turbine casing thus heating the bearings. When operation began the hot oil was pulled into the bearing causing a drastic increase in temperature. After the first run time the hot oil fell out of the turbine, and the temperature decreased during the rest period. When operation began again there was again an increase in temperature, but it was not as drastic as the increase before it. Figure 5.20 shows the

average temperature of the Governor and Motor Side bearings during operation. Unfortunately, a thermocouple failed on the Motor Side bearing so the average temperature was only computed using three thermocouples.

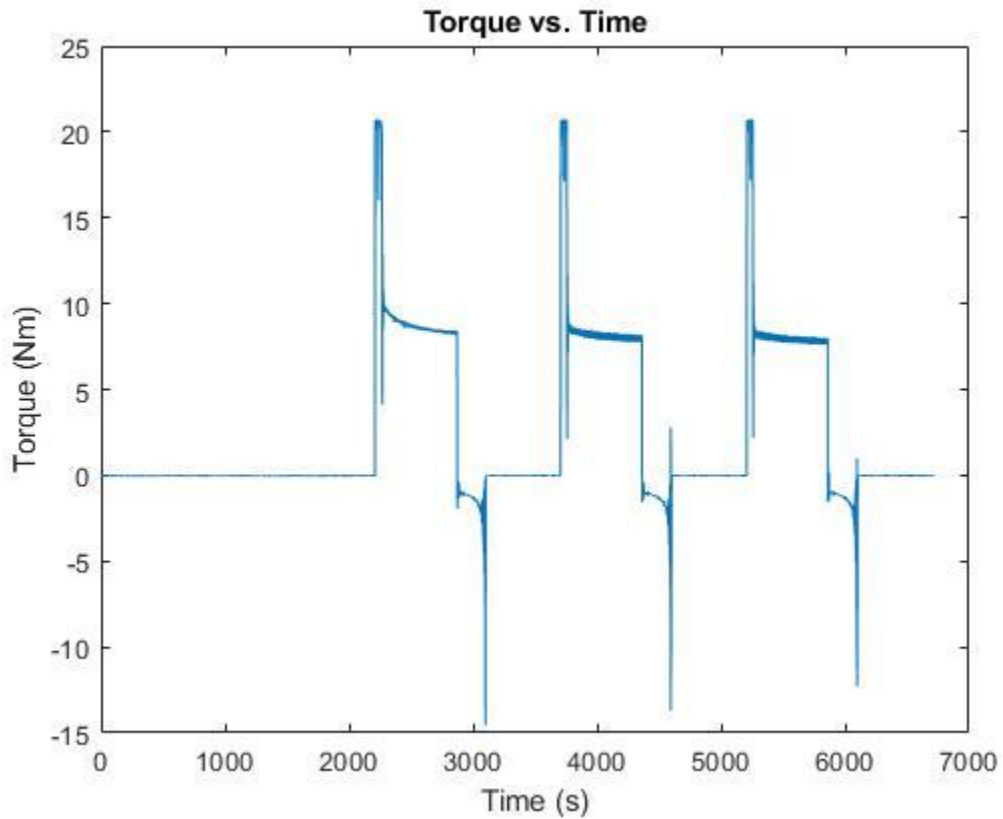


**Figure 5.20:** Comparison of the average Motor Side bearing temperature and Governor Side bearing temperature with respect to time.

Torque of the system followed the same profile as the unheated start-stop test. The initial steady state torque did see a decrease as it was slightly below 9 Nm after initial start-up. This torque



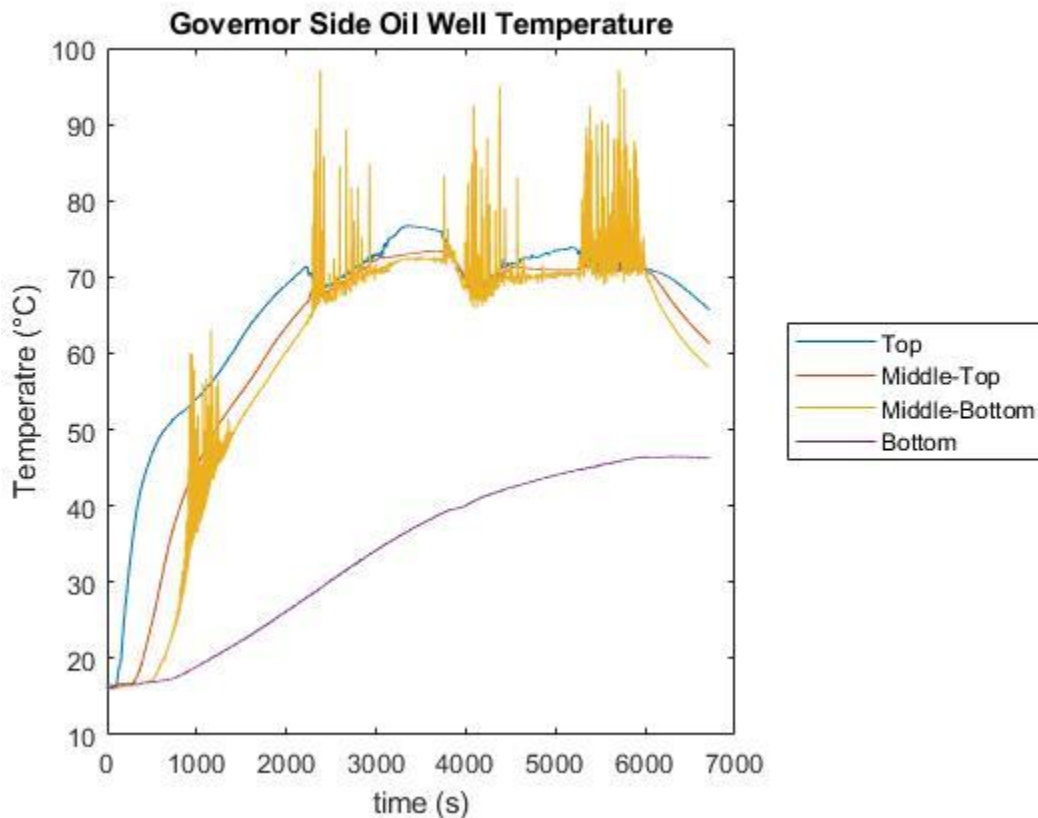
decreased throughout the test and reached a final steady state value just below 7 Nm. Figure 5.21 below show the torque of the system with respect to time.



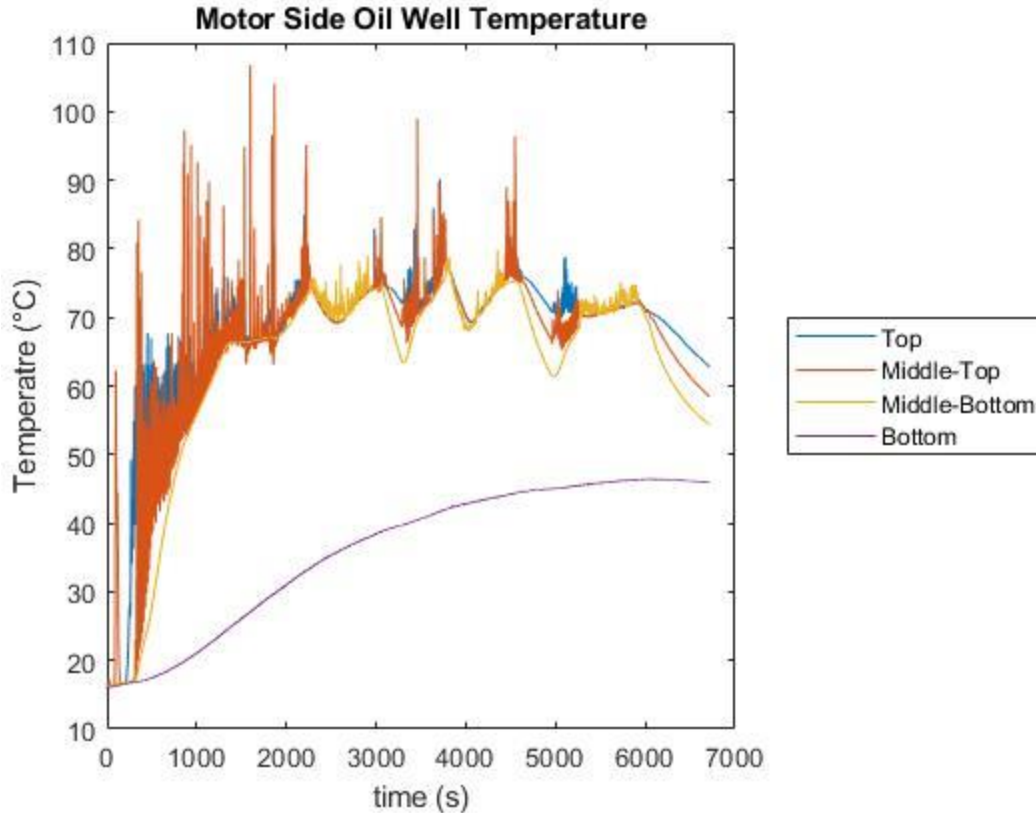
**Figure 5.21:** Torque profile of the system with respect to time.

Following the procedures set forth in section 4.2, the oil was heated to the desired temperature and maintained throughout the duration of the test. As seen in other heated tests, the thermocouples recorded spikes in temperature as oil interacted with the immersed heater and immediately rose to the surface of the oil well. After the hot oil passed over the thermocouple, the temperature reading

decreased back to the ambient oil temperature around it. A new phenomenon occurred in this test which had not been previously encountered. The oil was brought to temperature while the turbine was at rest, after this time period the turbine began rotating and actually caused a decrease in oil temperature. It is believed this cooling affect was caused by the movement of air within the turbine casing and the pulling of hot oil out of the oil well and into the bearing. Figure 5.22 below shows the temperature profile of the Governor Side oil well while Figure 5.23 on the following page shows the Motor Side oil well temperature profile.

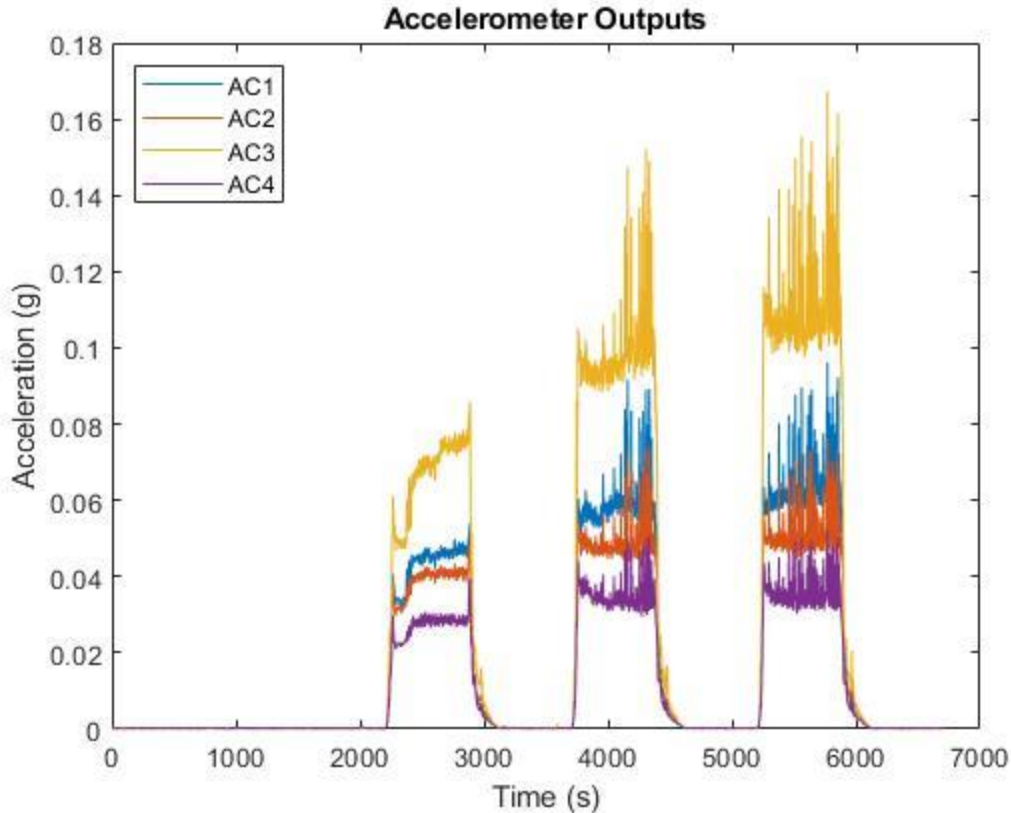


**Figure 2.22:** Governor Side oil well temperature profile with respect to time.



**Figure 5.23:** Governor Side oil well temperature profile with respect to time.

Vibrations of the system showed an increase in acceleration and was an indication of coupling damage. Each accelerometer showed an increase in acceleration compared to the unheated test, and increased between each test run in magnitude. Once again, operators heard an audible sound coming from the system during operation. Figure 5.24 on the following page shows the vibration profile of the system. After this test an inspection of the shaft alignment was conducted and it was found the shaft had come unaligned. Prior to conducting anymore tests the shaft system was realigned.

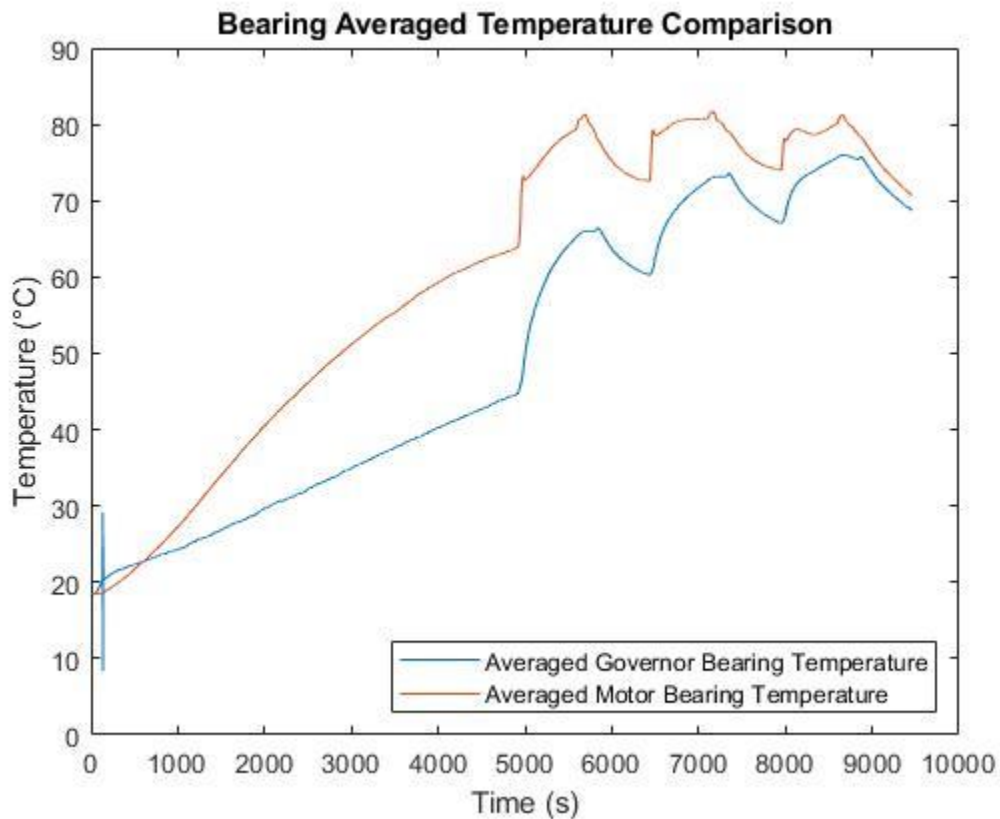


**Figure 5.24:** Output acceleration of all four accelerometers with respect to time.

### 5.2.3 93.3 °C Start-Stop Test

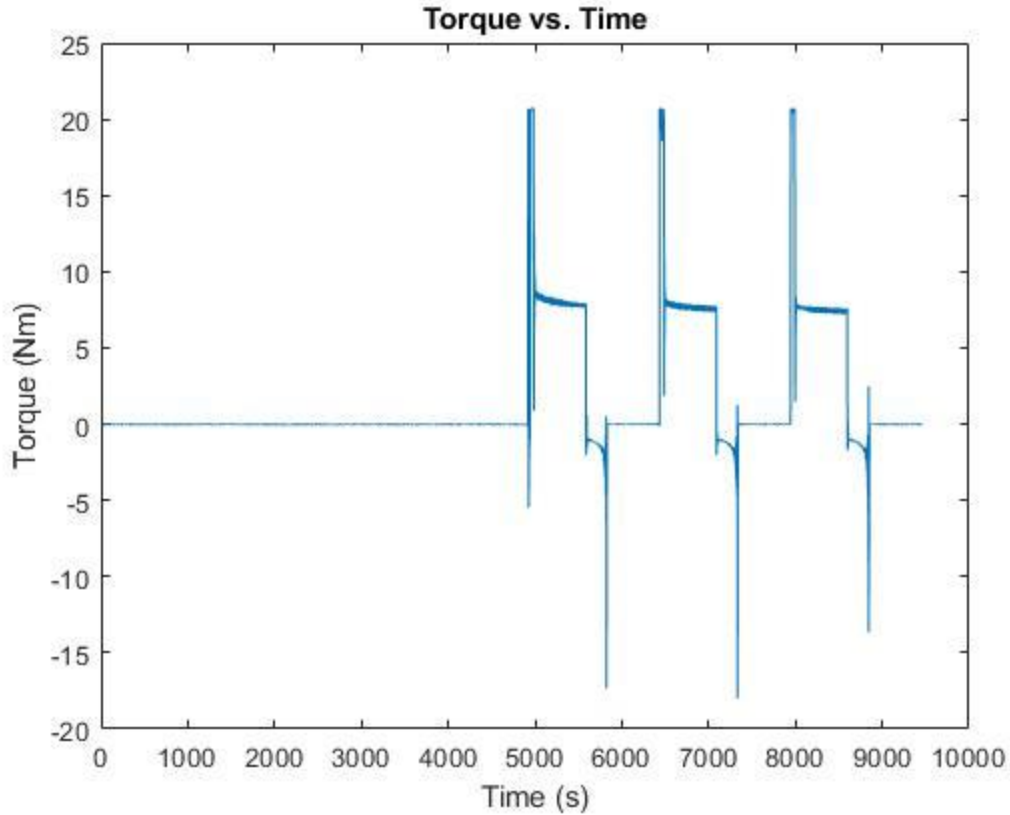
Following the realignment of the shaft system conducted after the 71.1 °C test, the 93.3 °C test was conducted. This test was chosen to see if the newly aligned system could handle the highest required oil temperature, and was completed on April 16<sup>th</sup>, 2020. Similar to the 71.1 °C start-stop test, the bearings had a linear increase in temperature during the oil heat up portion of the test and then underwent the heating and cooling cycle during operation. Of note, the operators made a mistake and overfilled the Motor Side oil well with oil. This led to a larger amount of conduction from the oil to the bearings causing a unique temperature profile. The averaged bearing

temperature comparison can be seen in Figure 5.25 below. Also, a brief failure of a thermocouple led to a discrepancy of the Governor Side bearing average temperature just after the test began.



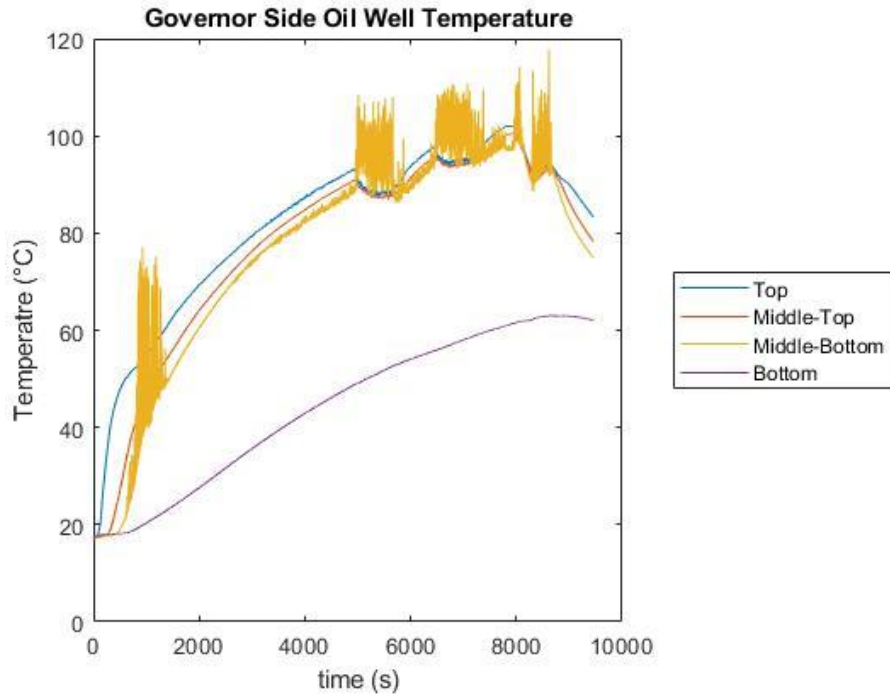
**Figure 5.25:** Comparison of the average Motor Side bearing temperature and Governor Side bearing temperature with respect to time.

The torque of the system experienced the same profile and phenomenon as the other tests conducted. The start-up torque was greater than the torque meter’s maximum readable limit, but the steady state torque decreased with the increase in oil temperature. Figure 5.26 on the following page shows the torque with respect to time.

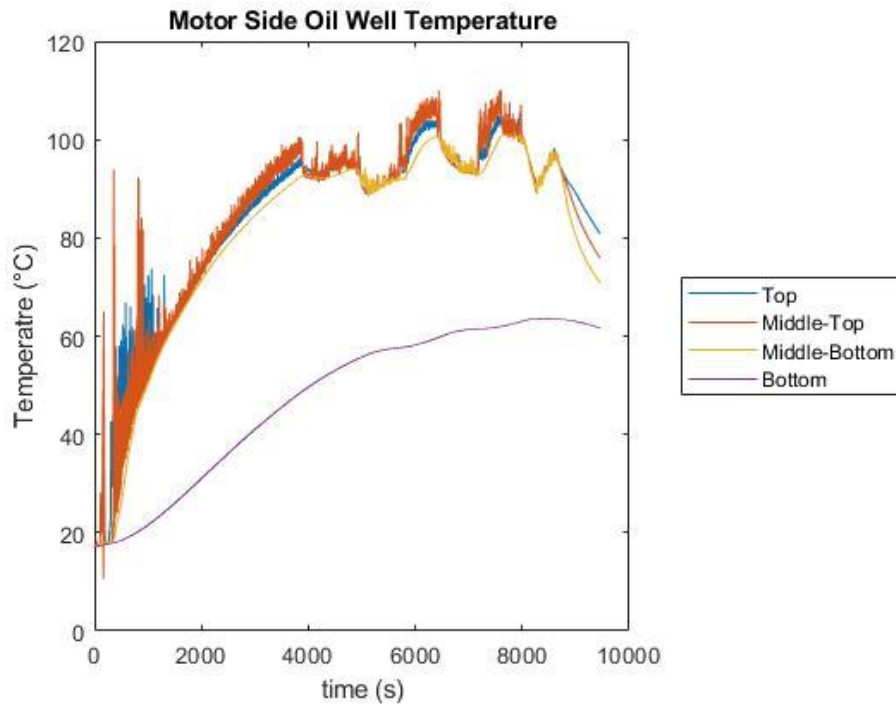


**Figure 5.26:** Torque profile of the system with respect to time.

The oil wells were heated and they experienced the same cooling effect seen during the 71.1 °C start-stop test. To account for the cooling affect and ensure the oil was at the desired temperature while the turbine was operating, the oil was heated above 93.3 °C. Once again, spikes in temperature are seen as hot oil passes over the thermocouples after interacting with the immersed heaters. Figures 5.27 and 5.28 on the following page show the temperature profiles of the Governor Side oil well and Motor Side oil well, respectively.

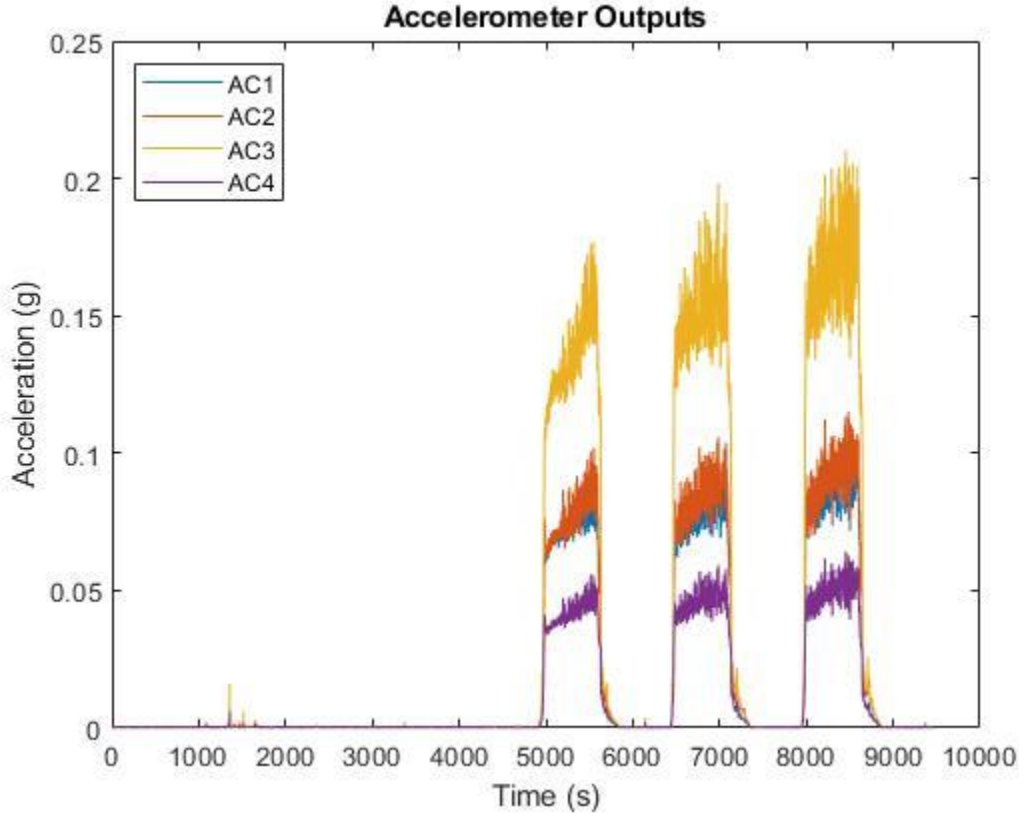


**Figure 5.27:** Governor Side oil well temperature profile with respect to time.



**Figure 5.28:** Motor Side oil well temperature profile with respect to time.

During the test no noise was heard as was noticed in previous tests, but an analysis of the vibrational data shows the highest acceleration value of all testing. Specifically, accelerometer 3 showed a higher acceleration profile than the others. There was possible source of error as the cover it was attached to had to be removed and reattached between each test leaving the possibility of it not being properly secured. Figure 5.29 below shows the accelerometer outputs.

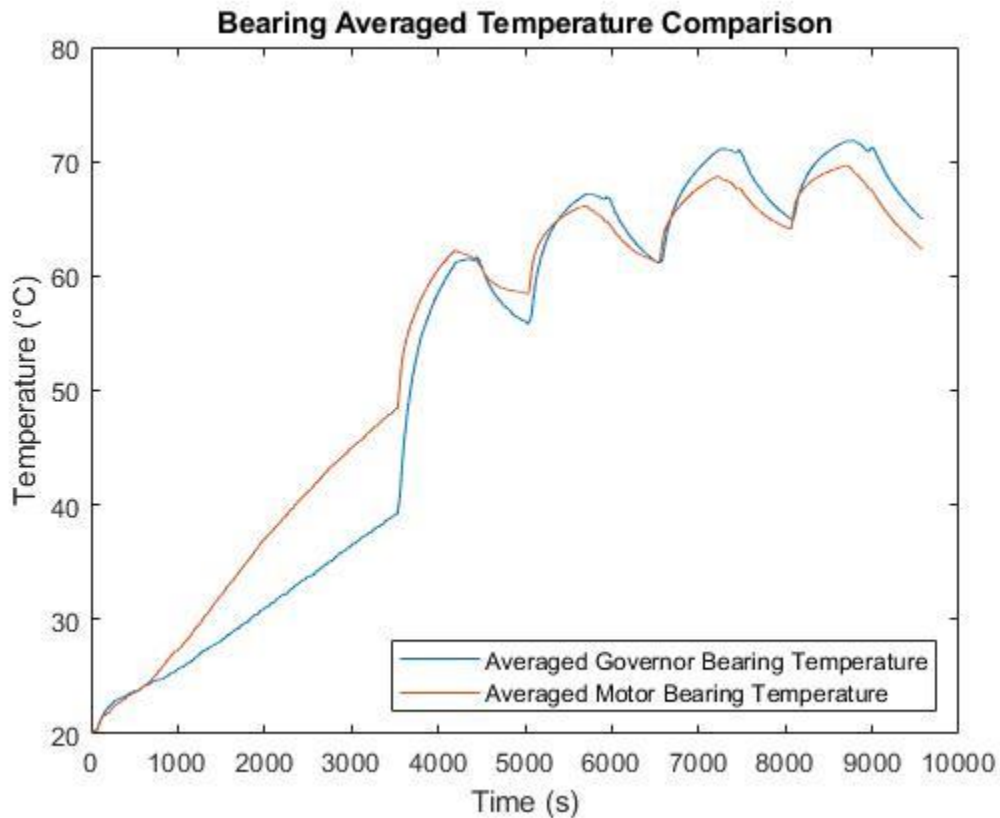


**Figure 5.29:** Output acceleration of all four accelerometers with respect to time.



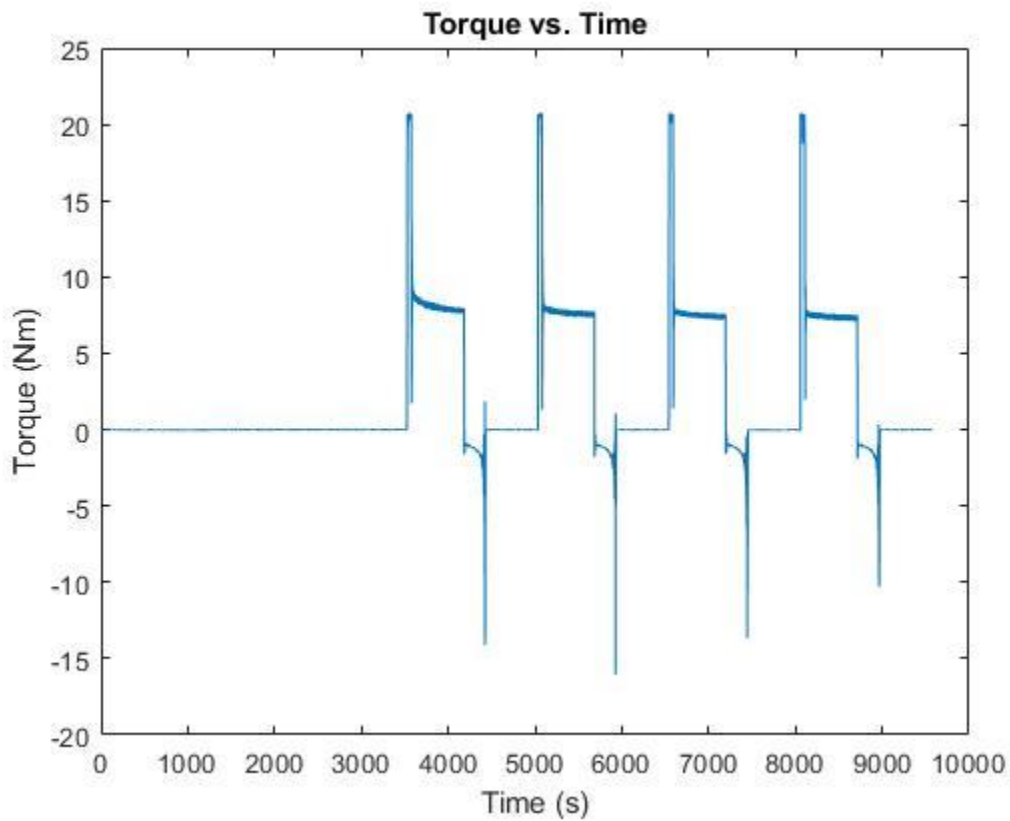
#### 5.2.4. 82.2 °C Start-Stop Test

The final start-stop test conducted was the 82.2 °C test which was completed on April 20<sup>th</sup>, 2020. This test was unique as a fourth 10-minute run cycle was completed to see if it resulted in the temperatures of the system stabilizing instead of continually increasing. The average temperatures of the bearings were plotted and compared. They showed the same trend as all previous start-stop tests, but during the fourth run cycle there was not a general increase in temperature, and the cycle mimicked the third run cycle. Figure 5.30 below shows the bearing temperatures with respect to time.



**Figure 5.30:** Comparison of the average Motor Side bearing temperature and Governor Side bearing temperature with respect to time.

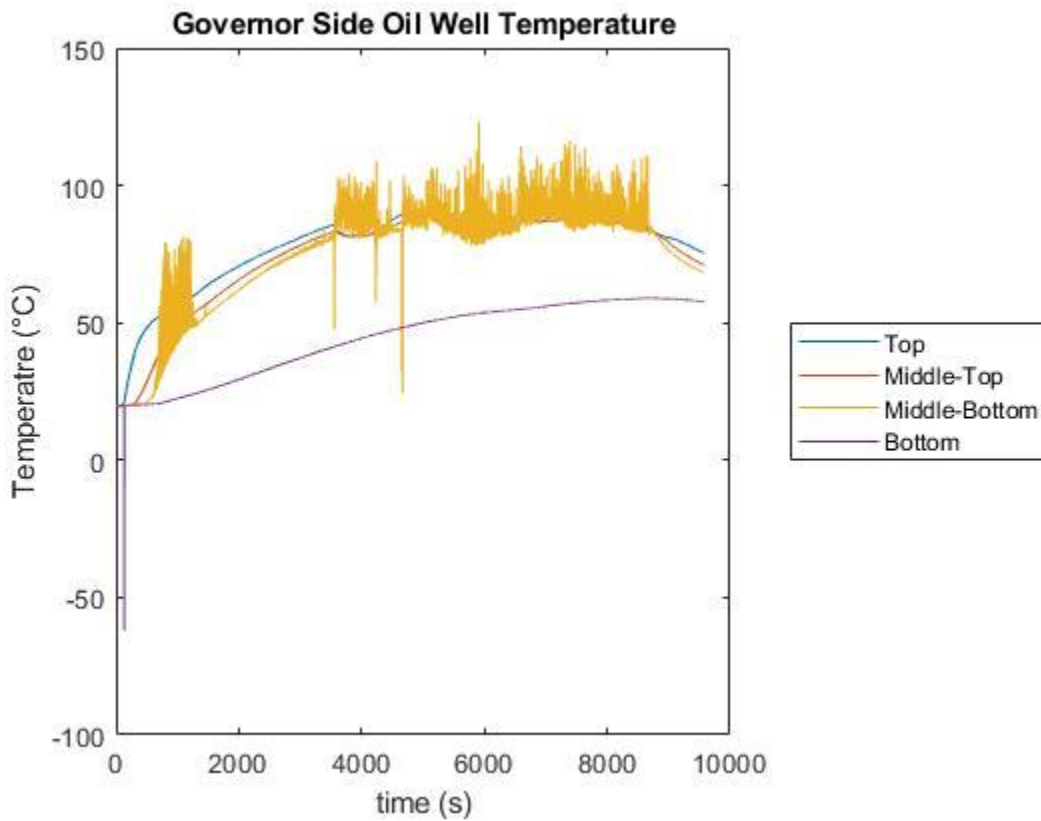
The torque of the system followed the same trend as the previous tests with an initial unreadable maximum torque at start-up followed by a steady state torque which decreased in time. This test was unique because there was a fourth torque curve corresponding to the fourth run time. Figure 5.31 below shows the torque with respect to time.



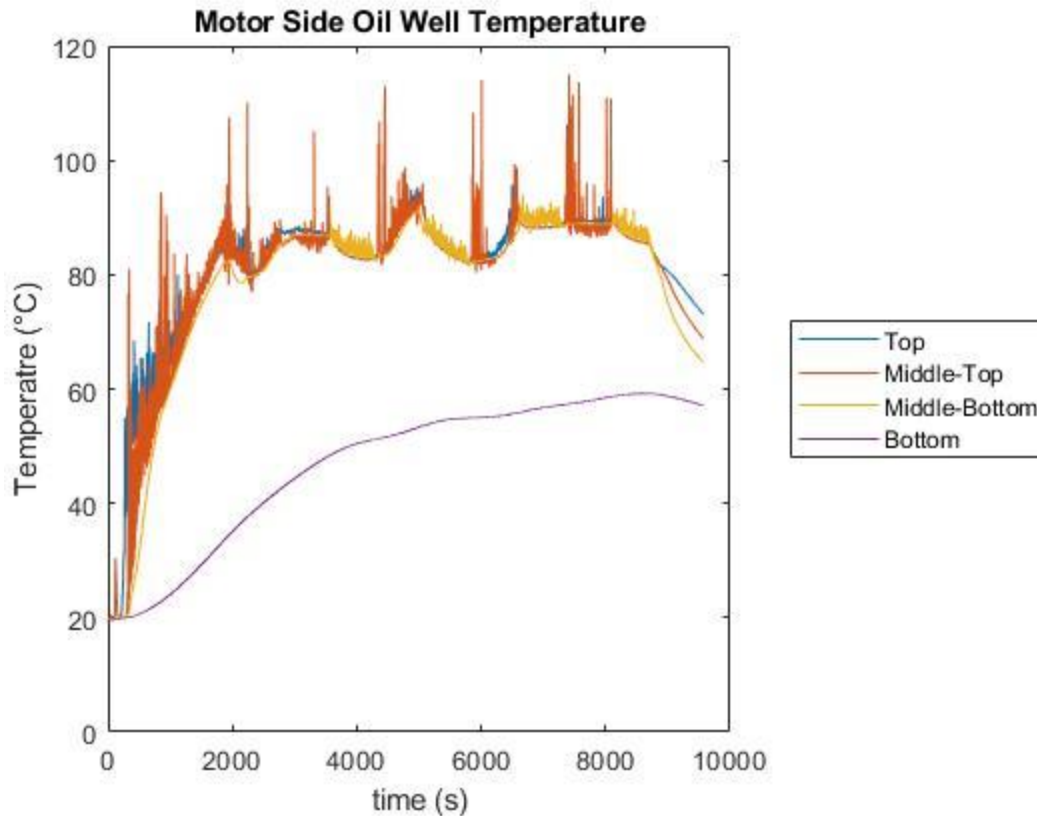
**Figure 5.31:** Torque profile of the system with respect to time.

Oil temperatures were again maintained at approximately 82.2 °C during the test and observed the rotational cooling affect. Operators expected this and allowed the oil to heat above 82.2 °C while the turbine was at rest so the oil was at the desired temperature during operation. Figure 5.32 shows

the Governor Side oil well temperature profile below, and Figure 5.33 on the following page shows the Motor Side oil well temperature profile. Unfortunately, the Bottom thermocouple in the Governor Side oil well failed at the beginning of the test and had to be corrected. This resulted in extraneous data showing a negative oil temperature which did not occur.

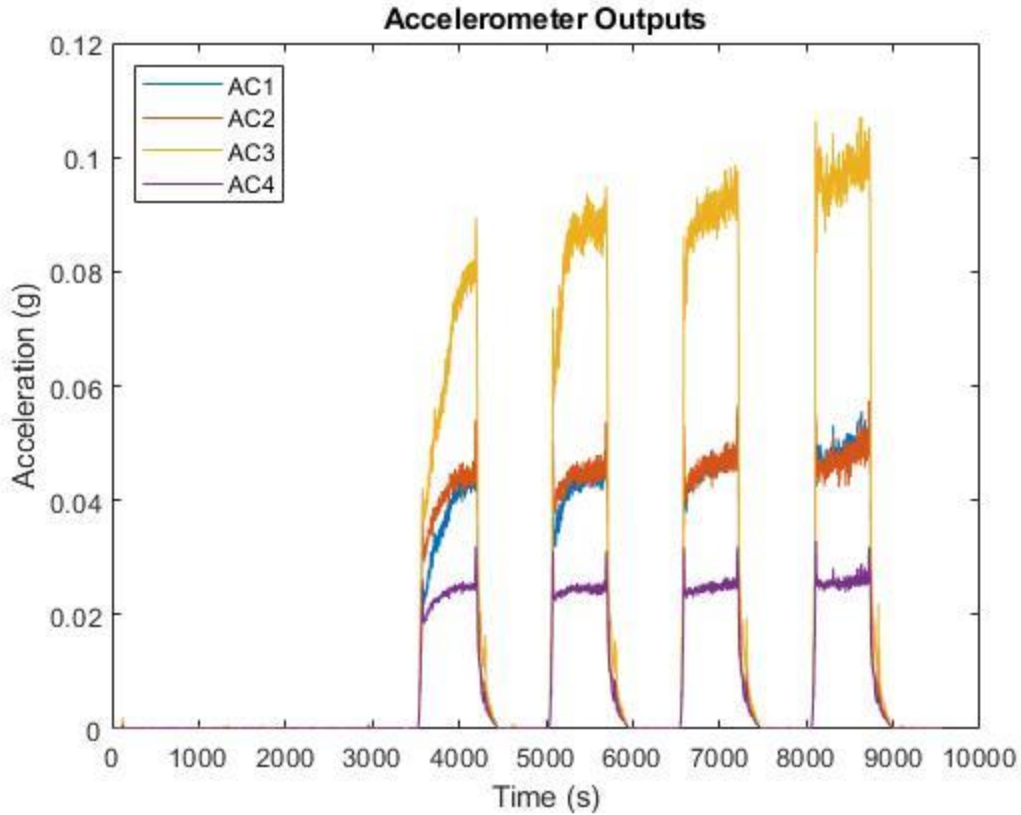


**Figure 5.32:** Governor Side oil well temperature profile with respect to time.



**Figure 5.33:** Governor Side oil well temperature profile with respect to time.

Vibrations were again recorded using the accelerometers. The vibrational profile of the system showed accelerations below those recorded in the hotter 93.3 °C test. Of note, accelerometers 1, 2, and 4 all experienced accelerations below 0.06 g for the entire test, while accelerometer 3 reached an acceleration as high as 0.1 g. This difference could have been caused by a multitude of factors such as poor tightening of the Motor Side casing which the accelerometer was attached to. Figure 5.34 on the following page shows the recorded accelerations of all four accelerometers with respect to time.

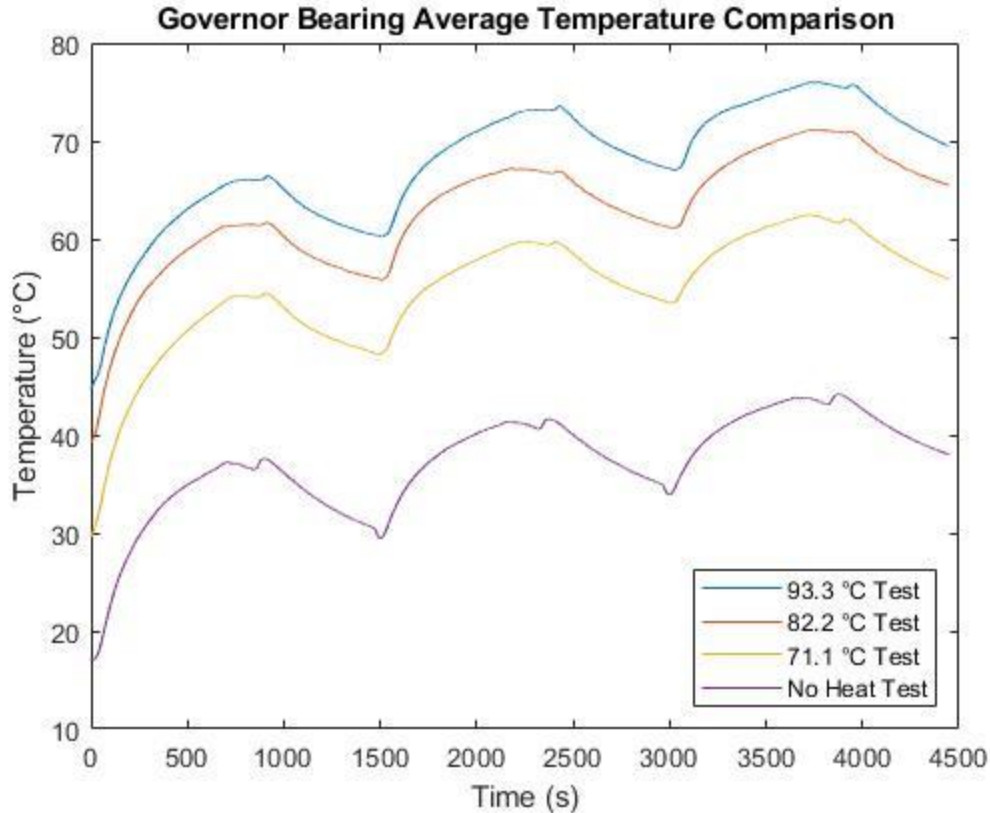


**Figure 5.34:** Output acceleration of all four accelerometers with respect to time.

### 5.3. Data Comparisons

#### 5.3.1. Bearing Temperatures

During the start-stop tests, as temperature of the oil increased, the average temperature of the bearings increased as well. This is easily visualized by comparing the bearing temperatures during the three run cycles of the unheated, 71.1 °C, 82.2 °C, and 93.3 °C tests. Figure 5.35 on the following page shows the average temperature of the Governor Side bearing during the three run cycles of each test. Of note, the fourth run cycle of the 82.2 °C test was not shown in this graph as well as the heat up periods for the heated tests.

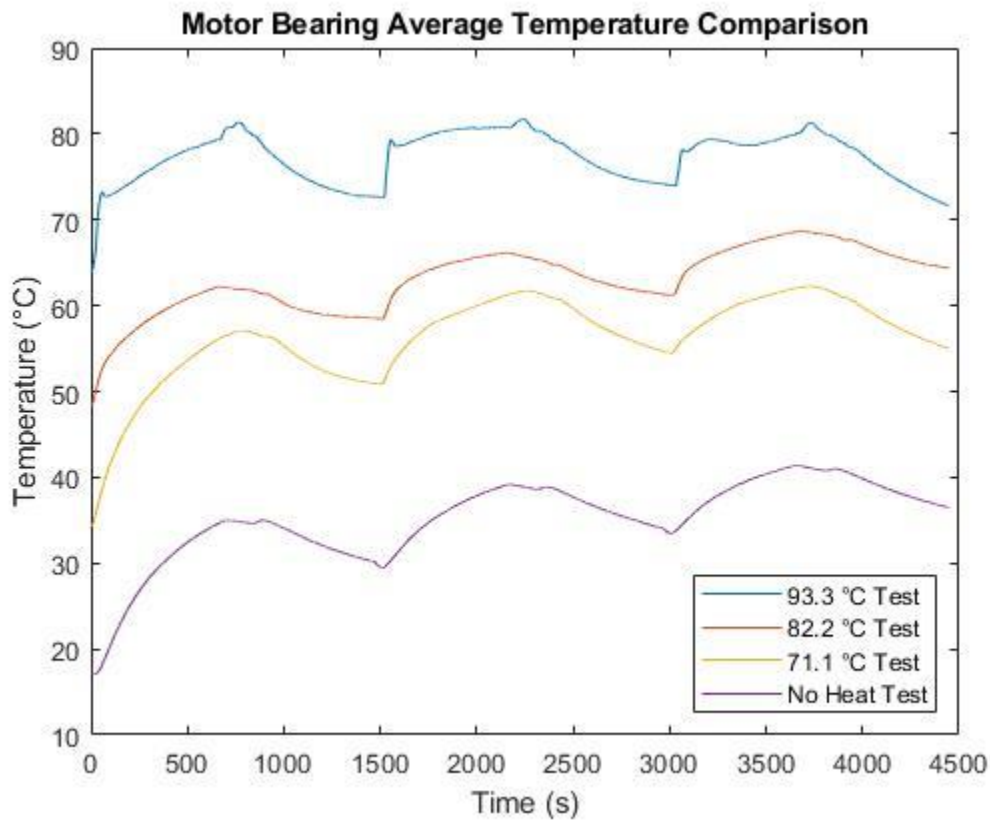


**Figure 5.35:** Comparison of the Governor Side bearing average temperature during the unheated, 71.1 °C, 82.2 °C, and 93.3 °C start-stop tests.

With the increase in oil temperature the bearing temperature increased by approximately 10 °C between each test except for between the 82.2 °C and 93.3 °C tests. In this case there was only a 5 °C temperature change in the bearing. All tests experienced the same cooling curve during rest periods of the test.

Similarly, the Motor Side bearing temperature profile of all tests was plotted together. As with the Governor Side bearings, the Motor Side bearings followed the same temperature profile for each test with an increase in the bearing temperature as the oil temperature increased. However, due to

operator error of overfilling the Bearing Side oil well during the 93.3 °C test, the temperature profile is less consistent for the Motor Bearing in the 93.3 °C test, and it resulted in a larger temperature difference between tests. Figure 5.36 below shows the comparison of the averaged Motor Side bearing temperature for the unheated, 71.1 °C, 82.2°C, and 93.3°C start-stop tests. Again, the heat up period and fourth run time of the 82.2 °C were omitted from the plot to make comparison consistent.



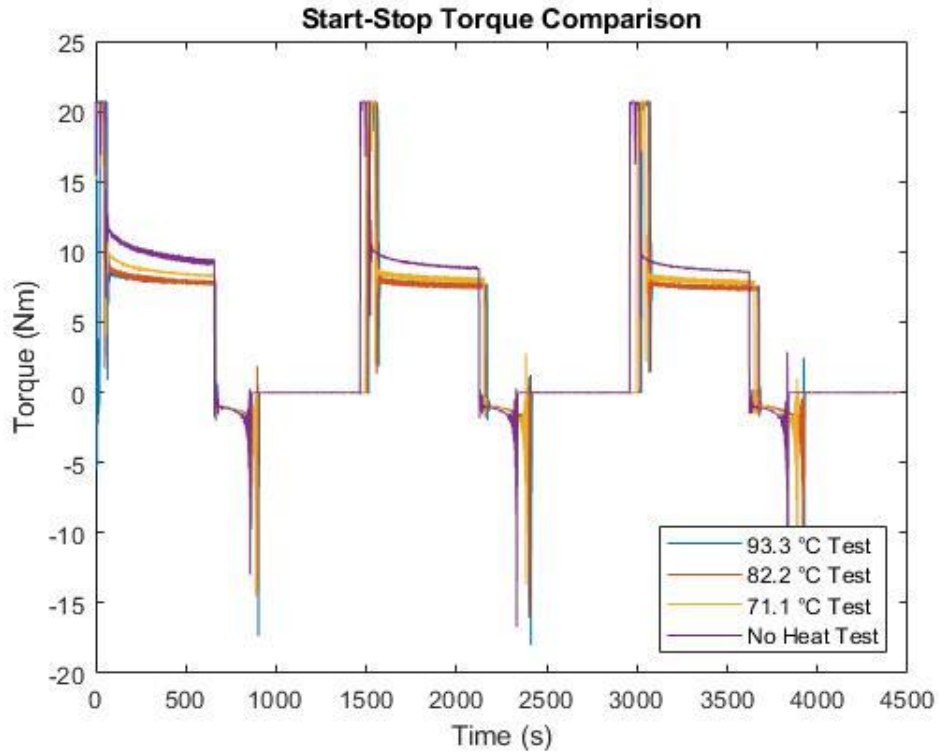
**Figure 5.36:** Comparison of the Motor Side bearing average temperature during the unheated, 71.1 °C, 82.2 °C, and 93.3 °C start-stop tests.

The bearing temperature difference between each test was more pronounced as there was a smaller volume within the oil well meaning the heat dissipated from the oil to the bearing at a greater rate than in the Governor Side bearing. As previously mentioned, the temperature difference between the 82.2 °C and 93.3 °C tests was exaggerated by operator error.

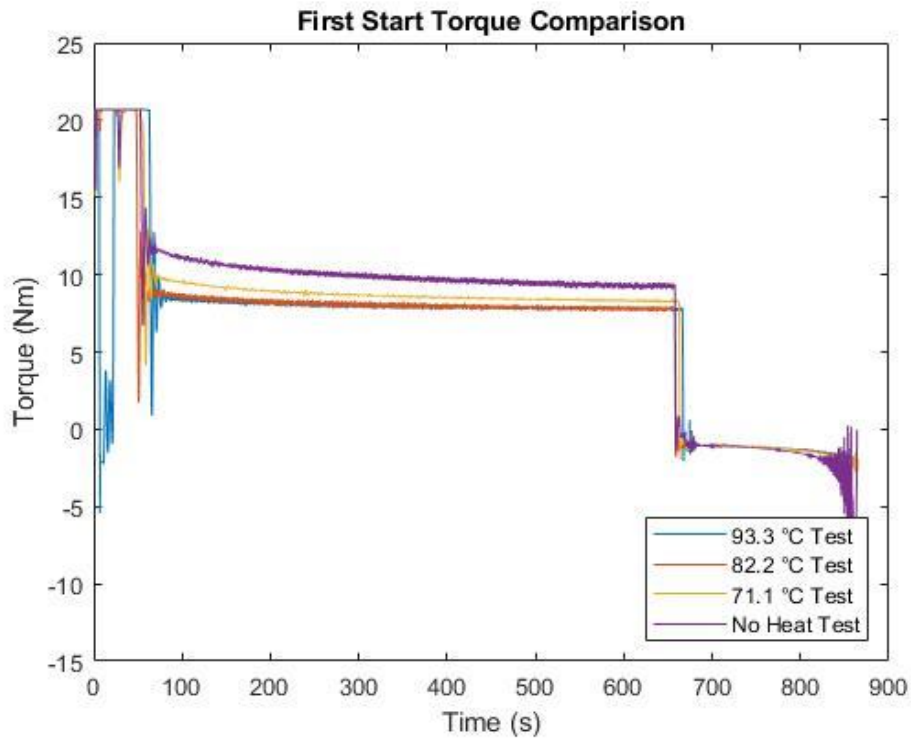
### ***5.3.2. Torque***

As the temperature of the oil increased its viscosity decreased resulting in a decreasing torque of the system. This phenomenon became less pronounced the hotter the oil became showing essentially no change between the torques of the 82.2 °C and 93.3 °C tests. Unfortunately, for all tests regardless of oil temperature, the peak start-up torque was too large to measure by the torque meter. Figure 5.37 on the following page shows the torque profiles of the unheated, 71.1 °C, 82.2 °C, and 93.3 °C start-stop tests excluding the fourth torque curve of the 82.2 °C and the heat up time required for each test. Figure 5.38 on the following page shows the same data as Figure 5.37, but highlighting only the first torque curve of all four tests.





**Figure 5.37:** Comparison of the torque profiles of the unheated, 71.1 °C, 82.2 °C, and 93.3 °C start-stop tests.

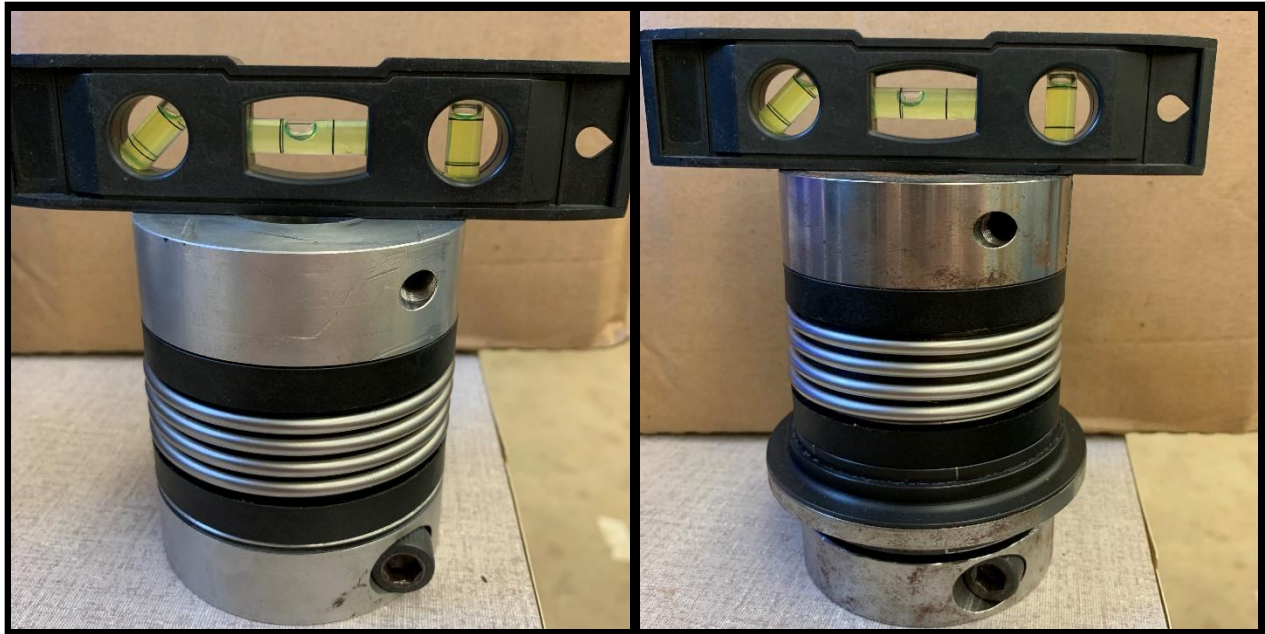


**Figure 5.38:** Comparison of the first torque curve of the unheated, 71.1 °C, 82.2 °C, and 93.3 °C start-stop tests.

### **5.3.3. Vibrations**

Unfortunately, vibrations of the system became difficult to compare as too many variables were affecting the accelerometers with each test. Accelerometers 1 and 3 were placed on the top of the removable covers of the Governor Side and Motor Side bearing housings. Because these covers had to be removed and reattached for the bearing inspection between each test, there was the possibility the covers were not attached to the turbine casing with the same tightness each time. If the cover was looser in one test compared to the other, there was the potential for excess rattling to occur which would lead to higher vibrations and recorded accelerations.

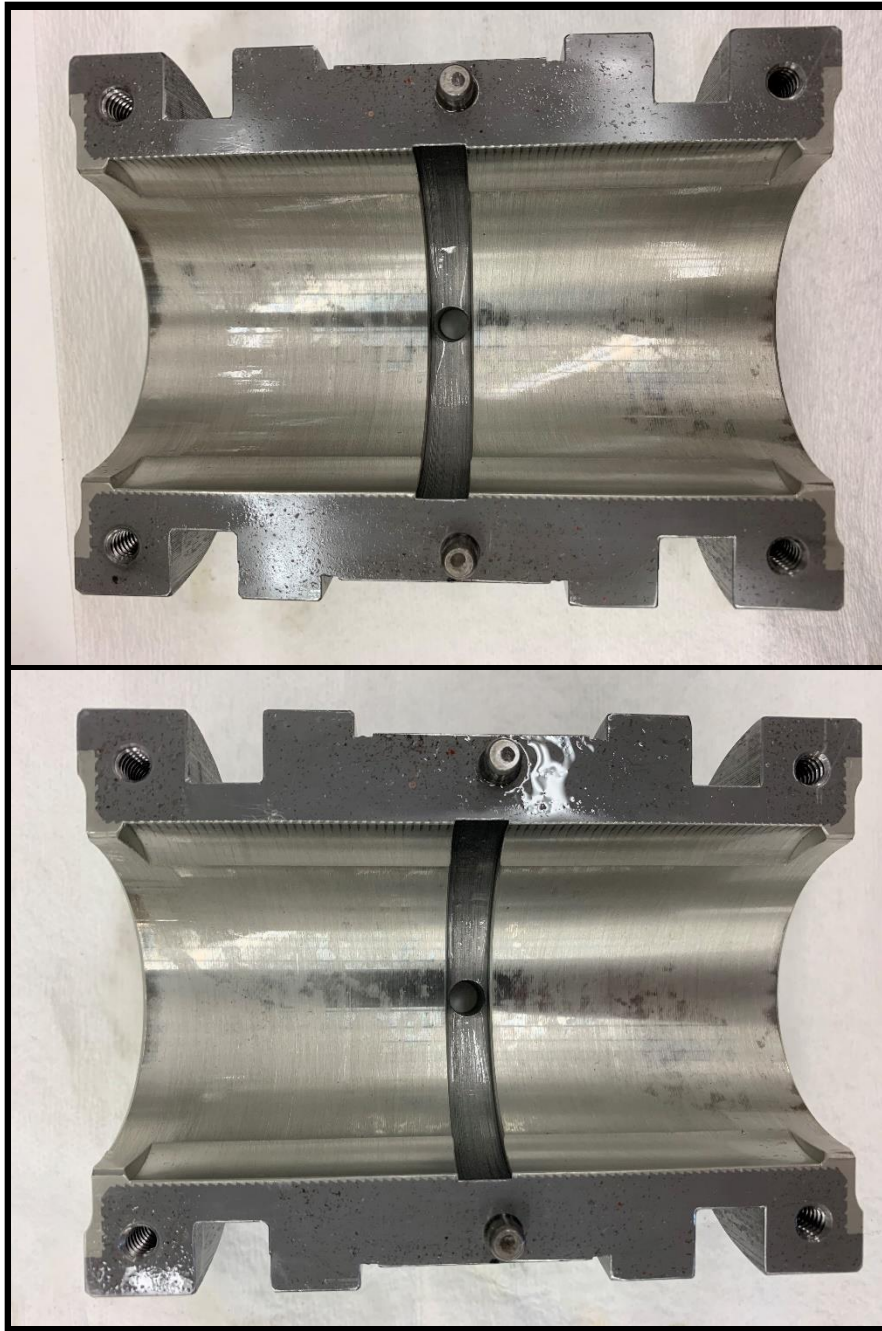
However, the largest source of vibrational error was caused by the failure of the couplings. As testing progressed the couplings began to experience physical damage as the torque values at initial start-up were higher than anticipated and greater than their physical limits. This caused a shifting of the motor which caused lateral deflection of the shaft couplings which were also outside the limitations of the couplings. Realignments were conducted between tests as previously stated which helped alleviate the problem, but the same issues would occur after successive start-ups of the system. The last two tests conducted, the 82.2 °C and 71.1 °C constant speed tests, were unable to be completed due to excessive audible noise and visual vibrations occurring from the broken couplings. Figure 5.39 on the following page shows the permanent deflection of the couplings noted after disassembly of the entire system.



**Figure 5.39:** Permanent deflection of couplings denoted by uneven level.

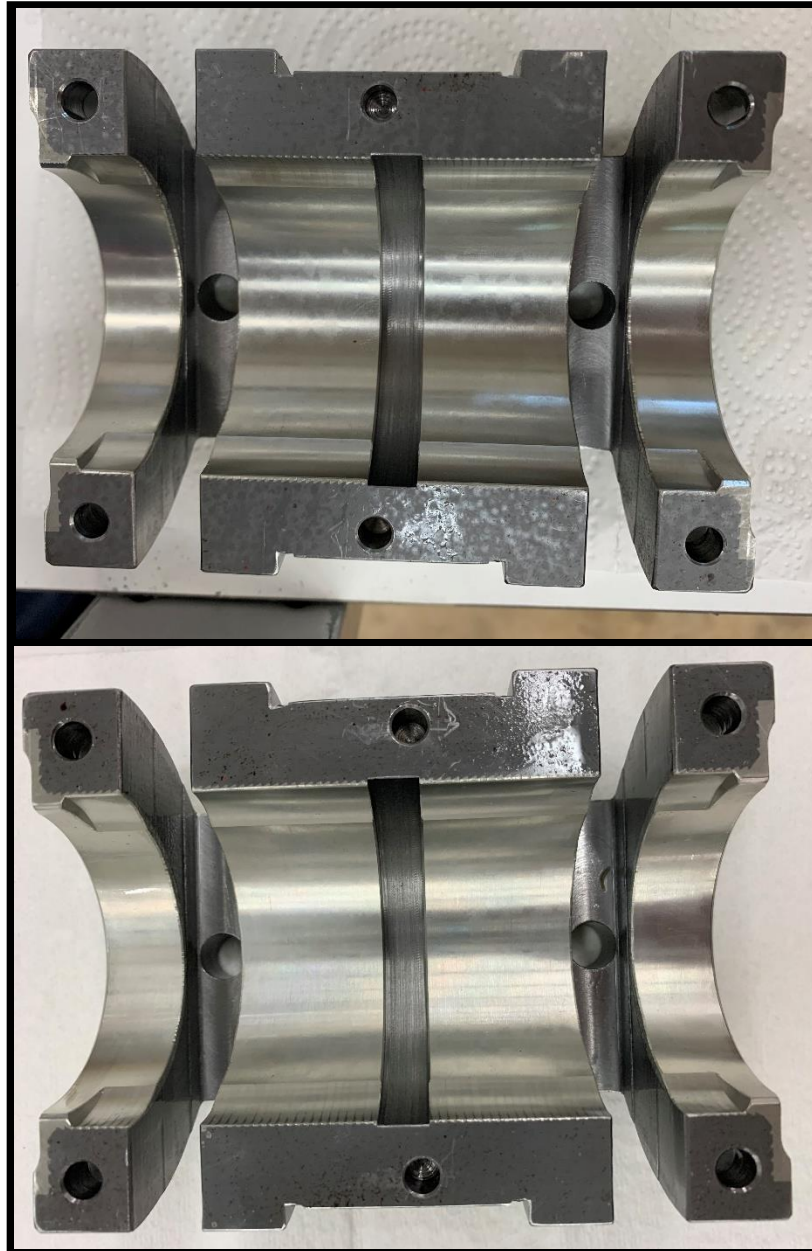
### **5.3. Bearing Inspection Photographs**

As mentioned in sections 4.1 and 4.2, a bearing inspection was to be conducted before and after each test. If no damage was observed in the post-test inspection of a bearing, the bearing could be placed back into the turbine and the inspection also counted as the pre-test inspection for the next upcoming test. During testing minimal wear was seen in the bottom bearings of both the Motor Side and Governor Side bearings. The wear was small enough that no apparent changes were seen between each individual test, but can be noticed when compared to photographs taken before all testing began. The top bearings of both sides showed no wear. Figure 5.40 on the following page shows the comparison between the Motor Side bottom bearing before testing and after all testing was completed



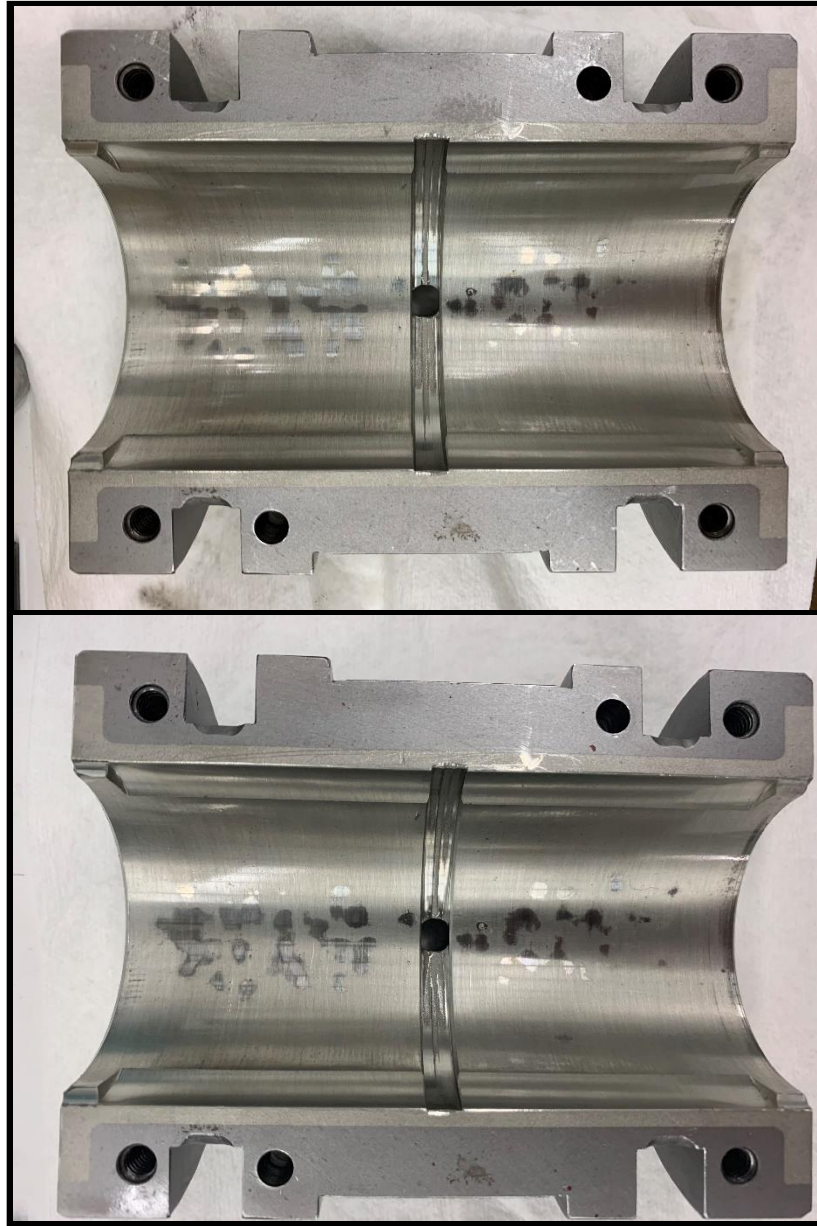
**Figure 5.40:** Motor Side bottom bearing before testing and after all testing comparison. Before photograph is on top and the after all testing photograph is on bottom.

Figure 5.41 shows the comparison of the top Motor Side bearing before testing began and after all testing was completed. No wear was visually observed on this piece of the bearing.



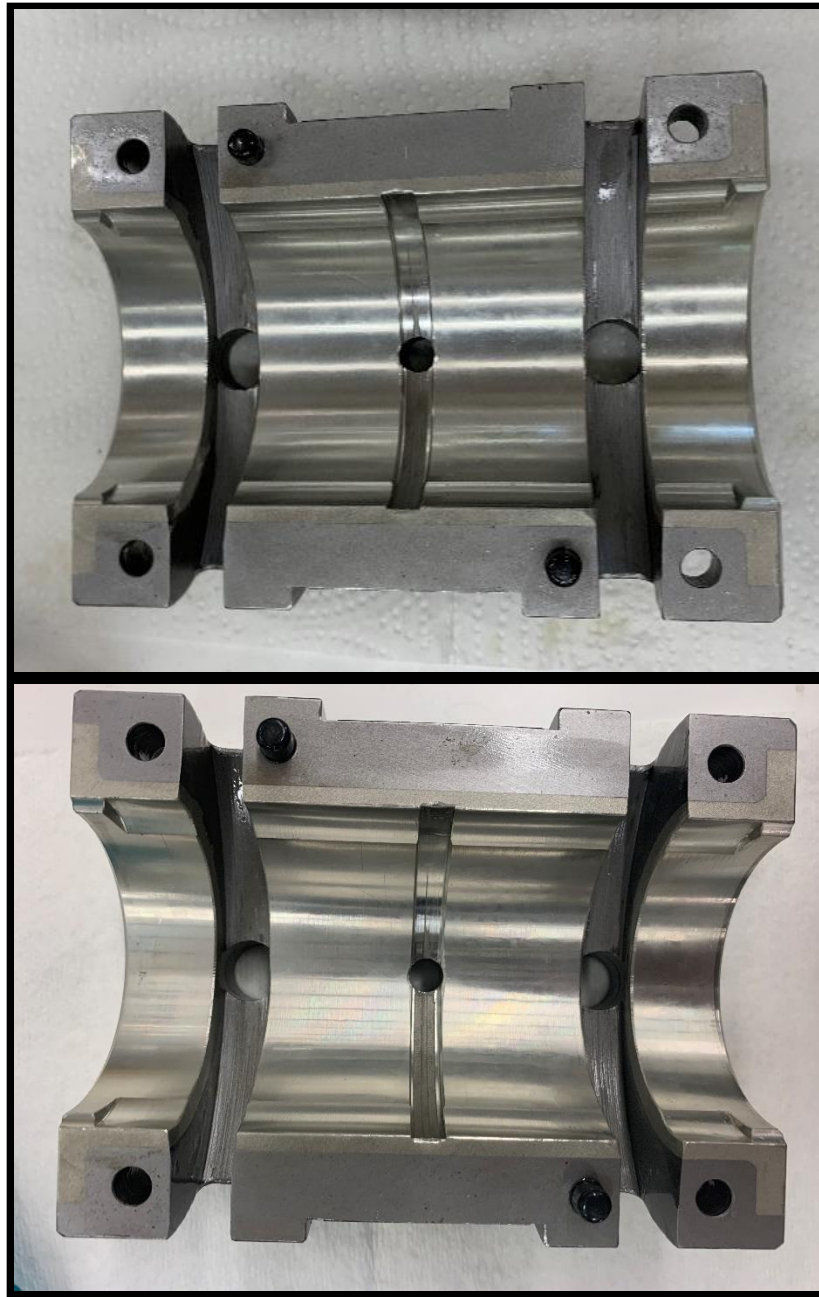
**Figure 5.41:** Motor Side top bearing before testing and after all testing comparison. Before photograph is on top and the after all testing photograph is on bottom.

Figure 5.42 shows the comparison of the bottom Governor Side bearing before testing began and after all testing was completed. Minimal wear of the bearing was visually noted.



**Figure 5.42:** Governor Side bottom bearing before testing and after all testing comparison. Before photograph is on top and the after all testing photograph is on bottom.

Figure 5.43 shows the comparison of the top Governor Side bearing before testing began and after all testing was completed. No visible wear of the bearing was observed.



**Figure 5.43:** Governor Side Top bearing before testing and after all testing comparison. Before photograph is on top and the after all testing photograph is on bottom.

#### 5.4. Error Analysis

For these experiments all statistical error relates to the data acquisition equipment as described in section 3.1. The turbine speed was maintained at  $3595 \pm 5$  RPM for all tests. At the upper bound of this range the turbine was spinning at 3600 RPM. When combined with the  $\pm 0.01\%$  error of the tachometer this means there was a maximum error of  $\pm 0.36$  RPM. The highest torque recorded exceeded the readable limit as discussed and therefore does not have a calculable error, but the largest steady state torque experienced was approximately 12 Nm, which combined with the torque meter uncertainty of  $\pm 0.2\%$ , resulted in a maximum steady-state torque error of  $\pm 0.024$  Nm. Accelerometers had a constant uncertainty of  $\pm 2\%$  g for their acceleration.

The only recorded data operated on mathematically were the bearing temperatures used to calculate the bearing average temperature. All thermocouples had an uncertainty of  $\pm 0.5$  °C. All averages of the bearing temperatures used 4 thermocouples to compute the average. Equation 5.1 below shows the error propagation for adding uncertainties.

$$\delta(a + b + c + d) = \sqrt{(\delta a^2) + (\delta b^2) + (\delta c^2) + (\delta d^2)} \quad (5.1)$$

To form an average the 4 thermocouples were summed together and divided by 4. Similarly, Equation 5.1 would be divided by 4 to create the average since 4 is a constant value and does not contain uncertainty. Solving Equation 5.1 using the constant thermocouple uncertainty of  $\pm 0.5$  °C and dividing by four results in an average temperature uncertainty of  $\pm 0.25$  °C.



## 6. CONCLUSION

### 6.1. Summary

The effect of oil temperature on the operation and bearing condition of a GS-2 Terry Turbine was investigated. These experiments aimed to record operational data such as bearing temperature, system torque, and system vibrations of the turbine while maintaining the lubrication oil at temperatures of 71.1 °C, 82.2 °C, and 93.3 °C (160 °F, 180 °F, and 200 °F). Also, the physical condition of the bearings was to be checked after each test to check for any signs of damage.

Results showed the increase in oil temperature led to an increase in the overall temperature of the bearings before and during operation. Similarly, as the oil temperature increased, its viscosity decreased causing a reduction in torque of the system. Vibrations of the system did increase with the increase in oil temperature, but they did not seem to hinder operation of the turbine. Unfortunately, torques experienced by the system caused damage to the couplings which created vibrations independent of the oil temperature making comparisons between tests difficult. The exact effect of the oil temperature on vibrations could not be determined.

Bearing inspections did not reveal any damage or wear that seemed to hinder the operation of the turbine. Minor wear on the bottom bearings was visible after running all 8 tests which, in total, included bringing the turbine from standing rest to full speed a total of 25 times, but this wear was deemed insignificant and superficial. It is concluded the oil temperatures tested did not hinder the integrity or capabilities of the bearings. This conclusion is also supported by the bearings ability to withstand the extra vibrations added by the failing couplings and alignment of the system.

## **6.2. Future Work**

Future tests could increase oil temperature to 250 °F to match testing completed on the ZS-1 Terry Turbine. If the turbine withstands oil temperatures of 250 °F, then the oil temperature could be increased until a ‘fatal’ oil temperature is found which renders the turbine inoperable. Also, testing could begin adding water to the oil to mimic water intrusion into the oil wells as experienced by the commercial nuclear power industry. The test facility will remain on standby for as long as the GS-2 Terry Turbine is still on loan from Exelon Corporation.

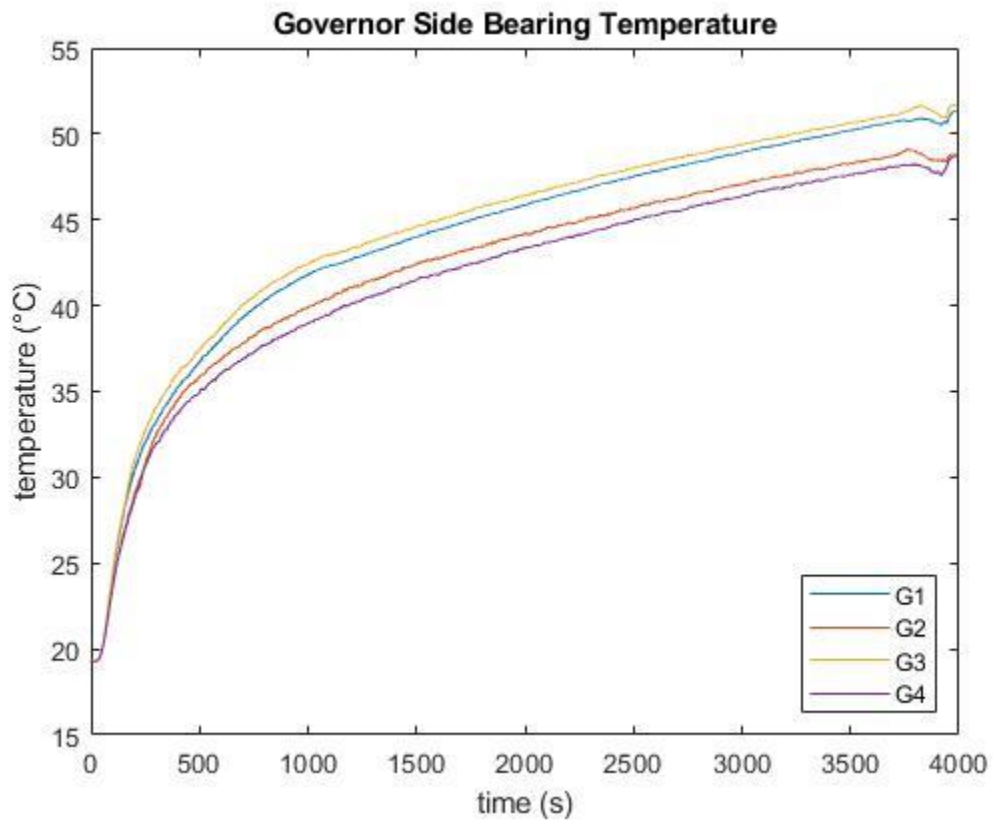
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2. Peck, Diana. *Turbine Oil Degradation and its Effects on Performance of a Terry Turbine in Nuclear Applications*. MS Thesis. Texas A&M University, 2019.
3. Green, Gage. *Effect of Degraded Oil on Terry Turbine Bearing Performance at High Temperature*. MS Thesis. Texas A&M University, 2020.
4. Zhao, O’Brien. “Preliminary Two-Phase Terry Turbine Nozzle Models for RCIC OFF-Design Operation Conditions” Idaho National Laboratory, Jun. 2017 <https://www.osti.gov/servlets/purl/1376860> Accessed 13 Jun 2020.
5. Patil, et al. “Two-phase operation of a Terry steam turbine using air and water mixtures as working fluids.” *Applied Thermal Engineering*, 25 Jan. 2020, pp. 1-12.
6. Childs, Peter. *Mechanical Design*. Elsevier Ltd, Burlington, MA: 2004.
7. Szeri, Andras. *Fluid Film Lubrication*, 2<sup>nd</sup> Ed. Cambridge University Press, New York 2011.
8. Dufrane, K. L., Kannel, J.W., McCloskey, T.H. “Wear of Steam Turbine Journal Bearings at Low Operating Speeds.” *Journal of Lubrication Tech*, Vol. 105 No. 3 (1983): pp. 313-317.

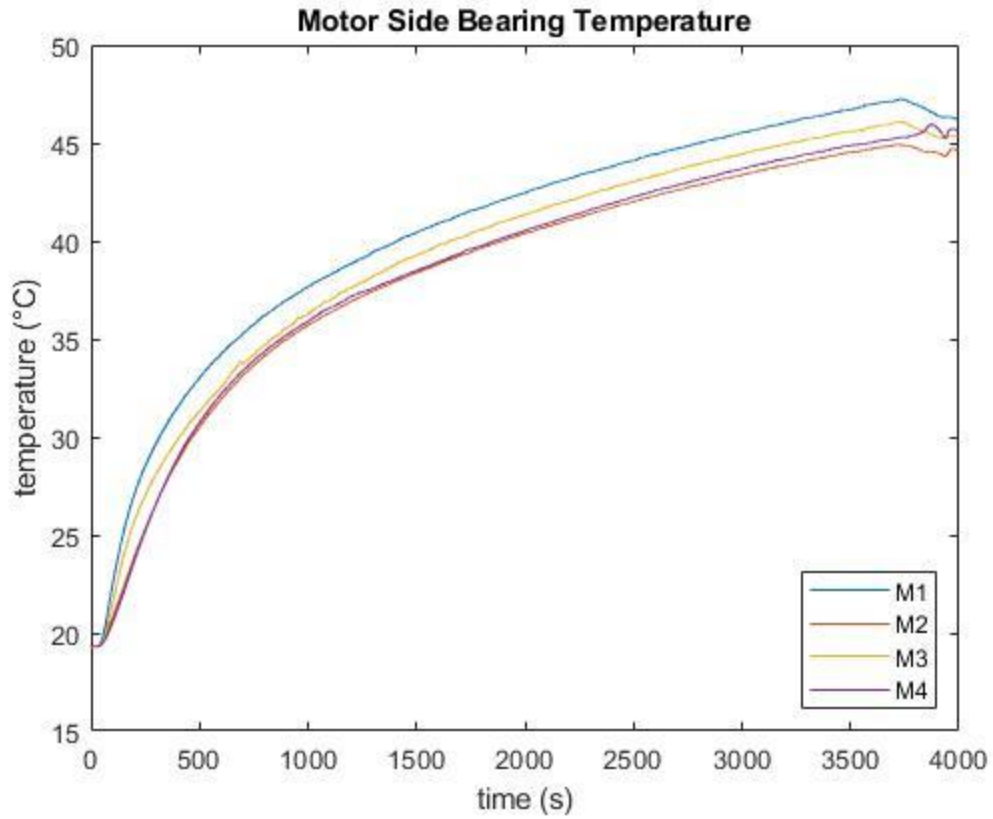
## APPENDIX A

### CONSTANT SPEED TEST PLOTS

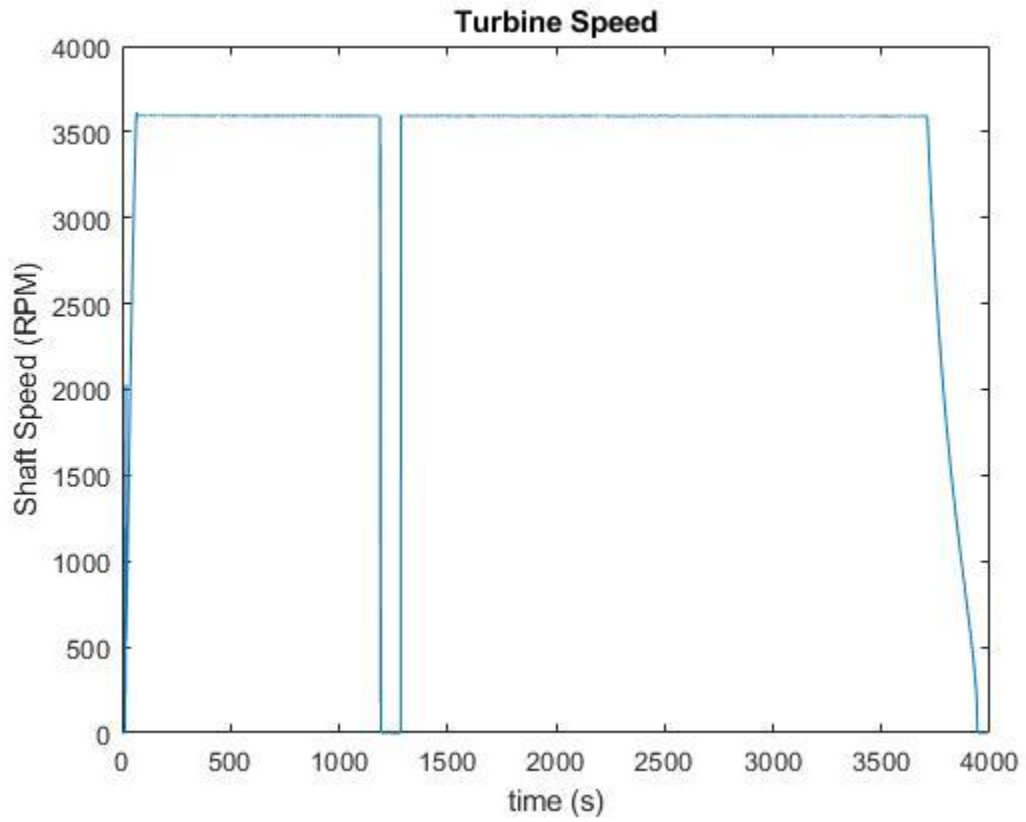
#### A.1. Unheated Constant Speed Test 4/10/2020



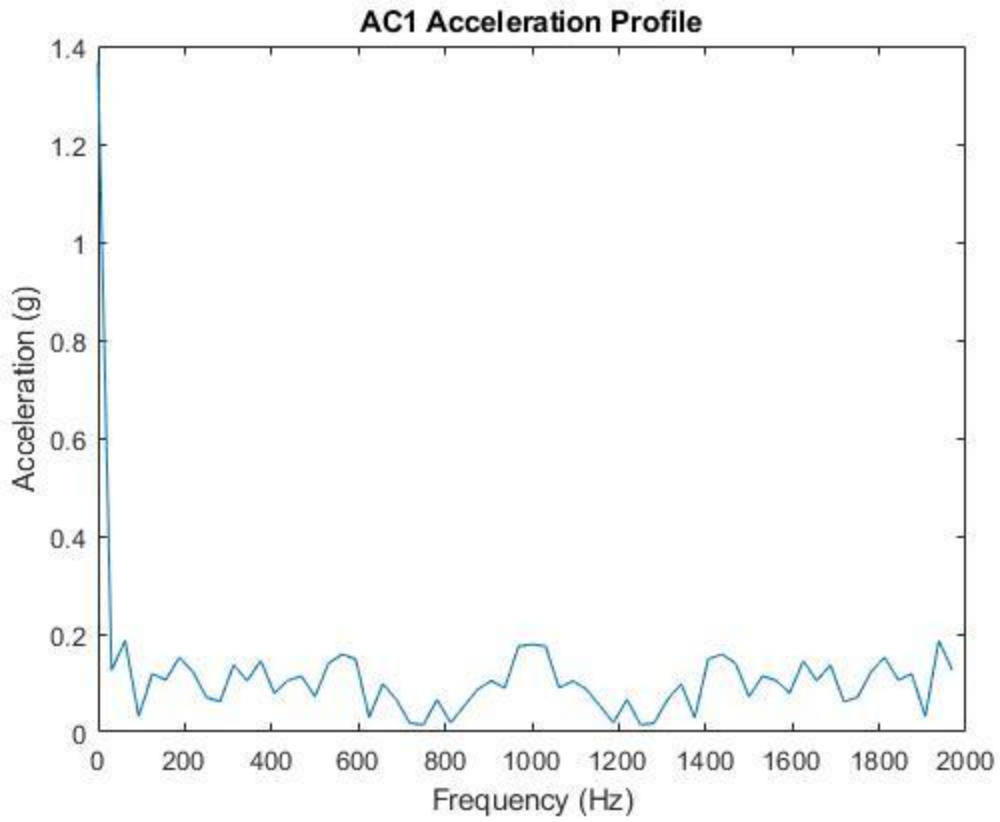
**Figure A-1:** Temperatures of all four Governor Side bearing thermocouples in the unheated constant speed test.



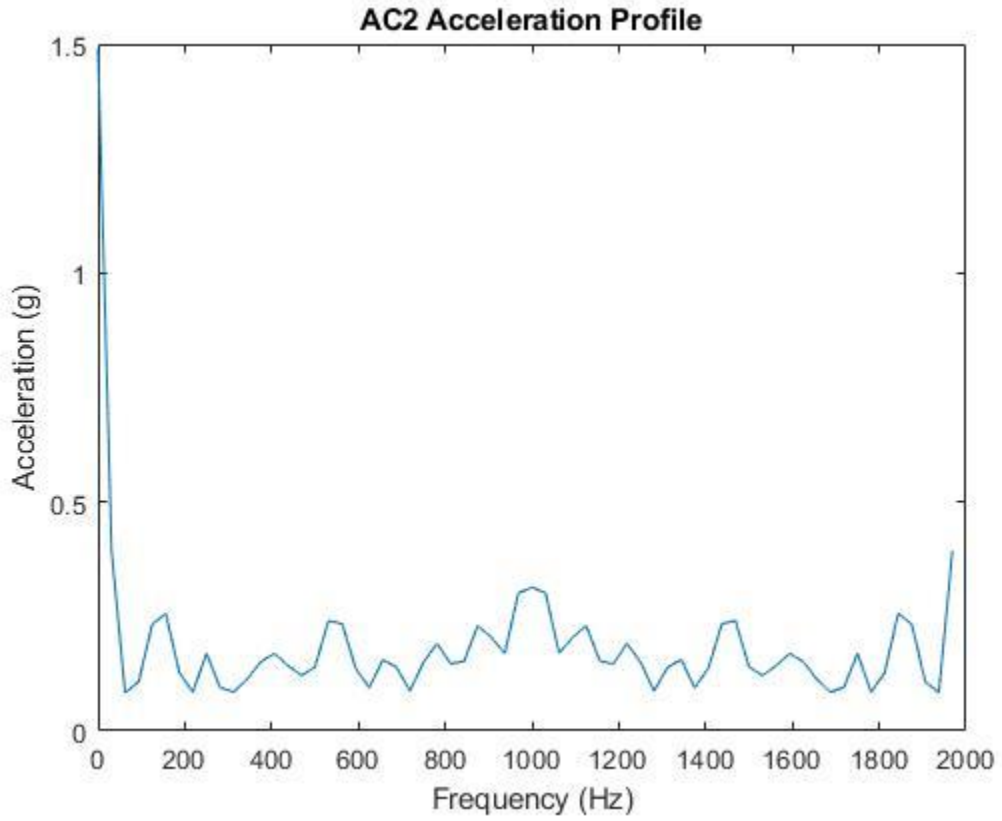
**Figure A-2:** Temperatures of all four Motor Side bearing thermocouples in the unheated constant speed test.



**Figure A-3:** Turbine speed during the unheated constant speed test.

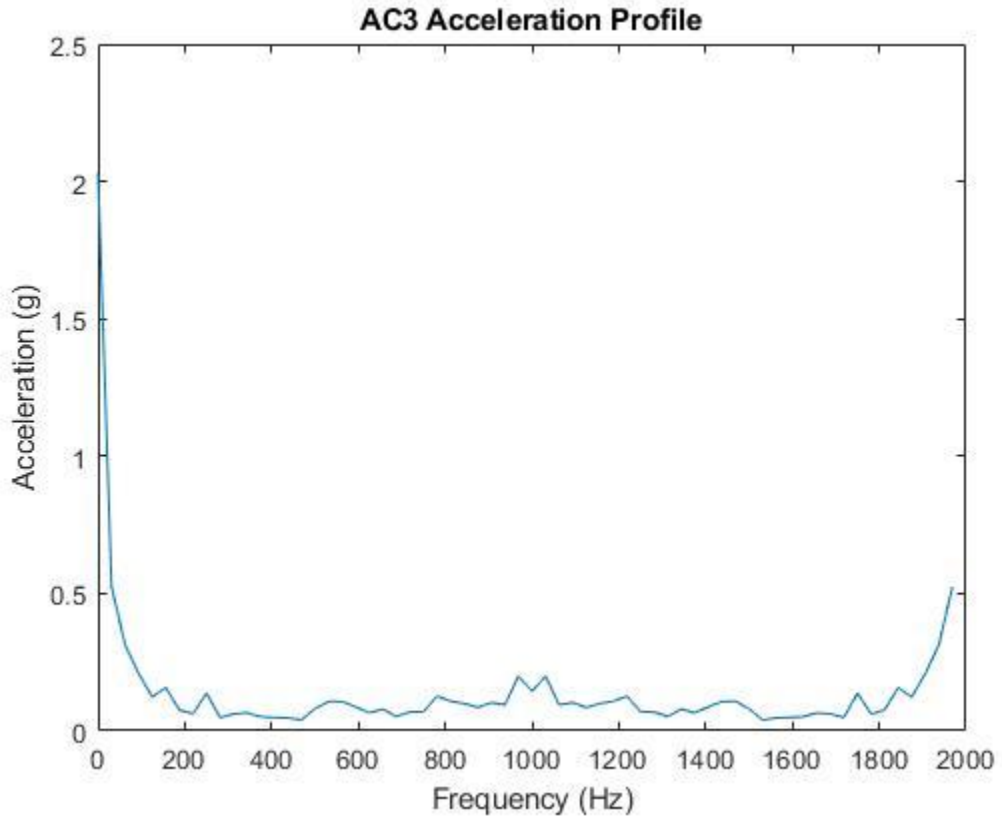


**Figure A-4:** Acceleration profile of accelerometer 1.

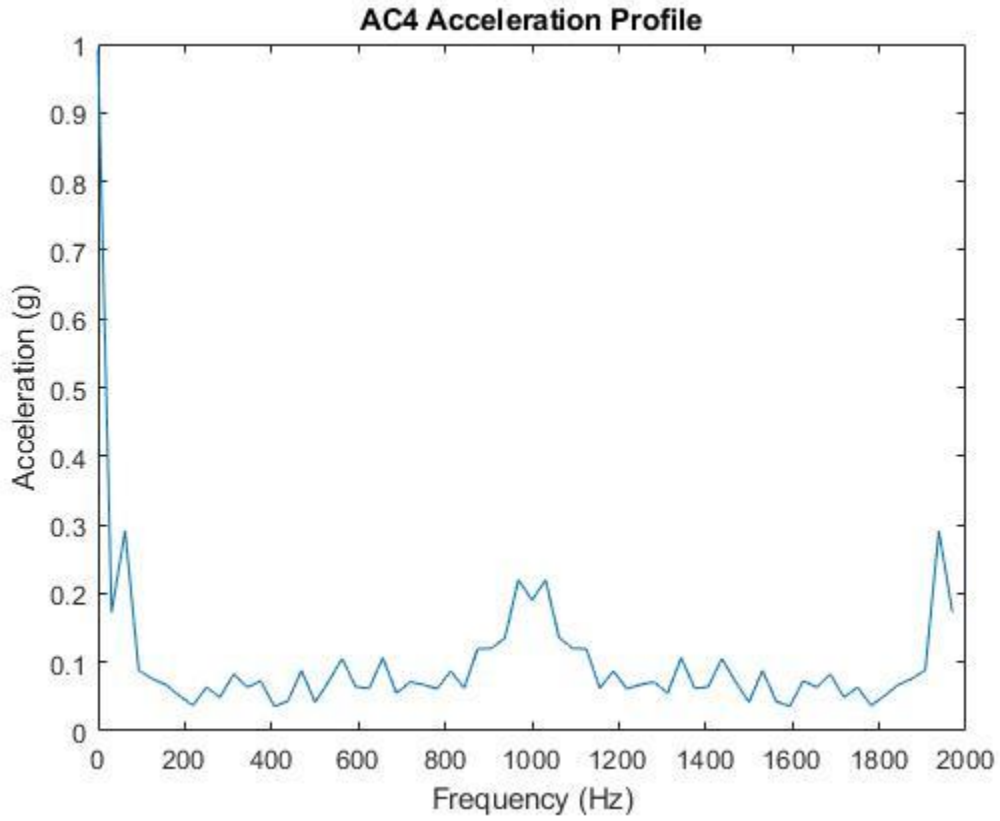


**Figure A-5:** Acceleration profile of accelerometer 2.



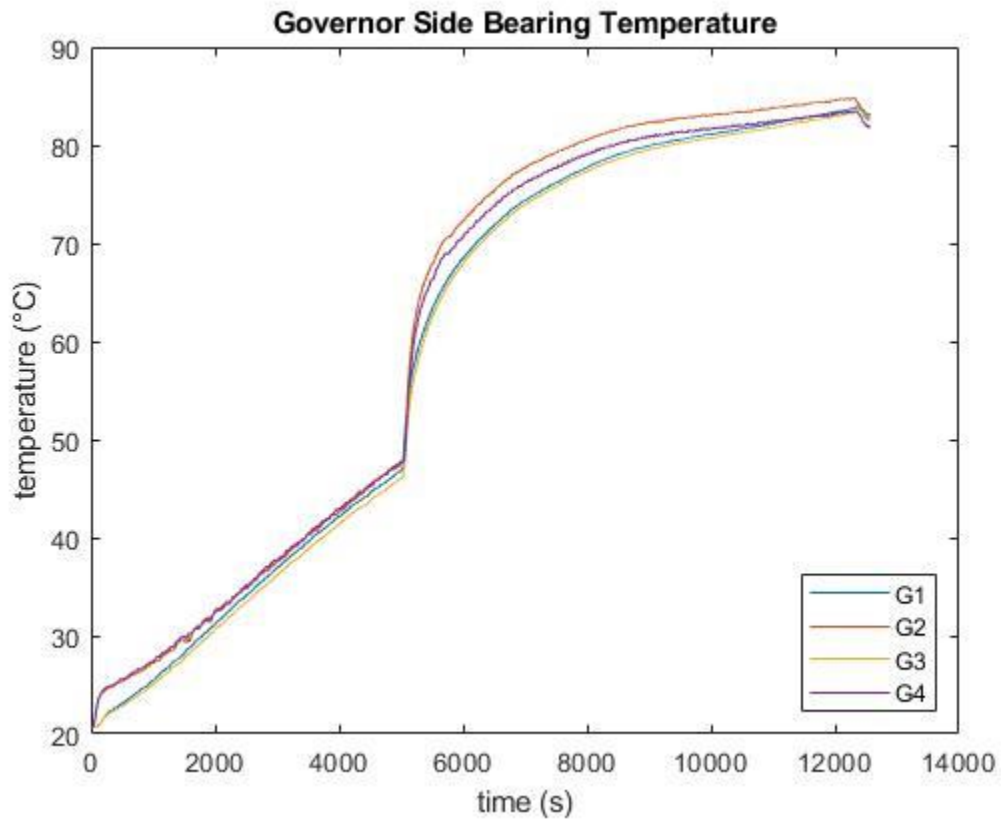


**Figure A-6:** Acceleration profile of accelerometer 3.

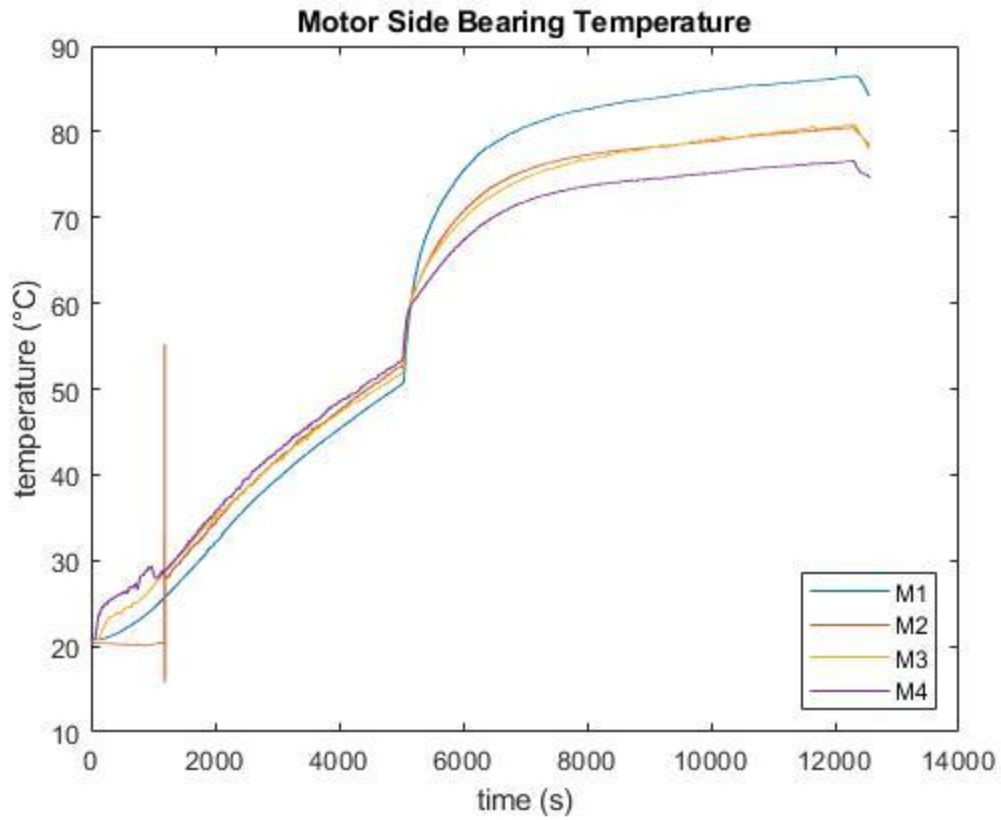


**Figure A-7:** Acceleration profile of accelerometer 4.

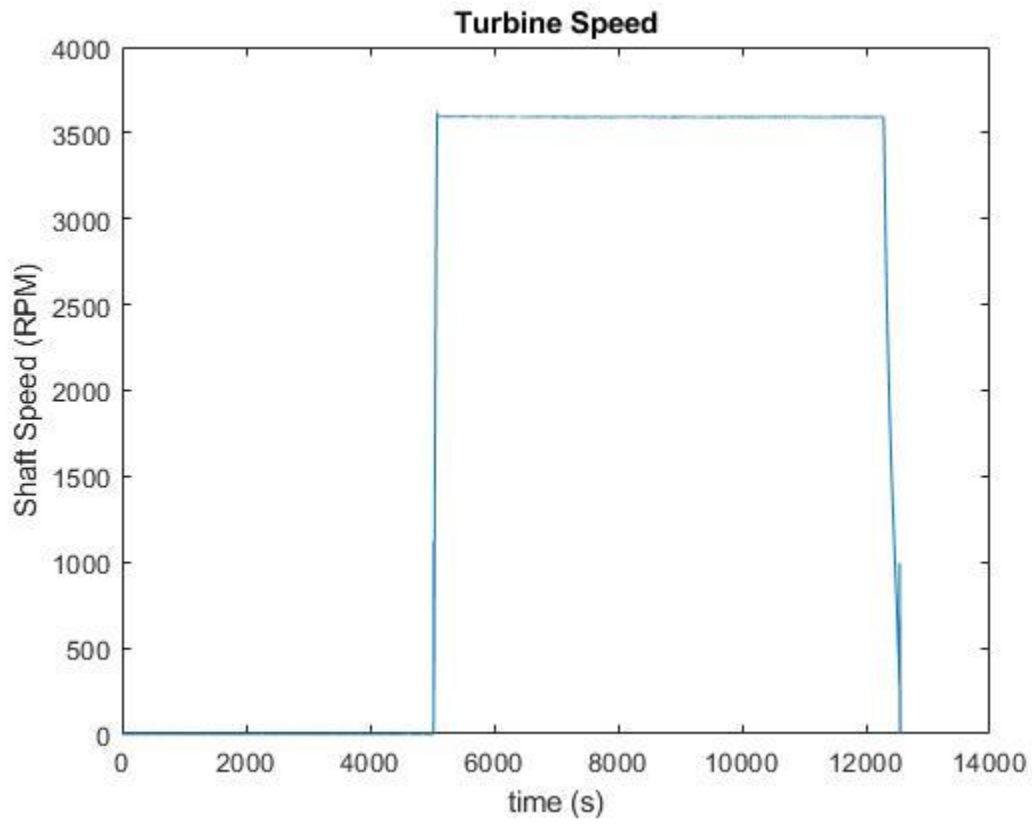
A.2. 93.3 °C Constant Speed Test 4/21/2020



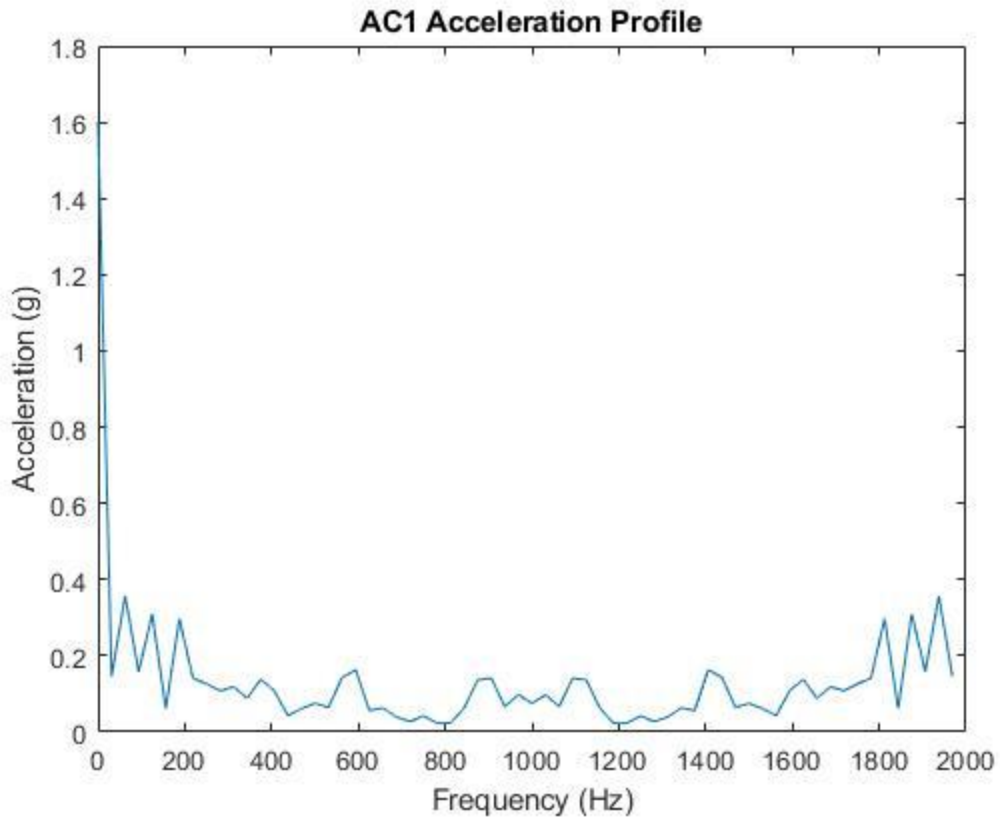
**Figure A-8:** Temperatures of all four Governor Side bearing thermocouples in the 93.3 °C constant speed test.



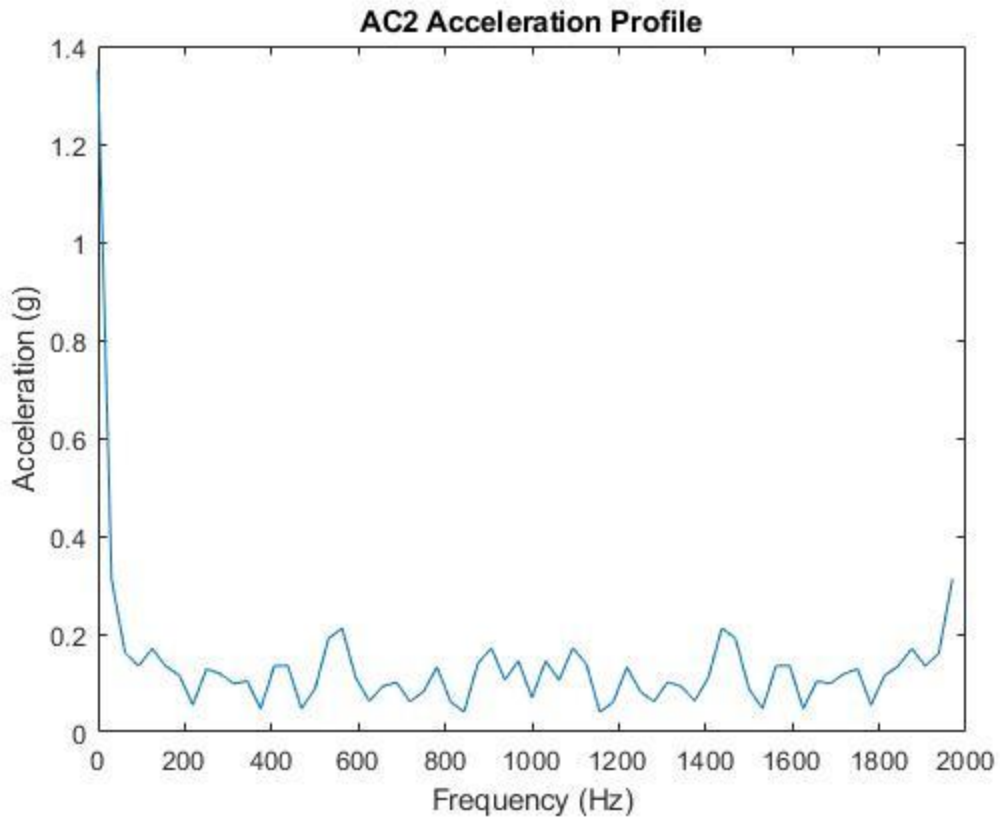
**Figure A-9:** Temperatures of all four Motor Side bearing thermocouples in the 93.3 °C constant speed test.



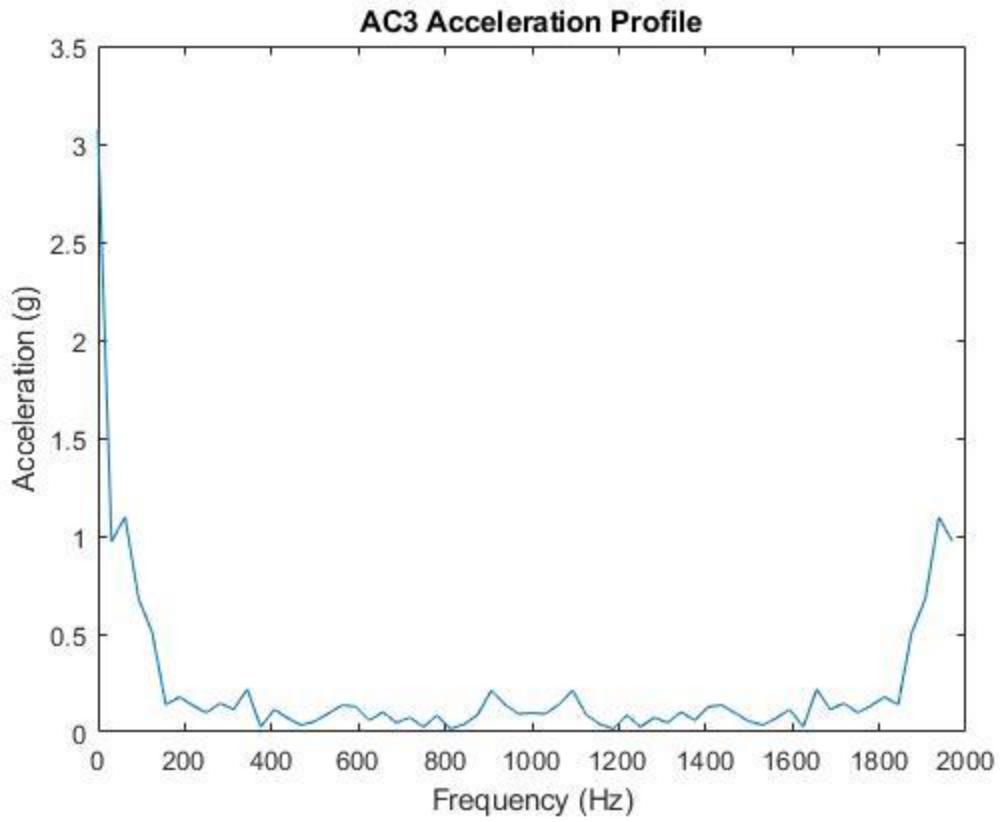
**Figure A-10:** Turbine speed during the 93.3 °C constant speed test.



**Figure A-11:** Acceleration profile of accelerometer 1.

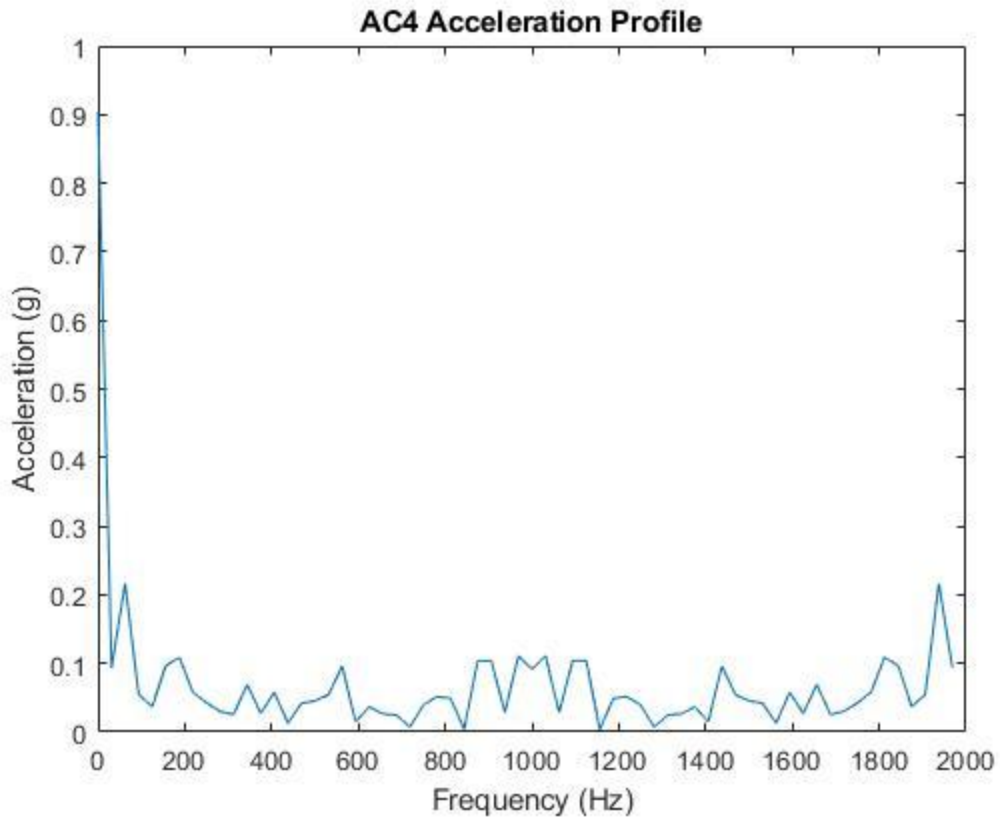


**Figure A-12:** Acceleration profile of accelerometer 2.



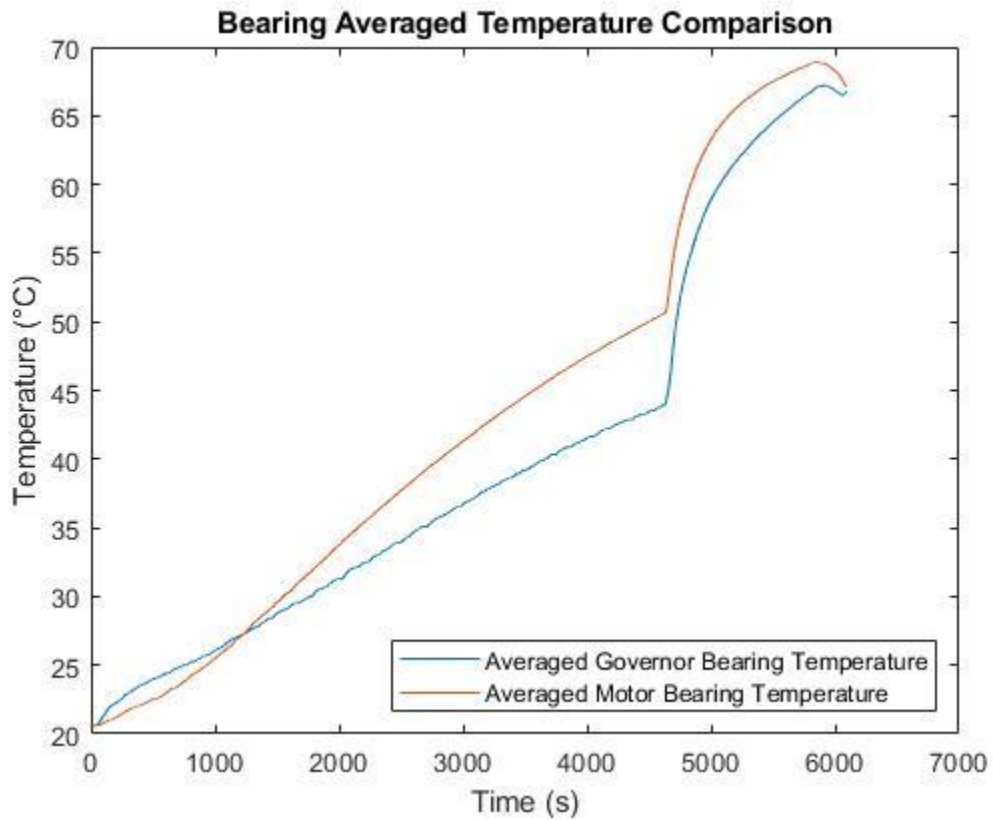
**Figure A-13:** Acceleration profile of accelerometer 3.



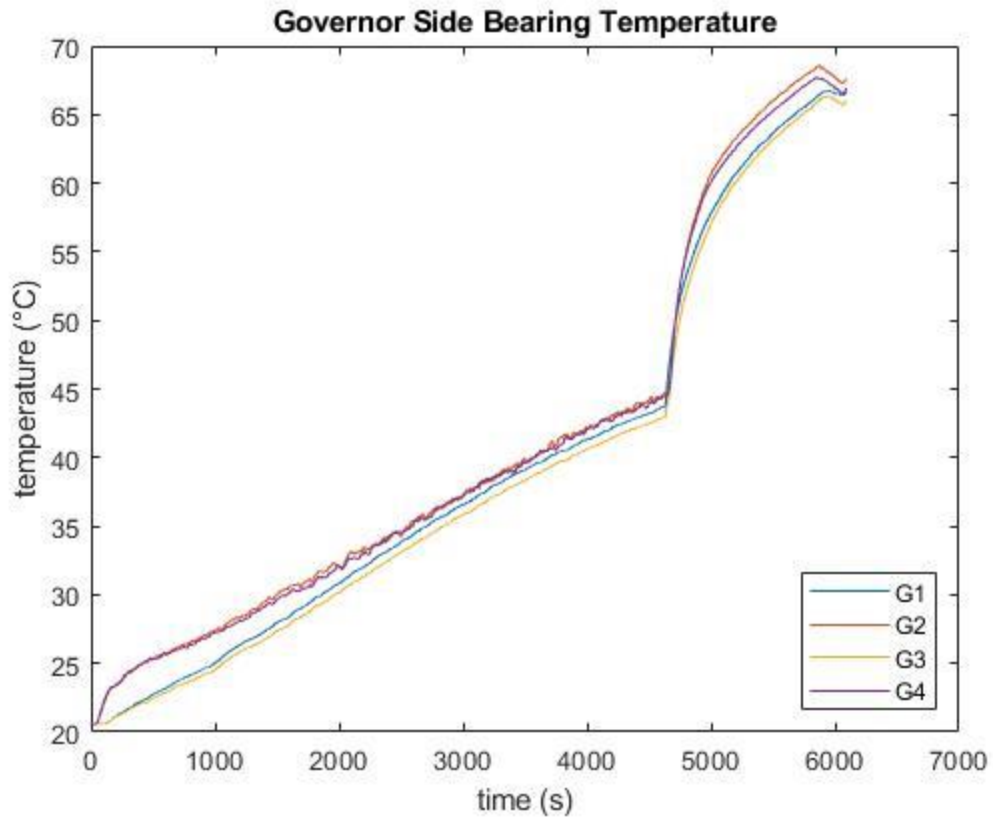


**Figure A-14:** Acceleration profile of accelerometer 4.

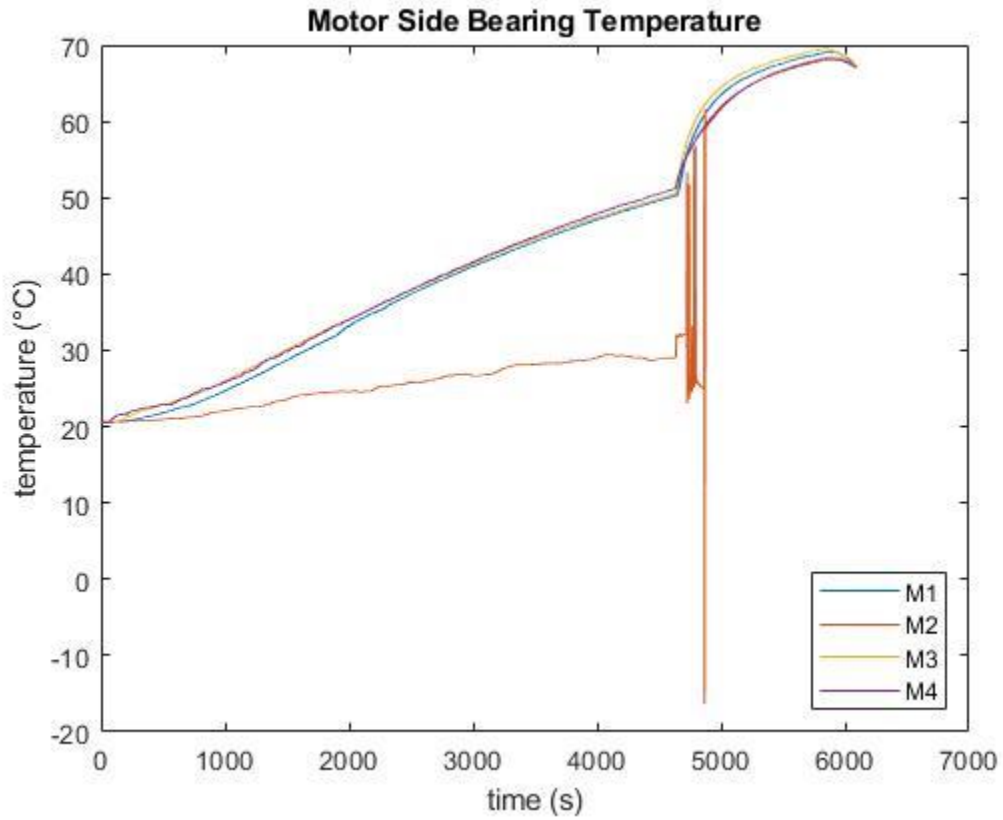
A.3. 82.2 °C Constant Speed Test 4/22/2020



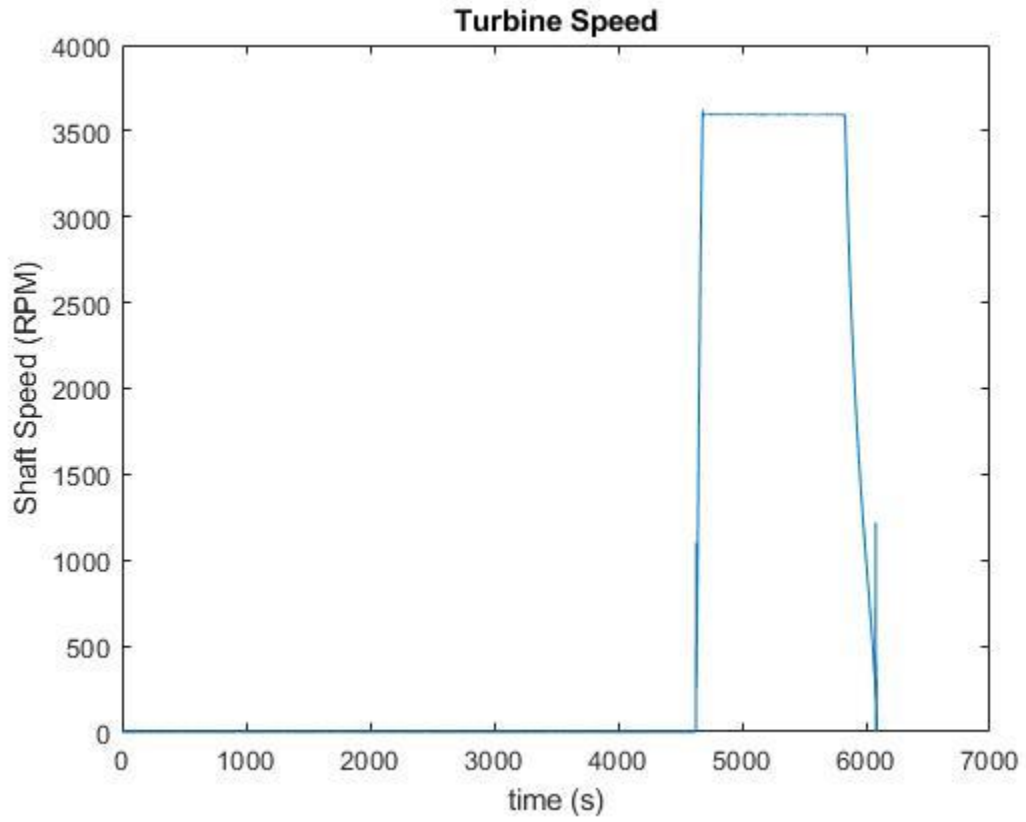
**Figure A-15:** Comparison of the average Motor Side bearing temperature and Governor Side bearing temperature with respect to time for the 82.2 °C constant speed test.



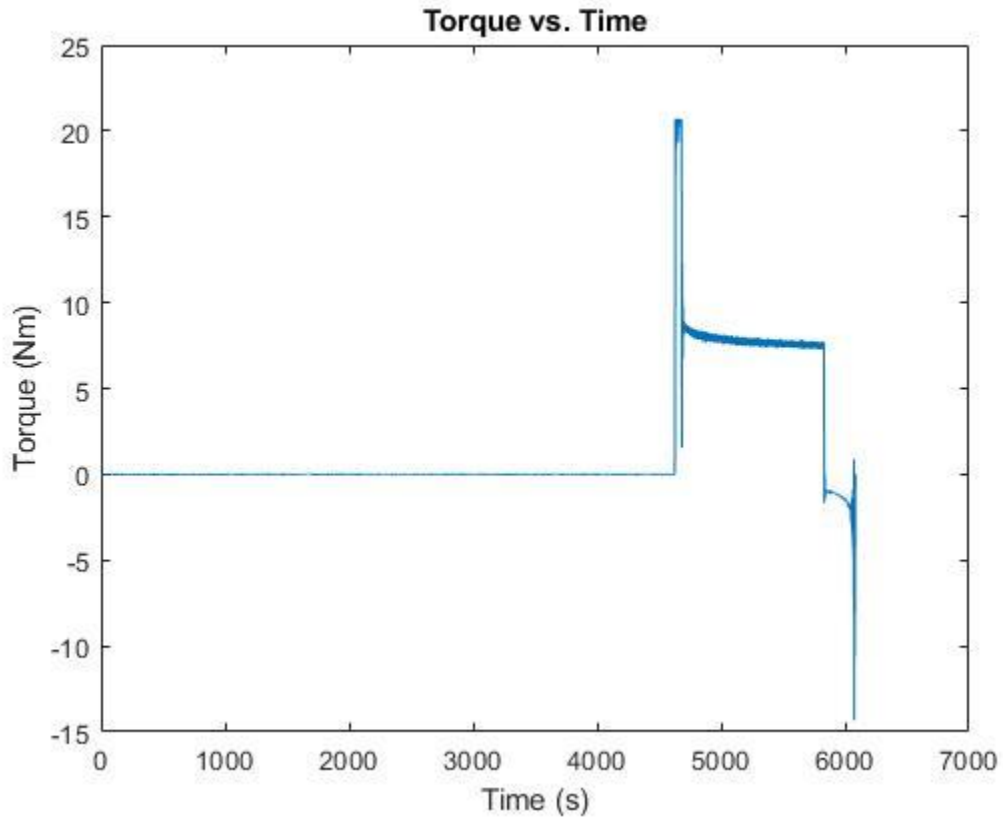
**Figure A-16:** Temperatures of all four Governor Side bearing thermocouples in the 82.2 °C constant speed test.



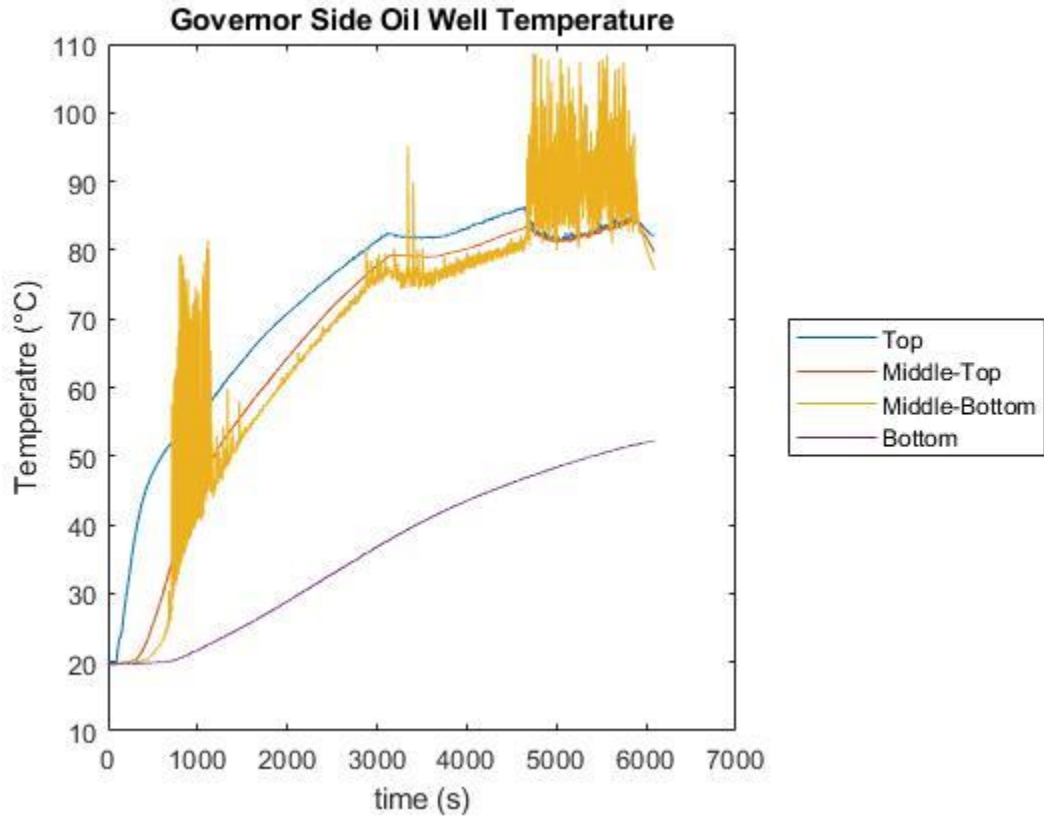
**Figure A-17:** Temperatures of all four Motor Side bearing thermocouples in the 82.2 °C constant speed test.



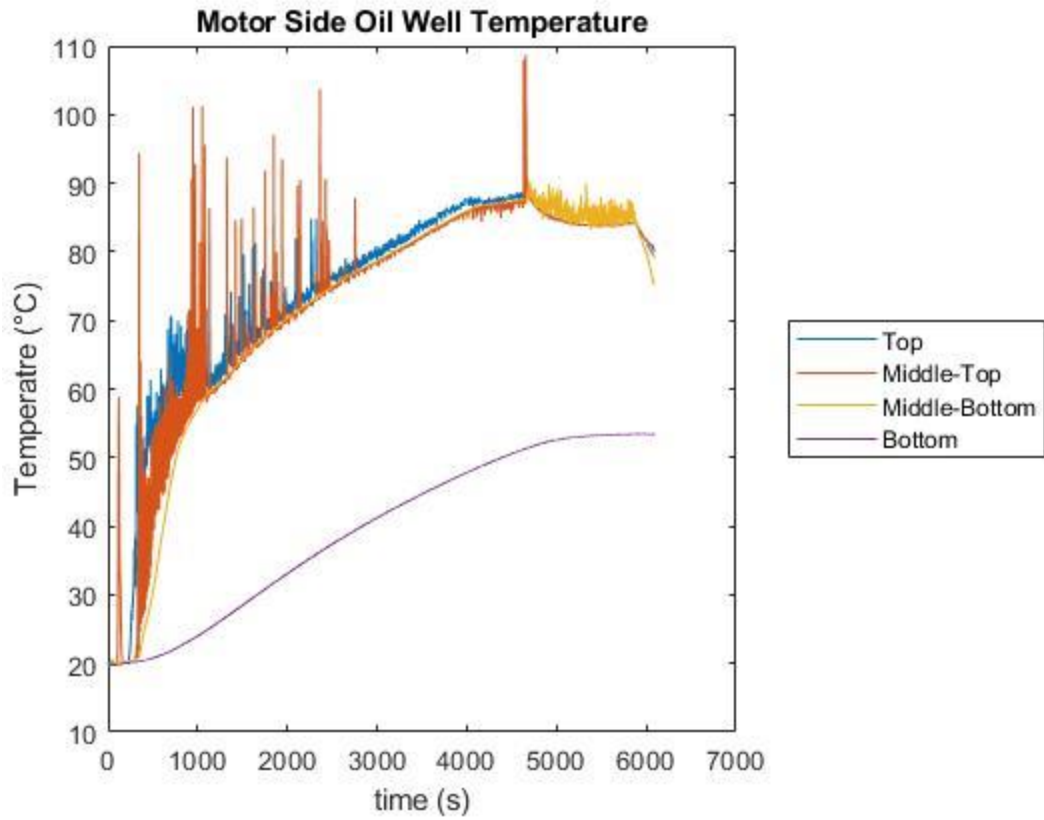
**Figure A-18:** Turbine speed during the 82.2 °C constant speed test.



**Figure A-19:** Torque profile of the system with respect to time during the 82.2 °C constant speed test.

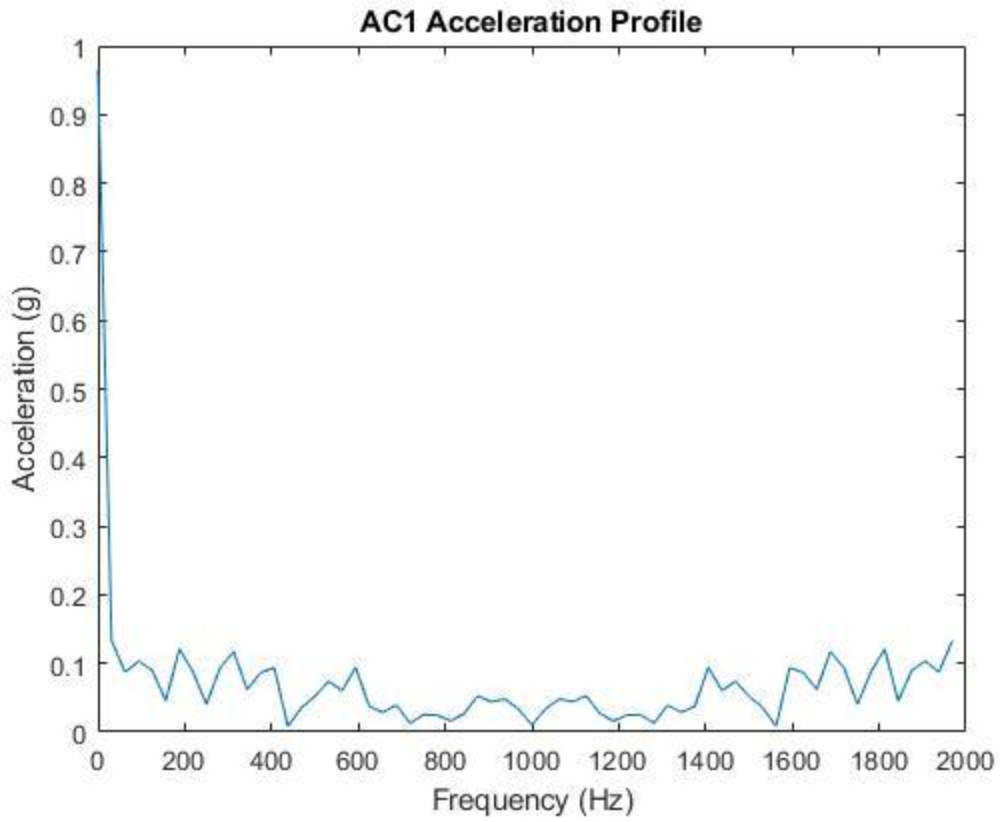


**Figure A-20:** Governor Side oil well temperature profile with respect to time for the 82.2 °C constant speed test.

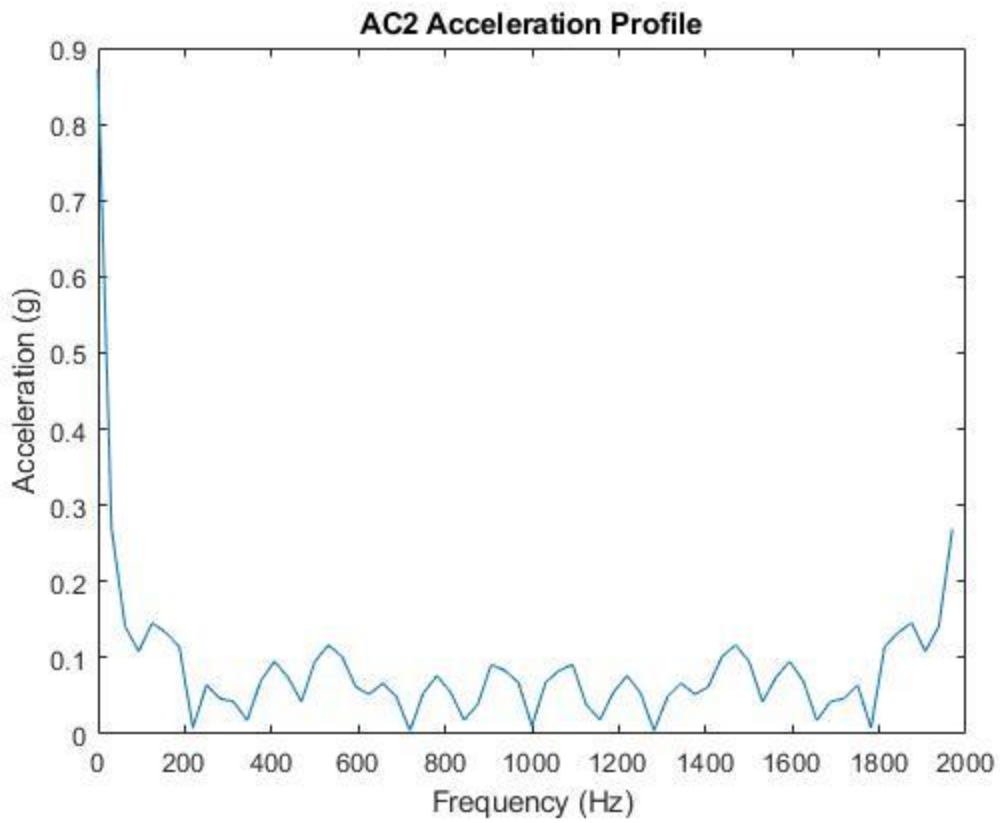


**Figure A-21:** Motor Side oil well temperature profile with respect to time for the 82.2 °C constant speed test.

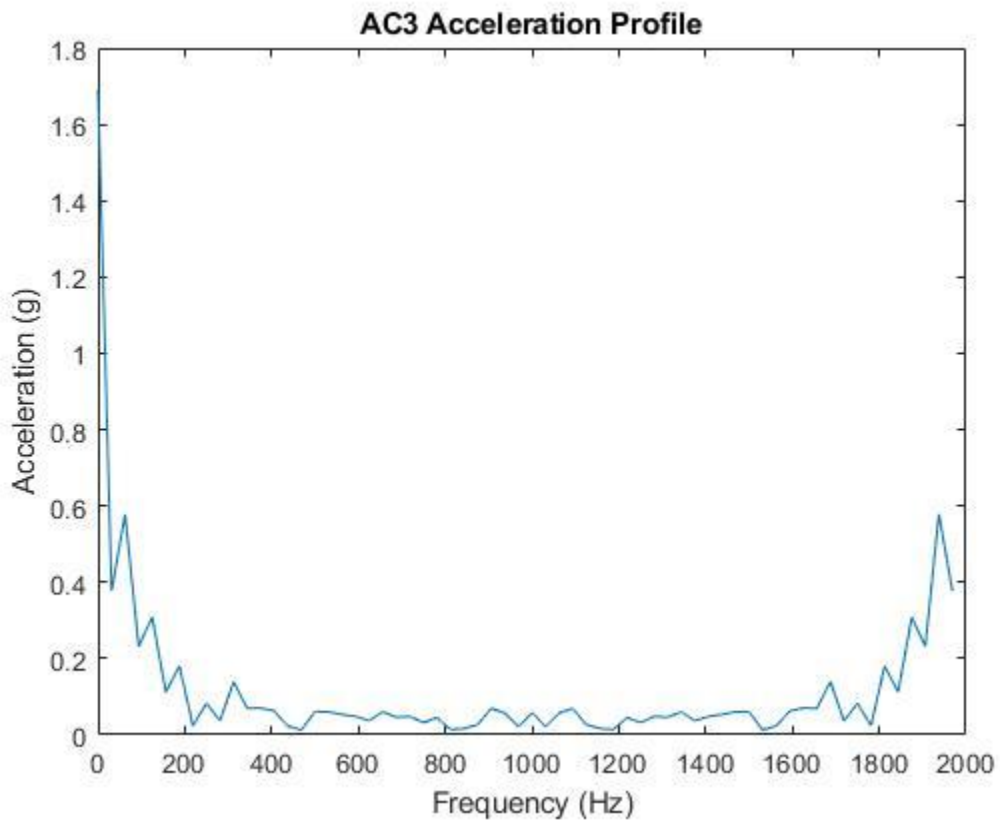




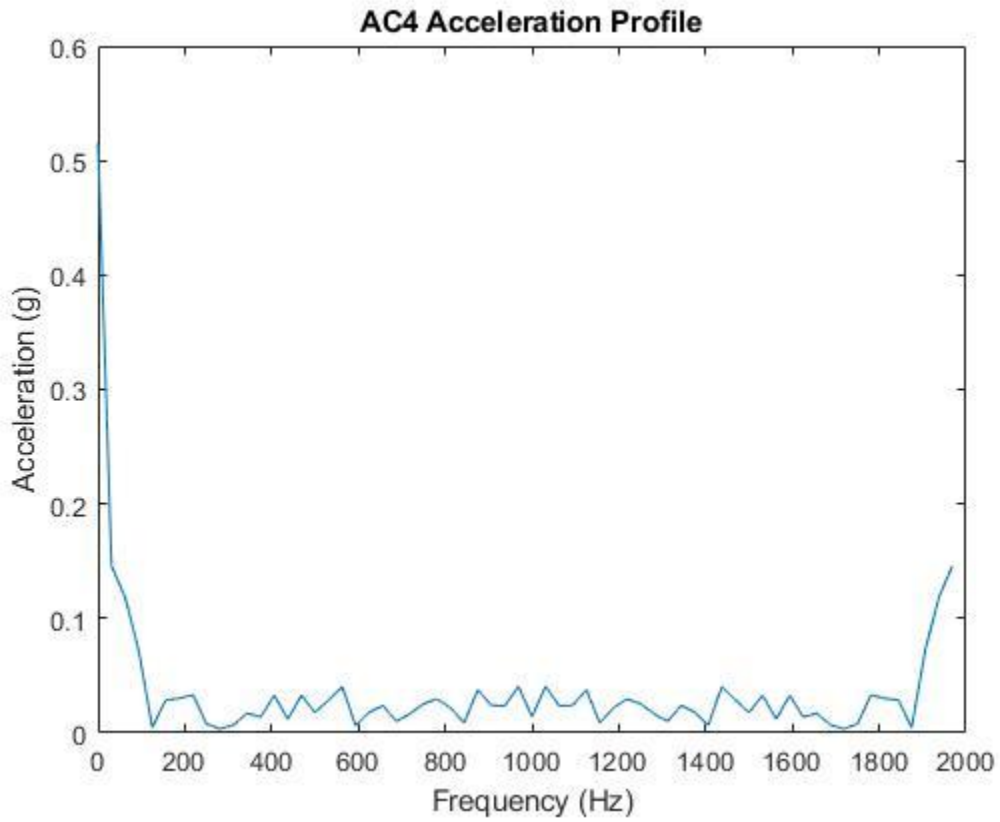
**Figure A-22:** Acceleration profile of accelerometer 1.



**Figure A-23:** Acceleration profile of accelerometer 2.

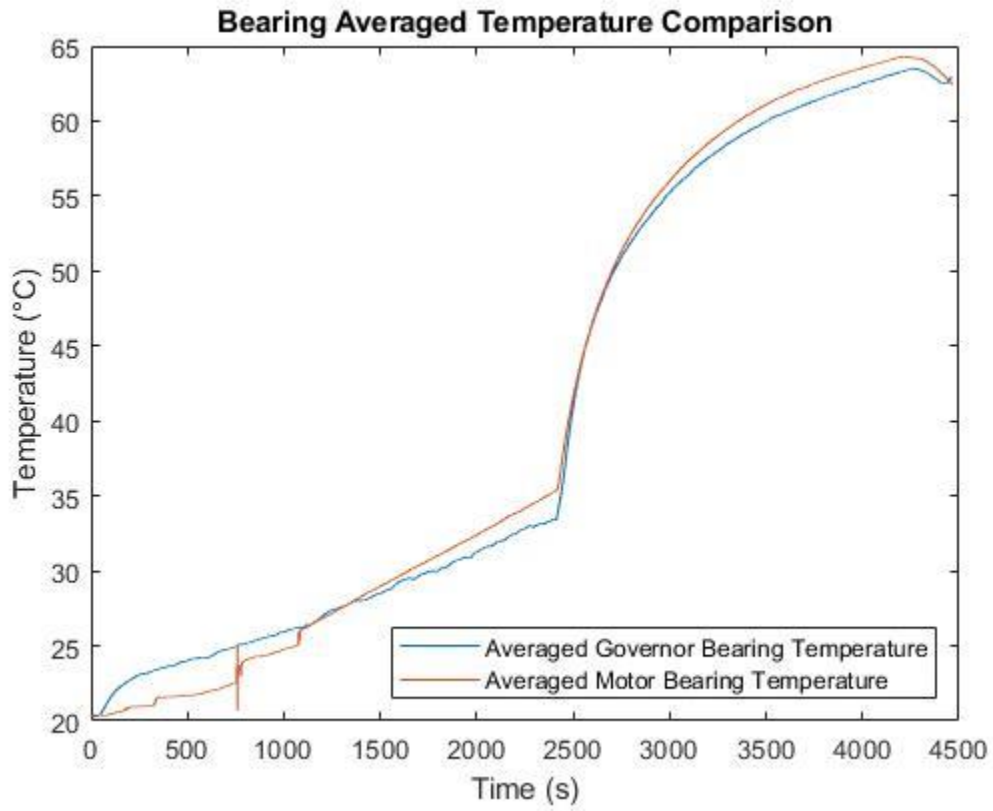


**Figure A-24:** Acceleration profile of accelerometer 3.

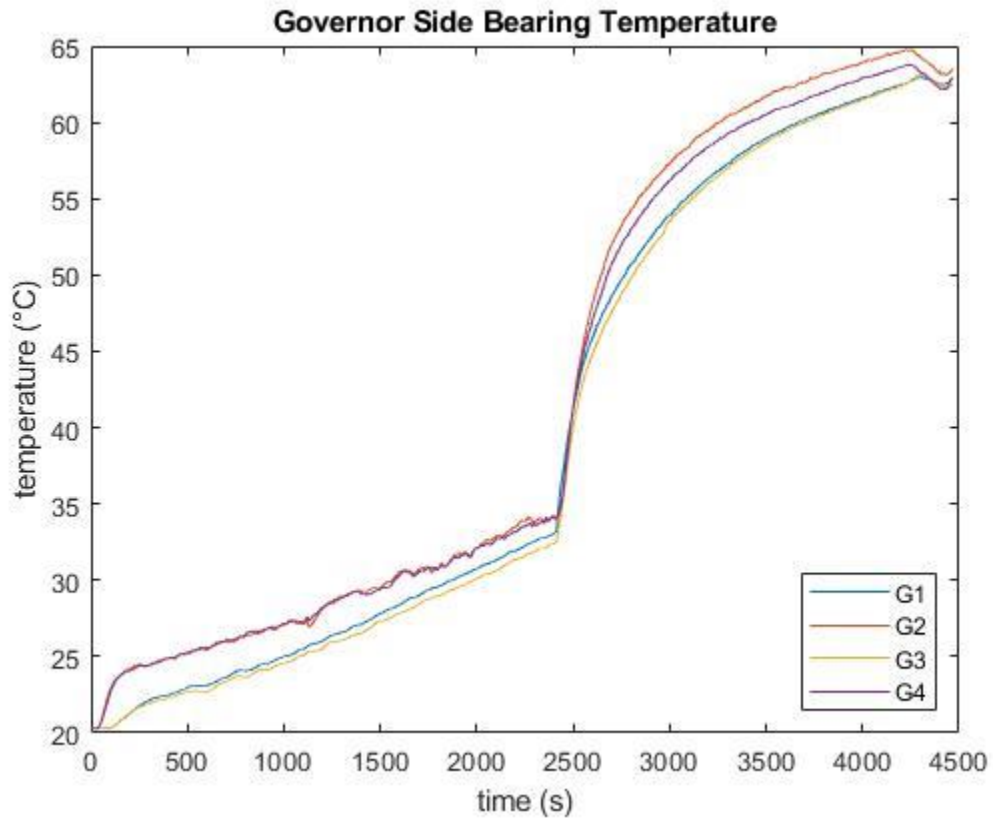


**Figure A-25:** Acceleration profile of accelerometer 4.

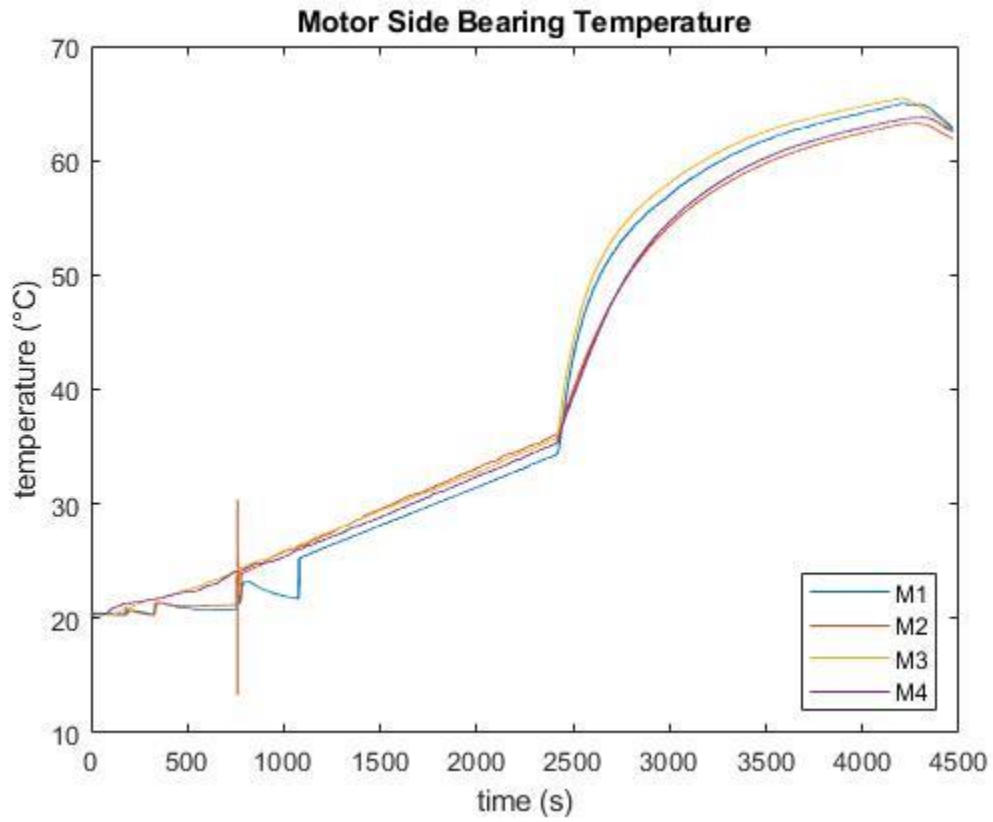
A.4. 71.1 °C Constant Speed Test 4/23/2020



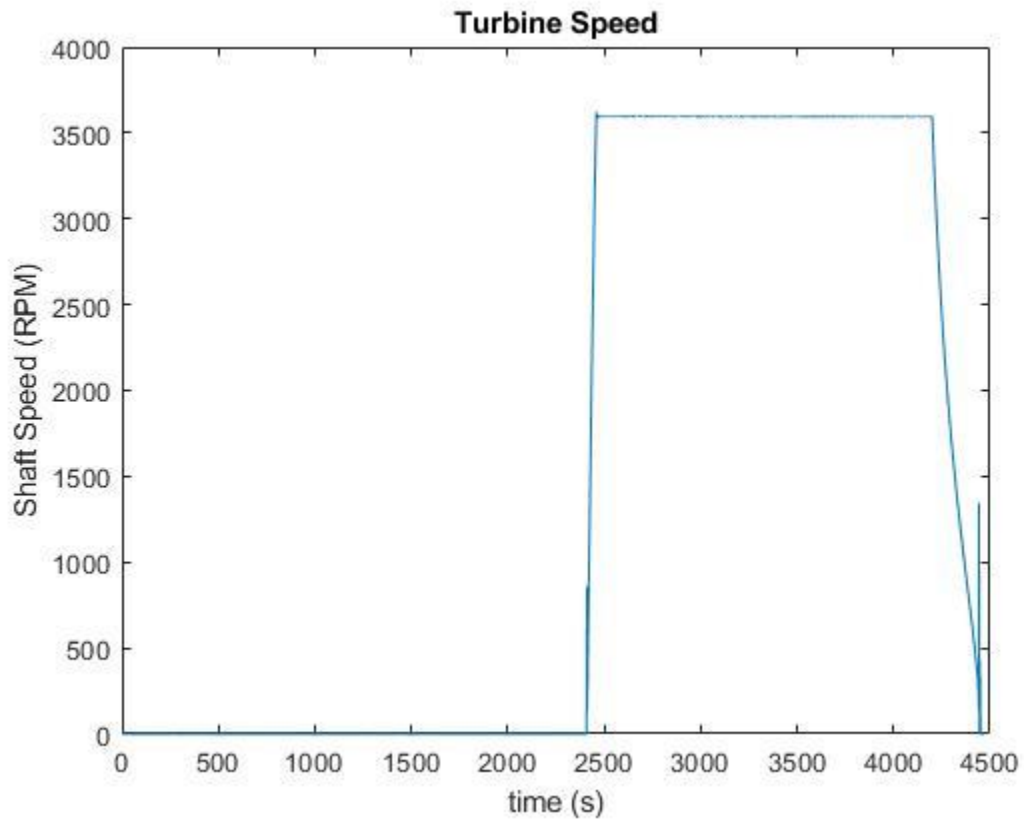
**Figure A-26:** Comparison of the average Motor Side bearing temperature and Governor Side bearing temperature with respect to time for the 71.1 °C constant speed test.



**Figure A-27:** Temperatures of all four Governor Side bearing thermocouples in the 71.1 °C constant speed test.

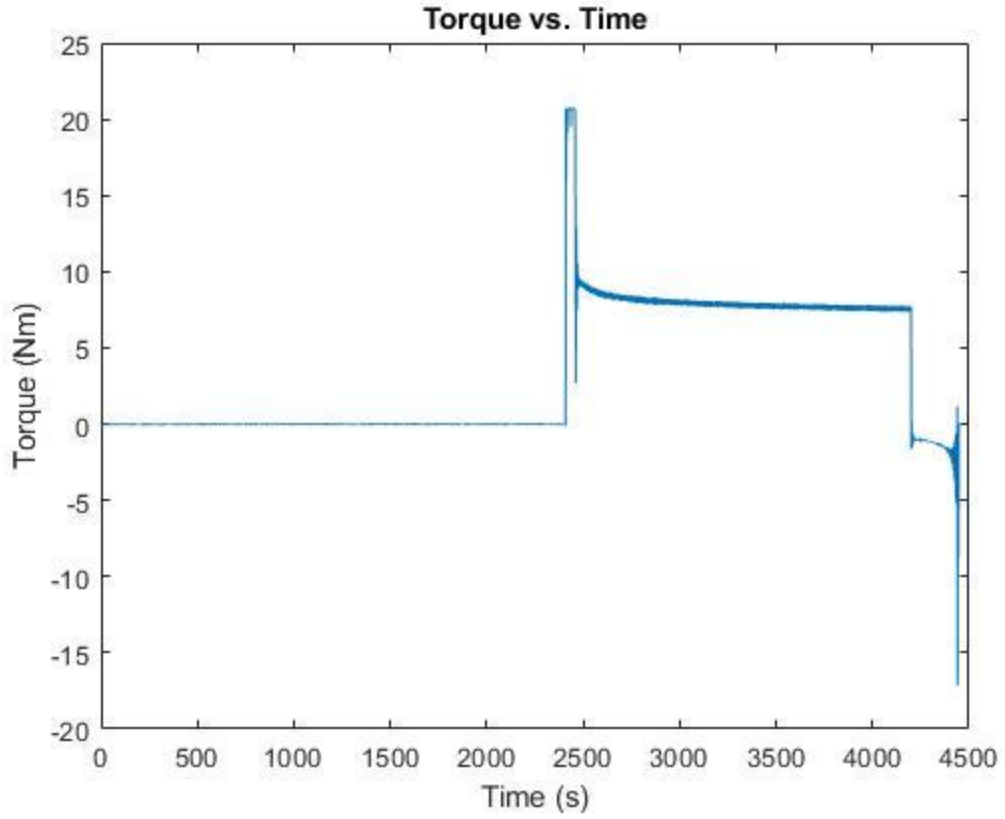


**Figure A-28:** Temperatures of all four Governor Side bearing thermocouples in the 71.1 °C constant speed test.

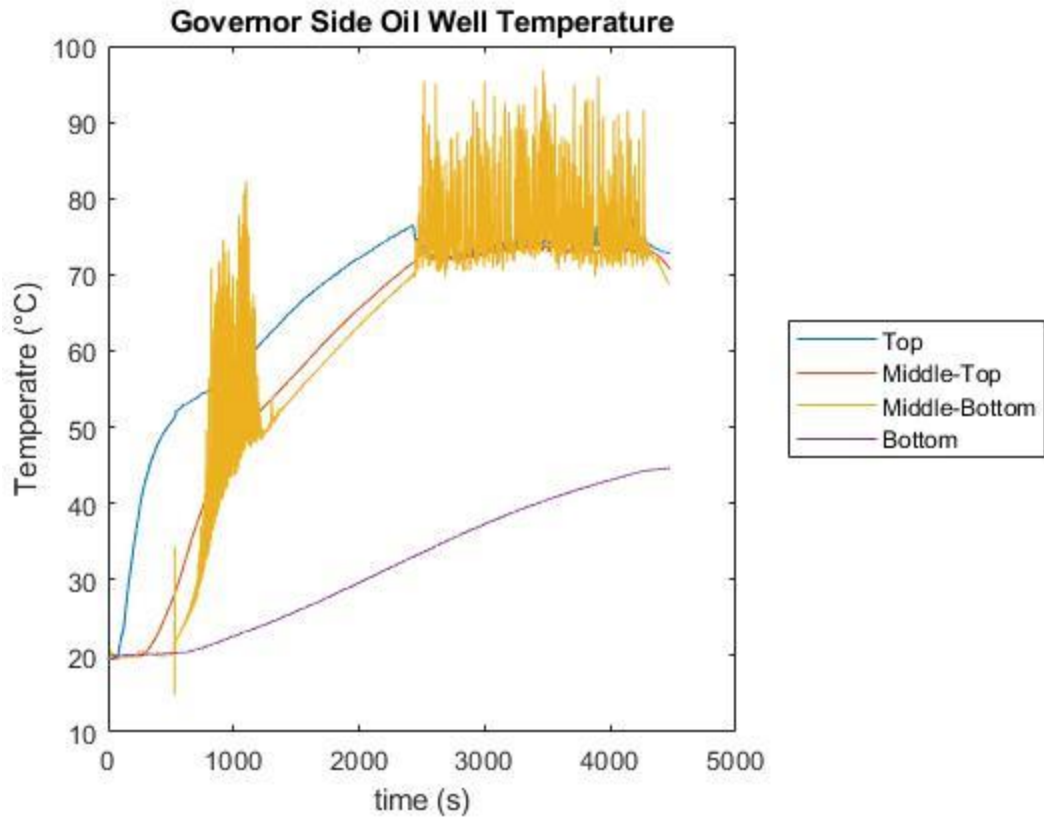


**Figure A-29:** Turbine speed during the 71.1 °C constant speed test.

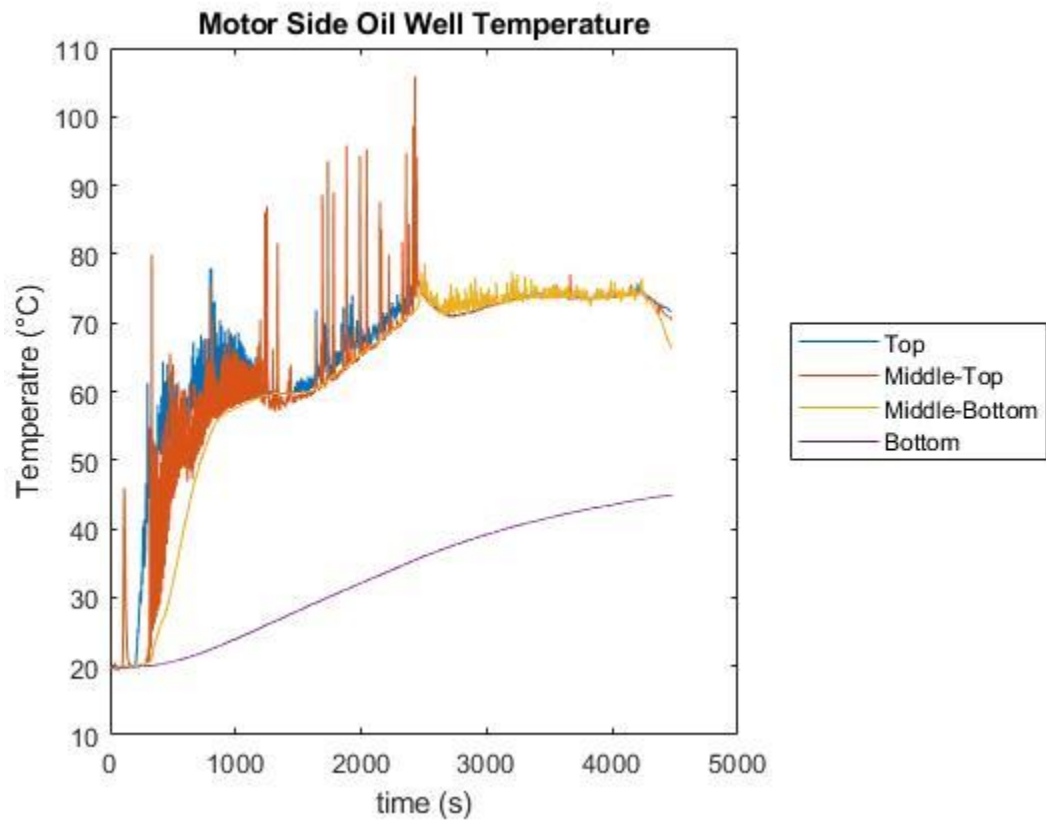




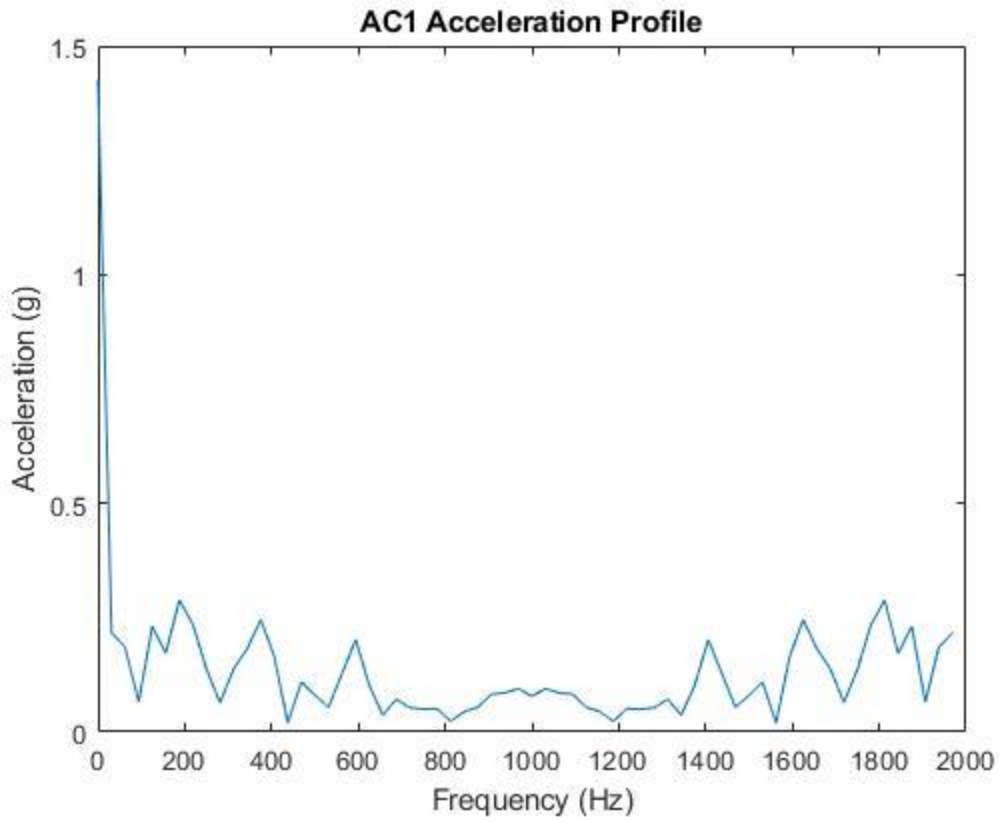
**Figure A-30:** Torque profile of the system with respect to time during the 71.1 °C constant speed test.



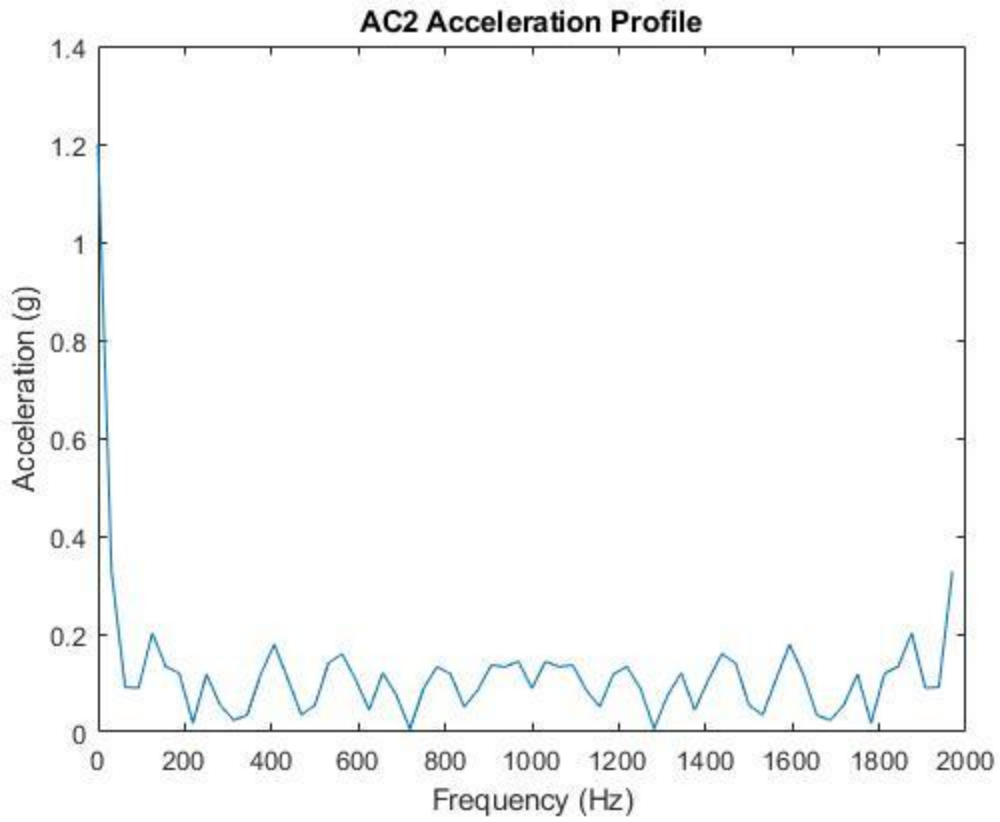
**Figure A-31:** Governor Side oil well temperature profile with respect to time for the 71.1 °C constant speed test.



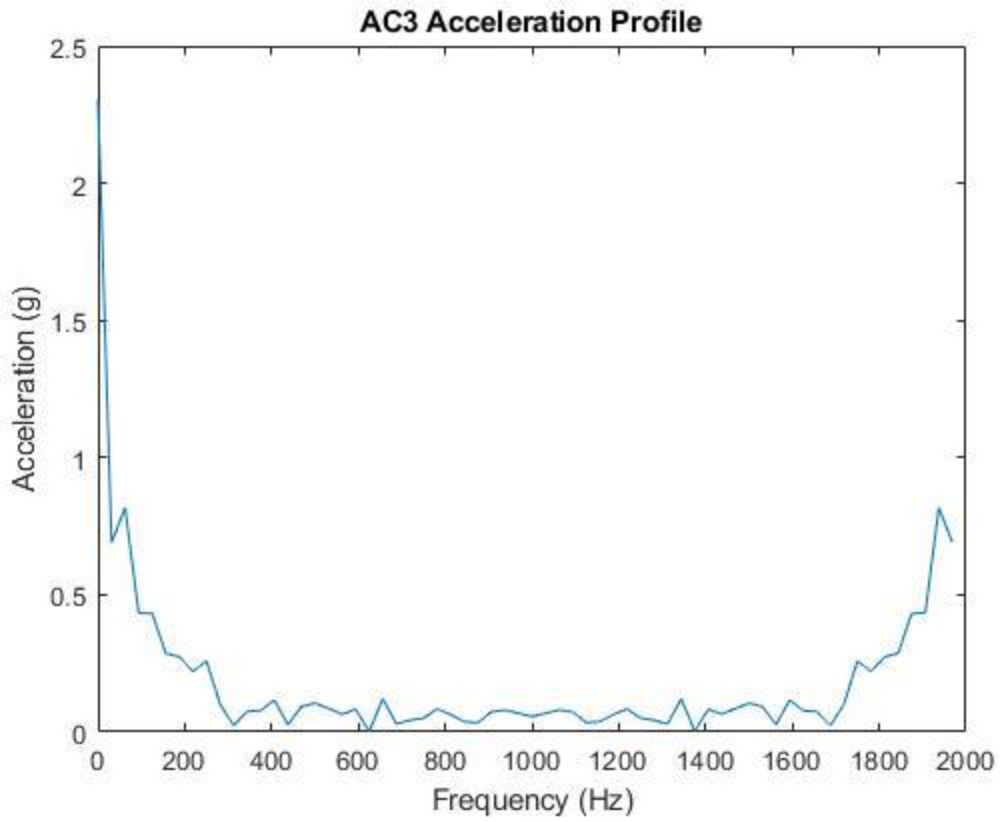
**Figure A-32:** Motor Side oil well temperature profile with respect to time for the 71.1 °C constant speed test.



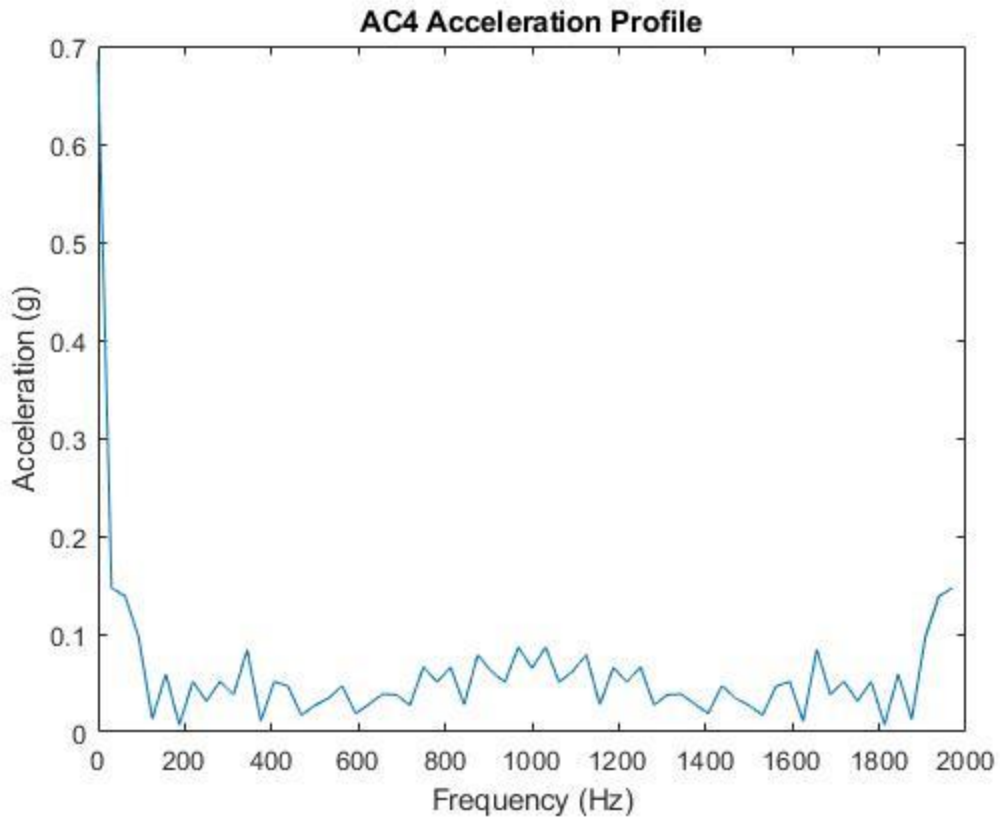
**Figure A-33:** Acceleration profile of accelerometer 1.



**Figure A-34:** Acceleration profile of accelerometer 2.



**Figure A-35:** Acceleration profile of accelerometer 3.

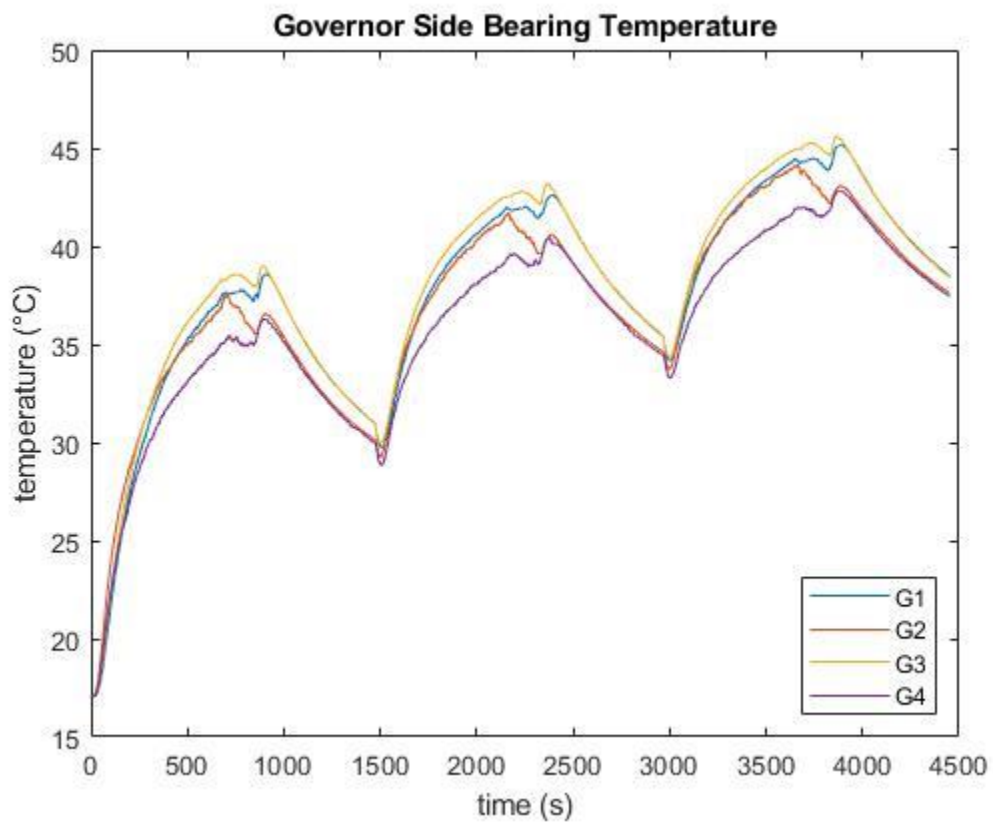


**Figure A-36:** Acceleration profile of accelerometer 4.

## APPENDIX B

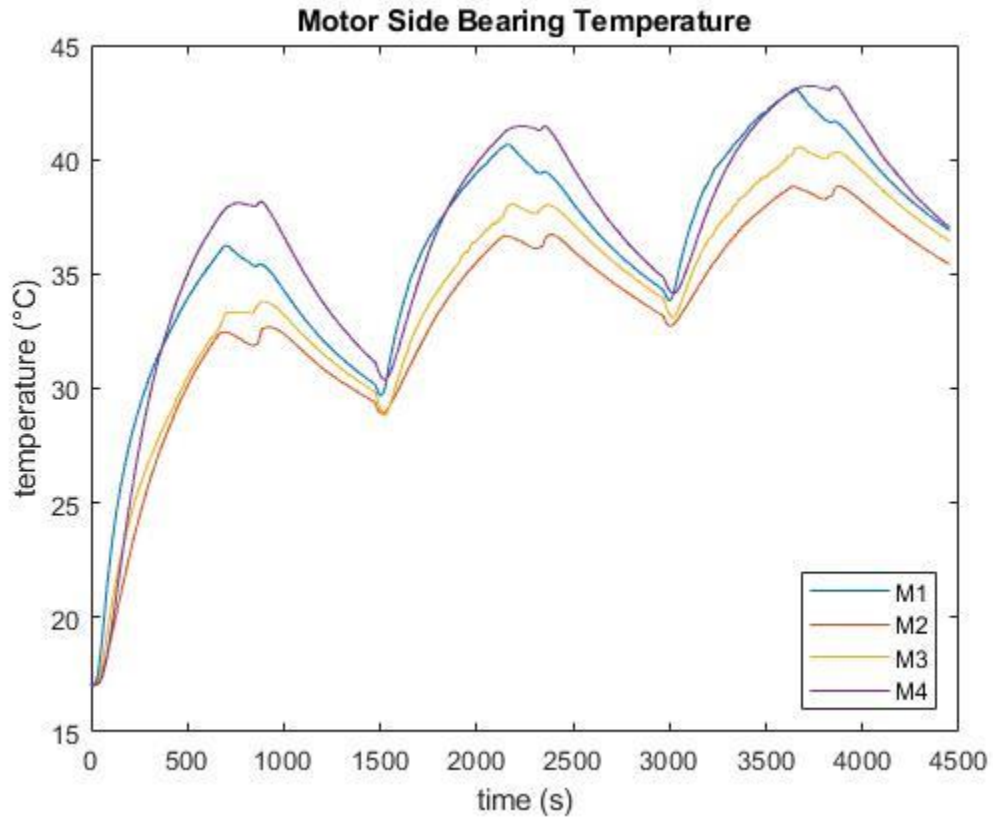
### START-STOP TEST PLOTS

#### B.1. Unheated Start-Stop Test 4/13/2020

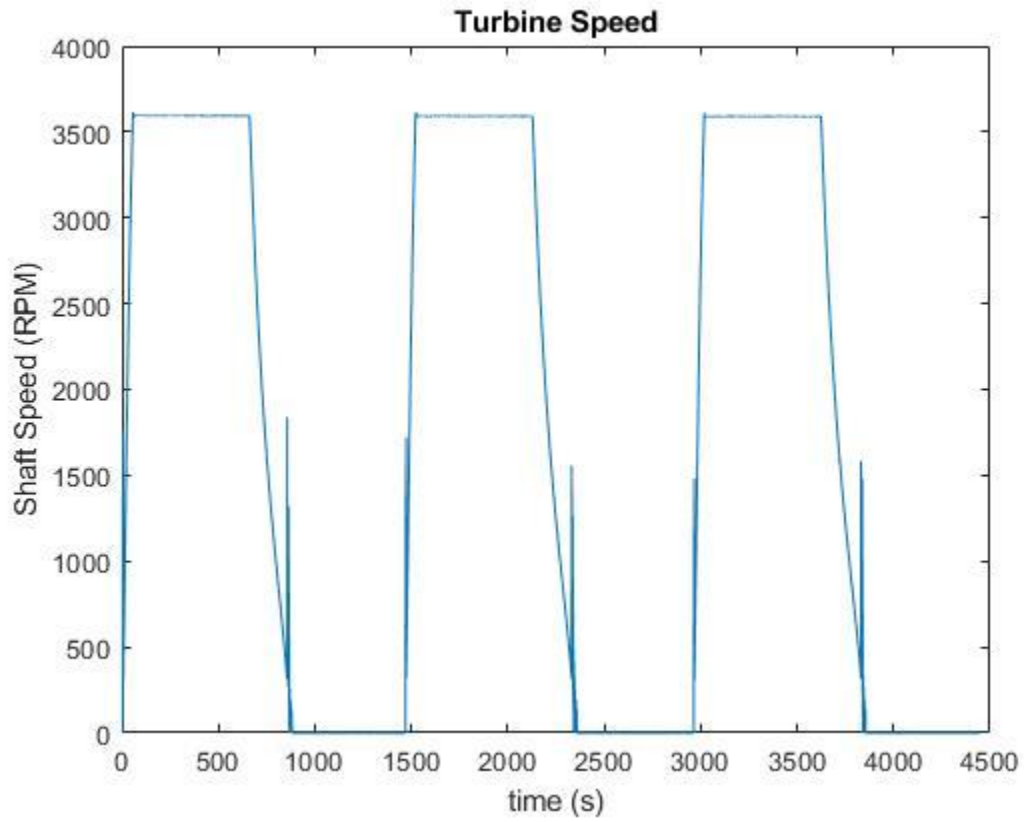


**Figure B-1:** Temperatures of all four Governor Side bearing thermocouples in the unheated start-stop test.

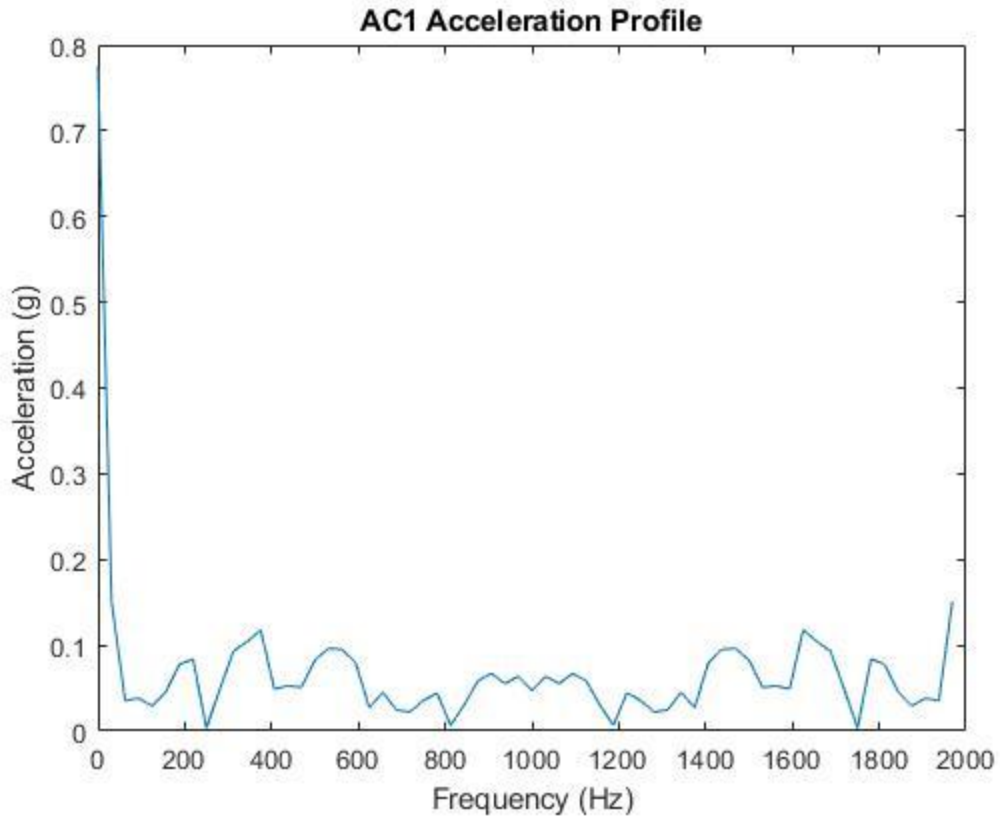




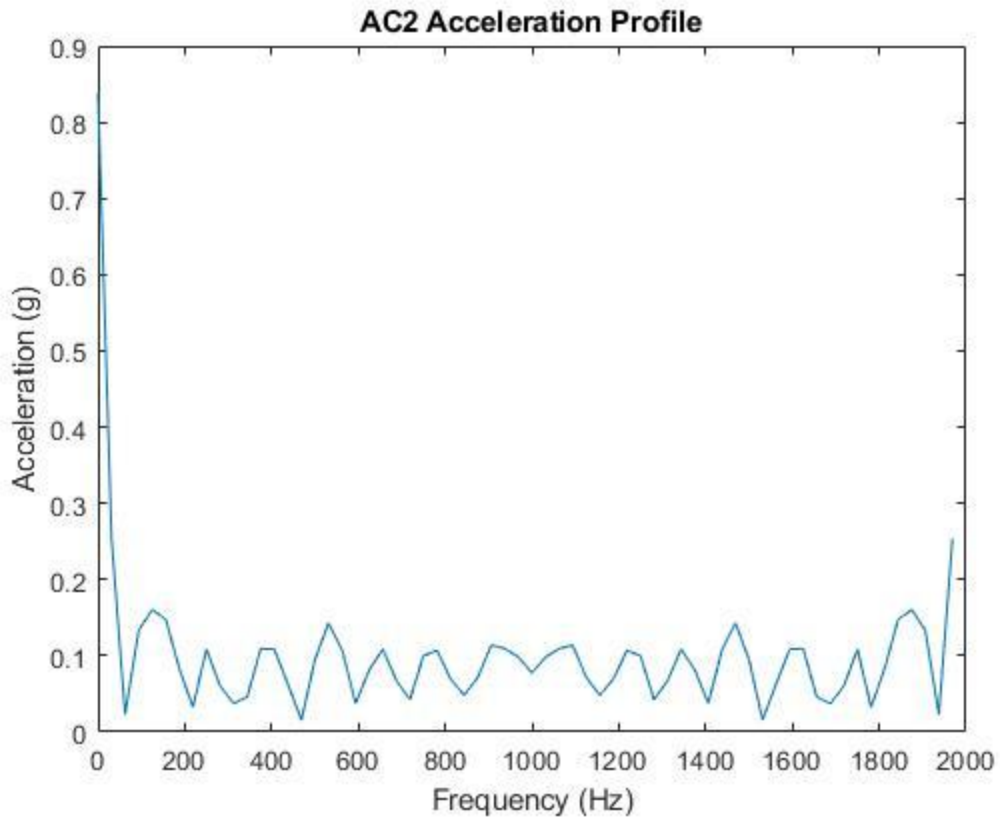
**Figure B-2:** Temperatures of all four Motor Side bearing thermocouples in the unheated start-stop test.



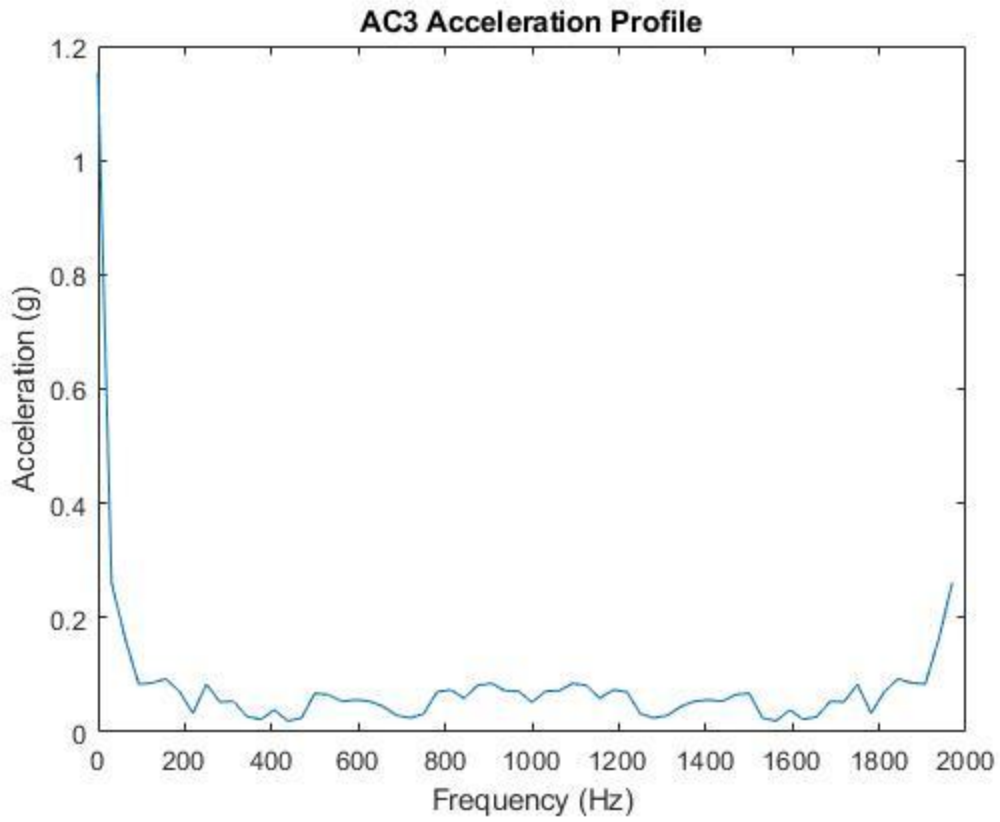
**Figure B-3:** Turbine speed during the unheated start-stop test.



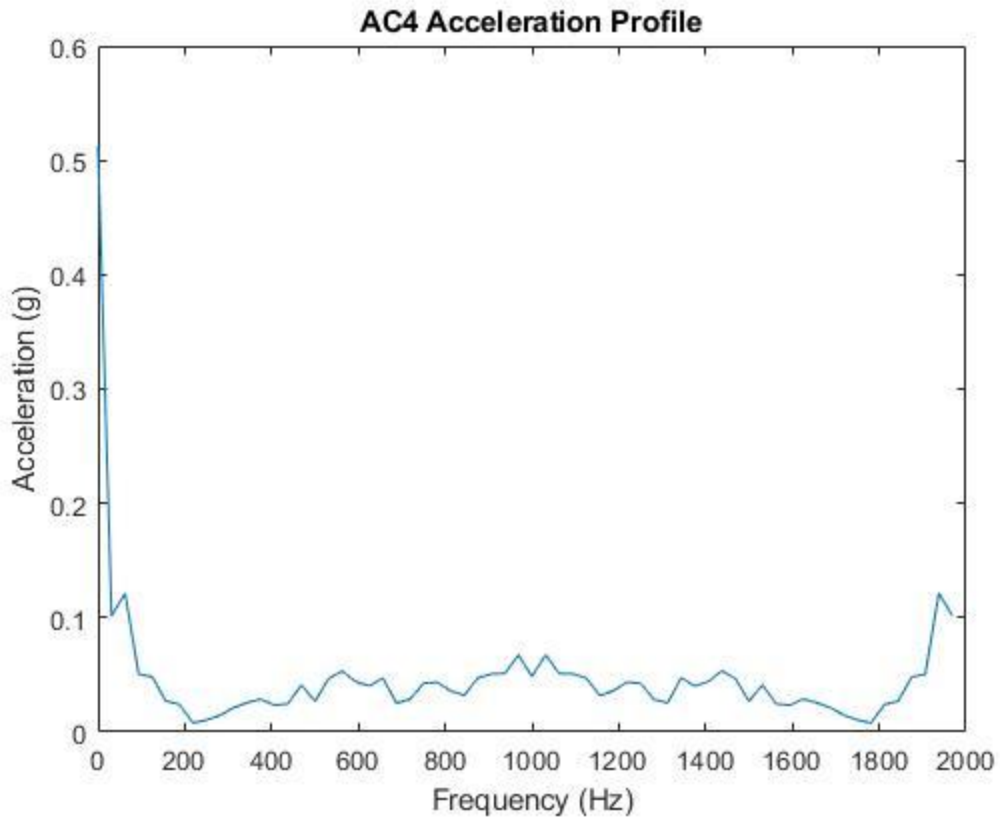
**Figure B-4:** Acceleration profile of accelerometer 1.



**Figure B-5:** Acceleration profile of accelerometer 2.

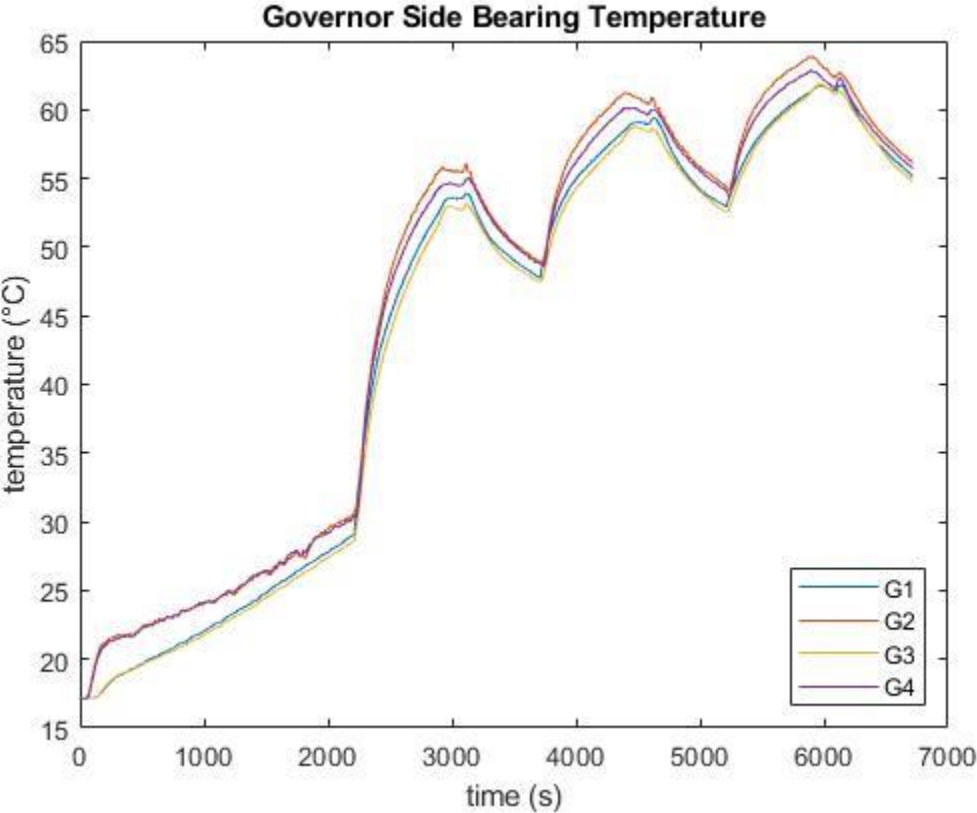


**Figure B-6:** Acceleration profile of accelerometer 3.

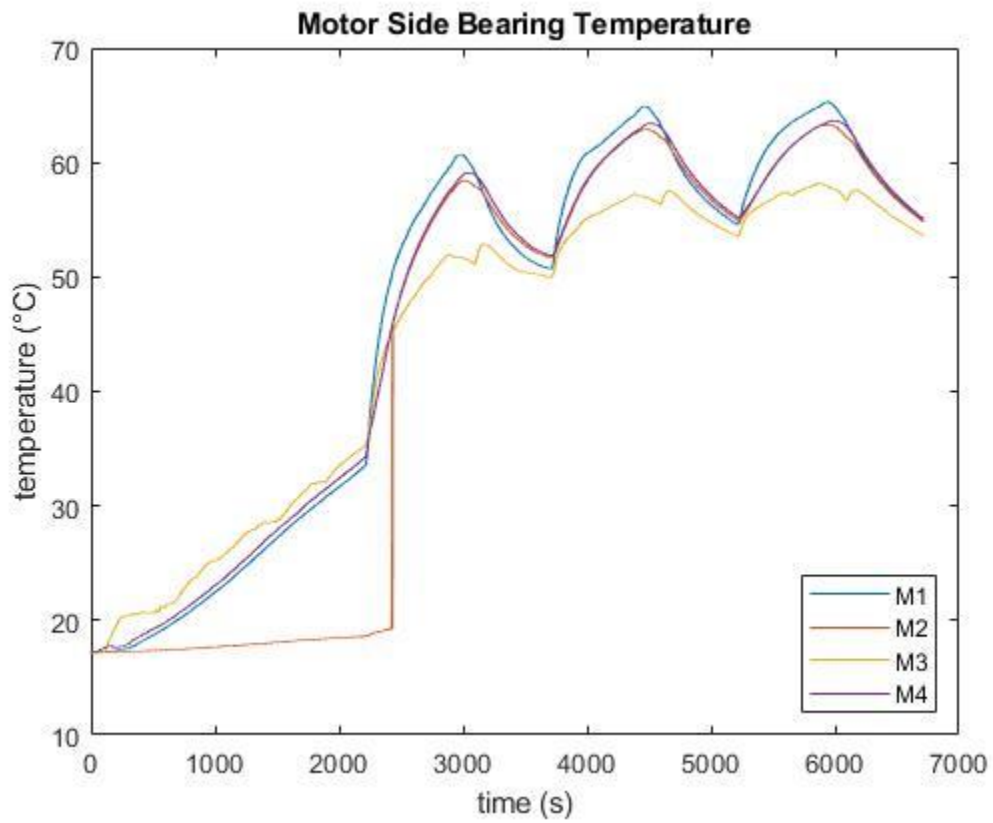


**Figure B-7:** Acceleration profile of accelerometer 4.

**B.2. 71.1 °C Start-Stop Test 4/14/2020**

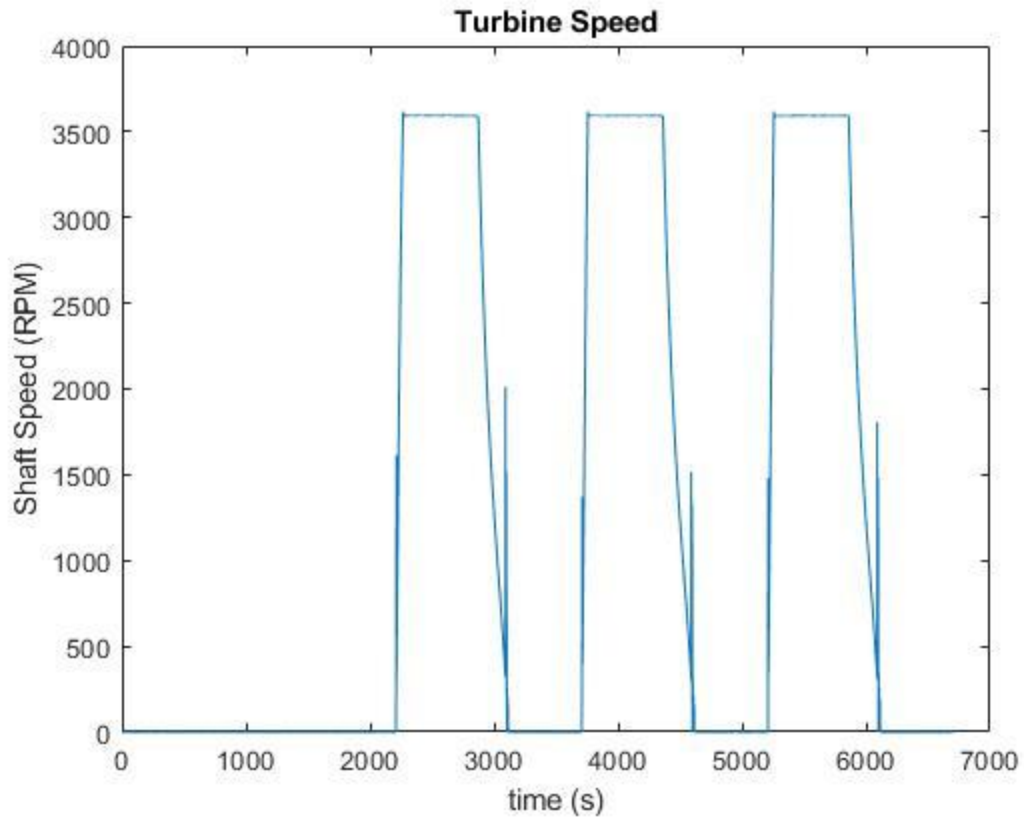


**Figure B-8:** Temperatures of all four Governor Side bearing thermocouples in the 71.1 °C start-stop test.

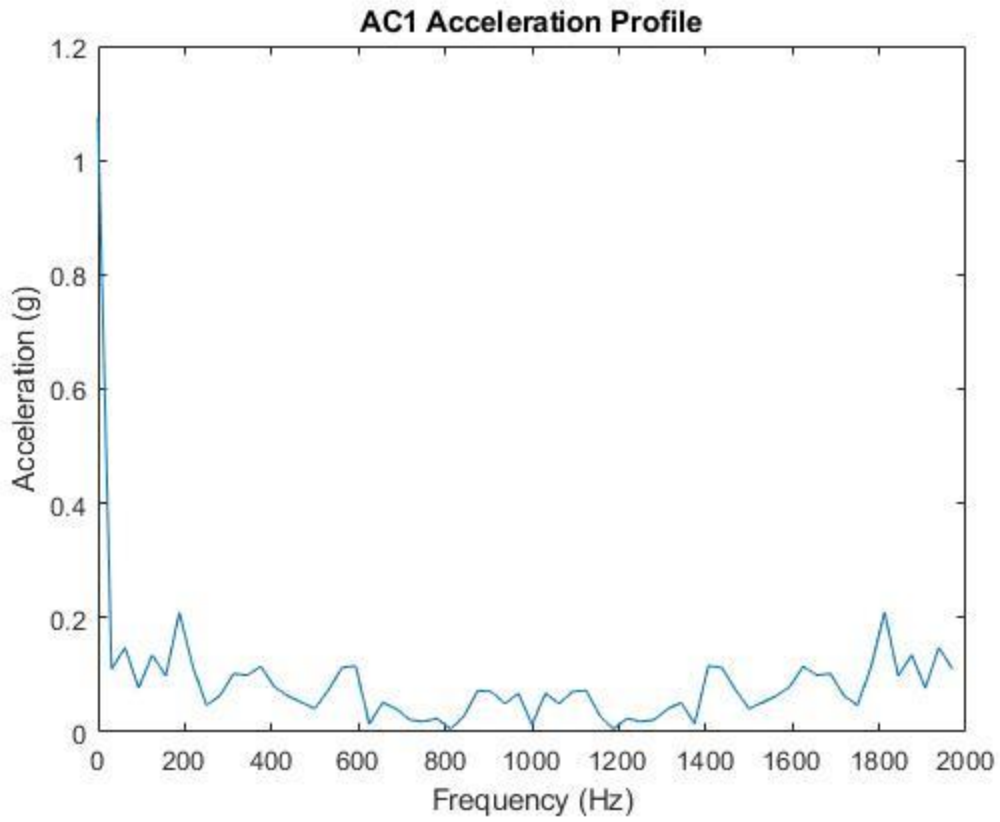


**Figure B-9:** Temperatures of all four Motor Side bearing thermocouples in the 71.1 °C start-stop test.

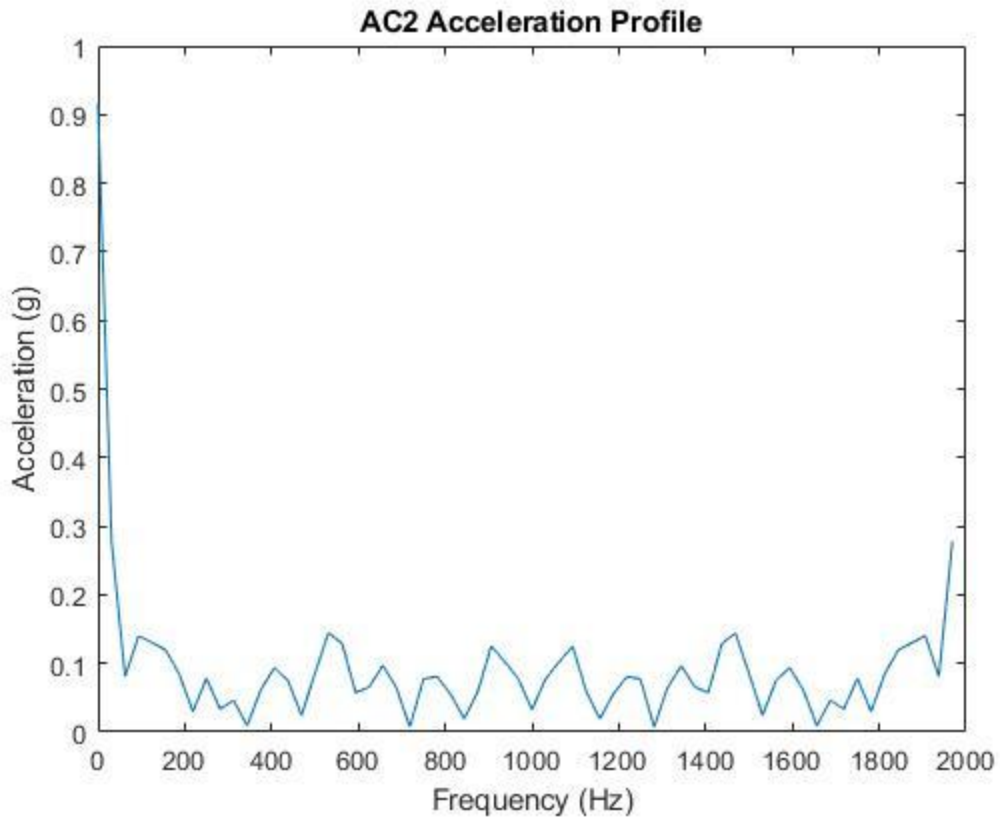




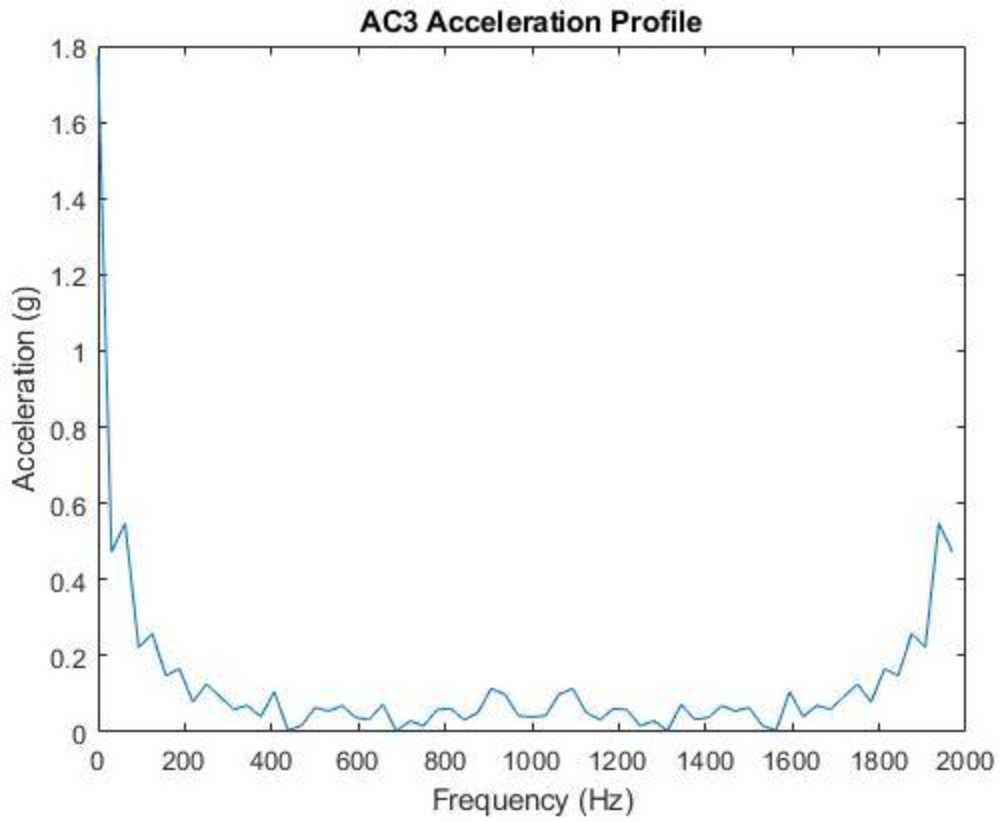
**Figure B-10:** Turbine speed during the 71.1 °C start-stop test.



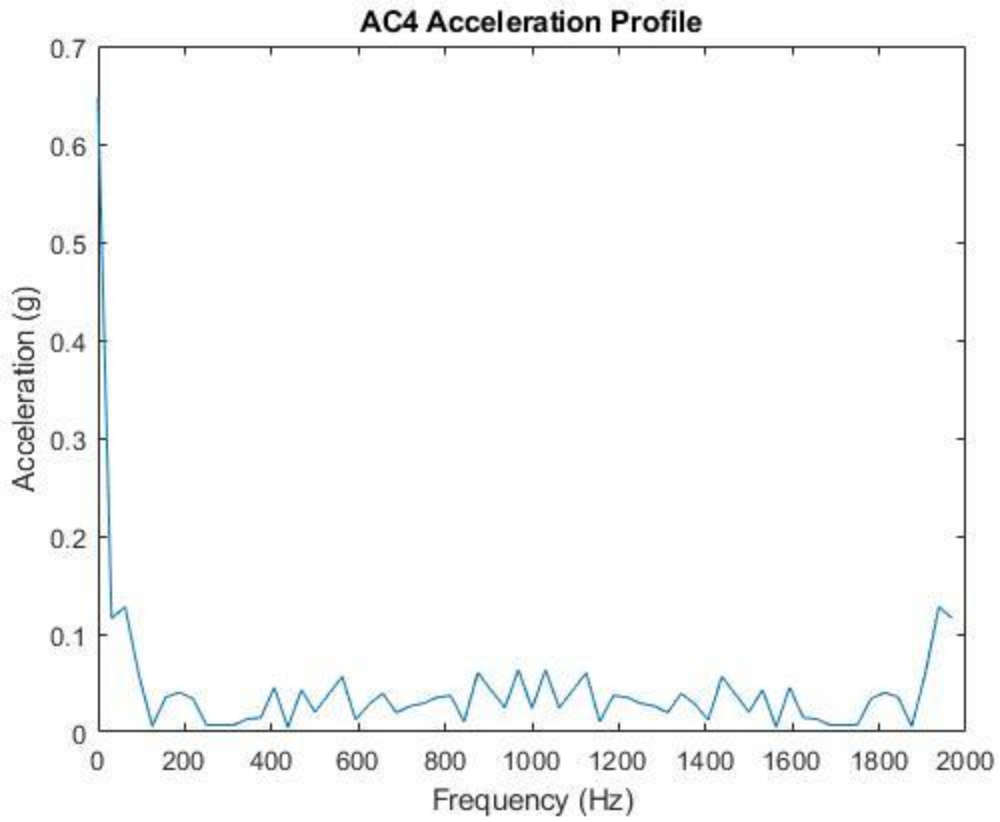
**Figure B-11:** Acceleration profile of accelerometer 1.



**Figure B-12:** Acceleration profile of accelerometer 2.

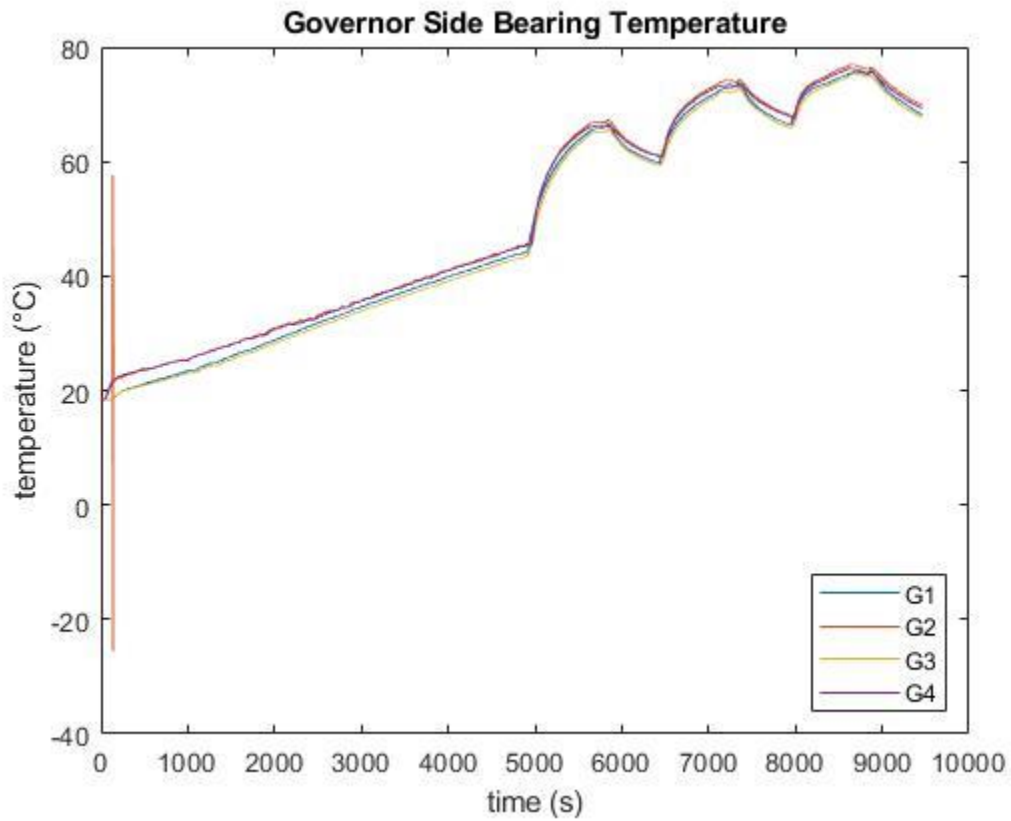


**Figure B-13:** Acceleration profile of accelerometer 3.

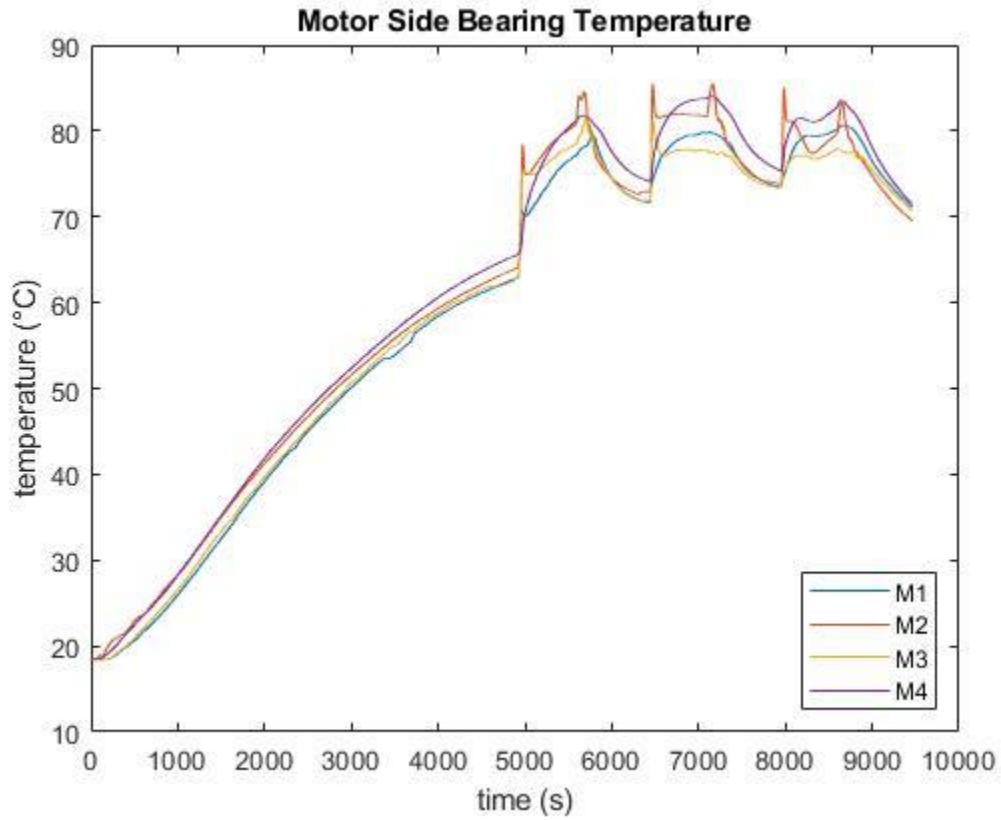


**Figure B-14:** Acceleration profile of accelerometer 4.

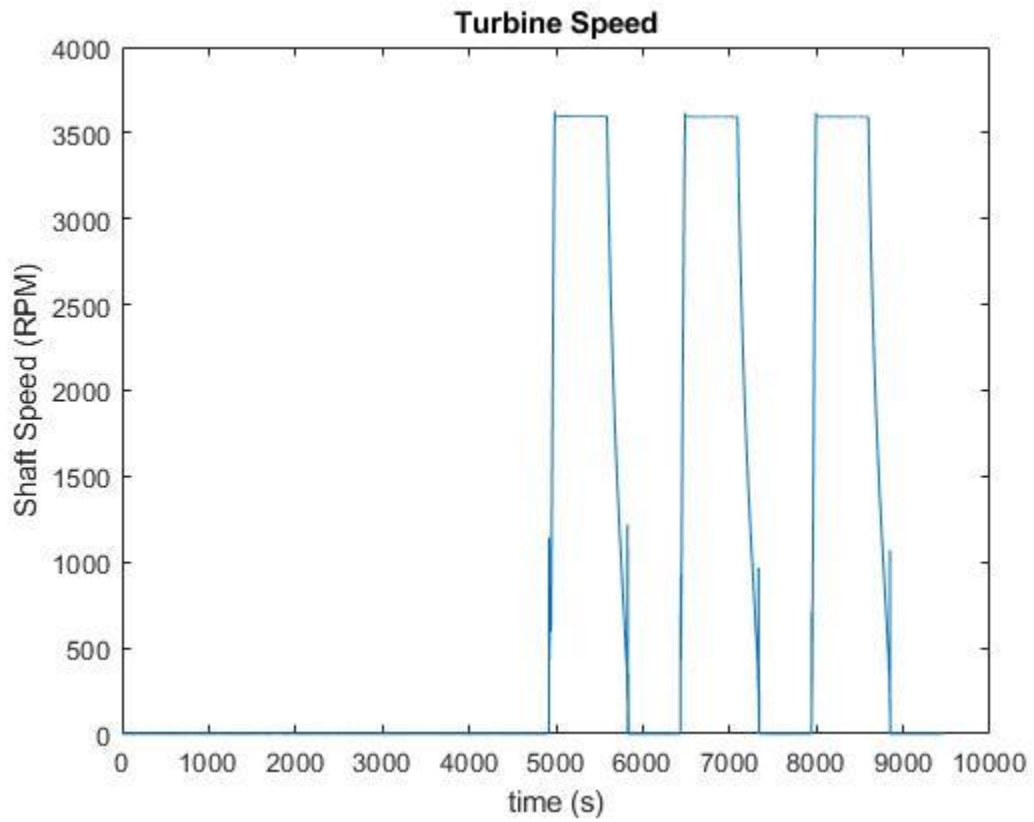
### B.3. 93.3 °C Start-Stop Test 4/16/2020



**Figure B-15:** Temperatures of all four Governor Side bearing thermocouples in the 93.3 °C start-stop test.

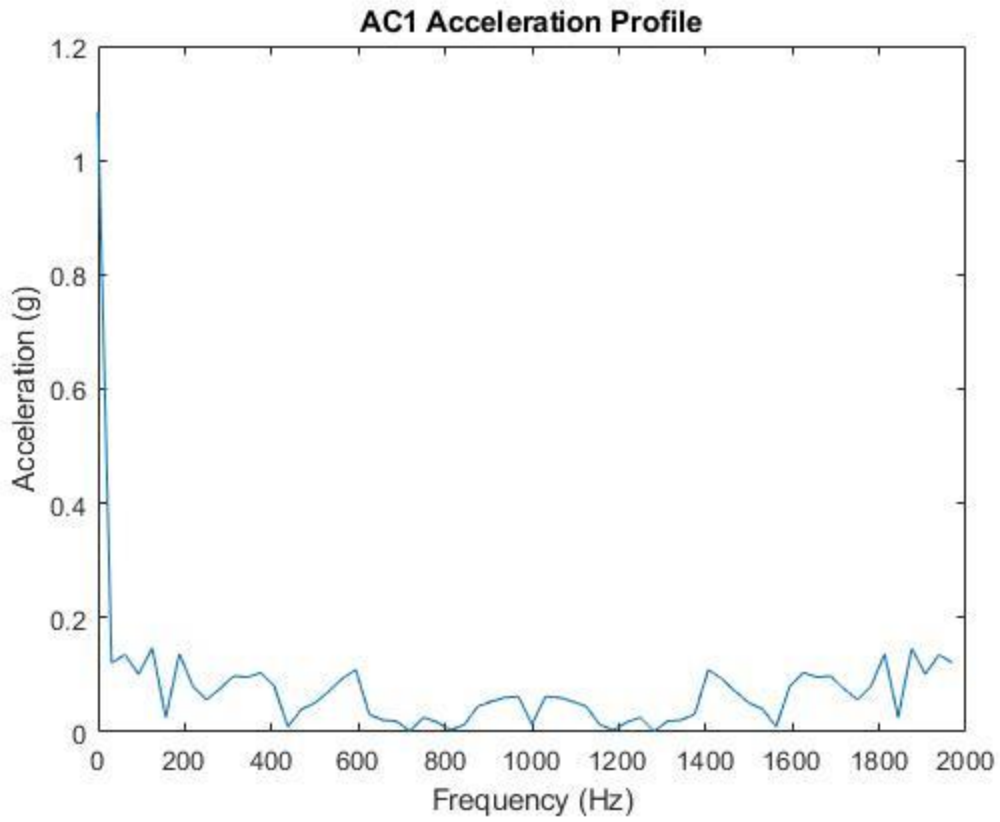


**Figure B-16:** Temperatures of all four Motor Side bearing thermocouples in the 93.3 °C start-stop test.

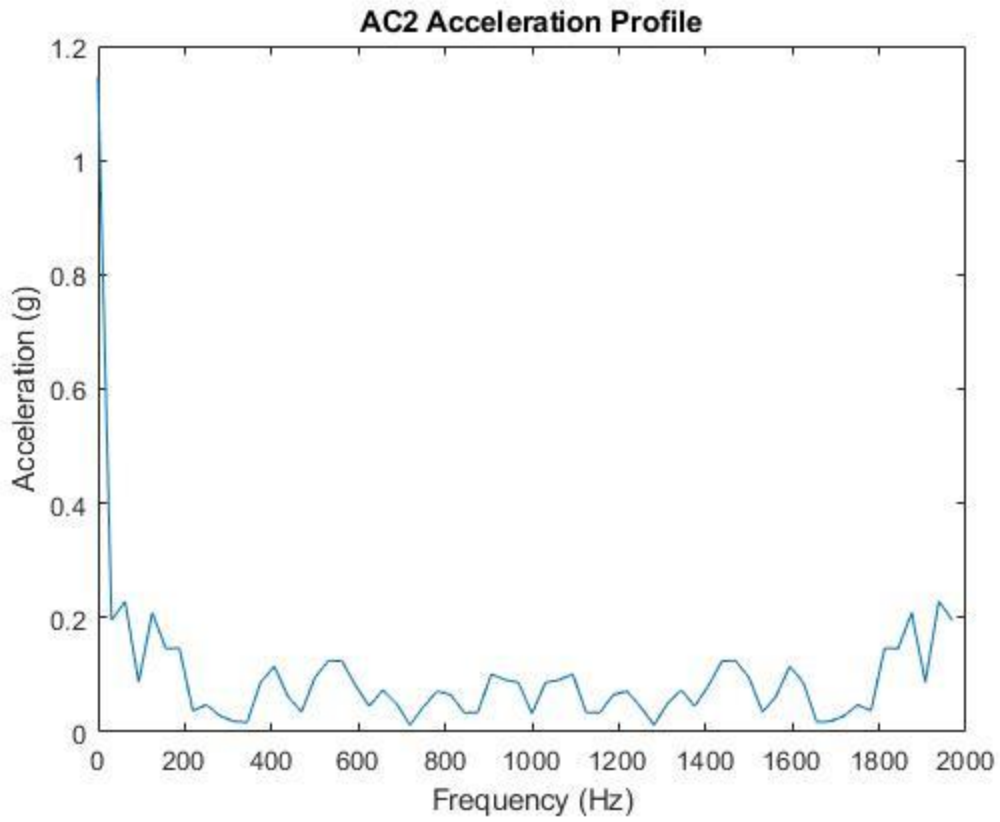


**Figure B-17:** Turbine speed during the 93.3 °C start-stop test.

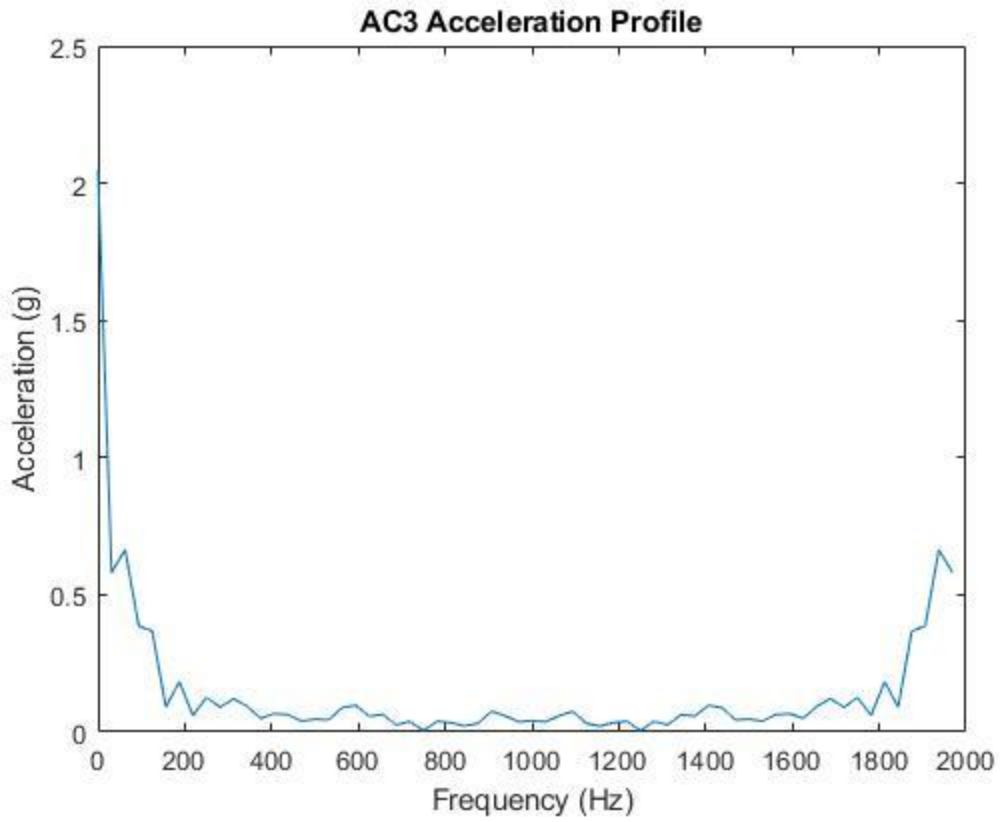




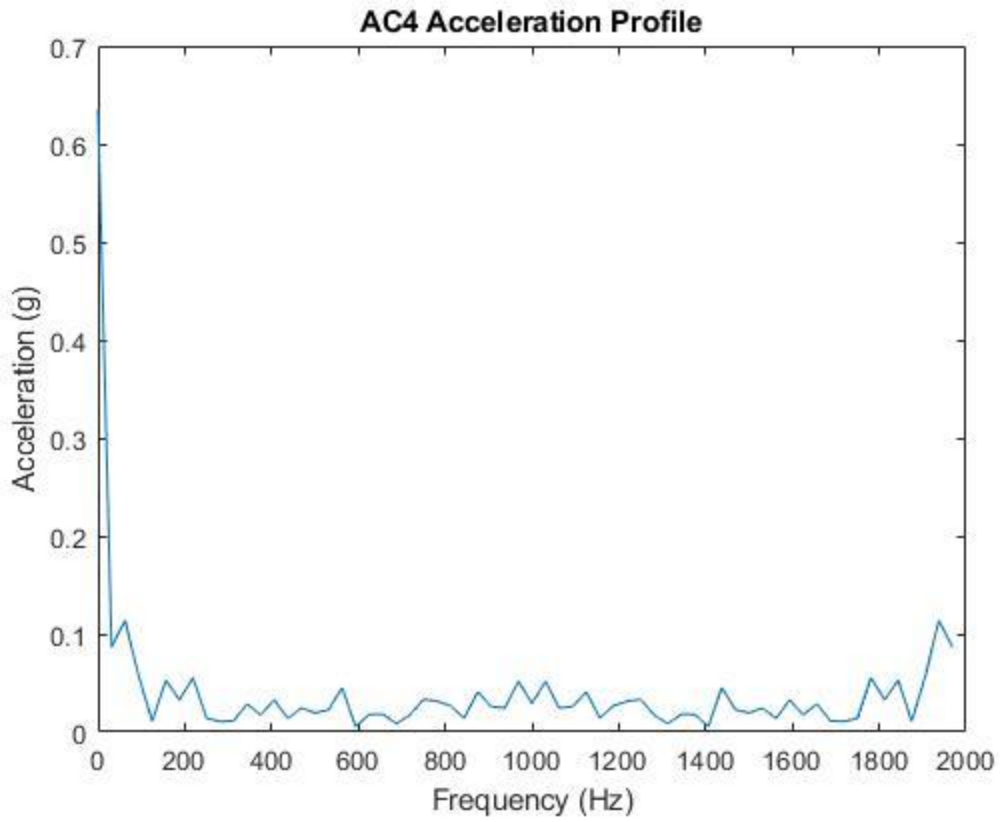
**Figure B-18:** Acceleration profile of accelerometer 1.



**Figure B-19:** Acceleration profile of accelerometer 2.

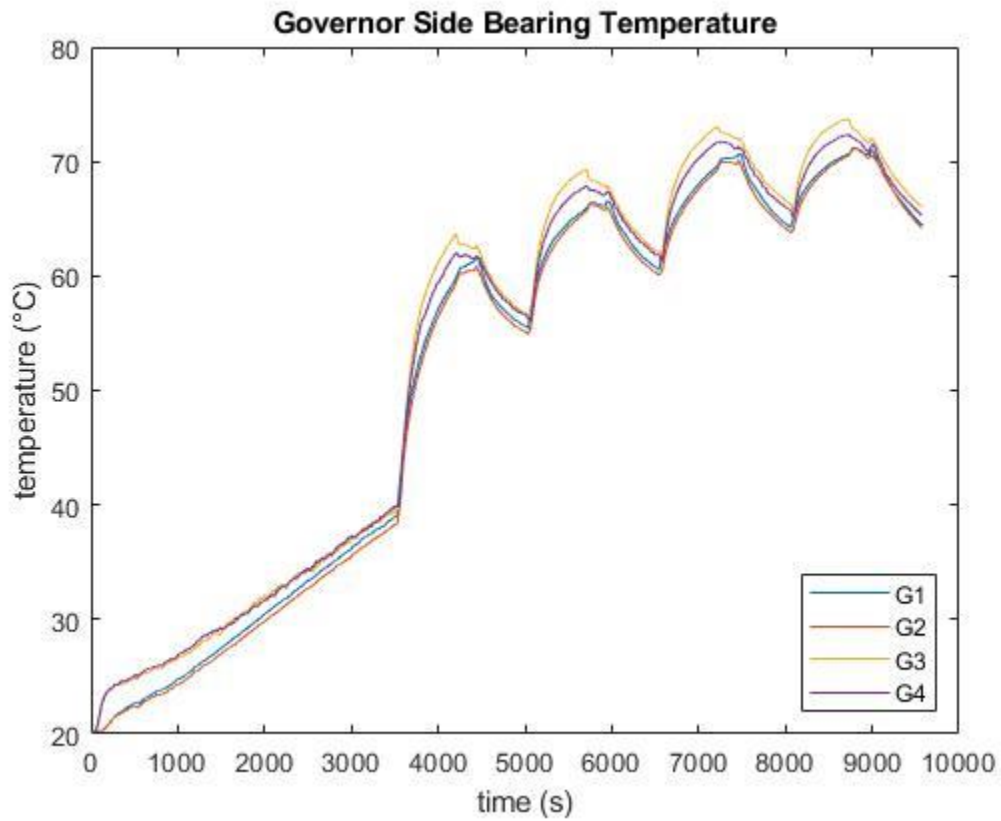


**Figure B-20:** Acceleration profile of accelerometer 3.

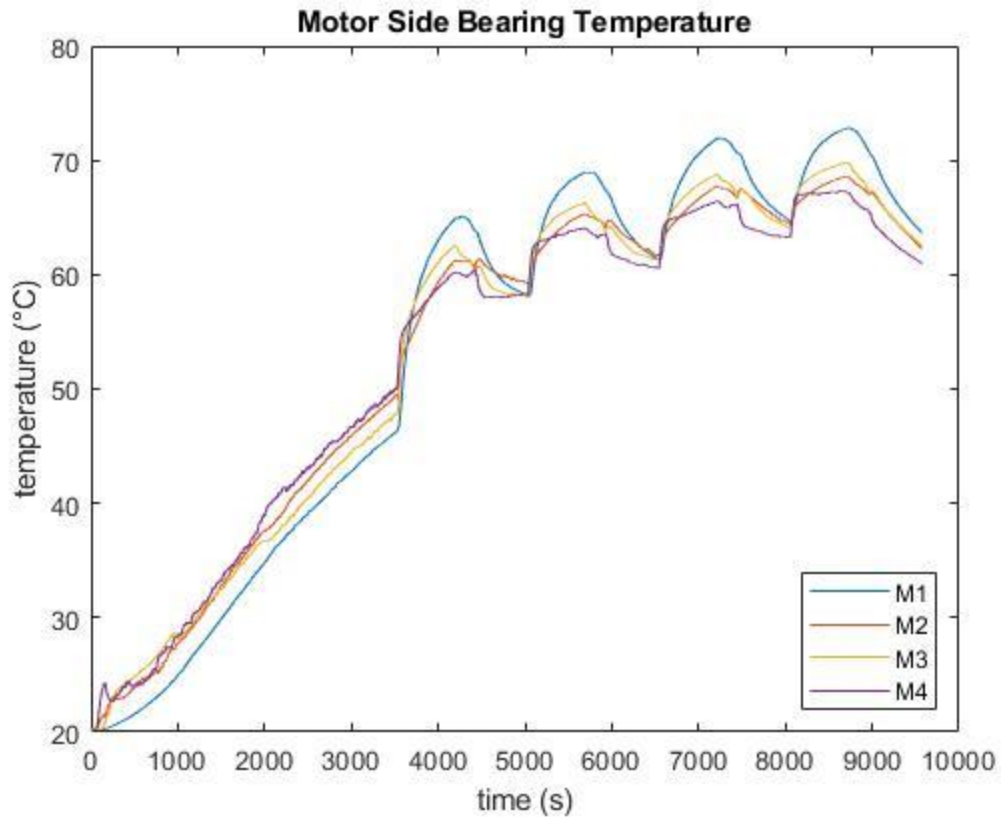


**Figure B-21:** Acceleration profile of accelerometer 4.

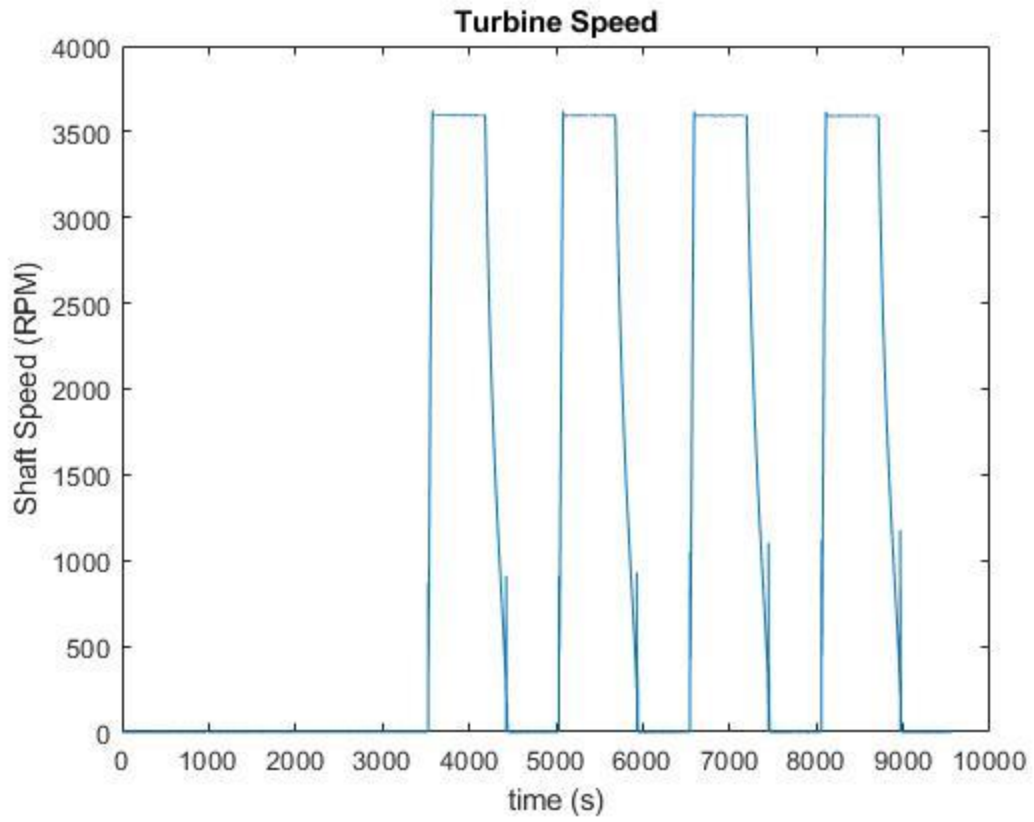
**B.4. 82.2 °C Start-Stop Test 4/20/2020**



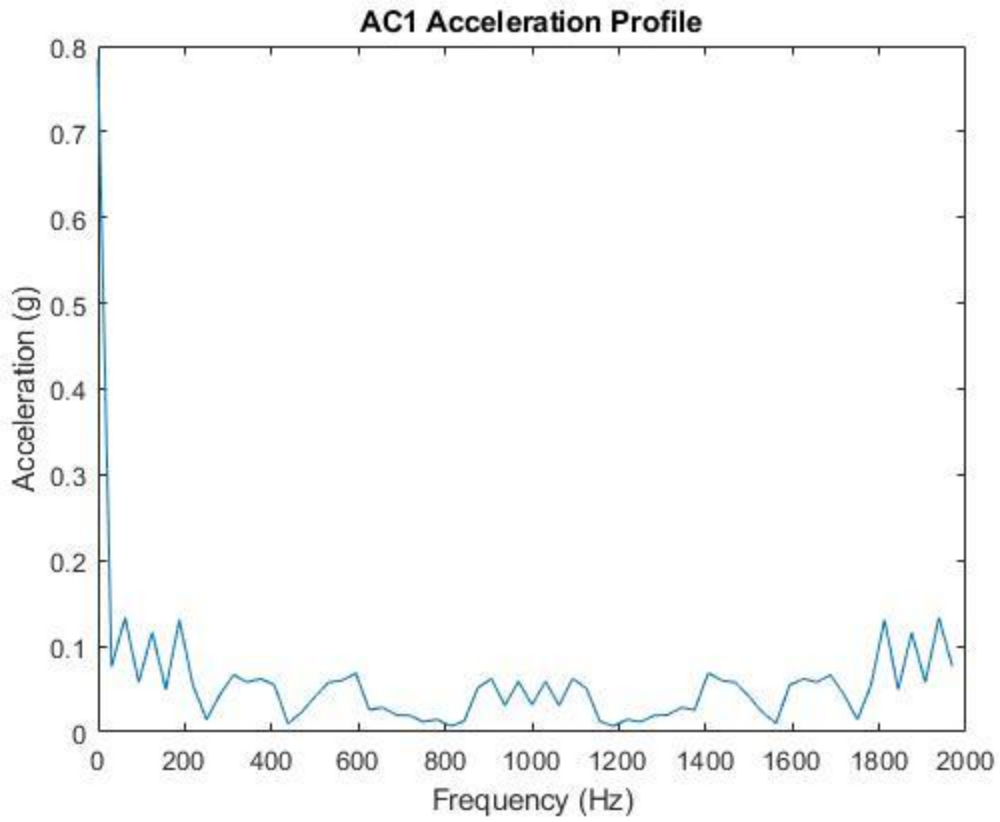
**Figure B-22:** Temperatures of all four Governor Side bearing thermocouples in the 82.2 °C start-stop test.



**Figure B-23:** Temperatures of all four Motor Side bearing thermocouples in the 82.2 °C start-stop test.

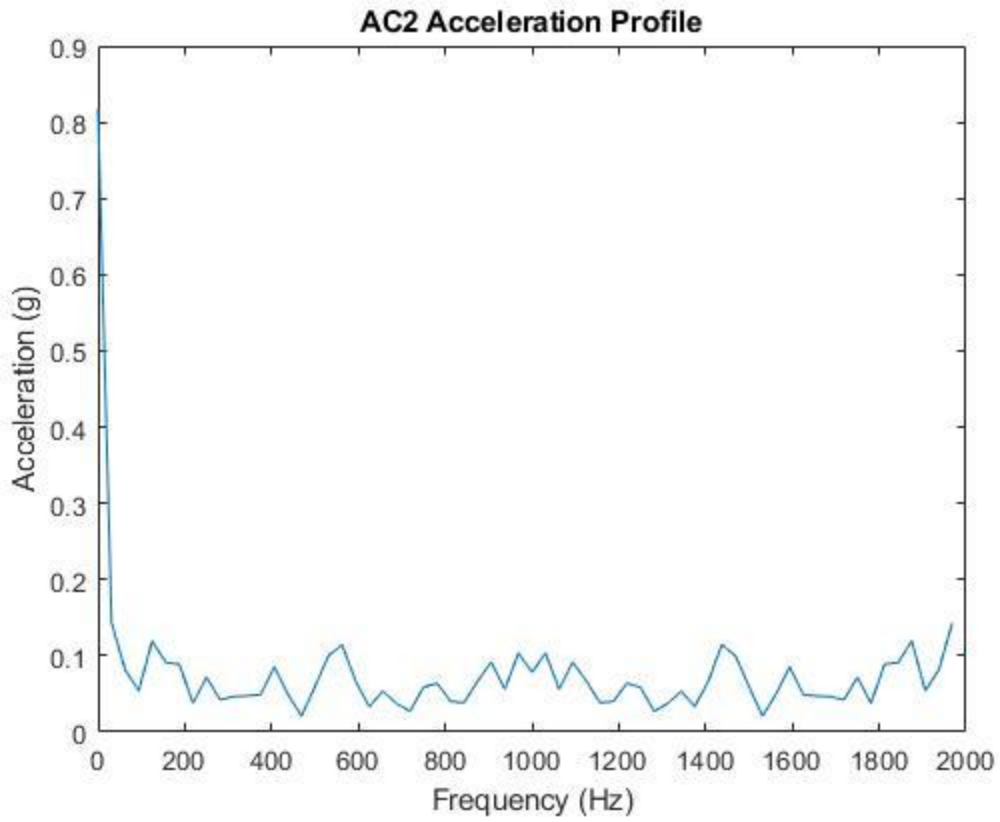


**Figure B-24:** Turbine speed during the 82.2 °C start-stop test.

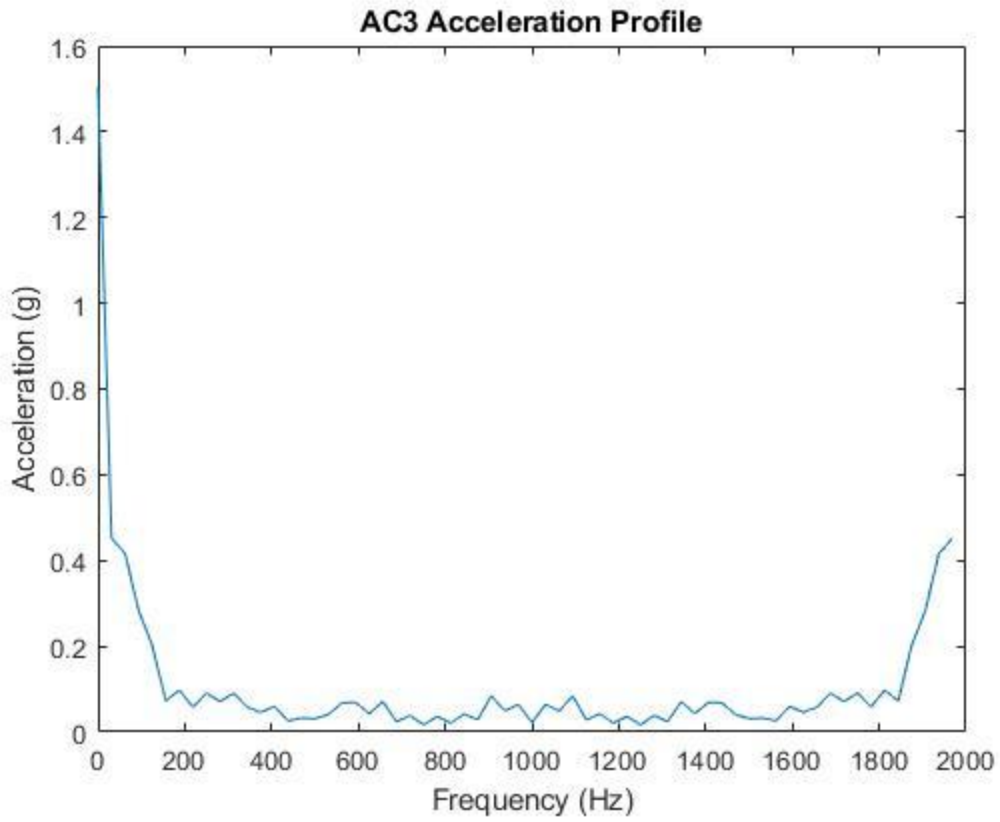


**Figure B-25:** Acceleration profile of accelerometer 1.

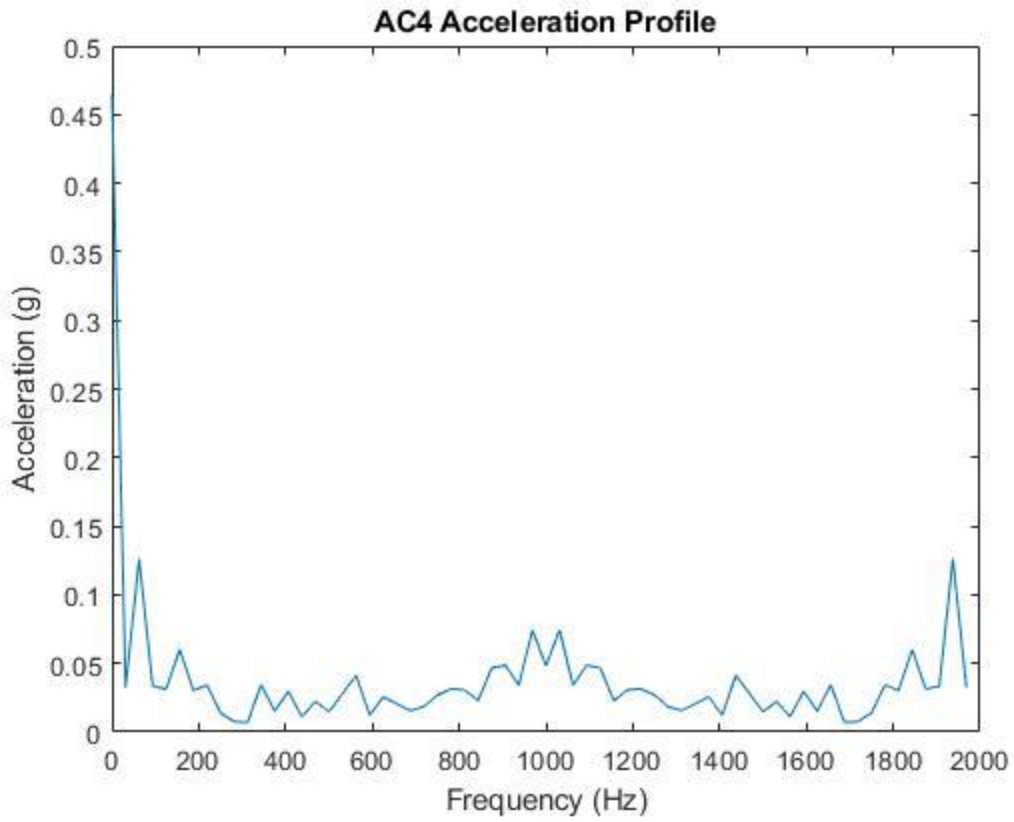




**Figure B-26:** Acceleration profile of accelerometer 2.



**Figure B-27:** Acceleration profile of accelerometer 3.



**Figure B-28:** Acceleration profile of accelerometer 4.

## APPENDIX C

### OPERATING PROCEDURES

#### C.1. General Operating Procedures

##### Pre-Test:

1. Visually inspect GS-2 Terry Turbine, electric motor, and shaft couplings.
2. Disconnect extension wire connectors from thermocouples penetrating top casing of governor and motor side oil wells.
3. Disconnect wiring from accelerometers on top of the top casing of governor and motor side oil wells.
4. Disassemble top casing of governor and motor side oil wells.
5. Fill governor and motor side oil wells with Mobil DTE-732 Light Turbine Oil to designated fill line marked on outside of the casing.
6. Reassemble top casing of the governor and motor side oil wells.
7. Reconnect extension wire connectors to thermocouples penetrating top casing of governor and motor side oil wells.
8. Reconnect wiring to accelerometers on top of the top casing of governor and motor side oil wells.
9. Visually inspect oil wells for leaks.
10. Install red blast-shield cage around motor-shaft coupling point.
11. Ensure all instrumentation wiring is connected and in good condition.
12. Turn on the Data Acquisition (DAQ) system.

13. Turn on the external power supply.
14. Plug in hygrometer to electrical outlet.
15. Remove cap from end of the hygrometer probe.
16. Turn on breakers 31, 33, and 35 of the 480V breaker panel.
17. Visually check power is supplied to VFD control panel.
18. Make note of any conditions in laboratory that could affect testing.

Test:

1. Turn on laboratory computer to the left of the fume hood
2. Open LabVIEW files titled “RT Main 1.5.vi” and “GS2.vi”.
3. Press the “run” button on “RT Main 1.5.vi” (arrow in top left corner of screen).
4. Press the “run” button on “GS2.vi” (arrow in top left corner of screen).
5. Ensure both programs begin operating, check to make sure all instrumentation are reading expected values (i.e. thermocouples are reading room temperature).
6. Click the “STOP” button on “GS2.vi”.
7. Type in desired name of file to be recorded in the WRITE TO FILE text box.
8. Select “Yes” under switch labeled WRITE TO FILE on “GS2.vi”.
9. Repeat steps 4 and 5. (NOTICE: At this point the program is now recording all data and saving to the designated file).

**(If test does not require heating of the oil wells skip steps 10-14)**

10. Plug in and turn on Vallin heater control box.
11. Connect to Vallin heater control box via Bluetooth from a mobile device.
12. Set the “Governor Side” and “Motor Side” heaters to 100% via mobile device.
13. Monitor oil temperature on computer until desired temperature is reached

14. Manually adjust heater power (0-100%) via mobile device to maintain desired temperature throughout the test.
15. Set VFD control panel to desired frequency via the rotating knob and press green start button. (**CAUTION:** at this point the motor and turbine shaft will begin rotating, constantly be aware of, and checking for, anything that might indicate a safety risk).
16. Monitor system and adjust turbine speed via the VFD control panel as necessary per test parameters.
17. When test is concluded bring system to a rest by setting the VFD control panel frequency to 0 Hz.
18. Set “Governor Side” and “Motor Side” heaters to 0% via mobile device and turn off Vallin heater control box.
19. Press the “STOP” button on “GS2.vi”.
20. Check data file to ensure data was recorded properly.

Post-Test:

1. Open LabVIEW files titled “RT Main 1.5.vi” and “GS2.vi”.
2. Press the “run” button on “RT Main 1.5.vi” (arrow in top left corner of screen).
3. Press the “run” button on “GS2.vi” (arrow in top left corner of screen).
4. Monitor temperature of both oil wells until it drops to a temperature that is safe for physical touching.
5. Drain oil from governor and motor side oil wells

6. Disconnect extension wire connectors from thermocouples penetrating top casing of governor and motor side oil wells.
7. Disconnect wiring from accelerometers on top of the top casing of governor and motor side oil wells.

**8. (Gloves must be worn for the following steps)**

9. Place a lint-free towel on a nearby table or open surface.
10. Disassemble top casing of governor and motor side oil wells.
11. Unscrew four screws from top bearing of the governor side bearing.
12. Remove top bearing and place on lint-free towel from step 8.
13. Move slinger rings out of bottom bearing ports.
14. Remove bottom bearing and place on lint-free towel from step 8.
15. Visually and physically (touching) inspect the bearings.
16. Photograph both bearings for documentation.
17. Reinstall bottom bearing.
18. Return slinger rings to bottom bearing ports.
19. Reinstall top bearing.
20. Screw in four screws into top bearing.
21. Repeat steps 10-19 on the motor side bearing.
22. Reassemble top casings of the governor and motor side oil wells.

## APPENDIX D

### MATLAB SCRIPTS

#### D.1. Unheated Constant Speed Test Data Analysis

```
clear;
close all;
clc;

A = importdata('2020_04_10_1hour_steady_state.dat');

TCM1 = transpose(A(:,3));
TCM2 = transpose(A(:,6));
TCM3 = transpose(A(:,9));
TCM4 = transpose(A(:,12));
TCMT = transpose(A(:,15));
TCMT_F = (TCMT * (9/5)) + 32;
TCMMT = transpose(A(:,18));
TCMMB = transpose(A(:,21));
TCMB = transpose(A(:,24));
TCG1 = transpose(A(:,27));
TCG2 = transpose(A(:,30));
TCG3 = transpose(A(:,33));
TCG4 = transpose(A(:,36));
TCGB = transpose(A(:,39));
TCGMB = transpose(A(:,42));
TCGMT = transpose(A(:,45));
TCGT = transpose(A(:,48));
TCGT_F = (TCGT * (9/5)) + 32;
Speed = transpose(A(:,66));
Torque = transpose(A(:,70));
TCM1_F = (TCM1 * (9/5)) + 32;
TCM2_F = (TCM2 * (9/5)) + 32;
TCM3_F = (TCM3 * (9/5)) + 32;
TCM4_F = (TCM4 * (9/5)) + 32;
TCG1_F = (TCG1 * (9/5)) + 32;
TCG2_F = (TCG2 * (9/5)) + 32;
TCG3_F = (TCG3 * (9/5)) + 32;
TCG4_F = (TCG4 * (9/5)) + 32;

motor_bearing_average = (TCM1 + TCM2 + TCM3 + TCM4)/4;
motor_bearing_average_F = (TCM1_F + TCM2_F + TCM3_F + TCM4_F)/4;
governor_bearing_average = (TCG1 + TCG2 + TCG3 + TCG4)/4;
governor_bearing_average_F = (TCG1_F + TCG2_F + TCG3_F + TCG4_F)/4;

time = [0:1:39899];
real_time = time/10;
```



```

figure(1);
plot(real_time,TCM1,real_time,TCM2,real_time,TCM3,real_time,TCM4)
title('Motor Side Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'M1','M2','M3','M4',},'Location','southeast');

figure(2);
plot(real_time,TCG1,real_time,TCG2,real_time,TCG3,real_time,TCG4)
title('Governor Side Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'G1','G2','G3','G4',},'Location','southeast');

figure(3);
plot(real_time,TCMT,real_time,TCMMT,real_time,TCMMB,real_time,TCMB)
title('Motor Side Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperatre (°C)');
legend({'Top','Middle-Top','Middle-
Bottom','Bottom'},'Location','eastoutside');

figure(4);
plot(real_time,TCGT,real_time,TCGMT,real_time,TCGMB,real_time,TCGB)
title('Governor Side Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperatre (°C)');
legend({'Top','Middle-Top','Middle-
Bottom','Bottom'},'Location','eastoutside');

figure(5);
plot(real_time,Speed)
title('Turbine Speed');
xlabel('Time (s)');
ylabel('Shaft Speed (RPM)');

figure(6);
plot(real_time,Torque)
title('Torque vs. Time');
xlabel('Time (s)');
ylabel('Torque (Nm)');

figure(7);
plot(real_time,motor_bearing_average)
title('Averaged Motor Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(8);
plot(real_time,governor_bearing_average)
title('Averaged Governor Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

```

```

figure(9);
plot(real_time,governor_bearing_average,real_time,motor_bearing_average)
title('Bearing Averaged Temperature Comparison')
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'Averaged Governor Bearing Temperature','Averaged Motor Bearing
Temperature'},'Location','southeast');

figure(10);
plot(real_time,governor_bearing_average_F,real_time,TCGT_F)
title('Governor Side Oil and Bearing Temperature Comparison');
xlabel('Time (s)');
ylabel('Temperature (°F)');
legend({'Governor Side Bearing Average','Top Governor Side Oil Well
TC'},'Location','southeast');

figure(11);
plot(real_time,motor_bearing_average_F,real_time,TCMT_F)
title('Motor Side Oil and Bearing Temperature Comparison');
xlabel('Time (s)');
ylabel('Temperature (°F)');
legend({'Motor Side Bearing Average','Top Motor Side Oil Well
TC'},'Location','southeast');

figure(12);
plot(real_time,governor_bearing_average_F,real_time,motor_bearing_average_F)
title('Bearing Averaged Temperature Comparison')
xlabel('Time (s)');
ylabel('Temperature (°F)');
legend({'Averaged Governor Bearing Temperature','Averaged Motor Bearing
Temperature'},'Location','southeast');

```

## D.2. Unheated Constant Speed Test Accelerometer Analysis

```
clear;
close all;
clc;
%accelerometer script
%71-AC1 force
%72-AC1 std
%73-136 AC1 bins
%137 AC2 force
%138 AC2 std
%139-202 AC2 Bins
%203-AC3 force
%204-AC3 std
%205-268 AC3 Bins
%269- AC4 Force
%270-AC4 std
%271-334 AC4 bins
A = importdata('2020_04_10_1hour_steady_state.dat');
time = [0:1:39899]/10;

AC1B1 = transpose(A(:,73));
AC1B2 = transpose(A(:,74));
AC1B3 = transpose(A(:,75));
AC1B4 = transpose(A(:,76));
AC1B5 = transpose(A(:,77));
AC1B6 = transpose(A(:,78));
AC1B7 = transpose(A(:,79));
AC1B8 = transpose(A(:,80));
AC1B9 = transpose(A(:,81));
AC1B10 = transpose(A(:,82));
AC1B11 = transpose(A(:,83));
AC1B12 = transpose(A(:,84));
AC1B13 = transpose(A(:,85));
AC1B14 = transpose(A(:,86));
AC1B15 = transpose(A(:,87));
AC1B16 = transpose(A(:,88));
AC1B17 = transpose(A(:,89));
AC1B18 = transpose(A(:,90));
AC1B19 = transpose(A(:,91));
AC1B20 = transpose(A(:,92));
AC1B21 = transpose(A(:,93));
AC1B22 = transpose(A(:,94));
AC1B23 = transpose(A(:,95));
AC1B24 = transpose(A(:,96));
AC1B25 = transpose(A(:,97));
AC1B26 = transpose(A(:,98));
AC1B27 = transpose(A(:,99));
AC1B28 = transpose(A(:,100));
AC1B29 = transpose(A(:,101));
AC1B30 = transpose(A(:,102));
AC1B31 = transpose(A(:,103));
AC1B32 = transpose(A(:,104));
AC1B33 = transpose(A(:,105));
AC1B34 = transpose(A(:,106));
AC1B35 = transpose(A(:,107));
```

```
AC1B36 = transpose(A(:,108));
AC1B37 = transpose(A(:,109));
AC1B38 = transpose(A(:,110));
AC1B39 = transpose(A(:,111));
AC1B40 = transpose(A(:,112));
AC1B41 = transpose(A(:,113));
AC1B42 = transpose(A(:,114));
AC1B43 = transpose(A(:,115));
AC1B44 = transpose(A(:,116));
AC1B45 = transpose(A(:,117));
AC1B46 = transpose(A(:,118));
AC1B47 = transpose(A(:,119));
AC1B48 = transpose(A(:,120));
AC1B49 = transpose(A(:,121));
AC1B50 = transpose(A(:,122));
AC1B51 = transpose(A(:,123));
AC1B52 = transpose(A(:,124));
AC1B53 = transpose(A(:,125));
AC1B54 = transpose(A(:,126));
AC1B55 = transpose(A(:,127));
AC1B56 = transpose(A(:,128));
AC1B57 = transpose(A(:,129));
AC1B58 = transpose(A(:,130));
AC1B59 = transpose(A(:,131));
AC1B60 = transpose(A(:,132));
AC1B61 = transpose(A(:,133));
AC1B62 = transpose(A(:,134));
AC1B63 = transpose(A(:,135));
AC1B64 = transpose(A(:,136));
```

```
AC2B1 = transpose(A(:,139));
AC2B2 = transpose(A(:,140));
AC2B3 = transpose(A(:,141));
AC2B4 = transpose(A(:,142));
AC2B5 = transpose(A(:,143));
AC2B6 = transpose(A(:,144));
AC2B7 = transpose(A(:,145));
AC2B8 = transpose(A(:,146));
AC2B9 = transpose(A(:,147));
AC2B10 = transpose(A(:,148));
AC2B11 = transpose(A(:,149));
AC2B12 = transpose(A(:,150));
AC2B13 = transpose(A(:,151));
AC2B14 = transpose(A(:,152));
AC2B15 = transpose(A(:,153));
AC2B16 = transpose(A(:,154));
AC2B17 = transpose(A(:,155));
AC2B18 = transpose(A(:,156));
AC2B19 = transpose(A(:,157));
AC2B20 = transpose(A(:,158));
AC2B21 = transpose(A(:,159));
AC2B22 = transpose(A(:,160));
AC2B23 = transpose(A(:,161));
AC2B24 = transpose(A(:,162));
AC2B25 = transpose(A(:,163));
AC2B26 = transpose(A(:,164));
AC2B27 = transpose(A(:,165));
```

```
AC2B28 = transpose(A(:,166));
AC2B29 = transpose(A(:,167));
AC2B30 = transpose(A(:,168));
AC2B31 = transpose(A(:,169));
AC2B32 = transpose(A(:,170));
AC2B33 = transpose(A(:,171));
AC2B34 = transpose(A(:,172));
AC2B35 = transpose(A(:,173));
AC2B36 = transpose(A(:,174));
AC2B37 = transpose(A(:,175));
AC2B38 = transpose(A(:,176));
AC2B39 = transpose(A(:,177));
AC2B40 = transpose(A(:,178));
AC2B41 = transpose(A(:,179));
AC2B42 = transpose(A(:,180));
AC2B43 = transpose(A(:,181));
AC2B44 = transpose(A(:,182));
AC2B45 = transpose(A(:,183));
AC2B46 = transpose(A(:,184));
AC2B47 = transpose(A(:,185));
AC2B48 = transpose(A(:,186));
AC2B49 = transpose(A(:,187));
AC2B50 = transpose(A(:,188));
AC2B51 = transpose(A(:,189));
AC2B52 = transpose(A(:,190));
AC2B53 = transpose(A(:,191));
AC2B54 = transpose(A(:,192));
AC2B55 = transpose(A(:,193));
AC2B56 = transpose(A(:,194));
AC2B57 = transpose(A(:,195));
AC2B58 = transpose(A(:,196));
AC2B59 = transpose(A(:,197));
AC2B60 = transpose(A(:,198));
AC2B61 = transpose(A(:,199));
AC2B62 = transpose(A(:,200));
AC2B63 = transpose(A(:,201));
AC2B64 = transpose(A(:,202));
```

```
AC3B1 = transpose(A(:,205));
AC3B2 = transpose(A(:,206));
AC3B3 = transpose(A(:,207));
AC3B4 = transpose(A(:,208));
AC3B5 = transpose(A(:,209));
AC3B6 = transpose(A(:,210));
AC3B7 = transpose(A(:,211));
AC3B8 = transpose(A(:,212));
AC3B9 = transpose(A(:,213));
AC3B10 = transpose(A(:,214));
AC3B11 = transpose(A(:,215));
AC3B12 = transpose(A(:,216));
AC3B13 = transpose(A(:,217));
AC3B14 = transpose(A(:,218));
AC3B15 = transpose(A(:,219));
AC3B16 = transpose(A(:,220));
AC3B17 = transpose(A(:,221));
AC3B18 = transpose(A(:,222));
AC3B19 = transpose(A(:,223));
```

```
AC3B20 = transpose(A(:,224));
AC3B21 = transpose(A(:,225));
AC3B22 = transpose(A(:,226));
AC3B23 = transpose(A(:,227));
AC3B24 = transpose(A(:,228));
AC3B25 = transpose(A(:,229));
AC3B26 = transpose(A(:,230));
AC3B27 = transpose(A(:,231));
AC3B28 = transpose(A(:,232));
AC3B29 = transpose(A(:,233));
AC3B30 = transpose(A(:,234));
AC3B31 = transpose(A(:,235));
AC3B32 = transpose(A(:,236));
AC3B33 = transpose(A(:,237));
AC3B34 = transpose(A(:,238));
AC3B35 = transpose(A(:,239));
AC3B36 = transpose(A(:,240));
AC3B37 = transpose(A(:,241));
AC3B38 = transpose(A(:,242));
AC3B39 = transpose(A(:,243));
AC3B40 = transpose(A(:,244));
AC3B41 = transpose(A(:,245));
AC3B42 = transpose(A(:,246));
AC3B43 = transpose(A(:,247));
AC3B44 = transpose(A(:,248));
AC3B45 = transpose(A(:,249));
AC3B46 = transpose(A(:,250));
AC3B47 = transpose(A(:,251));
AC3B48 = transpose(A(:,252));
AC3B49 = transpose(A(:,253));
AC3B50 = transpose(A(:,254));
AC3B51 = transpose(A(:,255));
AC3B52 = transpose(A(:,256));
AC3B53 = transpose(A(:,257));
AC3B54 = transpose(A(:,258));
AC3B55 = transpose(A(:,259));
AC3B56 = transpose(A(:,260));
AC3B57 = transpose(A(:,261));
AC3B58 = transpose(A(:,262));
AC3B59 = transpose(A(:,263));
AC3B60 = transpose(A(:,264));
AC3B61 = transpose(A(:,265));
AC3B62 = transpose(A(:,266));
AC3B63 = transpose(A(:,267));
AC3B64 = transpose(A(:,268));
```

```
AC4B1 = transpose(A(:,271));
AC4B2 = transpose(A(:,272));
AC4B3 = transpose(A(:,273));
AC4B4 = transpose(A(:,274));
AC4B5 = transpose(A(:,275));
AC4B6 = transpose(A(:,276));
AC4B7 = transpose(A(:,277));
AC4B8 = transpose(A(:,278));
AC4B9 = transpose(A(:,279));
AC4B10 = transpose(A(:,280));
AC4B11 = transpose(A(:,281));
```

```
AC4B12 = transpose(A(:,282));
AC4B13 = transpose(A(:,283));
AC4B14 = transpose(A(:,284));
AC4B15 = transpose(A(:,285));
AC4B16 = transpose(A(:,286));
AC4B17 = transpose(A(:,287));
AC4B18 = transpose(A(:,288));
AC4B19 = transpose(A(:,289));
AC4B20 = transpose(A(:,290));
AC4B21 = transpose(A(:,291));
AC4B22 = transpose(A(:,292));
AC4B23 = transpose(A(:,293));
AC4B24 = transpose(A(:,294));
AC4B25 = transpose(A(:,295));
AC4B26 = transpose(A(:,296));
AC4B27 = transpose(A(:,297));
AC4B28 = transpose(A(:,298));
AC4B29 = transpose(A(:,299));
AC4B30 = transpose(A(:,300));
AC4B31 = transpose(A(:,301));
AC4B32 = transpose(A(:,302));
AC4B33 = transpose(A(:,303));
AC4B34 = transpose(A(:,304));
AC4B35 = transpose(A(:,305));
AC4B36 = transpose(A(:,306));
AC4B37 = transpose(A(:,307));
AC4B38 = transpose(A(:,308));
AC4B39 = transpose(A(:,309));
AC4B40 = transpose(A(:,310));
AC4B41 = transpose(A(:,311));
AC4B42 = transpose(A(:,312));
AC4B43 = transpose(A(:,313));
AC4B44 = transpose(A(:,314));
AC4B45 = transpose(A(:,315));
AC4B46 = transpose(A(:,316));
AC4B47 = transpose(A(:,317));
AC4B48 = transpose(A(:,318));
AC4B49 = transpose(A(:,319));
AC4B50 = transpose(A(:,320));
AC4B51 = transpose(A(:,321));
AC4B52 = transpose(A(:,322));
AC4B53 = transpose(A(:,323));
AC4B54 = transpose(A(:,324));
AC4B55 = transpose(A(:,325));
AC4B56 = transpose(A(:,326));
AC4B57 = transpose(A(:,327));
AC4B58 = transpose(A(:,328));
AC4B59 = transpose(A(:,329));
AC4B60 = transpose(A(:,330));
AC4B61 = transpose(A(:,331));
AC4B62 = transpose(A(:,332));
AC4B63 = transpose(A(:,333));
AC4B64 = transpose(A(:,334));
```

```

AC1_avg = (AC1B1 + AC1B2+ AC1B3 + AC1B4 + AC1B5 + AC1B6 + AC1B7 + AC1B8 +
AC1B9 + AC1B10 + AC1B11 + AC1B12+ AC1B13 + AC1B14 + AC1B15 + AC1B16 + AC1B17
+ AC1B18 + AC1B19 + AC1B20 + AC1B21 + AC1B22+ AC1B23 + AC1B24 + AC1B25 +
AC1B26 + AC1B27 + AC1B28 + AC1B29 + AC1B30 + AC1B31 + AC1B32+ AC1B33 + AC1B34
+ AC1B35 + AC1B36 + AC1B37 + AC1B38 + AC1B39 + AC1B40 + AC1B41 + AC1B42+
AC1B43 + AC1B44 + AC1B45 + AC1B46 + AC1B47 + AC1B48 + AC1B49 + AC1B50 +
AC1B51 + AC1B52+ AC1B53 + AC1B54 + AC1B55 + AC1B56 + AC1B57 + AC1B58 + AC1B59
+ AC1B60 + AC1B61 + AC1B62 + AC1B63 + AC1B64)/64;
AC2_avg = (AC2B1 + AC2B2+ AC2B3 + AC2B4 + AC2B5 + AC2B6 + AC2B7 + AC2B8 +
AC2B9 + AC2B10 + AC2B11 + AC2B12+ AC2B13 + AC2B14 + AC2B15 + AC2B16 + AC2B17
+ AC2B18 + AC2B19 + AC2B20 + AC2B21 + AC2B22+ AC2B23 + AC2B24 + AC2B25 +
AC2B26 + AC2B27 + AC2B28 + AC2B29 + AC2B30 + AC2B31 + AC2B32+ AC2B33 + AC2B34
+ AC2B35 + AC2B36 + AC2B37 + AC2B38 + AC2B39 + AC2B40 + AC2B41 + AC2B42+
AC2B43 + AC2B44 + AC2B45 + AC2B46 + AC2B47 + AC2B48 + AC2B49 + AC2B50 +
AC2B51 + AC2B52+ AC2B53 + AC2B54 + AC2B55 + AC2B56 + AC2B57 + AC2B58 + AC2B59
+ AC2B60 + AC2B61 + AC2B62 + AC2B63 + AC2B64)/64;
AC3_avg = (AC3B1 + AC3B2+ AC3B3 + AC3B4 + AC3B5 + AC3B6 + AC3B7 + AC3B8 +
AC3B9 + AC3B10 + AC3B11 + AC3B12+ AC3B13 + AC3B14 + AC3B15 + AC3B16 + AC3B17
+ AC3B18 + AC3B19 + AC3B20 + AC3B21 + AC3B22+ AC3B23 + AC3B24 + AC3B25 +
AC3B26 + AC3B27 + AC3B28 + AC3B29 + AC3B30 + AC3B31 + AC3B32+ AC3B33 + AC3B34
+ AC3B35 + AC3B36 + AC3B37 + AC3B38 + AC3B39 + AC3B40 + AC3B41 + AC3B42+
AC3B43 + AC3B44 + AC3B45 + AC3B46 + AC3B47 + AC3B48 + AC3B49 + AC3B50 +
AC3B51 + AC3B52+ AC3B53 + AC3B54 + AC3B55 + AC3B56+ AC3B57 + AC3B58 + AC3B59
+ AC3B60 + AC3B61 + AC3B62 + AC3B63 + AC3B64)/64;
AC4_avg = (AC4B1 + AC4B2+ AC4B3 + AC4B4 + AC4B5 + AC4B6 + AC4B7 + AC4B8 +
AC4B9 + AC4B10 + AC4B11 + AC4B12+ AC4B13 + AC4B14 + AC4B15 + AC4B16 + AC4B17
+ AC4B18 + AC4B19 + AC4B20 + AC4B21 + AC4B22+ AC4B23 + AC4B24 + AC4B25 +
AC4B26 + AC4B27 + AC4B28 + AC4B29 + AC4B30 + AC4B31 + AC4B32+ AC4B33 + AC4B34
+ AC4B35 + AC4B36 + AC4B37 + AC4B38 + AC4B39 + AC4B40 + AC4B41 + AC4B42+
AC4B43 + AC4B44 + AC4B45 + AC4B46 + AC4B47 + AC4B48 + AC4B49 + AC4B50 +
AC4B51 + AC4B52+ AC4B53 + AC4B54 + AC4B55 + AC4B56 + AC4B57 + AC4B58 + AC4B59
+ AC4B60 + AC4B61 + AC4B62 + AC4B63 + AC4B64)/64;

```

```

figure(1)
plot(time,AC1_avg,time,AC2_avg,time,AC3_avg,time,AC4_avg);
title('Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC1', 'AC2', 'AC3', 'AC4'}, 'Location', 'northwest');

```

```

figure(2)
plot(time,AC1_avg,time,AC2_avg);
title('Governor Side Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC1', 'AC2'}, 'Location', 'northwest');

```

```

figure(3)
plot(time,AC3_avg,time,AC4_avg);
title('Motor Side Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC3', 'AC4'}, 'Location', 'northwest');

```

```

figure(4)
plot(time,AC3_avg,time,AC1_avg);

```



```
title('Vertical Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC3', 'AC1'}, 'Location', 'northwest');

figure(5)
plot(time, AC2_avg, time, AC4_avg);
title('Horizontal Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC2', 'AC4'}, 'Location', 'northwest');
```

### D.3. Unheated Constant Speed Test Accelerometer Fast Fourier Transform

```
clear;
close all;
clc;
%accelerometer script
%71-AC1 force
%72-AC1 std
%73-136 AC1 bins
%137 AC2 force
%138 AC2 std
%139-202 AC2 Bins
%203-AC3 force
%204-AC3 std
%205-268 AC3 Bins
%269- AC4 Force
%270-AC4 std
%271-334 AC4 bins
A = importdata('2020_04_10_1hour_steady_state.dat');
time = [0:1:39899]/10;

B(1,1) = sum(transpose(A(:,73)))/39900;
B(2,1) = sum(transpose(A(:,74)))/39900;
B(3,1) = sum(transpose(A(:,75)))/39900;
B(4,1) = sum(transpose(A(:,76)))/39900;
B(5,1) = sum(transpose(A(:,77)))/39900;
B(6,1) = sum(transpose(A(:,78)))/39900;
B(7,1) = sum(transpose(A(:,79)))/39900;
B(8,1) = sum(transpose(A(:,80)))/39900;
B(9,1) = sum(transpose(A(:,81)))/39900;
B(10,1) = sum(transpose(A(:,82)))/39900;
B(11,1) = sum(transpose(A(:,83)))/39900;
B(12,1) = sum(transpose(A(:,84)))/39900;
B(13,1) = sum(transpose(A(:,85)))/39900;
B(14,1) = sum(transpose(A(:,86)))/39900;
B(15,1) = sum(transpose(A(:,87)))/39900;
B(16,1) = sum(transpose(A(:,88)))/39900;
B(17,1) = sum(transpose(A(:,89)))/39900;
B(18,1) = sum(transpose(A(:,90)))/39900;
B(19,1) = sum(transpose(A(:,91)))/39900;
B(20,1) = sum(transpose(A(:,92)))/39900;
B(21,1) = sum(transpose(A(:,93)))/39900;
B(22,1) = sum(transpose(A(:,94)))/39900;
B(23,1) = sum(transpose(A(:,95)))/39900;
B(24,1) = sum(transpose(A(:,96)))/39900;
B(25,1) = sum(transpose(A(:,97)))/39900;
B(26,1) = sum(transpose(A(:,98)))/39900;
B(27,1) = sum(transpose(A(:,99)))/39900;
B(28,1) = sum(transpose(A(:,100)))/39900;
B(29,1) = sum(transpose(A(:,101)))/39900;
B(30,1) = sum(transpose(A(:,102)))/39900;
B(31,1) = sum(transpose(A(:,103)))/39900;
B(32,1) = sum(transpose(A(:,104)))/39900;
B(33,1) = sum(transpose(A(:,105)))/39900;
B(34,1) = sum(transpose(A(:,106)))/39900;
B(35,1) = sum(transpose(A(:,107)))/39900;
```

```

B(36,1) = sum(transpose(A(:,108)))/39900;
B(37,1) = sum(transpose(A(:,109)))/39900;
B(38,1) = sum(transpose(A(:,110)))/39900;
B(39,1) = sum(transpose(A(:,111)))/39900;
B(40,1) = sum(transpose(A(:,112)))/39900;
B(41,1) = sum(transpose(A(:,113)))/39900;
B(42,1) = sum(transpose(A(:,114)))/39900;
B(43,1) = sum(transpose(A(:,115)))/39900;
B(44,1) = sum(transpose(A(:,116)))/39900;
B(45,1) = sum(transpose(A(:,117)))/39900;
B(46,1) = sum(transpose(A(:,118)))/39900;
B(47,1) = sum(transpose(A(:,119)))/39900;
B(48,1) = sum(transpose(A(:,120)))/39900;
B(49,1) = sum(transpose(A(:,121)))/39900;
B(50,1) = sum(transpose(A(:,122)))/39900;
B(51,1) = sum(transpose(A(:,123)))/39900;
B(52,1) = sum(transpose(A(:,124)))/39900;
B(53,1) = sum(transpose(A(:,125)))/39900;
B(54,1) = sum(transpose(A(:,126)))/39900;
B(55,1) = sum(transpose(A(:,127)))/39900;
B(56,1) = sum(transpose(A(:,128)))/39900;
B(57,1) = sum(transpose(A(:,129)))/39900;
B(58,1) = sum(transpose(A(:,130)))/39900;
B(59,1) = sum(transpose(A(:,131)))/39900;
B(60,1) = sum(transpose(A(:,132)))/39900;
B(61,1) = sum(transpose(A(:,133)))/39900;
B(62,1) = sum(transpose(A(:,134)))/39900;
B(63,1) = sum(transpose(A(:,135)))/39900;
B(64,1) = sum(transpose(A(:,136)))/39900;

```

```

fax_bins = [0:31.25:1999];
plot(fax_bins, abs(fft(B)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC1 Acceleration Profile');

```

```

C(1,1) = sum(transpose(A(:,139)))/39900;
C(2,1) = sum(transpose(A(:,140)))/39900;
C(3,1) = sum(transpose(A(:,141)))/39900;
C(4,1) = sum(transpose(A(:,142)))/39900;
C(5,1) = sum(transpose(A(:,143)))/39900;
C(6,1) = sum(transpose(A(:,144)))/39900;
C(7,1) = sum(transpose(A(:,145)))/39900;
C(8,1) = sum(transpose(A(:,146)))/39900;
C(9,1) = sum(transpose(A(:,147)))/39900;
C(10,1) = sum(transpose(A(:,148)))/39900;
C(11,1) = sum(transpose(A(:,149)))/39900;
C(12,1) = sum(transpose(A(:,150)))/39900;
C(13,1) = sum(transpose(A(:,151)))/39900;
C(14,1) = sum(transpose(A(:,152)))/39900;
C(15,1) = sum(transpose(A(:,153)))/39900;
C(16,1) = sum(transpose(A(:,154)))/39900;
C(17,1) = sum(transpose(A(:,155)))/39900;
C(18,1) = sum(transpose(A(:,156)))/39900;
C(19,1) = sum(transpose(A(:,157)))/39900;
C(20,1) = sum(transpose(A(:,158)))/39900;

```

```

C(21,1) = sum(transpose(A(:,159)))/39900;
C(22,1) = sum(transpose(A(:,160)))/39900;
C(23,1) = sum(transpose(A(:,161)))/39900;
C(24,1) = sum(transpose(A(:,162)))/39900;
C(25,1) = sum(transpose(A(:,163)))/39900;
C(26,1) = sum(transpose(A(:,164)))/39900;
C(27,1) = sum(transpose(A(:,165)))/39900;
C(28,1) = sum(transpose(A(:,166)))/39900;
C(29,1) = sum(transpose(A(:,167)))/39900;
C(30,1) = sum(transpose(A(:,168)))/39900;
C(31,1) = sum(transpose(A(:,169)))/39900;
C(32,1) = sum(transpose(A(:,170)))/39900;
C(33,1) = sum(transpose(A(:,171)))/39900;
C(34,1) = sum(transpose(A(:,172)))/39900;
C(35,1) = sum(transpose(A(:,173)))/39900;
C(36,1) = sum(transpose(A(:,174)))/39900;
C(37,1) = sum(transpose(A(:,175)))/39900;
C(38,1) = sum(transpose(A(:,176)))/39900;
C(39,1) = sum(transpose(A(:,177)))/39900;
C(40,1) = sum(transpose(A(:,178)))/39900;
C(41,1) = sum(transpose(A(:,179)))/39900;
C(42,1) = sum(transpose(A(:,180)))/39900;
C(43,1) = sum(transpose(A(:,181)))/39900;
C(44,1) = sum(transpose(A(:,182)))/39900;
C(45,1) = sum(transpose(A(:,183)))/39900;
C(46,1) = sum(transpose(A(:,184)))/39900;
C(47,1) = sum(transpose(A(:,185)))/39900;
C(48,1) = sum(transpose(A(:,186)))/39900;
C(49,1) = sum(transpose(A(:,187)))/39900;
C(50,1) = sum(transpose(A(:,188)))/39900;
C(51,1) = sum(transpose(A(:,189)))/39900;
C(52,1) = sum(transpose(A(:,190)))/39900;
C(53,1) = sum(transpose(A(:,191)))/39900;
C(54,1) = sum(transpose(A(:,192)))/39900;
C(55,1) = sum(transpose(A(:,193)))/39900;
C(56,1) = sum(transpose(A(:,194)))/39900;
C(57,1) = sum(transpose(A(:,195)))/39900;
C(58,1) = sum(transpose(A(:,196)))/39900;
C(59,1) = sum(transpose(A(:,197)))/39900;
C(60,1) = sum(transpose(A(:,198)))/39900;
C(61,1) = sum(transpose(A(:,199)))/39900;
C(62,1) = sum(transpose(A(:,200)))/39900;
C(63,1) = sum(transpose(A(:,201)))/39900;
C(64,1) = sum(transpose(A(:,202)))/39900;

```

```

D(1,1) = sum(transpose(A(:,205)))/39900;
D(2,1) = sum(transpose(A(:,206)))/39900;
D(3,1) = sum(transpose(A(:,207)))/39900;
D(4,1) = sum(transpose(A(:,208)))/39900;
D(5,1) = sum(transpose(A(:,209)))/39900;
D(6,1) = sum(transpose(A(:,210)))/39900;
D(7,1) = sum(transpose(A(:,211)))/39900;
D(8,1) = sum(transpose(A(:,212)))/39900;
D(9,1) = sum(transpose(A(:,213)))/39900;
D(10,1) = sum(transpose(A(:,214)))/39900;
D(11,1) = sum(transpose(A(:,215)))/39900;
D(12,1) = sum(transpose(A(:,216)))/39900;

```

```

D(13,1) = sum(transpose(A(:,217)))/39900;
D(14,1) = sum(transpose(A(:,218)))/39900;
D(15,1) = sum(transpose(A(:,219)))/39900;
D(16,1) = sum(transpose(A(:,220)))/39900;
D(17,1) = sum(transpose(A(:,221)))/39900;
D(18,1) = sum(transpose(A(:,222)))/39900;
D(19,1) = sum(transpose(A(:,223)))/39900;
D(20,1) = sum(transpose(A(:,224)))/39900;
D(21,1) = sum(transpose(A(:,225)))/39900;
D(22,1) = sum(transpose(A(:,226)))/39900;
D(23,1) = sum(transpose(A(:,227)))/39900;
D(24,1) = sum(transpose(A(:,228)))/39900;
D(25,1) = sum(transpose(A(:,229)))/39900;
D(26,1) = sum(transpose(A(:,230)))/39900;
D(27,1) = sum(transpose(A(:,231)))/39900;
D(28,1) = sum(transpose(A(:,232)))/39900;
D(29,1) = sum(transpose(A(:,233)))/39900;
D(30,1) = sum(transpose(A(:,234)))/39900;
D(31,1) = sum(transpose(A(:,235)))/39900;
D(32,1) = sum(transpose(A(:,236)))/39900;
D(33,1) = sum(transpose(A(:,237)))/39900;
D(34,1) = sum(transpose(A(:,238)))/39900;
D(35,1) = sum(transpose(A(:,239)))/39900;
D(36,1) = sum(transpose(A(:,240)))/39900;
D(37,1) = sum(transpose(A(:,241)))/39900;
D(38,1) = sum(transpose(A(:,242)))/39900;
D(39,1) = sum(transpose(A(:,243)))/39900;
D(40,1) = sum(transpose(A(:,244)))/39900;
D(41,1) = sum(transpose(A(:,245)))/39900;
D(42,1) = sum(transpose(A(:,246)))/39900;
D(43,1) = sum(transpose(A(:,247)))/39900;
D(44,1) = sum(transpose(A(:,248)))/39900;
D(45,1) = sum(transpose(A(:,249)))/39900;
D(46,1) = sum(transpose(A(:,250)))/39900;
D(47,1) = sum(transpose(A(:,251)))/39900;
D(48,1) = sum(transpose(A(:,252)))/39900;
D(49,1) = sum(transpose(A(:,253)))/39900;
D(50,1) = sum(transpose(A(:,254)))/39900;
D(51,1) = sum(transpose(A(:,255)))/39900;
D(52,1) = sum(transpose(A(:,256)))/39900;
D(53,1) = sum(transpose(A(:,257)))/39900;
D(54,1) = sum(transpose(A(:,258)))/39900;
D(55,1) = sum(transpose(A(:,259)))/39900;
D(56,1) = sum(transpose(A(:,260)))/39900;
D(57,1) = sum(transpose(A(:,261)))/39900;
D(58,1) = sum(transpose(A(:,262)))/39900;
D(59,1) = sum(transpose(A(:,263)))/39900;
D(60,1) = sum(transpose(A(:,264)))/39900;
D(61,1) = sum(transpose(A(:,265)))/39900;
D(62,1) = sum(transpose(A(:,266)))/39900;
D(63,1) = sum(transpose(A(:,267)))/39900;
D(64,1) = sum(transpose(A(:,268)))/39900;

E(1,1) = sum(transpose(A(:,271)))/39900;
E(2,1) = sum(transpose(A(:,272)))/39900;
E(3,1) = sum(transpose(A(:,273)))/39900;
E(4,1) = sum(transpose(A(:,274)))/39900;

```

```
E(5,1) = sum(transpose(A(:,275)))/39900;
E(6,1) = sum(transpose(A(:,276)))/39900;
E(7,1) = sum(transpose(A(:,277)))/39900;
E(8,1) = sum(transpose(A(:,278)))/39900;
E(9,1) = sum(transpose(A(:,279)))/39900;
E(10,1) = sum(transpose(A(:,280)))/39900;
E(11,1) = sum(transpose(A(:,281)))/39900;
E(12,1) = sum(transpose(A(:,282)))/39900;
E(13,1) = sum(transpose(A(:,283)))/39900;
E(14,1) = sum(transpose(A(:,284)))/39900;
E(15,1) = sum(transpose(A(:,285)))/39900;
E(16,1) = sum(transpose(A(:,286)))/39900;
E(17,1) = sum(transpose(A(:,287)))/39900;
E(18,1) = sum(transpose(A(:,288)))/39900;
E(19,1) = sum(transpose(A(:,289)))/39900;
E(20,1) = sum(transpose(A(:,290)))/39900;
E(21,1) = sum(transpose(A(:,291)))/39900;
E(22,1) = sum(transpose(A(:,292)))/39900;
E(23,1) = sum(transpose(A(:,293)))/39900;
E(24,1) = sum(transpose(A(:,294)))/39900;
E(25,1) = sum(transpose(A(:,295)))/39900;
E(26,1) = sum(transpose(A(:,296)))/39900;
E(27,1) = sum(transpose(A(:,297)))/39900;
E(28,1) = sum(transpose(A(:,298)))/39900;
E(29,1) = sum(transpose(A(:,299)))/39900;
E(30,1) = sum(transpose(A(:,300)))/39900;
E(31,1) = sum(transpose(A(:,301)))/39900;
E(32,1) = sum(transpose(A(:,302)))/39900;
E(33,1) = sum(transpose(A(:,303)))/39900;
E(34,1) = sum(transpose(A(:,304)))/39900;
E(35,1) = sum(transpose(A(:,305)))/39900;
E(36,1) = sum(transpose(A(:,306)))/39900;
E(37,1) = sum(transpose(A(:,307)))/39900;
E(38,1) = sum(transpose(A(:,308)))/39900;
E(39,1) = sum(transpose(A(:,309)))/39900;
E(40,1) = sum(transpose(A(:,310)))/39900;
E(41,1) = sum(transpose(A(:,311)))/39900;
E(42,1) = sum(transpose(A(:,312)))/39900;
E(43,1) = sum(transpose(A(:,313)))/39900;
E(44,1) = sum(transpose(A(:,314)))/39900;
E(45,1) = sum(transpose(A(:,315)))/39900;
E(46,1) = sum(transpose(A(:,316)))/39900;
E(47,1) = sum(transpose(A(:,317)))/39900;
E(48,1) = sum(transpose(A(:,318)))/39900;
E(49,1) = sum(transpose(A(:,319)))/39900;
E(50,1) = sum(transpose(A(:,320)))/39900;
E(51,1) = sum(transpose(A(:,321)))/39900;
E(52,1) = sum(transpose(A(:,322)))/39900;
E(53,1) = sum(transpose(A(:,323)))/39900;
E(54,1) = sum(transpose(A(:,324)))/39900;
E(55,1) = sum(transpose(A(:,325)))/39900;
E(56,1) = sum(transpose(A(:,326)))/39900;
E(57,1) = sum(transpose(A(:,327)))/39900;
E(58,1) = sum(transpose(A(:,328)))/39900;
E(59,1) = sum(transpose(A(:,329)))/39900;
E(60,1) = sum(transpose(A(:,330)))/39900;
E(61,1) = sum(transpose(A(:,331)))/39900;
```

```

E(62,1) = sum(transpose(A(:,332)))/39900;
E(63,1) = sum(transpose(A(:,333)))/39900;
E(64,1) = sum(transpose(A(:,334)))/39900;

fax_bins = [0:31.25:1999];
figure(1)
plot(fax_bins, abs(fft(B)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC1 Acceleration Profile');

figure(2)
plot(fax_bins, abs(fft(C)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC2 Acceleration Profile');

figure(3)
plot(fax_bins, abs(fft(D)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC3 Acceleration Profile');

figure(4)
plot(fax_bins, abs(fft(E)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC4 Acceleration Profile');

```

## D.4. 71.1 °C Constant Speed Test Data Analysis

```
clear;
close all;
clc;

A = importdata('2020_04_23_160F_steady_state.dat');

TCM1 = transpose(A(:,3));
TCM2 = transpose(A(:,6));
TCM3 = transpose(A(:,9));
TCM4 = transpose(A(:,12));
TCMT = transpose(A(:,15));
TCMMT = transpose(A(:,18));
TCMMB = transpose(A(:,21));
TCMB = transpose(A(:,24));
TCG1 = transpose(A(:,27));
TCG2 = transpose(A(:,30));
TCG3 = transpose(A(:,33));
TCG4 = transpose(A(:,36));
TCGB = transpose(A(:,39));
TCGMB = transpose(A(:,42));
TCGMT = transpose(A(:,45));
TCGT = transpose(A(:,48));
Speed = transpose(A(:,66));
Torque = transpose(A(:,70));

motor_bearing_average = (TCM1 + TCM2 + TCM3 + TCM4)/4;
governor_bearing_average = (TCG1 + TCG2 + TCG3 + TCG4)/4;

time = [0:1:44689];
real_time = time/10;

figure(1);
plot(real_time,TCM1,real_time,TCM2,real_time,TCM3,real_time,TCM4)
title('Motor Side Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'M1', 'M2', 'M3', 'M4',}, 'Location', 'southeast');

figure(2);
plot(real_time,TCG1,real_time,TCG2,real_time,TCG3,real_time,TCG4)
title('Governor Side Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'G1', 'G2', 'G3', 'G4',}, 'Location', 'southeast');

figure(3);
plot(real_time,TCMT,real_time,TCMMT,real_time,TCMMB,real_time,TCMB)
title('Motor Side Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperatre (°C)');
legend({'Top', 'Middle-Top', 'Middle-
Bottom', 'Bottom'}, 'Location', 'eastoutside');
```



```

figure(4);
plot(real_time,TCGT,real_time,TCGMT,real_time,TCGMB,real_time,TCGB)
title('Governor Side Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperatre (°C)');
legend({'Top', 'Middle-Top', 'Middle-
Bottom', 'Bottom'}, 'Location', 'eastoutside');

figure(5);
plot(real_time,Speed)
title('Turbine Speed');
xlabel('Time (s)');
ylabel('Shaft Speed (RPM)');

figure(6);
plot(real_time,Torque)
title('Torque vs. Time');
xlabel('Time (s)');
ylabel('Torque (Nm)');

figure(7);
plot(real_time,motor_bearing_average)
title('Averaged Motor Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(8);
plot(real_time,governor_bearing_average)
title('Averaged Governor Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(9);
plot(real_time,governor_bearing_average,real_time,motor_bearing_average)
title('Bearing Averaged Temperature Comparison')
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'Averaged Governor Bearing Temperature', 'Averaged Motor Bearing
Temperature'}, 'Location', 'southeast');

```

## D.5. 71.1 °C Constant Speed Test Accelerometer Analysis

```
clear;
close all;
clc;
%accelerometer script
%71-AC1 force
%72-AC1 std
%73-136 AC1 bins
%137 AC2 force
%138 AC2 std
%139-202 AC2 Bins
%203-AC3 force
%204-AC3 std
%205-268 AC3 Bins
%269- AC4 Force
%270-AC4 std
%271-334 AC4 bins
A = importdata('2020_04_23_160F_steady_state.dat');
time = [0:1:44689]/10;
```

```
AC1B1 = transpose(A(:,73));
AC1B2 = transpose(A(:,74));
AC1B3 = transpose(A(:,75));
AC1B4 = transpose(A(:,76));
AC1B5 = transpose(A(:,77));
AC1B6 = transpose(A(:,78));
AC1B7 = transpose(A(:,79));
AC1B8 = transpose(A(:,80));
AC1B9 = transpose(A(:,81));
AC1B10 = transpose(A(:,82));
AC1B11 = transpose(A(:,83));
AC1B12 = transpose(A(:,84));
AC1B13 = transpose(A(:,85));
AC1B14 = transpose(A(:,86));
AC1B15 = transpose(A(:,87));
AC1B16 = transpose(A(:,88));
AC1B17 = transpose(A(:,89));
AC1B18 = transpose(A(:,90));
AC1B19 = transpose(A(:,91));
AC1B20 = transpose(A(:,92));
AC1B21 = transpose(A(:,93));
AC1B22 = transpose(A(:,94));
AC1B23 = transpose(A(:,95));
AC1B24 = transpose(A(:,96));
AC1B25 = transpose(A(:,97));
AC1B26 = transpose(A(:,98));
AC1B27 = transpose(A(:,99));
AC1B28 = transpose(A(:,100));
AC1B29 = transpose(A(:,101));
AC1B30 = transpose(A(:,102));
AC1B31 = transpose(A(:,103));
AC1B32 = transpose(A(:,104));
AC1B33 = transpose(A(:,105));
AC1B34 = transpose(A(:,106));
AC1B35 = transpose(A(:,107));
```

```
AC1B36 = transpose(A(:,108));
AC1B37 = transpose(A(:,109));
AC1B38 = transpose(A(:,110));
AC1B39 = transpose(A(:,111));
AC1B40 = transpose(A(:,112));
AC1B41 = transpose(A(:,113));
AC1B42 = transpose(A(:,114));
AC1B43 = transpose(A(:,115));
AC1B44 = transpose(A(:,116));
AC1B45 = transpose(A(:,117));
AC1B46 = transpose(A(:,118));
AC1B47 = transpose(A(:,119));
AC1B48 = transpose(A(:,120));
AC1B49 = transpose(A(:,121));
AC1B50 = transpose(A(:,122));
AC1B51 = transpose(A(:,123));
AC1B52 = transpose(A(:,124));
AC1B53 = transpose(A(:,125));
AC1B54 = transpose(A(:,126));
AC1B55 = transpose(A(:,127));
AC1B56 = transpose(A(:,128));
AC1B57 = transpose(A(:,129));
AC1B58 = transpose(A(:,130));
AC1B59 = transpose(A(:,131));
AC1B60 = transpose(A(:,132));
AC1B61 = transpose(A(:,133));
AC1B62 = transpose(A(:,134));
AC1B63 = transpose(A(:,135));
AC1B64 = transpose(A(:,136));
```

```
AC2B1 = transpose(A(:,139));
AC2B2 = transpose(A(:,140));
AC2B3 = transpose(A(:,141));
AC2B4 = transpose(A(:,142));
AC2B5 = transpose(A(:,143));
AC2B6 = transpose(A(:,144));
AC2B7 = transpose(A(:,145));
AC2B8 = transpose(A(:,146));
AC2B9 = transpose(A(:,147));
AC2B10 = transpose(A(:,148));
AC2B11 = transpose(A(:,149));
AC2B12 = transpose(A(:,150));
AC2B13 = transpose(A(:,151));
AC2B14 = transpose(A(:,152));
AC2B15 = transpose(A(:,153));
AC2B16 = transpose(A(:,154));
AC2B17 = transpose(A(:,155));
AC2B18 = transpose(A(:,156));
AC2B19 = transpose(A(:,157));
AC2B20 = transpose(A(:,158));
AC2B21 = transpose(A(:,159));
AC2B22 = transpose(A(:,160));
AC2B23 = transpose(A(:,161));
AC2B24 = transpose(A(:,162));
AC2B25 = transpose(A(:,163));
AC2B26 = transpose(A(:,164));
AC2B27 = transpose(A(:,165));
```

```
AC2B28 = transpose(A(:,166));
AC2B29 = transpose(A(:,167));
AC2B30 = transpose(A(:,168));
AC2B31 = transpose(A(:,169));
AC2B32 = transpose(A(:,170));
AC2B33 = transpose(A(:,171));
AC2B34 = transpose(A(:,172));
AC2B35 = transpose(A(:,173));
AC2B36 = transpose(A(:,174));
AC2B37 = transpose(A(:,175));
AC2B38 = transpose(A(:,176));
AC2B39 = transpose(A(:,177));
AC2B40 = transpose(A(:,178));
AC2B41 = transpose(A(:,179));
AC2B42 = transpose(A(:,180));
AC2B43 = transpose(A(:,181));
AC2B44 = transpose(A(:,182));
AC2B45 = transpose(A(:,183));
AC2B46 = transpose(A(:,184));
AC2B47 = transpose(A(:,185));
AC2B48 = transpose(A(:,186));
AC2B49 = transpose(A(:,187));
AC2B50 = transpose(A(:,188));
AC2B51 = transpose(A(:,189));
AC2B52 = transpose(A(:,190));
AC2B53 = transpose(A(:,191));
AC2B54 = transpose(A(:,192));
AC2B55 = transpose(A(:,193));
AC2B56 = transpose(A(:,194));
AC2B57 = transpose(A(:,195));
AC2B58 = transpose(A(:,196));
AC2B59 = transpose(A(:,197));
AC2B60 = transpose(A(:,198));
AC2B61 = transpose(A(:,199));
AC2B62 = transpose(A(:,200));
AC2B63 = transpose(A(:,201));
AC2B64 = transpose(A(:,202));
```

```
AC3B1 = transpose(A(:,205));
AC3B2 = transpose(A(:,206));
AC3B3 = transpose(A(:,207));
AC3B4 = transpose(A(:,208));
AC3B5 = transpose(A(:,209));
AC3B6 = transpose(A(:,210));
AC3B7 = transpose(A(:,211));
AC3B8 = transpose(A(:,212));
AC3B9 = transpose(A(:,213));
AC3B10 = transpose(A(:,214));
AC3B11 = transpose(A(:,215));
AC3B12 = transpose(A(:,216));
AC3B13 = transpose(A(:,217));
AC3B14 = transpose(A(:,218));
AC3B15 = transpose(A(:,219));
AC3B16 = transpose(A(:,220));
AC3B17 = transpose(A(:,221));
AC3B18 = transpose(A(:,222));
AC3B19 = transpose(A(:,223));
```

```
AC3B20 = transpose(A(:,224));
AC3B21 = transpose(A(:,225));
AC3B22 = transpose(A(:,226));
AC3B23 = transpose(A(:,227));
AC3B24 = transpose(A(:,228));
AC3B25 = transpose(A(:,229));
AC3B26 = transpose(A(:,230));
AC3B27 = transpose(A(:,231));
AC3B28 = transpose(A(:,232));
AC3B29 = transpose(A(:,233));
AC3B30 = transpose(A(:,234));
AC3B31 = transpose(A(:,235));
AC3B32 = transpose(A(:,236));
AC3B33 = transpose(A(:,237));
AC3B34 = transpose(A(:,238));
AC3B35 = transpose(A(:,239));
AC3B36 = transpose(A(:,240));
AC3B37 = transpose(A(:,241));
AC3B38 = transpose(A(:,242));
AC3B39 = transpose(A(:,243));
AC3B40 = transpose(A(:,244));
AC3B41 = transpose(A(:,245));
AC3B42 = transpose(A(:,246));
AC3B43 = transpose(A(:,247));
AC3B44 = transpose(A(:,248));
AC3B45 = transpose(A(:,249));
AC3B46 = transpose(A(:,250));
AC3B47 = transpose(A(:,251));
AC3B48 = transpose(A(:,252));
AC3B49 = transpose(A(:,253));
AC3B50 = transpose(A(:,254));
AC3B51 = transpose(A(:,255));
AC3B52 = transpose(A(:,256));
AC3B53 = transpose(A(:,257));
AC3B54 = transpose(A(:,258));
AC3B55 = transpose(A(:,259));
AC3B56 = transpose(A(:,260));
AC3B57 = transpose(A(:,261));
AC3B58 = transpose(A(:,262));
AC3B59 = transpose(A(:,263));
AC3B60 = transpose(A(:,264));
AC3B61 = transpose(A(:,265));
AC3B62 = transpose(A(:,266));
AC3B63 = transpose(A(:,267));
AC3B64 = transpose(A(:,268));
```

```
AC4B1 = transpose(A(:,271));
AC4B2 = transpose(A(:,272));
AC4B3 = transpose(A(:,273));
AC4B4 = transpose(A(:,274));
AC4B5 = transpose(A(:,275));
AC4B6 = transpose(A(:,276));
AC4B7 = transpose(A(:,277));
AC4B8 = transpose(A(:,278));
AC4B9 = transpose(A(:,279));
AC4B10 = transpose(A(:,280));
AC4B11 = transpose(A(:,281));
```

```
AC4B12 = transpose(A(:,282));
AC4B13 = transpose(A(:,283));
AC4B14 = transpose(A(:,284));
AC4B15 = transpose(A(:,285));
AC4B16 = transpose(A(:,286));
AC4B17 = transpose(A(:,287));
AC4B18 = transpose(A(:,288));
AC4B19 = transpose(A(:,289));
AC4B20 = transpose(A(:,290));
AC4B21 = transpose(A(:,291));
AC4B22 = transpose(A(:,292));
AC4B23 = transpose(A(:,293));
AC4B24 = transpose(A(:,294));
AC4B25 = transpose(A(:,295));
AC4B26 = transpose(A(:,296));
AC4B27 = transpose(A(:,297));
AC4B28 = transpose(A(:,298));
AC4B29 = transpose(A(:,299));
AC4B30 = transpose(A(:,300));
AC4B31 = transpose(A(:,301));
AC4B32 = transpose(A(:,302));
AC4B33 = transpose(A(:,303));
AC4B34 = transpose(A(:,304));
AC4B35 = transpose(A(:,305));
AC4B36 = transpose(A(:,306));
AC4B37 = transpose(A(:,307));
AC4B38 = transpose(A(:,308));
AC4B39 = transpose(A(:,309));
AC4B40 = transpose(A(:,310));
AC4B41 = transpose(A(:,311));
AC4B42 = transpose(A(:,312));
AC4B43 = transpose(A(:,313));
AC4B44 = transpose(A(:,314));
AC4B45 = transpose(A(:,315));
AC4B46 = transpose(A(:,316));
AC4B47 = transpose(A(:,317));
AC4B48 = transpose(A(:,318));
AC4B49 = transpose(A(:,319));
AC4B50 = transpose(A(:,320));
AC4B51 = transpose(A(:,321));
AC4B52 = transpose(A(:,322));
AC4B53 = transpose(A(:,323));
AC4B54 = transpose(A(:,324));
AC4B55 = transpose(A(:,325));
AC4B56 = transpose(A(:,326));
AC4B57 = transpose(A(:,327));
AC4B58 = transpose(A(:,328));
AC4B59 = transpose(A(:,329));
AC4B60 = transpose(A(:,330));
AC4B61 = transpose(A(:,331));
AC4B62 = transpose(A(:,332));
AC4B63 = transpose(A(:,333));
AC4B64 = transpose(A(:,334));
```

```

AC1_avg = (AC1B1 + AC1B2+ AC1B3 + AC1B4 + AC1B5 + AC1B6 + AC1B7 + AC1B8 +
AC1B9 + AC1B10 + AC1B11 + AC1B12+ AC1B13 + AC1B14 + AC1B15 + AC1B16 + AC1B17
+ AC1B18 + AC1B19 + AC1B20 + AC1B21 + AC1B22+ AC1B23 + AC1B24 + AC1B25 +
AC1B26 + AC1B27 + AC1B28 + AC1B29 + AC1B30 + AC1B31 + AC1B32+ AC1B33 + AC1B34
+ AC1B35 + AC1B36 + AC1B37 + AC1B38 + AC1B39 + AC1B40 + AC1B41 + AC1B42+
AC1B43 + AC1B44 + AC1B45 + AC1B46 + AC1B47 + AC1B48 + AC1B49 + AC1B50 +
AC1B51 + AC1B52+ AC1B53 + AC1B54 + AC1B55 + AC1B56 + AC1B57 + AC1B58 + AC1B59
+ AC1B60 + AC1B61 + AC1B62 + AC1B63 + AC1B64)/64;
AC2_avg = (AC2B1 + AC2B2+ AC2B3 + AC2B4 + AC2B5 + AC2B6 + AC2B7 + AC2B8 +
AC2B9 + AC2B10 + AC2B11 + AC2B12+ AC2B13 + AC2B14 + AC2B15 + AC2B16 + AC2B17
+ AC2B18 + AC2B19 + AC2B20 + AC2B21 + AC2B22+ AC2B23 + AC2B24 + AC2B25 +
AC2B26 + AC2B27 + AC2B28 + AC2B29 + AC2B30 + AC2B31 + AC2B32+ AC2B33 + AC2B34
+ AC2B35 + AC2B36 + AC2B37 + AC2B38 + AC2B39 + AC2B40 + AC2B41 + AC2B42+
AC2B43 + AC2B44 + AC2B45 + AC2B46 + AC2B47 + AC2B48 + AC2B49 + AC2B50 +
AC2B51 + AC2B52+ AC2B53 + AC2B54 + AC2B55 + AC2B56 + AC2B57 + AC2B58 + AC2B59
+ AC2B60 + AC2B61 + AC2B62 + AC2B63 + AC2B64)/64;
AC3_avg = (AC3B1 + AC3B2+ AC3B3 + AC3B4 + AC3B5 + AC3B6 + AC3B7 + AC3B8 +
AC3B9 + AC3B10 + AC3B11 + AC3B12+ AC3B13 + AC3B14 + AC3B15 + AC3B16 + AC3B17
+ AC3B18 + AC3B19 + AC3B20 + AC3B21 + AC3B22+ AC3B23 + AC3B24 + AC3B25 +
AC3B26 + AC3B27 + AC3B28 + AC3B29 + AC3B30 + AC3B31 + AC3B32+ AC3B33 + AC3B34
+ AC3B35 + AC3B36 + AC3B37 + AC3B38 + AC3B39 + AC3B40 + AC3B41 + AC3B42+
AC3B43 + AC3B44 + AC3B45 + AC3B46 + AC3B47 + AC3B48 + AC3B49 + AC3B50 +
AC3B51 + AC3B52+ AC3B53 + AC3B54 + AC3B55 + AC3B56+ AC3B57 + AC3B58 + AC3B59
+ AC3B60 + AC3B61 + AC3B62 + AC3B63 + AC3B64)/64;
AC4_avg = (AC4B1 + AC4B2+ AC4B3 + AC4B4 + AC4B5 + AC4B6 + AC4B7 + AC4B8 +
AC4B9 + AC4B10 + AC4B11 + AC4B12+ AC4B13 + AC4B14 + AC4B15 + AC4B16 + AC4B17
+ AC4B18 + AC4B19 + AC4B20 + AC4B21 + AC4B22+ AC4B23 + AC4B24 + AC4B25 +
AC4B26 + AC4B27 + AC4B28 + AC4B29 + AC4B30 + AC4B31 + AC4B32+ AC4B33 + AC4B34
+ AC4B35 + AC4B36 + AC4B37 + AC4B38 + AC4B39 + AC4B40 + AC4B41 + AC4B42+
AC4B43 + AC4B44 + AC4B45 + AC4B46 + AC4B47 + AC4B48 + AC4B49 + AC4B50 +
AC4B51 + AC4B52+ AC4B53 + AC4B54 + AC4B55 + AC4B56 + AC4B57 + AC4B58 + AC4B59
+ AC4B60 + AC4B61 + AC4B62 + AC4B63 + AC4B64)/64;

```

```

figure(1)
plot(time,AC1_avg,time,AC2_avg,time,AC3_avg,time,AC4_avg);
title('Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC1', 'AC2', 'AC3', 'AC4'}, 'Location', 'northwest');

```

```

figure(2)
plot(time,AC1_avg,time,AC2_avg);
title('Governor Side Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC1', 'AC2'}, 'Location', 'northwest');

```

```

figure(3)
plot(time,AC3_avg,time,AC4_avg);
title('Motor Side Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC3', 'AC4'}, 'Location', 'northwest');

```

```

figure(4)
plot(time,AC3_avg,time,AC1_avg);

```

```
title('Vertical Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC3', 'AC1'}, 'Location', 'northwest');

figure(5)
plot(time, AC2_avg, time, AC4_avg);
title('Horizontal Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC2', 'AC4'}, 'Location', 'northwest');
```



## D.6. 71.1 °C Constant Speed Test Accelerometer Fast Fourier Transform

```
clear;
close all;
clc;
%accelerometer script
%71-AC1 force
%72-AC1 std
%73-136 AC1 bins
%137 AC2 force
%138 AC2 std
%139-202 AC2 Bins
%203-AC3 force
%204-AC3 std
%205-268 AC3 Bins
%269- AC4 Force
%270-AC4 std
%271-334 AC4 bins
A = importdata('2020_04_23_160F_steady_state.dat');
time = [0:1:44689]/10;

B(1,1) = sum(transpose(A(:,73)))/44690;
B(2,1) = sum(transpose(A(:,74)))/44690;
B(3,1) = sum(transpose(A(:,75)))/44690;
B(4,1) = sum(transpose(A(:,76)))/44690;
B(5,1) = sum(transpose(A(:,77)))/44690;
B(6,1) = sum(transpose(A(:,78)))/44690;
B(7,1) = sum(transpose(A(:,79)))/44690;
B(8,1) = sum(transpose(A(:,80)))/44690;
B(9,1) = sum(transpose(A(:,81)))/44690;
B(10,1) = sum(transpose(A(:,82)))/44690;
B(11,1) = sum(transpose(A(:,83)))/44690;
B(12,1) = sum(transpose(A(:,84)))/44690;
B(13,1) = sum(transpose(A(:,85)))/44690;
B(14,1) = sum(transpose(A(:,86)))/44690;
B(15,1) = sum(transpose(A(:,87)))/44690;
B(16,1) = sum(transpose(A(:,88)))/44690;
B(17,1) = sum(transpose(A(:,89)))/44690;
B(18,1) = sum(transpose(A(:,90)))/44690;
B(19,1) = sum(transpose(A(:,91)))/44690;
B(20,1) = sum(transpose(A(:,92)))/44690;
B(21,1) = sum(transpose(A(:,93)))/44690;
B(22,1) = sum(transpose(A(:,94)))/44690;
B(23,1) = sum(transpose(A(:,95)))/44690;
B(24,1) = sum(transpose(A(:,96)))/44690;
B(25,1) = sum(transpose(A(:,97)))/44690;
B(26,1) = sum(transpose(A(:,98)))/44690;
B(27,1) = sum(transpose(A(:,99)))/44690;
B(28,1) = sum(transpose(A(:,100)))/44690;
B(29,1) = sum(transpose(A(:,101)))/44690;
B(30,1) = sum(transpose(A(:,102)))/44690;
B(31,1) = sum(transpose(A(:,103)))/44690;
B(32,1) = sum(transpose(A(:,104)))/44690;
B(33,1) = sum(transpose(A(:,105)))/44690;
B(34,1) = sum(transpose(A(:,106)))/44690;
B(35,1) = sum(transpose(A(:,107)))/44690;
```

```

B(36,1) = sum(transpose(A(:,108)))/44690;
B(37,1) = sum(transpose(A(:,109)))/44690;
B(38,1) = sum(transpose(A(:,110)))/44690;
B(39,1) = sum(transpose(A(:,111)))/44690;
B(40,1) = sum(transpose(A(:,112)))/44690;
B(41,1) = sum(transpose(A(:,113)))/44690;
B(42,1) = sum(transpose(A(:,114)))/44690;
B(43,1) = sum(transpose(A(:,115)))/44690;
B(44,1) = sum(transpose(A(:,116)))/44690;
B(45,1) = sum(transpose(A(:,117)))/44690;
B(46,1) = sum(transpose(A(:,118)))/44690;
B(47,1) = sum(transpose(A(:,119)))/44690;
B(48,1) = sum(transpose(A(:,120)))/44690;
B(49,1) = sum(transpose(A(:,121)))/44690;
B(50,1) = sum(transpose(A(:,122)))/44690;
B(51,1) = sum(transpose(A(:,123)))/44690;
B(52,1) = sum(transpose(A(:,124)))/44690;
B(53,1) = sum(transpose(A(:,125)))/44690;
B(54,1) = sum(transpose(A(:,126)))/44690;
B(55,1) = sum(transpose(A(:,127)))/44690;
B(56,1) = sum(transpose(A(:,128)))/44690;
B(57,1) = sum(transpose(A(:,129)))/44690;
B(58,1) = sum(transpose(A(:,130)))/44690;
B(59,1) = sum(transpose(A(:,131)))/44690;
B(60,1) = sum(transpose(A(:,132)))/44690;
B(61,1) = sum(transpose(A(:,133)))/44690;
B(62,1) = sum(transpose(A(:,134)))/44690;
B(63,1) = sum(transpose(A(:,135)))/44690;
B(64,1) = sum(transpose(A(:,136)))/44690;

```

```

C(1,1) = sum(transpose(A(:,139)))/44690;
C(2,1) = sum(transpose(A(:,140)))/44690;
C(3,1) = sum(transpose(A(:,141)))/44690;
C(4,1) = sum(transpose(A(:,142)))/44690;
C(5,1) = sum(transpose(A(:,143)))/44690;
C(6,1) = sum(transpose(A(:,144)))/44690;
C(7,1) = sum(transpose(A(:,145)))/44690;
C(8,1) = sum(transpose(A(:,146)))/44690;
C(9,1) = sum(transpose(A(:,147)))/44690;
C(10,1) = sum(transpose(A(:,148)))/44690;
C(11,1) = sum(transpose(A(:,149)))/44690;
C(12,1) = sum(transpose(A(:,150)))/44690;
C(13,1) = sum(transpose(A(:,151)))/44690;
C(14,1) = sum(transpose(A(:,152)))/44690;
C(15,1) = sum(transpose(A(:,153)))/44690;
C(16,1) = sum(transpose(A(:,154)))/44690;
C(17,1) = sum(transpose(A(:,155)))/44690;
C(18,1) = sum(transpose(A(:,156)))/44690;
C(19,1) = sum(transpose(A(:,157)))/44690;
C(20,1) = sum(transpose(A(:,158)))/44690;
C(21,1) = sum(transpose(A(:,159)))/44690;
C(22,1) = sum(transpose(A(:,160)))/44690;
C(23,1) = sum(transpose(A(:,161)))/44690;
C(24,1) = sum(transpose(A(:,162)))/44690;
C(25,1) = sum(transpose(A(:,163)))/44690;
C(26,1) = sum(transpose(A(:,164)))/44690;
C(27,1) = sum(transpose(A(:,165)))/44690;

```

```

C(28,1) = sum(transpose(A(:,166)))/44690;
C(29,1) = sum(transpose(A(:,167)))/44690;
C(30,1) = sum(transpose(A(:,168)))/44690;
C(31,1) = sum(transpose(A(:,169)))/44690;
C(32,1) = sum(transpose(A(:,170)))/44690;
C(33,1) = sum(transpose(A(:,171)))/44690;
C(34,1) = sum(transpose(A(:,172)))/44690;
C(35,1) = sum(transpose(A(:,173)))/44690;
C(36,1) = sum(transpose(A(:,174)))/44690;
C(37,1) = sum(transpose(A(:,175)))/44690;
C(38,1) = sum(transpose(A(:,176)))/44690;
C(39,1) = sum(transpose(A(:,177)))/44690;
C(40,1) = sum(transpose(A(:,178)))/44690;
C(41,1) = sum(transpose(A(:,179)))/44690;
C(42,1) = sum(transpose(A(:,180)))/44690;
C(43,1) = sum(transpose(A(:,181)))/44690;
C(44,1) = sum(transpose(A(:,182)))/44690;
C(45,1) = sum(transpose(A(:,183)))/44690;
C(46,1) = sum(transpose(A(:,184)))/44690;
C(47,1) = sum(transpose(A(:,185)))/44690;
C(48,1) = sum(transpose(A(:,186)))/44690;
C(49,1) = sum(transpose(A(:,187)))/44690;
C(50,1) = sum(transpose(A(:,188)))/44690;
C(51,1) = sum(transpose(A(:,189)))/44690;
C(52,1) = sum(transpose(A(:,190)))/44690;
C(53,1) = sum(transpose(A(:,191)))/44690;
C(54,1) = sum(transpose(A(:,192)))/44690;
C(55,1) = sum(transpose(A(:,193)))/44690;
C(56,1) = sum(transpose(A(:,194)))/44690;
C(57,1) = sum(transpose(A(:,195)))/44690;
C(58,1) = sum(transpose(A(:,196)))/44690;
C(59,1) = sum(transpose(A(:,197)))/44690;
C(60,1) = sum(transpose(A(:,198)))/44690;
C(61,1) = sum(transpose(A(:,199)))/44690;
C(62,1) = sum(transpose(A(:,200)))/44690;
C(63,1) = sum(transpose(A(:,201)))/44690;
C(64,1) = sum(transpose(A(:,202)))/44690;

```

```

D(1,1) = sum(transpose(A(:,205)))/44690;
D(2,1) = sum(transpose(A(:,206)))/44690;
D(3,1) = sum(transpose(A(:,207)))/44690;
D(4,1) = sum(transpose(A(:,208)))/44690;
D(5,1) = sum(transpose(A(:,209)))/44690;
D(6,1) = sum(transpose(A(:,210)))/44690;
D(7,1) = sum(transpose(A(:,211)))/44690;
D(8,1) = sum(transpose(A(:,212)))/44690;
D(9,1) = sum(transpose(A(:,213)))/44690;
D(10,1) = sum(transpose(A(:,214)))/44690;
D(11,1) = sum(transpose(A(:,215)))/44690;
D(12,1) = sum(transpose(A(:,216)))/44690;
D(13,1) = sum(transpose(A(:,217)))/44690;
D(14,1) = sum(transpose(A(:,218)))/44690;
D(15,1) = sum(transpose(A(:,219)))/44690;
D(16,1) = sum(transpose(A(:,220)))/44690;
D(17,1) = sum(transpose(A(:,221)))/44690;
D(18,1) = sum(transpose(A(:,222)))/44690;
D(19,1) = sum(transpose(A(:,223)))/44690;

```

```

D(20,1) = sum(transpose(A(:,224)))/44690;
D(21,1) = sum(transpose(A(:,225)))/44690;
D(22,1) = sum(transpose(A(:,226)))/44690;
D(23,1) = sum(transpose(A(:,227)))/44690;
D(24,1) = sum(transpose(A(:,228)))/44690;
D(25,1) = sum(transpose(A(:,229)))/44690;
D(26,1) = sum(transpose(A(:,230)))/44690;
D(27,1) = sum(transpose(A(:,231)))/44690;
D(28,1) = sum(transpose(A(:,232)))/44690;
D(29,1) = sum(transpose(A(:,233)))/44690;
D(30,1) = sum(transpose(A(:,234)))/44690;
D(31,1) = sum(transpose(A(:,235)))/44690;
D(32,1) = sum(transpose(A(:,236)))/44690;
D(33,1) = sum(transpose(A(:,237)))/44690;
D(34,1) = sum(transpose(A(:,238)))/44690;
D(35,1) = sum(transpose(A(:,239)))/44690;
D(36,1) = sum(transpose(A(:,240)))/44690;
D(37,1) = sum(transpose(A(:,241)))/44690;
D(38,1) = sum(transpose(A(:,242)))/44690;
D(39,1) = sum(transpose(A(:,243)))/44690;
D(40,1) = sum(transpose(A(:,244)))/44690;
D(41,1) = sum(transpose(A(:,245)))/44690;
D(42,1) = sum(transpose(A(:,246)))/44690;
D(43,1) = sum(transpose(A(:,247)))/44690;
D(44,1) = sum(transpose(A(:,248)))/44690;
D(45,1) = sum(transpose(A(:,249)))/44690;
D(46,1) = sum(transpose(A(:,250)))/44690;
D(47,1) = sum(transpose(A(:,251)))/44690;
D(48,1) = sum(transpose(A(:,252)))/44690;
D(49,1) = sum(transpose(A(:,253)))/44690;
D(50,1) = sum(transpose(A(:,254)))/44690;
D(51,1) = sum(transpose(A(:,255)))/44690;
D(52,1) = sum(transpose(A(:,256)))/44690;
D(53,1) = sum(transpose(A(:,257)))/44690;
D(54,1) = sum(transpose(A(:,258)))/44690;
D(55,1) = sum(transpose(A(:,259)))/44690;
D(56,1) = sum(transpose(A(:,260)))/44690;
D(57,1) = sum(transpose(A(:,261)))/44690;
D(58,1) = sum(transpose(A(:,262)))/44690;
D(59,1) = sum(transpose(A(:,263)))/44690;
D(60,1) = sum(transpose(A(:,264)))/44690;
D(61,1) = sum(transpose(A(:,265)))/44690;
D(62,1) = sum(transpose(A(:,266)))/44690;
D(63,1) = sum(transpose(A(:,267)))/44690;
D(64,1) = sum(transpose(A(:,268)))/44690;

```

```

E(1,1) = sum(transpose(A(:,271)))/44690;
E(2,1) = sum(transpose(A(:,272)))/44690;
E(3,1) = sum(transpose(A(:,273)))/44690;
E(4,1) = sum(transpose(A(:,274)))/44690;
E(5,1) = sum(transpose(A(:,275)))/44690;
E(6,1) = sum(transpose(A(:,276)))/44690;
E(7,1) = sum(transpose(A(:,277)))/44690;
E(8,1) = sum(transpose(A(:,278)))/44690;
E(9,1) = sum(transpose(A(:,279)))/44690;
E(10,1) = sum(transpose(A(:,280)))/44690;
E(11,1) = sum(transpose(A(:,281)))/44690;

```

```

E(12,1) = sum(transpose(A(:,282)))/44690;
E(13,1) = sum(transpose(A(:,283)))/44690;
E(14,1) = sum(transpose(A(:,284)))/44690;
E(15,1) = sum(transpose(A(:,285)))/44690;
E(16,1) = sum(transpose(A(:,286)))/44690;
E(17,1) = sum(transpose(A(:,287)))/44690;
E(18,1) = sum(transpose(A(:,288)))/44690;
E(19,1) = sum(transpose(A(:,289)))/44690;
E(20,1) = sum(transpose(A(:,290)))/44690;
E(21,1) = sum(transpose(A(:,291)))/44690;
E(22,1) = sum(transpose(A(:,292)))/44690;
E(23,1) = sum(transpose(A(:,293)))/44690;
E(24,1) = sum(transpose(A(:,294)))/44690;
E(25,1) = sum(transpose(A(:,295)))/44690;
E(26,1) = sum(transpose(A(:,296)))/44690;
E(27,1) = sum(transpose(A(:,297)))/44690;
E(28,1) = sum(transpose(A(:,298)))/44690;
E(29,1) = sum(transpose(A(:,299)))/44690;
E(30,1) = sum(transpose(A(:,300)))/44690;
E(31,1) = sum(transpose(A(:,301)))/44690;
E(32,1) = sum(transpose(A(:,302)))/44690;
E(33,1) = sum(transpose(A(:,303)))/44690;
E(34,1) = sum(transpose(A(:,304)))/44690;
E(35,1) = sum(transpose(A(:,305)))/44690;
E(36,1) = sum(transpose(A(:,306)))/44690;
E(37,1) = sum(transpose(A(:,307)))/44690;
E(38,1) = sum(transpose(A(:,308)))/44690;
E(39,1) = sum(transpose(A(:,309)))/44690;
E(40,1) = sum(transpose(A(:,310)))/44690;
E(41,1) = sum(transpose(A(:,311)))/44690;
E(42,1) = sum(transpose(A(:,312)))/44690;
E(43,1) = sum(transpose(A(:,313)))/44690;
E(44,1) = sum(transpose(A(:,314)))/44690;
E(45,1) = sum(transpose(A(:,315)))/44690;
E(46,1) = sum(transpose(A(:,316)))/44690;
E(47,1) = sum(transpose(A(:,317)))/44690;
E(48,1) = sum(transpose(A(:,318)))/44690;
E(49,1) = sum(transpose(A(:,319)))/44690;
E(50,1) = sum(transpose(A(:,320)))/44690;
E(51,1) = sum(transpose(A(:,321)))/44690;
E(52,1) = sum(transpose(A(:,322)))/44690;
E(53,1) = sum(transpose(A(:,323)))/44690;
E(54,1) = sum(transpose(A(:,324)))/44690;
E(55,1) = sum(transpose(A(:,325)))/44690;
E(56,1) = sum(transpose(A(:,326)))/44690;
E(57,1) = sum(transpose(A(:,327)))/44690;
E(58,1) = sum(transpose(A(:,328)))/44690;
E(59,1) = sum(transpose(A(:,329)))/44690;
E(60,1) = sum(transpose(A(:,330)))/44690;
E(61,1) = sum(transpose(A(:,331)))/44690;
E(62,1) = sum(transpose(A(:,332)))/44690;
E(63,1) = sum(transpose(A(:,333)))/44690;
E(64,1) = sum(transpose(A(:,334)))/44690;

```

```

fax_bins = [0:31.25:1999];
figure(1)
plot(fax_bins, abs(fft(B)))

```

```
xlabel('Frequency (Hz)');  
ylabel('Acceleration (g)');  
title('AC1 Acceleration Profile');
```

```
figure(2)  
plot(fax_bins, abs(fft(C)))  
xlabel('Frequency (Hz)');  
ylabel('Acceleration (g)');  
title('AC2 Acceleration Profile');
```

```
figure(3)  
plot(fax_bins, abs(fft(D)))  
xlabel('Frequency (Hz)');  
ylabel('Acceleration (g)');  
title('AC3 Acceleration Profile');
```

```
figure(4)  
plot(fax_bins, abs(fft(E)))  
xlabel('Frequency (Hz)');  
ylabel('Acceleration (g)');  
title('AC4 Acceleration Profile');
```

## D.7. 82.2 °C Constant Speed Test Data Analysis

```
clear;
close all;
clc;

A = importdata('2020_04_22_180F_steady_state.dat');

TCM1 = transpose(A(:,3));
TCM2 = transpose(A(:,6));
TCM3 = transpose(A(:,9));
TCM4 = transpose(A(:,12));
TCMT = transpose(A(:,15));
TCMMT = transpose(A(:,18));
TCMMB = transpose(A(:,21));
TCMB = transpose(A(:,24));
TCG1 = transpose(A(:,27));
TCG2 = transpose(A(:,30));
TCG3 = transpose(A(:,33));
TCG4 = transpose(A(:,36));
TCGB = transpose(A(:,39));
TCGMB = transpose(A(:,42));
TCGMT = transpose(A(:,45));
TCGT = transpose(A(:,48));
Speed = transpose(A(:,66));
Torque = transpose(A(:,70));

motor_bearing_average = (TCM1 + TCM3 + TCM4)/3;
governor_bearing_average = (TCG1 + TCG2 + TCG3 + TCG4)/4;

time = [0:1:60899];
real_time = time/10;

figure(1);
plot(real_time,TCM1,real_time,TCM2,real_time,TCM3,real_time,TCM4)
title('Motor Side Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'M1', 'M2', 'M3', 'M4', }, 'Location', 'southeast');

figure(2);
plot(real_time,TCG1,real_time,TCG2,real_time,TCG3,real_time,TCG4)
title('Governor Side Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'G1', 'G2', 'G3', 'G4', }, 'Location', 'southeast');

figure(3);
plot(real_time,TCMT,real_time,TCMMT,real_time,TCMMB,real_time,TCMB)
title('Motor Side Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperatre (°C)');
legend({'Top', 'Middle-Top', 'Middle-
Bottom', 'Bottom'}, 'Location', 'eastoutside');
```

```

figure(4);
plot(real_time,TCGT,real_time,TCGMT,real_time,TCGMB,real_time,TCGB)
title('Governor Side Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperatre (°C)');
legend({'Top', 'Middle-Top', 'Middle-
Bottom', 'Bottom'}, 'Location', 'eastoutside');

figure(5);
plot(real_time,Speed)
title('Turbine Speed');
xlabel('Time (s)');
ylabel('Shaft Speed (RPM)');

figure(6);
plot(real_time,Torque)
title('Torque vs. Time');
xlabel('Time (s)');
ylabel('Torque (Nm)');

figure(7);
plot(real_time,motor_bearing_average)
title('Averaged Motor Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(8);
plot(real_time,governor_bearing_average)
title('Averaged Governor Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(9);
plot(real_time,governor_bearing_average,real_time,motor_bearing_average)
title('Bearing Averaged Temperature Comparison')
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'Averaged Governor Bearing Temperature', 'Averaged Motor Bearing
Temperature'}, 'Location', 'southeast');

```



## D.8. 82.2 °C Constant Speed Test Accelerometer Analysis

```
clear;
close all;
clc;
%accelerometer script
%71-AC1 force
%72-AC1 std
%73-136 AC1 bins
%137 AC2 force
%138 AC2 std
%139-202 AC2 Bins
%203-AC3 force
%204-AC3 std
%205-268 AC3 Bins
%269- AC4 Force
%270-AC4 std
%271-334 AC4 bins
A = importdata('2020_04_22_180F_steady_state.dat');
time = [0:1:60899]/10;
```

```
AC1B1 = transpose(A(:,73));
AC1B2 = transpose(A(:,74));
AC1B3 = transpose(A(:,75));
AC1B4 = transpose(A(:,76));
AC1B5 = transpose(A(:,77));
AC1B6 = transpose(A(:,78));
AC1B7 = transpose(A(:,79));
AC1B8 = transpose(A(:,80));
AC1B9 = transpose(A(:,81));
AC1B10 = transpose(A(:,82));
AC1B11 = transpose(A(:,83));
AC1B12 = transpose(A(:,84));
AC1B13 = transpose(A(:,85));
AC1B14 = transpose(A(:,86));
AC1B15 = transpose(A(:,87));
AC1B16 = transpose(A(:,88));
AC1B17 = transpose(A(:,89));
AC1B18 = transpose(A(:,90));
AC1B19 = transpose(A(:,91));
AC1B20 = transpose(A(:,92));
AC1B21 = transpose(A(:,93));
AC1B22 = transpose(A(:,94));
AC1B23 = transpose(A(:,95));
AC1B24 = transpose(A(:,96));
AC1B25 = transpose(A(:,97));
AC1B26 = transpose(A(:,98));
AC1B27 = transpose(A(:,99));
AC1B28 = transpose(A(:,100));
AC1B29 = transpose(A(:,101));
AC1B30 = transpose(A(:,102));
AC1B31 = transpose(A(:,103));
AC1B32 = transpose(A(:,104));
AC1B33 = transpose(A(:,105));
AC1B34 = transpose(A(:,106));
AC1B35 = transpose(A(:,107));
```

```
AC1B36 = transpose(A(:,108));
AC1B37 = transpose(A(:,109));
AC1B38 = transpose(A(:,110));
AC1B39 = transpose(A(:,111));
AC1B40 = transpose(A(:,112));
AC1B41 = transpose(A(:,113));
AC1B42 = transpose(A(:,114));
AC1B43 = transpose(A(:,115));
AC1B44 = transpose(A(:,116));
AC1B45 = transpose(A(:,117));
AC1B46 = transpose(A(:,118));
AC1B47 = transpose(A(:,119));
AC1B48 = transpose(A(:,120));
AC1B49 = transpose(A(:,121));
AC1B50 = transpose(A(:,122));
AC1B51 = transpose(A(:,123));
AC1B52 = transpose(A(:,124));
AC1B53 = transpose(A(:,125));
AC1B54 = transpose(A(:,126));
AC1B55 = transpose(A(:,127));
AC1B56 = transpose(A(:,128));
AC1B57 = transpose(A(:,129));
AC1B58 = transpose(A(:,130));
AC1B59 = transpose(A(:,131));
AC1B60 = transpose(A(:,132));
AC1B61 = transpose(A(:,133));
AC1B62 = transpose(A(:,134));
AC1B63 = transpose(A(:,135));
AC1B64 = transpose(A(:,136));
```

```
AC2B1 = transpose(A(:,139));
AC2B2 = transpose(A(:,140));
AC2B3 = transpose(A(:,141));
AC2B4 = transpose(A(:,142));
AC2B5 = transpose(A(:,143));
AC2B6 = transpose(A(:,144));
AC2B7 = transpose(A(:,145));
AC2B8 = transpose(A(:,146));
AC2B9 = transpose(A(:,147));
AC2B10 = transpose(A(:,148));
AC2B11 = transpose(A(:,149));
AC2B12 = transpose(A(:,150));
AC2B13 = transpose(A(:,151));
AC2B14 = transpose(A(:,152));
AC2B15 = transpose(A(:,153));
AC2B16 = transpose(A(:,154));
AC2B17 = transpose(A(:,155));
AC2B18 = transpose(A(:,156));
AC2B19 = transpose(A(:,157));
AC2B20 = transpose(A(:,158));
AC2B21 = transpose(A(:,159));
AC2B22 = transpose(A(:,160));
AC2B23 = transpose(A(:,161));
AC2B24 = transpose(A(:,162));
AC2B25 = transpose(A(:,163));
AC2B26 = transpose(A(:,164));
AC2B27 = transpose(A(:,165));
```

```
AC2B28 = transpose(A(:,166));
AC2B29 = transpose(A(:,167));
AC2B30 = transpose(A(:,168));
AC2B31 = transpose(A(:,169));
AC2B32 = transpose(A(:,170));
AC2B33 = transpose(A(:,171));
AC2B34 = transpose(A(:,172));
AC2B35 = transpose(A(:,173));
AC2B36 = transpose(A(:,174));
AC2B37 = transpose(A(:,175));
AC2B38 = transpose(A(:,176));
AC2B39 = transpose(A(:,177));
AC2B40 = transpose(A(:,178));
AC2B41 = transpose(A(:,179));
AC2B42 = transpose(A(:,180));
AC2B43 = transpose(A(:,181));
AC2B44 = transpose(A(:,182));
AC2B45 = transpose(A(:,183));
AC2B46 = transpose(A(:,184));
AC2B47 = transpose(A(:,185));
AC2B48 = transpose(A(:,186));
AC2B49 = transpose(A(:,187));
AC2B50 = transpose(A(:,188));
AC2B51 = transpose(A(:,189));
AC2B52 = transpose(A(:,190));
AC2B53 = transpose(A(:,191));
AC2B54 = transpose(A(:,192));
AC2B55 = transpose(A(:,193));
AC2B56 = transpose(A(:,194));
AC2B57 = transpose(A(:,195));
AC2B58 = transpose(A(:,196));
AC2B59 = transpose(A(:,197));
AC2B60 = transpose(A(:,198));
AC2B61 = transpose(A(:,199));
AC2B62 = transpose(A(:,200));
AC2B63 = transpose(A(:,201));
AC2B64 = transpose(A(:,202));
```

```
AC3B1 = transpose(A(:,205));
AC3B2 = transpose(A(:,206));
AC3B3 = transpose(A(:,207));
AC3B4 = transpose(A(:,208));
AC3B5 = transpose(A(:,209));
AC3B6 = transpose(A(:,210));
AC3B7 = transpose(A(:,211));
AC3B8 = transpose(A(:,212));
AC3B9 = transpose(A(:,213));
AC3B10 = transpose(A(:,214));
AC3B11 = transpose(A(:,215));
AC3B12 = transpose(A(:,216));
AC3B13 = transpose(A(:,217));
AC3B14 = transpose(A(:,218));
AC3B15 = transpose(A(:,219));
AC3B16 = transpose(A(:,220));
AC3B17 = transpose(A(:,221));
AC3B18 = transpose(A(:,222));
AC3B19 = transpose(A(:,223));
```

```
AC3B20 = transpose(A(:,224));
AC3B21 = transpose(A(:,225));
AC3B22 = transpose(A(:,226));
AC3B23 = transpose(A(:,227));
AC3B24 = transpose(A(:,228));
AC3B25 = transpose(A(:,229));
AC3B26 = transpose(A(:,230));
AC3B27 = transpose(A(:,231));
AC3B28 = transpose(A(:,232));
AC3B29 = transpose(A(:,233));
AC3B30 = transpose(A(:,234));
AC3B31 = transpose(A(:,235));
AC3B32 = transpose(A(:,236));
AC3B33 = transpose(A(:,237));
AC3B34 = transpose(A(:,238));
AC3B35 = transpose(A(:,239));
AC3B36 = transpose(A(:,240));
AC3B37 = transpose(A(:,241));
AC3B38 = transpose(A(:,242));
AC3B39 = transpose(A(:,243));
AC3B40 = transpose(A(:,244));
AC3B41 = transpose(A(:,245));
AC3B42 = transpose(A(:,246));
AC3B43 = transpose(A(:,247));
AC3B44 = transpose(A(:,248));
AC3B45 = transpose(A(:,249));
AC3B46 = transpose(A(:,250));
AC3B47 = transpose(A(:,251));
AC3B48 = transpose(A(:,252));
AC3B49 = transpose(A(:,253));
AC3B50 = transpose(A(:,254));
AC3B51 = transpose(A(:,255));
AC3B52 = transpose(A(:,256));
AC3B53 = transpose(A(:,257));
AC3B54 = transpose(A(:,258));
AC3B55 = transpose(A(:,259));
AC3B56 = transpose(A(:,260));
AC3B57 = transpose(A(:,261));
AC3B58 = transpose(A(:,262));
AC3B59 = transpose(A(:,263));
AC3B60 = transpose(A(:,264));
AC3B61 = transpose(A(:,265));
AC3B62 = transpose(A(:,266));
AC3B63 = transpose(A(:,267));
AC3B64 = transpose(A(:,268));
```

```
AC4B1 = transpose(A(:,271));
AC4B2 = transpose(A(:,272));
AC4B3 = transpose(A(:,273));
AC4B4 = transpose(A(:,274));
AC4B5 = transpose(A(:,275));
AC4B6 = transpose(A(:,276));
AC4B7 = transpose(A(:,277));
AC4B8 = transpose(A(:,278));
AC4B9 = transpose(A(:,279));
AC4B10 = transpose(A(:,280));
AC4B11 = transpose(A(:,281));
```

```
AC4B12 = transpose(A(:,282));
AC4B13 = transpose(A(:,283));
AC4B14 = transpose(A(:,284));
AC4B15 = transpose(A(:,285));
AC4B16 = transpose(A(:,286));
AC4B17 = transpose(A(:,287));
AC4B18 = transpose(A(:,288));
AC4B19 = transpose(A(:,289));
AC4B20 = transpose(A(:,290));
AC4B21 = transpose(A(:,291));
AC4B22 = transpose(A(:,292));
AC4B23 = transpose(A(:,293));
AC4B24 = transpose(A(:,294));
AC4B25 = transpose(A(:,295));
AC4B26 = transpose(A(:,296));
AC4B27 = transpose(A(:,297));
AC4B28 = transpose(A(:,298));
AC4B29 = transpose(A(:,299));
AC4B30 = transpose(A(:,300));
AC4B31 = transpose(A(:,301));
AC4B32 = transpose(A(:,302));
AC4B33 = transpose(A(:,303));
AC4B34 = transpose(A(:,304));
AC4B35 = transpose(A(:,305));
AC4B36 = transpose(A(:,306));
AC4B37 = transpose(A(:,307));
AC4B38 = transpose(A(:,308));
AC4B39 = transpose(A(:,309));
AC4B40 = transpose(A(:,310));
AC4B41 = transpose(A(:,311));
AC4B42 = transpose(A(:,312));
AC4B43 = transpose(A(:,313));
AC4B44 = transpose(A(:,314));
AC4B45 = transpose(A(:,315));
AC4B46 = transpose(A(:,316));
AC4B47 = transpose(A(:,317));
AC4B48 = transpose(A(:,318));
AC4B49 = transpose(A(:,319));
AC4B50 = transpose(A(:,320));
AC4B51 = transpose(A(:,321));
AC4B52 = transpose(A(:,322));
AC4B53 = transpose(A(:,323));
AC4B54 = transpose(A(:,324));
AC4B55 = transpose(A(:,325));
AC4B56 = transpose(A(:,326));
AC4B57 = transpose(A(:,327));
AC4B58 = transpose(A(:,328));
AC4B59 = transpose(A(:,329));
AC4B60 = transpose(A(:,330));
AC4B61 = transpose(A(:,331));
AC4B62 = transpose(A(:,332));
AC4B63 = transpose(A(:,333));
AC4B64 = transpose(A(:,334));
```

```

AC1_avg = (AC1B1 + AC1B2+ AC1B3 + AC1B4 + AC1B5 + AC1B6 + AC1B7 + AC1B8 +
AC1B9 + AC1B10 + AC1B11 + AC1B12+ AC1B13 + AC1B14 + AC1B15 + AC1B16 + AC1B17
+ AC1B18 + AC1B19 + AC1B20 + AC1B21 + AC1B22+ AC1B23 + AC1B24 + AC1B25 +
AC1B26 + AC1B27 + AC1B28 + AC1B29 + AC1B30 + AC1B31 + AC1B32+ AC1B33 + AC1B34
+ AC1B35 + AC1B36 + AC1B37 + AC1B38 + AC1B39 + AC1B40 + AC1B41 + AC1B42+
AC1B43 + AC1B44 + AC1B45 + AC1B46 + AC1B47 + AC1B48 + AC1B49 + AC1B50 +
AC1B51 + AC1B52+ AC1B53 + AC1B54 + AC1B55 + AC1B56 + AC1B57 + AC1B58 + AC1B59
+ AC1B60 + AC1B61 + AC1B62 + AC1B63 + AC1B64)/64;
AC2_avg = (AC2B1 + AC2B2+ AC2B3 + AC2B4 + AC2B5 + AC2B6 + AC2B7 + AC2B8 +
AC2B9 + AC2B10 + AC2B11 + AC2B12+ AC2B13 + AC2B14 + AC2B15 + AC2B16 + AC2B17
+ AC2B18 + AC2B19 + AC2B20 + AC2B21 + AC2B22+ AC2B23 + AC2B24 + AC2B25 +
AC2B26 + AC2B27 + AC2B28 + AC2B29 + AC2B30 + AC2B31 + AC2B32+ AC2B33 + AC2B34
+ AC2B35 + AC2B36 + AC2B37 + AC2B38 + AC2B39 + AC2B40 + AC2B41 + AC2B42+
AC2B43 + AC2B44 + AC2B45 + AC2B46 + AC2B47 + AC2B48 + AC2B49 + AC2B50 +
AC2B51 + AC2B52+ AC2B53 + AC2B54 + AC2B55 + AC2B56 + AC2B57 + AC2B58 + AC2B59
+ AC2B60 + AC2B61 + AC2B62 + AC2B63 + AC2B64)/64;
AC3_avg = (AC3B1 + AC3B2+ AC3B3 + AC3B4 + AC3B5 + AC3B6 + AC3B7 + AC3B8 +
AC3B9 + AC3B10 + AC3B11 + AC3B12+ AC3B13 + AC3B14 + AC3B15 + AC3B16 + AC3B17
+ AC3B18 + AC3B19 + AC3B20 + AC3B21 + AC3B22+ AC3B23 + AC3B24 + AC3B25 +
AC3B26 + AC3B27 + AC3B28 + AC3B29 + AC3B30 + AC3B31 + AC3B32+ AC3B33 + AC3B34
+ AC3B35 + AC3B36 + AC3B37 + AC3B38 + AC3B39 + AC3B40 + AC3B41 + AC3B42+
AC3B43 + AC3B44 + AC3B45 + AC3B46 + AC3B47 + AC3B48 + AC3B49 + AC3B50 +
AC3B51 + AC3B52+ AC3B53 + AC3B54 + AC3B55 + AC3B56+ AC3B57 + AC3B58 + AC3B59
+ AC3B60 + AC3B61 + AC3B62 + AC3B63 + AC3B64)/64;
AC4_avg = (AC4B1 + AC4B2+ AC4B3 + AC4B4 + AC4B5 + AC4B6 + AC4B7 + AC4B8 +
AC4B9 + AC4B10 + AC4B11 + AC4B12+ AC4B13 + AC4B14 + AC4B15 + AC4B16 + AC4B17
+ AC4B18 + AC4B19 + AC4B20 + AC4B21 + AC4B22+ AC4B23 + AC4B24 + AC4B25 +
AC4B26 + AC4B27 + AC4B28 + AC4B29 + AC4B30 + AC4B31 + AC4B32+ AC4B33 + AC4B34
+ AC4B35 + AC4B36 + AC4B37 + AC4B38 + AC4B39 + AC4B40 + AC4B41 + AC4B42+
AC4B43 + AC4B44 + AC4B45 + AC4B46 + AC4B47 + AC4B48 + AC4B49 + AC4B50 +
AC4B51 + AC4B52+ AC4B53 + AC4B54 + AC4B55 + AC4B56 + AC4B57 + AC4B58 + AC4B59
+ AC4B60 + AC4B61 + AC4B62 + AC4B63 + AC4B64)/64;

```

```

figure(1)
plot(time,AC1_avg,time,AC2_avg,time,AC3_avg,time,AC4_avg);
title('Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC1', 'AC2', 'AC3', 'AC4'}, 'Location', 'northwest');

```

```

figure(2)
plot(time,AC1_avg,time,AC2_avg);
title('Governor Side Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC1', 'AC2'}, 'Location', 'northwest');

```

```

figure(3)
plot(time,AC3_avg,time,AC4_avg);
title('Motor Side Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC3', 'AC4'}, 'Location', 'northwest');

```

```

figure(4)
plot(time,AC3_avg,time,AC1_avg);

```

```
title('Vertical Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC3', 'AC1'}, 'Location', 'northwest');

figure(5)
plot(time, AC2_avg, time, AC4_avg);
title('Horizontal Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC2', 'AC4'}, 'Location', 'northwest');
```

## D.9. 82.2 °C Constant Speed Test Accelerometer Fast Fourier Transform

```
clear;
close all;
clc;
%accelerometer script
%71-AC1 force
%72-AC1 std
%73-136 AC1 bins
%137 AC2 force
%138 AC2 std
%139-202 AC2 Bins
%203-AC3 force
%204-AC3 std
%205-268 AC3 Bins
%269- AC4 Force
%270-AC4 std
%271-334 AC4 bins
A = importdata('2020_04_22_180F_steady_state.dat');
time = [0:1:60899]/10;

B(1,1) = sum(transpose(A(:,73)))/60900;
B(2,1) = sum(transpose(A(:,74)))/60900;
B(3,1) = sum(transpose(A(:,75)))/60900;
B(4,1) = sum(transpose(A(:,76)))/60900;
B(5,1) = sum(transpose(A(:,77)))/60900;
B(6,1) = sum(transpose(A(:,78)))/60900;
B(7,1) = sum(transpose(A(:,79)))/60900;
B(8,1) = sum(transpose(A(:,80)))/60900;
B(9,1) = sum(transpose(A(:,81)))/60900;
B(10,1) = sum(transpose(A(:,82)))/60900;
B(11,1) = sum(transpose(A(:,83)))/60900;
B(12,1) = sum(transpose(A(:,84)))/60900;
B(13,1) = sum(transpose(A(:,85)))/60900;
B(14,1) = sum(transpose(A(:,86)))/60900;
B(15,1) = sum(transpose(A(:,87)))/60900;
B(16,1) = sum(transpose(A(:,88)))/60900;
B(17,1) = sum(transpose(A(:,89)))/60900;
B(18,1) = sum(transpose(A(:,90)))/60900;
B(19,1) = sum(transpose(A(:,91)))/60900;
B(20,1) = sum(transpose(A(:,92)))/60900;
B(21,1) = sum(transpose(A(:,93)))/60900;
B(22,1) = sum(transpose(A(:,94)))/60900;
B(23,1) = sum(transpose(A(:,95)))/60900;
B(24,1) = sum(transpose(A(:,96)))/60900;
B(25,1) = sum(transpose(A(:,97)))/60900;
B(26,1) = sum(transpose(A(:,98)))/60900;
B(27,1) = sum(transpose(A(:,99)))/60900;
B(28,1) = sum(transpose(A(:,100)))/60900;
B(29,1) = sum(transpose(A(:,101)))/60900;
B(30,1) = sum(transpose(A(:,102)))/60900;
B(31,1) = sum(transpose(A(:,103)))/60900;
B(32,1) = sum(transpose(A(:,104)))/60900;
B(33,1) = sum(transpose(A(:,105)))/60900;
B(34,1) = sum(transpose(A(:,106)))/60900;
B(35,1) = sum(transpose(A(:,107)))/60900;
```



```

B(36,1) = sum(transpose(A(:,108)))/60900;
B(37,1) = sum(transpose(A(:,109)))/60900;
B(38,1) = sum(transpose(A(:,110)))/60900;
B(39,1) = sum(transpose(A(:,111)))/60900;
B(40,1) = sum(transpose(A(:,112)))/60900;
B(41,1) = sum(transpose(A(:,113)))/60900;
B(42,1) = sum(transpose(A(:,114)))/60900;
B(43,1) = sum(transpose(A(:,115)))/60900;
B(44,1) = sum(transpose(A(:,116)))/60900;
B(45,1) = sum(transpose(A(:,117)))/60900;
B(46,1) = sum(transpose(A(:,118)))/60900;
B(47,1) = sum(transpose(A(:,119)))/60900;
B(48,1) = sum(transpose(A(:,120)))/60900;
B(49,1) = sum(transpose(A(:,121)))/60900;
B(50,1) = sum(transpose(A(:,122)))/60900;
B(51,1) = sum(transpose(A(:,123)))/60900;
B(52,1) = sum(transpose(A(:,124)))/60900;
B(53,1) = sum(transpose(A(:,125)))/60900;
B(54,1) = sum(transpose(A(:,126)))/60900;
B(55,1) = sum(transpose(A(:,127)))/60900;
B(56,1) = sum(transpose(A(:,128)))/60900;
B(57,1) = sum(transpose(A(:,129)))/60900;
B(58,1) = sum(transpose(A(:,130)))/60900;
B(59,1) = sum(transpose(A(:,131)))/60900;
B(60,1) = sum(transpose(A(:,132)))/60900;
B(61,1) = sum(transpose(A(:,133)))/60900;
B(62,1) = sum(transpose(A(:,134)))/60900;
B(63,1) = sum(transpose(A(:,135)))/60900;
B(64,1) = sum(transpose(A(:,136)))/60900;

```

```

C(1,1) = sum(transpose(A(:,139)))/60900;
C(2,1) = sum(transpose(A(:,140)))/60900;
C(3,1) = sum(transpose(A(:,141)))/60900;
C(4,1) = sum(transpose(A(:,142)))/60900;
C(5,1) = sum(transpose(A(:,143)))/60900;
C(6,1) = sum(transpose(A(:,144)))/60900;
C(7,1) = sum(transpose(A(:,145)))/60900;
C(8,1) = sum(transpose(A(:,146)))/60900;
C(9,1) = sum(transpose(A(:,147)))/60900;
C(10,1) = sum(transpose(A(:,148)))/60900;
C(11,1) = sum(transpose(A(:,149)))/60900;
C(12,1) = sum(transpose(A(:,150)))/60900;
C(13,1) = sum(transpose(A(:,151)))/60900;
C(14,1) = sum(transpose(A(:,152)))/60900;
C(15,1) = sum(transpose(A(:,153)))/60900;
C(16,1) = sum(transpose(A(:,154)))/60900;
C(17,1) = sum(transpose(A(:,155)))/60900;
C(18,1) = sum(transpose(A(:,156)))/60900;
C(19,1) = sum(transpose(A(:,157)))/60900;
C(20,1) = sum(transpose(A(:,158)))/60900;
C(21,1) = sum(transpose(A(:,159)))/60900;
C(22,1) = sum(transpose(A(:,160)))/60900;
C(23,1) = sum(transpose(A(:,161)))/60900;
C(24,1) = sum(transpose(A(:,162)))/60900;
C(25,1) = sum(transpose(A(:,163)))/60900;
C(26,1) = sum(transpose(A(:,164)))/60900;
C(27,1) = sum(transpose(A(:,165)))/60900;

```

```

C(28,1) = sum(transpose(A(:,166)))/60900;
C(29,1) = sum(transpose(A(:,167)))/60900;
C(30,1) = sum(transpose(A(:,168)))/60900;
C(31,1) = sum(transpose(A(:,169)))/60900;
C(32,1) = sum(transpose(A(:,170)))/60900;
C(33,1) = sum(transpose(A(:,171)))/60900;
C(34,1) = sum(transpose(A(:,172)))/60900;
C(35,1) = sum(transpose(A(:,173)))/60900;
C(36,1) = sum(transpose(A(:,174)))/60900;
C(37,1) = sum(transpose(A(:,175)))/60900;
C(38,1) = sum(transpose(A(:,176)))/60900;
C(39,1) = sum(transpose(A(:,177)))/60900;
C(40,1) = sum(transpose(A(:,178)))/60900;
C(41,1) = sum(transpose(A(:,179)))/60900;
C(42,1) = sum(transpose(A(:,180)))/60900;
C(43,1) = sum(transpose(A(:,181)))/60900;
C(44,1) = sum(transpose(A(:,182)))/60900;
C(45,1) = sum(transpose(A(:,183)))/60900;
C(46,1) = sum(transpose(A(:,184)))/60900;
C(47,1) = sum(transpose(A(:,185)))/60900;
C(48,1) = sum(transpose(A(:,186)))/60900;
C(49,1) = sum(transpose(A(:,187)))/60900;
C(50,1) = sum(transpose(A(:,188)))/60900;
C(51,1) = sum(transpose(A(:,189)))/60900;
C(52,1) = sum(transpose(A(:,190)))/60900;
C(53,1) = sum(transpose(A(:,191)))/60900;
C(54,1) = sum(transpose(A(:,192)))/60900;
C(55,1) = sum(transpose(A(:,193)))/60900;
C(56,1) = sum(transpose(A(:,194)))/60900;
C(57,1) = sum(transpose(A(:,195)))/60900;
C(58,1) = sum(transpose(A(:,196)))/60900;
C(59,1) = sum(transpose(A(:,197)))/60900;
C(60,1) = sum(transpose(A(:,198)))/60900;
C(61,1) = sum(transpose(A(:,199)))/60900;
C(62,1) = sum(transpose(A(:,200)))/60900;
C(63,1) = sum(transpose(A(:,201)))/60900;
C(64,1) = sum(transpose(A(:,202)))/60900;

```

```

D(1,1) = sum(transpose(A(:,205)))/60900;
D(2,1) = sum(transpose(A(:,206)))/60900;
D(3,1) = sum(transpose(A(:,207)))/60900;
D(4,1) = sum(transpose(A(:,208)))/60900;
D(5,1) = sum(transpose(A(:,209)))/60900;
D(6,1) = sum(transpose(A(:,210)))/60900;
D(7,1) = sum(transpose(A(:,211)))/60900;
D(8,1) = sum(transpose(A(:,212)))/60900;
D(9,1) = sum(transpose(A(:,213)))/60900;
D(10,1) = sum(transpose(A(:,214)))/60900;
D(11,1) = sum(transpose(A(:,215)))/60900;
D(12,1) = sum(transpose(A(:,216)))/60900;
D(13,1) = sum(transpose(A(:,217)))/60900;
D(14,1) = sum(transpose(A(:,218)))/60900;
D(15,1) = sum(transpose(A(:,219)))/60900;
D(16,1) = sum(transpose(A(:,220)))/60900;
D(17,1) = sum(transpose(A(:,221)))/60900;
D(18,1) = sum(transpose(A(:,222)))/60900;
D(19,1) = sum(transpose(A(:,223)))/60900;

```

```

D(20,1) = sum(transpose(A(:,224)))/60900;
D(21,1) = sum(transpose(A(:,225)))/60900;
D(22,1) = sum(transpose(A(:,226)))/60900;
D(23,1) = sum(transpose(A(:,227)))/60900;
D(24,1) = sum(transpose(A(:,228)))/60900;
D(25,1) = sum(transpose(A(:,229)))/60900;
D(26,1) = sum(transpose(A(:,230)))/60900;
D(27,1) = sum(transpose(A(:,231)))/60900;
D(28,1) = sum(transpose(A(:,232)))/60900;
D(29,1) = sum(transpose(A(:,233)))/60900;
D(30,1) = sum(transpose(A(:,234)))/60900;
D(31,1) = sum(transpose(A(:,235)))/60900;
D(32,1) = sum(transpose(A(:,236)))/60900;
D(33,1) = sum(transpose(A(:,237)))/60900;
D(34,1) = sum(transpose(A(:,238)))/60900;
D(35,1) = sum(transpose(A(:,239)))/60900;
D(36,1) = sum(transpose(A(:,240)))/60900;
D(37,1) = sum(transpose(A(:,241)))/60900;
D(38,1) = sum(transpose(A(:,242)))/60900;
D(39,1) = sum(transpose(A(:,243)))/60900;
D(40,1) = sum(transpose(A(:,244)))/60900;
D(41,1) = sum(transpose(A(:,245)))/60900;
D(42,1) = sum(transpose(A(:,246)))/60900;
D(43,1) = sum(transpose(A(:,247)))/60900;
D(44,1) = sum(transpose(A(:,248)))/60900;
D(45,1) = sum(transpose(A(:,249)))/60900;
D(46,1) = sum(transpose(A(:,250)))/60900;
D(47,1) = sum(transpose(A(:,251)))/60900;
D(48,1) = sum(transpose(A(:,252)))/60900;
D(49,1) = sum(transpose(A(:,253)))/60900;
D(50,1) = sum(transpose(A(:,254)))/60900;
D(51,1) = sum(transpose(A(:,255)))/60900;
D(52,1) = sum(transpose(A(:,256)))/60900;
D(53,1) = sum(transpose(A(:,257)))/60900;
D(54,1) = sum(transpose(A(:,258)))/60900;
D(55,1) = sum(transpose(A(:,259)))/60900;
D(56,1) = sum(transpose(A(:,260)))/60900;
D(57,1) = sum(transpose(A(:,261)))/60900;
D(58,1) = sum(transpose(A(:,262)))/60900;
D(59,1) = sum(transpose(A(:,263)))/60900;
D(60,1) = sum(transpose(A(:,264)))/60900;
D(61,1) = sum(transpose(A(:,265)))/60900;
D(62,1) = sum(transpose(A(:,266)))/60900;
D(63,1) = sum(transpose(A(:,267)))/60900;
D(64,1) = sum(transpose(A(:,268)))/60900;

```

```

E(1,1) = sum(transpose(A(:,271)))/60900;
E(2,1) = sum(transpose(A(:,272)))/60900;
E(3,1) = sum(transpose(A(:,273)))/60900;
E(4,1) = sum(transpose(A(:,274)))/60900;
E(5,1) = sum(transpose(A(:,275)))/60900;
E(6,1) = sum(transpose(A(:,276)))/60900;
E(7,1) = sum(transpose(A(:,277)))/60900;
E(8,1) = sum(transpose(A(:,278)))/60900;
E(9,1) = sum(transpose(A(:,279)))/60900;
E(10,1) = sum(transpose(A(:,280)))/60900;
E(11,1) = sum(transpose(A(:,281)))/60900;

```

```
E(12,1) = sum(transpose(A(:,282)))/60900;
E(13,1) = sum(transpose(A(:,283)))/60900;
E(14,1) = sum(transpose(A(:,284)))/60900;
E(15,1) = sum(transpose(A(:,285)))/60900;
E(16,1) = sum(transpose(A(:,286)))/60900;
E(17,1) = sum(transpose(A(:,287)))/60900;
E(18,1) = sum(transpose(A(:,288)))/60900;
E(19,1) = sum(transpose(A(:,289)))/60900;
E(20,1) = sum(transpose(A(:,290)))/60900;
E(21,1) = sum(transpose(A(:,291)))/60900;
E(22,1) = sum(transpose(A(:,292)))/60900;
E(23,1) = sum(transpose(A(:,293)))/60900;
E(24,1) = sum(transpose(A(:,294)))/60900;
E(25,1) = sum(transpose(A(:,295)))/60900;
E(26,1) = sum(transpose(A(:,296)))/60900;
E(27,1) = sum(transpose(A(:,297)))/60900;
E(28,1) = sum(transpose(A(:,298)))/60900;
E(29,1) = sum(transpose(A(:,299)))/60900;
E(30,1) = sum(transpose(A(:,300)))/60900;
E(31,1) = sum(transpose(A(:,301)))/60900;
E(32,1) = sum(transpose(A(:,302)))/60900;
E(33,1) = sum(transpose(A(:,303)))/60900;
E(34,1) = sum(transpose(A(:,304)))/60900;
E(35,1) = sum(transpose(A(:,305)))/60900;
E(36,1) = sum(transpose(A(:,306)))/60900;
E(37,1) = sum(transpose(A(:,307)))/60900;
E(38,1) = sum(transpose(A(:,308)))/60900;
E(39,1) = sum(transpose(A(:,309)))/60900;
E(40,1) = sum(transpose(A(:,310)))/60900;
E(41,1) = sum(transpose(A(:,311)))/60900;
E(42,1) = sum(transpose(A(:,312)))/60900;
E(43,1) = sum(transpose(A(:,313)))/60900;
E(44,1) = sum(transpose(A(:,314)))/60900;
E(45,1) = sum(transpose(A(:,315)))/60900;
E(46,1) = sum(transpose(A(:,316)))/60900;
E(47,1) = sum(transpose(A(:,317)))/60900;
E(48,1) = sum(transpose(A(:,318)))/60900;
E(49,1) = sum(transpose(A(:,319)))/60900;
E(50,1) = sum(transpose(A(:,320)))/60900;
E(51,1) = sum(transpose(A(:,321)))/60900;
E(52,1) = sum(transpose(A(:,322)))/60900;
E(53,1) = sum(transpose(A(:,323)))/60900;
E(54,1) = sum(transpose(A(:,324)))/60900;
E(55,1) = sum(transpose(A(:,325)))/60900;
E(56,1) = sum(transpose(A(:,326)))/60900;
E(57,1) = sum(transpose(A(:,327)))/60900;
E(58,1) = sum(transpose(A(:,328)))/60900;
E(59,1) = sum(transpose(A(:,329)))/60900;
E(60,1) = sum(transpose(A(:,330)))/60900;
E(61,1) = sum(transpose(A(:,331)))/60900;
E(62,1) = sum(transpose(A(:,332)))/60900;
E(63,1) = sum(transpose(A(:,333)))/60900;
E(64,1) = sum(transpose(A(:,334)))/60900;
```

```
fax_bins = [0:31.25:1999];
```

```
figure(1)
plot(fax_bins, abs(fft(B)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC1 Acceleration Profile');
```

```
figure(2)
plot(fax_bins, abs(fft(C)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC2 Acceleration Profile');
```

```
figure(3)
plot(fax_bins, abs(fft(D)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC3 Acceleration Profile');
```

```
figure(4)
plot(fax_bins, abs(fft(E)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC4 Acceleration Profile');
```

## D.10. 93.3 °C Constant Speed Test Data Analysis

```
clear;
close all;
clc;

A = importdata('2020_04_21_200F_steady_state.dat');

TCM1 = transpose(A(:,3));
TCM2 = transpose(A(:,6));
TCM3 = transpose(A(:,9));
TCM4 = transpose(A(:,12));
TCMT = transpose(A(:,15));
TCMMT = transpose(A(:,18));
TCMMB = transpose(A(:,21));
TCMB = transpose(A(:,24));
TCG1 = transpose(A(:,27));
TCG2 = transpose(A(:,30));
TCG3 = transpose(A(:,33));
TCG4 = transpose(A(:,36));
TCGB = transpose(A(:,39));
TCGMB = transpose(A(:,42));
TCGMT = transpose(A(:,45));
TCGT = transpose(A(:,48));
Speed = transpose(A(:,66));
Torque = transpose(A(:,70));

motor_bearing_average = (TCM1 + TCM2 + TCM3 + TCM4)/4;
governor_bearing_average = (TCG1 + TCG2 + TCG3 + TCG4)/4;

time = [0:1:125539];
real_time = time/10;

figure(1);
plot(real_time,TCM1,real_time,TCM2,real_time,TCM3,real_time,TCM4)
title('Motor Side Bearing Temperature');
xlabel('time (s)');
ylabel('temperature (°C)');
legend({'M1', 'M2', 'M3', 'M4',}, 'Location', 'southeast');

figure(2);
plot(real_time,TCG1,real_time,TCG2,real_time,TCG3,real_time,TCG4)
title('Governor Side Bearing Temperature');
xlabel('time (s)');
ylabel('temperature (°C)');
legend({'G1', 'G2', 'G3', 'G4',}, 'Location', 'southeast');

figure(3);
plot(real_time,TCMT,real_time,TCMMT,real_time,TCMMB,real_time,TCMB)
title('Motor Side Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperatre (°C)');
legend({'Top', 'Middle-Top', 'Middle-
Bottom', 'Bottom'}, 'Location', 'eastoutside');
```

```

figure(4);
plot(real_time,TCGT,real_time,TCGMT,real_time,TCGMB,real_time,TCGB)
title('Governor Side Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperatre (°C)');
legend({'Top', 'Middle-Top', 'Middle-
Bottom', 'Bottom'}, 'Location', 'eastoutside');

figure(5);
plot(real_time,Speed)
title('Turbine Speed');
xlabel('time (s)');
ylabel('Shaft Speed (RPM)');

figure(6);
plot(real_time,Torque)
title('Torque vs. Time');
xlabel('Time (s)');
ylabel('Torque (Nm)');

figure(7);
plot(real_time,motor_bearing_average)
title('Averaged Motor Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(8);
plot(real_time,governor_bearing_average)
title('Averaged Governor Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(9);
plot(real_time,governor_bearing_average,real_time,motor_bearing_average)
title('Bearing Averaged Temperature Comparison')
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'Averaged Governor Bearing Temperature', 'Averaged Motor Bearing
Temperature'}, 'Location', 'southeast');

```

## D.11. 93.3 °C Constant Speed Test Accelerometer Analysis

```
clear;
close all;
clc;
%accelerometer script
%71-AC1 force
%72-AC1 std
%73-136 AC1 bins
%137 AC2 force
%138 AC2 std
%139-202 AC2 Bins
%203-AC3 force
%204-AC3 std
%205-268 AC3 Bins
%269- AC4 Force
%270-AC4 std
%271-334 AC4 bins
A = importdata('2020_04_21_200F_steady_state.dat');
time = [0:1:125539]/10;
```

```
AC1B1 = transpose(A(:,73));
AC1B2 = transpose(A(:,74));
AC1B3 = transpose(A(:,75));
AC1B4 = transpose(A(:,76));
AC1B5 = transpose(A(:,77));
AC1B6 = transpose(A(:,78));
AC1B7 = transpose(A(:,79));
AC1B8 = transpose(A(:,80));
AC1B9 = transpose(A(:,81));
AC1B10 = transpose(A(:,82));
AC1B11 = transpose(A(:,83));
AC1B12 = transpose(A(:,84));
AC1B13 = transpose(A(:,85));
AC1B14 = transpose(A(:,86));
AC1B15 = transpose(A(:,87));
AC1B16 = transpose(A(:,88));
AC1B17 = transpose(A(:,89));
AC1B18 = transpose(A(:,90));
AC1B19 = transpose(A(:,91));
AC1B20 = transpose(A(:,92));
AC1B21 = transpose(A(:,93));
AC1B22 = transpose(A(:,94));
AC1B23 = transpose(A(:,95));
AC1B24 = transpose(A(:,96));
AC1B25 = transpose(A(:,97));
AC1B26 = transpose(A(:,98));
AC1B27 = transpose(A(:,99));
AC1B28 = transpose(A(:,100));
AC1B29 = transpose(A(:,101));
AC1B30 = transpose(A(:,102));
AC1B31 = transpose(A(:,103));
AC1B32 = transpose(A(:,104));
AC1B33 = transpose(A(:,105));
AC1B34 = transpose(A(:,106));
AC1B35 = transpose(A(:,107));
```



```
AC1B36 = transpose(A(:,108));
AC1B37 = transpose(A(:,109));
AC1B38 = transpose(A(:,110));
AC1B39 = transpose(A(:,111));
AC1B40 = transpose(A(:,112));
AC1B41 = transpose(A(:,113));
AC1B42 = transpose(A(:,114));
AC1B43 = transpose(A(:,115));
AC1B44 = transpose(A(:,116));
AC1B45 = transpose(A(:,117));
AC1B46 = transpose(A(:,118));
AC1B47 = transpose(A(:,119));
AC1B48 = transpose(A(:,120));
AC1B49 = transpose(A(:,121));
AC1B50 = transpose(A(:,122));
AC1B51 = transpose(A(:,123));
AC1B52 = transpose(A(:,124));
AC1B53 = transpose(A(:,125));
AC1B54 = transpose(A(:,126));
AC1B55 = transpose(A(:,127));
AC1B56 = transpose(A(:,128));
AC1B57 = transpose(A(:,129));
AC1B58 = transpose(A(:,130));
AC1B59 = transpose(A(:,131));
AC1B60 = transpose(A(:,132));
AC1B61 = transpose(A(:,133));
AC1B62 = transpose(A(:,134));
AC1B63 = transpose(A(:,135));
AC1B64 = transpose(A(:,136));
```

```
AC2B1 = transpose(A(:,139));
AC2B2 = transpose(A(:,140));
AC2B3 = transpose(A(:,141));
AC2B4 = transpose(A(:,142));
AC2B5 = transpose(A(:,143));
AC2B6 = transpose(A(:,144));
AC2B7 = transpose(A(:,145));
AC2B8 = transpose(A(:,146));
AC2B9 = transpose(A(:,147));
AC2B10 = transpose(A(:,148));
AC2B11 = transpose(A(:,149));
AC2B12 = transpose(A(:,150));
AC2B13 = transpose(A(:,151));
AC2B14 = transpose(A(:,152));
AC2B15 = transpose(A(:,153));
AC2B16 = transpose(A(:,154));
AC2B17 = transpose(A(:,155));
AC2B18 = transpose(A(:,156));
AC2B19 = transpose(A(:,157));
AC2B20 = transpose(A(:,158));
AC2B21 = transpose(A(:,159));
AC2B22 = transpose(A(:,160));
AC2B23 = transpose(A(:,161));
AC2B24 = transpose(A(:,162));
AC2B25 = transpose(A(:,163));
AC2B26 = transpose(A(:,164));
AC2B27 = transpose(A(:,165));
```

```
AC2B28 = transpose(A(:,166));
AC2B29 = transpose(A(:,167));
AC2B30 = transpose(A(:,168));
AC2B31 = transpose(A(:,169));
AC2B32 = transpose(A(:,170));
AC2B33 = transpose(A(:,171));
AC2B34 = transpose(A(:,172));
AC2B35 = transpose(A(:,173));
AC2B36 = transpose(A(:,174));
AC2B37 = transpose(A(:,175));
AC2B38 = transpose(A(:,176));
AC2B39 = transpose(A(:,177));
AC2B40 = transpose(A(:,178));
AC2B41 = transpose(A(:,179));
AC2B42 = transpose(A(:,180));
AC2B43 = transpose(A(:,181));
AC2B44 = transpose(A(:,182));
AC2B45 = transpose(A(:,183));
AC2B46 = transpose(A(:,184));
AC2B47 = transpose(A(:,185));
AC2B48 = transpose(A(:,186));
AC2B49 = transpose(A(:,187));
AC2B50 = transpose(A(:,188));
AC2B51 = transpose(A(:,189));
AC2B52 = transpose(A(:,190));
AC2B53 = transpose(A(:,191));
AC2B54 = transpose(A(:,192));
AC2B55 = transpose(A(:,193));
AC2B56 = transpose(A(:,194));
AC2B57 = transpose(A(:,195));
AC2B58 = transpose(A(:,196));
AC2B59 = transpose(A(:,197));
AC2B60 = transpose(A(:,198));
AC2B61 = transpose(A(:,199));
AC2B62 = transpose(A(:,200));
AC2B63 = transpose(A(:,201));
AC2B64 = transpose(A(:,202));
```

```
AC3B1 = transpose(A(:,205));
AC3B2 = transpose(A(:,206));
AC3B3 = transpose(A(:,207));
AC3B4 = transpose(A(:,208));
AC3B5 = transpose(A(:,209));
AC3B6 = transpose(A(:,210));
AC3B7 = transpose(A(:,211));
AC3B8 = transpose(A(:,212));
AC3B9 = transpose(A(:,213));
AC3B10 = transpose(A(:,214));
AC3B11 = transpose(A(:,215));
AC3B12 = transpose(A(:,216));
AC3B13 = transpose(A(:,217));
AC3B14 = transpose(A(:,218));
AC3B15 = transpose(A(:,219));
AC3B16 = transpose(A(:,220));
AC3B17 = transpose(A(:,221));
AC3B18 = transpose(A(:,222));
AC3B19 = transpose(A(:,223));
```

```
AC3B20 = transpose(A(:,224));
AC3B21 = transpose(A(:,225));
AC3B22 = transpose(A(:,226));
AC3B23 = transpose(A(:,227));
AC3B24 = transpose(A(:,228));
AC3B25 = transpose(A(:,229));
AC3B26 = transpose(A(:,230));
AC3B27 = transpose(A(:,231));
AC3B28 = transpose(A(:,232));
AC3B29 = transpose(A(:,233));
AC3B30 = transpose(A(:,234));
AC3B31 = transpose(A(:,235));
AC3B32 = transpose(A(:,236));
AC3B33 = transpose(A(:,237));
AC3B34 = transpose(A(:,238));
AC3B35 = transpose(A(:,239));
AC3B36 = transpose(A(:,240));
AC3B37 = transpose(A(:,241));
AC3B38 = transpose(A(:,242));
AC3B39 = transpose(A(:,243));
AC3B40 = transpose(A(:,244));
AC3B41 = transpose(A(:,245));
AC3B42 = transpose(A(:,246));
AC3B43 = transpose(A(:,247));
AC3B44 = transpose(A(:,248));
AC3B45 = transpose(A(:,249));
AC3B46 = transpose(A(:,250));
AC3B47 = transpose(A(:,251));
AC3B48 = transpose(A(:,252));
AC3B49 = transpose(A(:,253));
AC3B50 = transpose(A(:,254));
AC3B51 = transpose(A(:,255));
AC3B52 = transpose(A(:,256));
AC3B53 = transpose(A(:,257));
AC3B54 = transpose(A(:,258));
AC3B55 = transpose(A(:,259));
AC3B56 = transpose(A(:,260));
AC3B57 = transpose(A(:,261));
AC3B58 = transpose(A(:,262));
AC3B59 = transpose(A(:,263));
AC3B60 = transpose(A(:,264));
AC3B61 = transpose(A(:,265));
AC3B62 = transpose(A(:,266));
AC3B63 = transpose(A(:,267));
AC3B64 = transpose(A(:,268));
```

```
AC4B1 = transpose(A(:,271));
AC4B2 = transpose(A(:,272));
AC4B3 = transpose(A(:,273));
AC4B4 = transpose(A(:,274));
AC4B5 = transpose(A(:,275));
AC4B6 = transpose(A(:,276));
AC4B7 = transpose(A(:,277));
AC4B8 = transpose(A(:,278));
AC4B9 = transpose(A(:,279));
AC4B10 = transpose(A(:,280));
AC4B11 = transpose(A(:,281));
```

```
AC4B12 = transpose(A(:,282));
AC4B13 = transpose(A(:,283));
AC4B14 = transpose(A(:,284));
AC4B15 = transpose(A(:,285));
AC4B16 = transpose(A(:,286));
AC4B17 = transpose(A(:,287));
AC4B18 = transpose(A(:,288));
AC4B19 = transpose(A(:,289));
AC4B20 = transpose(A(:,290));
AC4B21 = transpose(A(:,291));
AC4B22 = transpose(A(:,292));
AC4B23 = transpose(A(:,293));
AC4B24 = transpose(A(:,294));
AC4B25 = transpose(A(:,295));
AC4B26 = transpose(A(:,296));
AC4B27 = transpose(A(:,297));
AC4B28 = transpose(A(:,298));
AC4B29 = transpose(A(:,299));
AC4B30 = transpose(A(:,300));
AC4B31 = transpose(A(:,301));
AC4B32 = transpose(A(:,302));
AC4B33 = transpose(A(:,303));
AC4B34 = transpose(A(:,304));
AC4B35 = transpose(A(:,305));
AC4B36 = transpose(A(:,306));
AC4B37 = transpose(A(:,307));
AC4B38 = transpose(A(:,308));
AC4B39 = transpose(A(:,309));
AC4B40 = transpose(A(:,310));
AC4B41 = transpose(A(:,311));
AC4B42 = transpose(A(:,312));
AC4B43 = transpose(A(:,313));
AC4B44 = transpose(A(:,314));
AC4B45 = transpose(A(:,315));
AC4B46 = transpose(A(:,316));
AC4B47 = transpose(A(:,317));
AC4B48 = transpose(A(:,318));
AC4B49 = transpose(A(:,319));
AC4B50 = transpose(A(:,320));
AC4B51 = transpose(A(:,321));
AC4B52 = transpose(A(:,322));
AC4B53 = transpose(A(:,323));
AC4B54 = transpose(A(:,324));
AC4B55 = transpose(A(:,325));
AC4B56 = transpose(A(:,326));
AC4B57 = transpose(A(:,327));
AC4B58 = transpose(A(:,328));
AC4B59 = transpose(A(:,329));
AC4B60 = transpose(A(:,330));
AC4B61 = transpose(A(:,331));
AC4B62 = transpose(A(:,332));
AC4B63 = transpose(A(:,333));
AC4B64 = transpose(A(:,334));
```

```

AC1_avg = (AC1B1 + AC1B2+ AC1B3 + AC1B4 + AC1B5 + AC1B6 + AC1B7 + AC1B8 +
AC1B9 + AC1B10 + AC1B11 + AC1B12+ AC1B13 + AC1B14 + AC1B15 + AC1B16 + AC1B17
+ AC1B18 + AC1B19 + AC1B20 + AC1B21 + AC1B22+ AC1B23 + AC1B24 + AC1B25 +
AC1B26 + AC1B27 + AC1B28 + AC1B29 + AC1B30 + AC1B31 + AC1B32+ AC1B33 + AC1B34
+ AC1B35 + AC1B36 + AC1B37 + AC1B38 + AC1B39 + AC1B40 + AC1B41 + AC1B42+
AC1B43 + AC1B44 + AC1B45 + AC1B46 + AC1B47 + AC1B48 + AC1B49 + AC1B50 +
AC1B51 + AC1B52+ AC1B53 + AC1B54 + AC1B55 + AC1B56 + AC1B57 + AC1B58 + AC1B59
+ AC1B60 + AC1B61 + AC1B62 + AC1B63 + AC1B64)/64;
AC2_avg = (AC2B1 + AC2B2+ AC2B3 + AC2B4 + AC2B5 + AC2B6 + AC2B7 + AC2B8 +
AC2B9 + AC2B10 + AC2B11 + AC2B12+ AC2B13 + AC2B14 + AC2B15 + AC2B16 + AC2B17
+ AC2B18 + AC2B19 + AC2B20 + AC2B21 + AC2B22+ AC2B23 + AC2B24 + AC2B25 +
AC2B26 + AC2B27 + AC2B28 + AC2B29 + AC2B30 + AC2B31 + AC2B32+ AC2B33 + AC2B34
+ AC2B35 + AC2B36 + AC2B37 + AC2B38 + AC2B39 + AC2B40 + AC2B41 + AC2B42+
AC2B43 + AC2B44 + AC2B45 + AC2B46 + AC2B47 + AC2B48 + AC2B49 + AC2B50 +
AC2B51 + AC2B52+ AC2B53 + AC2B54 + AC2B55 + AC2B56 + AC2B57 + AC2B58 + AC2B59
+ AC2B60 + AC2B61 + AC2B62 + AC2B63 + AC2B64)/64;
AC3_avg = (AC3B1 + AC3B2+ AC3B3 + AC3B4 + AC3B5 + AC3B6 + AC3B7 + AC3B8 +
AC3B9 + AC3B10 + AC3B11 + AC3B12+ AC3B13 + AC3B14 + AC3B15 + AC3B16 + AC3B17
+ AC3B18 + AC3B19 + AC3B20 + AC3B21 + AC3B22+ AC3B23 + AC3B24 + AC3B25 +
AC3B26 + AC3B27 + AC3B28 + AC3B29 + AC3B30 + AC3B31 + AC3B32+ AC3B33 + AC3B34
+ AC3B35 + AC3B36 + AC3B37 + AC3B38 + AC3B39 + AC3B40 + AC3B41 + AC3B42+
AC3B43 + AC3B44 + AC3B45 + AC3B46 + AC3B47 + AC3B48 + AC3B49 + AC3B50 +
AC3B51 + AC3B52+ AC3B53 + AC3B54 + AC3B55 + AC3B56+ AC3B57 + AC3B58 + AC3B59
+ AC3B60 + AC3B61 + AC3B62 + AC3B63 + AC3B64)/64;
AC4_avg = (AC4B1 + AC4B2+ AC4B3 + AC4B4 + AC4B5 + AC4B6 + AC4B7 + AC4B8 +
AC4B9 + AC4B10 + AC4B11 + AC4B12+ AC4B13 + AC4B14 + AC4B15 + AC4B16 + AC4B17
+ AC4B18 + AC4B19 + AC4B20 + AC4B21 + AC4B22+ AC4B23 + AC4B24 + AC4B25 +
AC4B26 + AC4B27 + AC4B28 + AC4B29 + AC4B30 + AC4B31 + AC4B32+ AC4B33 + AC4B34
+ AC4B35 + AC4B36 + AC4B37 + AC4B38 + AC4B39 + AC4B40 + AC4B41 + AC4B42+
AC4B43 + AC4B44 + AC4B45 + AC4B46 + AC4B47 + AC4B48 + AC4B49 + AC4B50 +
AC4B51 + AC4B52+ AC4B53 + AC4B54 + AC4B55 + AC4B56 + AC4B57 + AC4B58 + AC4B59
+ AC4B60 + AC4B61 + AC4B62 + AC4B63 + AC4B64)/64;

```

```

figure(1)
plot(time,AC1_avg,time,AC2_avg,time,AC3_avg,time,AC4_avg);
title('Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC1', 'AC2', 'AC3', 'AC4'}, 'Location', 'northwest');

```

```

figure(2)
plot(time,AC1_avg,time,AC2_avg);
title('Governor Side Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC1', 'AC2'}, 'Location', 'northwest');

```

```

figure(3)
plot(time,AC3_avg,time,AC4_avg);
title('Motor Side Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC3', 'AC4'}, 'Location', 'northwest');

```

```

figure(4)
plot(time,AC3_avg,time,AC1_avg);

```

```
title('Vertical Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC3', 'AC1'}, 'Location', 'northwest');

figure(5)
plot(time, AC2_avg, time, AC4_avg);
title('Horizontal Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC2', 'AC4'}, 'Location', 'northwest');
```

## D.12. 93.3 °C Constant Speed Test Accelerometer Fast Fourier Transform

```
clear;
close all;
clc;
%accelerometer script
%71-AC1 force
%72-AC1 std
%73-136 AC1 bins
%137 AC2 force
%138 AC2 std
%139-202 AC2 Bins
%203-AC3 force
%204-AC3 std
%205-268 AC3 Bins
%269- AC4 Force
%270-AC4 std
%271-334 AC4 bins
A = importdata('2020_04_21_200F_steady_state.dat');
time = [0:1:125539]/10;

B(1,1) = sum(transpose(A(:,73)))/125540;
B(2,1) = sum(transpose(A(:,74)))/125540;
B(3,1) = sum(transpose(A(:,75)))/125540;
B(4,1) = sum(transpose(A(:,76)))/125540;
B(5,1) = sum(transpose(A(:,77)))/125540;
B(6,1) = sum(transpose(A(:,78)))/125540;
B(7,1) = sum(transpose(A(:,79)))/125540;
B(8,1) = sum(transpose(A(:,80)))/125540;
B(9,1) = sum(transpose(A(:,81)))/125540;
B(10,1) = sum(transpose(A(:,82)))/125540;
B(11,1) = sum(transpose(A(:,83)))/125540;
B(12,1) = sum(transpose(A(:,84)))/125540;
B(13,1) = sum(transpose(A(:,85)))/125540;
B(14,1) = sum(transpose(A(:,86)))/125540;
B(15,1) = sum(transpose(A(:,87)))/125540;
B(16,1) = sum(transpose(A(:,88)))/125540;
B(17,1) = sum(transpose(A(:,89)))/125540;
B(18,1) = sum(transpose(A(:,90)))/125540;
B(19,1) = sum(transpose(A(:,91)))/125540;
B(20,1) = sum(transpose(A(:,92)))/125540;
B(21,1) = sum(transpose(A(:,93)))/125540;
B(22,1) = sum(transpose(A(:,94)))/125540;
B(23,1) = sum(transpose(A(:,95)))/125540;
B(24,1) = sum(transpose(A(:,96)))/125540;
B(25,1) = sum(transpose(A(:,97)))/125540;
B(26,1) = sum(transpose(A(:,98)))/125540;
B(27,1) = sum(transpose(A(:,99)))/125540;
B(28,1) = sum(transpose(A(:,100)))/125540;
B(29,1) = sum(transpose(A(:,101)))/125540;
B(30,1) = sum(transpose(A(:,102)))/125540;
B(31,1) = sum(transpose(A(:,103)))/125540;
B(32,1) = sum(transpose(A(:,104)))/125540;
B(33,1) = sum(transpose(A(:,105)))/125540;
B(34,1) = sum(transpose(A(:,106)))/125540;
B(35,1) = sum(transpose(A(:,107)))/125540;
```

```

B(36,1) = sum(transpose(A(:,108)))/125540;
B(37,1) = sum(transpose(A(:,109)))/125540;
B(38,1) = sum(transpose(A(:,110)))/125540;
B(39,1) = sum(transpose(A(:,111)))/125540;
B(40,1) = sum(transpose(A(:,112)))/125540;
B(41,1) = sum(transpose(A(:,113)))/125540;
B(42,1) = sum(transpose(A(:,114)))/125540;
B(43,1) = sum(transpose(A(:,115)))/125540;
B(44,1) = sum(transpose(A(:,116)))/125540;
B(45,1) = sum(transpose(A(:,117)))/125540;
B(46,1) = sum(transpose(A(:,118)))/125540;
B(47,1) = sum(transpose(A(:,119)))/125540;
B(48,1) = sum(transpose(A(:,120)))/125540;
B(49,1) = sum(transpose(A(:,121)))/125540;
B(50,1) = sum(transpose(A(:,122)))/125540;
B(51,1) = sum(transpose(A(:,123)))/125540;
B(52,1) = sum(transpose(A(:,124)))/125540;
B(53,1) = sum(transpose(A(:,125)))/125540;
B(54,1) = sum(transpose(A(:,126)))/125540;
B(55,1) = sum(transpose(A(:,127)))/125540;
B(56,1) = sum(transpose(A(:,128)))/125540;
B(57,1) = sum(transpose(A(:,129)))/125540;
B(58,1) = sum(transpose(A(:,130)))/125540;
B(59,1) = sum(transpose(A(:,131)))/125540;
B(60,1) = sum(transpose(A(:,132)))/125540;
B(61,1) = sum(transpose(A(:,133)))/125540;
B(62,1) = sum(transpose(A(:,134)))/125540;
B(63,1) = sum(transpose(A(:,135)))/125540;
B(64,1) = sum(transpose(A(:,136)))/125540;

```

```

C(1,1) = sum(transpose(A(:,139)))/125540;
C(2,1) = sum(transpose(A(:,140)))/125540;
C(3,1) = sum(transpose(A(:,141)))/125540;
C(4,1) = sum(transpose(A(:,142)))/125540;
C(5,1) = sum(transpose(A(:,143)))/125540;
C(6,1) = sum(transpose(A(:,144)))/125540;
C(7,1) = sum(transpose(A(:,145)))/125540;
C(8,1) = sum(transpose(A(:,146)))/125540;
C(9,1) = sum(transpose(A(:,147)))/125540;
C(10,1) = sum(transpose(A(:,148)))/125540;
C(11,1) = sum(transpose(A(:,149)))/125540;
C(12,1) = sum(transpose(A(:,150)))/125540;
C(13,1) = sum(transpose(A(:,151)))/125540;
C(14,1) = sum(transpose(A(:,152)))/125540;
C(15,1) = sum(transpose(A(:,153)))/125540;
C(16,1) = sum(transpose(A(:,154)))/125540;
C(17,1) = sum(transpose(A(:,155)))/125540;
C(18,1) = sum(transpose(A(:,156)))/125540;
C(19,1) = sum(transpose(A(:,157)))/125540;
C(20,1) = sum(transpose(A(:,158)))/125540;
C(21,1) = sum(transpose(A(:,159)))/125540;
C(22,1) = sum(transpose(A(:,160)))/125540;
C(23,1) = sum(transpose(A(:,161)))/125540;
C(24,1) = sum(transpose(A(:,162)))/125540;
C(25,1) = sum(transpose(A(:,163)))/125540;
C(26,1) = sum(transpose(A(:,164)))/125540;
C(27,1) = sum(transpose(A(:,165)))/125540;

```



```

C(28,1) = sum(transpose(A(:,166)))/125540;
C(29,1) = sum(transpose(A(:,167)))/125540;
C(30,1) = sum(transpose(A(:,168)))/125540;
C(31,1) = sum(transpose(A(:,169)))/125540;
C(32,1) = sum(transpose(A(:,170)))/125540;
C(33,1) = sum(transpose(A(:,171)))/125540;
C(34,1) = sum(transpose(A(:,172)))/125540;
C(35,1) = sum(transpose(A(:,173)))/125540;
C(36,1) = sum(transpose(A(:,174)))/125540;
C(37,1) = sum(transpose(A(:,175)))/125540;
C(38,1) = sum(transpose(A(:,176)))/125540;
C(39,1) = sum(transpose(A(:,177)))/125540;
C(40,1) = sum(transpose(A(:,178)))/125540;
C(41,1) = sum(transpose(A(:,179)))/125540;
C(42,1) = sum(transpose(A(:,180)))/125540;
C(43,1) = sum(transpose(A(:,181)))/125540;
C(44,1) = sum(transpose(A(:,182)))/125540;
C(45,1) = sum(transpose(A(:,183)))/125540;
C(46,1) = sum(transpose(A(:,184)))/125540;
C(47,1) = sum(transpose(A(:,185)))/125540;
C(48,1) = sum(transpose(A(:,186)))/125540;
C(49,1) = sum(transpose(A(:,187)))/125540;
C(50,1) = sum(transpose(A(:,188)))/125540;
C(51,1) = sum(transpose(A(:,189)))/125540;
C(52,1) = sum(transpose(A(:,190)))/125540;
C(53,1) = sum(transpose(A(:,191)))/125540;
C(54,1) = sum(transpose(A(:,192)))/125540;
C(55,1) = sum(transpose(A(:,193)))/125540;
C(56,1) = sum(transpose(A(:,194)))/125540;
C(57,1) = sum(transpose(A(:,195)))/125540;
C(58,1) = sum(transpose(A(:,196)))/125540;
C(59,1) = sum(transpose(A(:,197)))/125540;
C(60,1) = sum(transpose(A(:,198)))/125540;
C(61,1) = sum(transpose(A(:,199)))/125540;
C(62,1) = sum(transpose(A(:,200)))/125540;
C(63,1) = sum(transpose(A(:,201)))/125540;
C(64,1) = sum(transpose(A(:,202)))/125540;

```

```

D(1,1) = sum(transpose(A(:,205)))/125540;
D(2,1) = sum(transpose(A(:,206)))/125540;
D(3,1) = sum(transpose(A(:,207)))/125540;
D(4,1) = sum(transpose(A(:,208)))/125540;
D(5,1) = sum(transpose(A(:,209)))/125540;
D(6,1) = sum(transpose(A(:,210)))/125540;
D(7,1) = sum(transpose(A(:,211)))/125540;
D(8,1) = sum(transpose(A(:,212)))/125540;
D(9,1) = sum(transpose(A(:,213)))/125540;
D(10,1) = sum(transpose(A(:,214)))/125540;
D(11,1) = sum(transpose(A(:,215)))/125540;
D(12,1) = sum(transpose(A(:,216)))/125540;
D(13,1) = sum(transpose(A(:,217)))/125540;
D(14,1) = sum(transpose(A(:,218)))/125540;
D(15,1) = sum(transpose(A(:,219)))/125540;
D(16,1) = sum(transpose(A(:,220)))/125540;
D(17,1) = sum(transpose(A(:,221)))/125540;
D(18,1) = sum(transpose(A(:,222)))/125540;
D(19,1) = sum(transpose(A(:,223)))/125540;

```

```

D(20,1) = sum(transpose(A(:,224)))/125540;
D(21,1) = sum(transpose(A(:,225)))/125540;
D(22,1) = sum(transpose(A(:,226)))/125540;
D(23,1) = sum(transpose(A(:,227)))/125540;
D(24,1) = sum(transpose(A(:,228)))/125540;
D(25,1) = sum(transpose(A(:,229)))/125540;
D(26,1) = sum(transpose(A(:,230)))/125540;
D(27,1) = sum(transpose(A(:,231)))/125540;
D(28,1) = sum(transpose(A(:,232)))/125540;
D(29,1) = sum(transpose(A(:,233)))/125540;
D(30,1) = sum(transpose(A(:,234)))/125540;
D(31,1) = sum(transpose(A(:,235)))/125540;
D(32,1) = sum(transpose(A(:,236)))/125540;
D(33,1) = sum(transpose(A(:,237)))/125540;
D(34,1) = sum(transpose(A(:,238)))/125540;
D(35,1) = sum(transpose(A(:,239)))/125540;
D(36,1) = sum(transpose(A(:,240)))/125540;
D(37,1) = sum(transpose(A(:,241)))/125540;
D(38,1) = sum(transpose(A(:,242)))/125540;
D(39,1) = sum(transpose(A(:,243)))/125540;
D(40,1) = sum(transpose(A(:,244)))/125540;
D(41,1) = sum(transpose(A(:,245)))/125540;
D(42,1) = sum(transpose(A(:,246)))/125540;
D(43,1) = sum(transpose(A(:,247)))/125540;
D(44,1) = sum(transpose(A(:,248)))/125540;
D(45,1) = sum(transpose(A(:,249)))/125540;
D(46,1) = sum(transpose(A(:,250)))/125540;
D(47,1) = sum(transpose(A(:,251)))/125540;
D(48,1) = sum(transpose(A(:,252)))/125540;
D(49,1) = sum(transpose(A(:,253)))/125540;
D(50,1) = sum(transpose(A(:,254)))/125540;
D(51,1) = sum(transpose(A(:,255)))/125540;
D(52,1) = sum(transpose(A(:,256)))/125540;
D(53,1) = sum(transpose(A(:,257)))/125540;
D(54,1) = sum(transpose(A(:,258)))/125540;
D(55,1) = sum(transpose(A(:,259)))/125540;
D(56,1) = sum(transpose(A(:,260)))/125540;
D(57,1) = sum(transpose(A(:,261)))/125540;
D(58,1) = sum(transpose(A(:,262)))/125540;
D(59,1) = sum(transpose(A(:,263)))/125540;
D(60,1) = sum(transpose(A(:,264)))/125540;
D(61,1) = sum(transpose(A(:,265)))/125540;
D(62,1) = sum(transpose(A(:,266)))/125540;
D(63,1) = sum(transpose(A(:,267)))/125540;
D(64,1) = sum(transpose(A(:,268)))/125540;

```

```

E(1,1) = sum(transpose(A(:,271)))/125540;
E(2,1) = sum(transpose(A(:,272)))/125540;
E(3,1) = sum(transpose(A(:,273)))/125540;
E(4,1) = sum(transpose(A(:,274)))/125540;
E(5,1) = sum(transpose(A(:,275)))/125540;
E(6,1) = sum(transpose(A(:,276)))/125540;
E(7,1) = sum(transpose(A(:,277)))/125540;
E(8,1) = sum(transpose(A(:,278)))/125540;
E(9,1) = sum(transpose(A(:,279)))/125540;
E(10,1) = sum(transpose(A(:,280)))/125540;
E(11,1) = sum(transpose(A(:,281)))/125540;

```

```

E(12,1) = sum(transpose(A(:,282)))/125540;
E(13,1) = sum(transpose(A(:,283)))/125540;
E(14,1) = sum(transpose(A(:,284)))/125540;
E(15,1) = sum(transpose(A(:,285)))/125540;
E(16,1) = sum(transpose(A(:,286)))/125540;
E(17,1) = sum(transpose(A(:,287)))/125540;
E(18,1) = sum(transpose(A(:,288)))/125540;
E(19,1) = sum(transpose(A(:,289)))/125540;
E(20,1) = sum(transpose(A(:,290)))/125540;
E(21,1) = sum(transpose(A(:,291)))/125540;
E(22,1) = sum(transpose(A(:,292)))/125540;
E(23,1) = sum(transpose(A(:,293)))/125540;
E(24,1) = sum(transpose(A(:,294)))/125540;
E(25,1) = sum(transpose(A(:,295)))/125540;
E(26,1) = sum(transpose(A(:,296)))/125540;
E(27,1) = sum(transpose(A(:,297)))/125540;
E(28,1) = sum(transpose(A(:,298)))/125540;
E(29,1) = sum(transpose(A(:,299)))/125540;
E(30,1) = sum(transpose(A(:,300)))/125540;
E(31,1) = sum(transpose(A(:,301)))/125540;
E(32,1) = sum(transpose(A(:,302)))/125540;
E(33,1) = sum(transpose(A(:,303)))/125540;
E(34,1) = sum(transpose(A(:,304)))/125540;
E(35,1) = sum(transpose(A(:,305)))/125540;
E(36,1) = sum(transpose(A(:,306)))/125540;
E(37,1) = sum(transpose(A(:,307)))/125540;
E(38,1) = sum(transpose(A(:,308)))/125540;
E(39,1) = sum(transpose(A(:,309)))/125540;
E(40,1) = sum(transpose(A(:,310)))/125540;
E(41,1) = sum(transpose(A(:,311)))/125540;
E(42,1) = sum(transpose(A(:,312)))/125540;
E(43,1) = sum(transpose(A(:,313)))/125540;
E(44,1) = sum(transpose(A(:,314)))/125540;
E(45,1) = sum(transpose(A(:,315)))/125540;
E(46,1) = sum(transpose(A(:,316)))/125540;
E(47,1) = sum(transpose(A(:,317)))/125540;
E(48,1) = sum(transpose(A(:,318)))/125540;
E(49,1) = sum(transpose(A(:,319)))/125540;
E(50,1) = sum(transpose(A(:,320)))/125540;
E(51,1) = sum(transpose(A(:,321)))/125540;
E(52,1) = sum(transpose(A(:,322)))/125540;
E(53,1) = sum(transpose(A(:,323)))/125540;
E(54,1) = sum(transpose(A(:,324)))/125540;
E(55,1) = sum(transpose(A(:,325)))/125540;
E(56,1) = sum(transpose(A(:,326)))/125540;
E(57,1) = sum(transpose(A(:,327)))/125540;
E(58,1) = sum(transpose(A(:,328)))/125540;
E(59,1) = sum(transpose(A(:,329)))/125540;
E(60,1) = sum(transpose(A(:,330)))/125540;
E(61,1) = sum(transpose(A(:,331)))/125540;
E(62,1) = sum(transpose(A(:,332)))/125540;
E(63,1) = sum(transpose(A(:,333)))/125540;
E(64,1) = sum(transpose(A(:,334)))/125540;

```

```

fax_bins = [0:31.25:1999];
figure(1)
plot(fax_bins, abs(fft(B)))

```

```
xlabel('Frequency (Hz)');  
ylabel('Acceleration (g)');  
title('AC1 Acceleration Profile');
```

```
figure(2)  
plot(fax_bins, abs(fft(C)))  
xlabel('Frequency (Hz)');  
ylabel('Acceleration (g)');  
title('AC2 Acceleration Profile');
```

```
figure(3)  
plot(fax_bins, abs(fft(D)))  
xlabel('Frequency (Hz)');  
ylabel('Acceleration (g)');  
title('AC3 Acceleration Profile');
```

```
figure(4)  
plot(fax_bins, abs(fft(E)))  
xlabel('Frequency (Hz)');  
ylabel('Acceleration (g)');  
title('AC4 Acceleration Profile');
```

### D.13. Unheated Start-Stop Test Data Analysis

```
clear;
close all;
clc;

A = importdata('2020_04_13_start_stop_no_heat.dat');

TCM1 = transpose(A(:,3));
TCM1_F = (TCM1 * (9/5)) + 32;
TCM2 = transpose(A(:,6));
TCM2_F = (TCM2 * (9/5)) + 32;
TCM3 = transpose(A(:,9));
TCM3_F = (TCM3 * (9/5)) + 32;
TCM4 = transpose(A(:,12));
TCM4_F = (TCM4 * (9/5)) + 32;
TCMT = transpose(A(:,15));
TCMT_F = (TCMT * (9/5)) + 32;
TCMMT = transpose(A(:,18));
TCMMT_F = (TCMMT * (9/5)) + 32;
TCMMB = transpose(A(:,21));
TCMMB_F = (TCMMB * (9/5)) + 32;
TCMB = transpose(A(:,24));
TCMB_F = (TCMB * (9/5)) + 32;
TCG1 = transpose(A(:,27));
TCG1_F = (TCG1 * (9/5)) + 32;
TCG2 = transpose(A(:,30));
TCG2_F = (TCG2 * (9/5)) + 32;
TCG3 = transpose(A(:,33));
TCG3_F = (TCG3 * (9/5)) + 32;
TCG4 = transpose(A(:,36));
TCG4_F = (TCG4 * (9/5)) + 32;
TCGB = transpose(A(:,39));
TCGB_F = (TCGB * (9/5)) + 32;
TCGMB = transpose(A(:,42));
TCGMB_F = (TCGMB * (9/5)) + 32;
TCGMT = transpose(A(:,45));
TCGMT_F = (TCGMT * (9/5)) + 32;
TCGT = transpose(A(:,48));
TCGT_F = (TCGT * (9/5)) + 32;
Speed = transpose(A(:,66));
Torque = transpose(A(:,70));
motor_bearing_average = (TCM1 + TCM2 + TCM3 + TCM4)/4;
motor_bearing_average_F = (TCM1_F + TCM2_F + TCM3_F + TCM4_F)/4;
governor_bearing_average = (TCG1 + TCG2 + TCG3 + TCG4)/4;
governor_bearing_average_F = (TCG1_F + TCG2_F + TCG3_F + TCG4_F)/4;

time = [0:1:44499];
real_time = time/10;

figure(1);
plot(real_time,TCM1,real_time,TCM2,real_time,TCM3,real_time,TCM4)
title('Motor Side Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');
```

```

legend({'M1', 'M2', 'M3', 'M4', }, 'Location', 'southeast');

figure(2);
plot(real_time, TCG1, real_time, TCG2, real_time, TCG3, real_time, TCG4)
title('Governor Side Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'G1', 'G2', 'G3', 'G4', }, 'Location', 'southeast');

figure(3);
plot(real_time, TCMT, real_time, TCMMT, real_time, TCMMB, real_time, TCMB)
title('Motor Side Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperatre (°C)');
legend({'Top', 'Middle-Top', 'Middle-
Bottom', 'Bottom'}, 'Location', 'eastoutside');

figure(4);
plot(real_time, TCGT, real_time, TCGMT, real_time, TCGMB, real_time, TCGB)
title('Governor Side Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperatre (°C)');
legend({'Top', 'Middle-Top', 'Middle-
Bottom', 'Bottom'}, 'Location', 'eastoutside');

figure(5);
plot(real_time, Speed)
title('Turbine Speed');
xlabel('Time (s)');
ylabel('Shaft Speed (RPM)');

figure(6);
plot(real_time, Torque)
title('Torque vs. Time');
xlabel('Time (s)');
ylabel('Torque (Nm)');

figure(7);
plot(real_time, motor_bearing_average)
title('Averaged Motor Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(8);
plot(real_time, governor_bearing_average)
title('Averaged Governor Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(9);
plot(real_time, governor_bearing_average, real_time, motor_bearing_average)
title('Bearing Averaged Temperature Comparison')
xlabel('Time (s)');
ylabel('Temperature (°C)');

```

```

legend({'Averaged Governor Bearing Temperature', 'Averaged Motor Bearing
Temperature'}, 'Location', 'southeast');

figure(10);
plot(real_time, TCMT, real_time, motor_bearing_average)
title('Motor Side Oil and Bearing Comparison');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'TCMT', 'Bearing Average'}, 'Location', 'southeast');

figure(11);
plot(real_time, TCGT, real_time, governor_bearing_average)
title('Governor Side Oil and Bearing Comparison');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'TCGT', 'Bearing Average'}, 'Location', 'southeast');

figure(12);
plot(real_time, governor_bearing_average_F, real_time, TCGT_F)
title('Governor Side Oil and Bearing Temperature Comparison');
xlabel('Time (s)');
ylabel('Temperature (°F)');
legend({'Governor Side Bearing Average', 'Top Governor Side Oil Well
TC'}, 'Location', 'southeast');

figure(13);
plot(real_time, motor_bearing_average_F, real_time, TCMT_F)
title('Motor Side Oil and Bearing Temperature Comparison');
xlabel('Time (s)');
ylabel('Temperature (°F)');
legend({'Motor Side Bearing Average', 'Top Motor Side Oil Well
TC'}, 'Location', 'southeast');

figure(14);
plot(real_time, governor_bearing_average_F, real_time, motor_bearing_average_F)
title('Bearing Averaged Temperature Comparison')
xlabel('Time (s)');
ylabel('Temperature (°F)');
legend({'Averaged Governor Side Bearing Temperature', 'Averaged Motor Side
Bearing Temperature'}, 'Location', 'southeast');

```

## D.14. Unheated Start-Stop Test Accelerometer Analysis

```
clear;
close all;
clc;
%accelerometer script
%71-AC1 force
%72-AC1 std
%73-136 AC1 bins
%137 AC2 force
%138 AC2 std
%139-202 AC2 Bins
%203-AC3 force
%204-AC3 std
%205-268 AC3 Bins
%269- AC4 Force
%270-AC4 std
%271-334 AC4 bins
A = importdata('2020_04_13_start_stop_no_heat.dat');
time = [0:1:44499]/10;

AC1B1 = transpose(A(:,73));
AC1B2 = transpose(A(:,74));
AC1B3 = transpose(A(:,75));
AC1B4 = transpose(A(:,76));
AC1B5 = transpose(A(:,77));
AC1B6 = transpose(A(:,78));
AC1B7 = transpose(A(:,79));
AC1B8 = transpose(A(:,80));
AC1B9 = transpose(A(:,81));
AC1B10 = transpose(A(:,82));
AC1B11 = transpose(A(:,83));
AC1B12 = transpose(A(:,84));
AC1B13 = transpose(A(:,85));
AC1B14 = transpose(A(:,86));
AC1B15 = transpose(A(:,87));
AC1B16 = transpose(A(:,88));
AC1B17 = transpose(A(:,89));
AC1B18 = transpose(A(:,90));
AC1B19 = transpose(A(:,91));
AC1B20 = transpose(A(:,92));
AC1B21 = transpose(A(:,93));
AC1B22 = transpose(A(:,94));
AC1B23 = transpose(A(:,95));
AC1B24 = transpose(A(:,96));
AC1B25 = transpose(A(:,97));
AC1B26 = transpose(A(:,98));
AC1B27 = transpose(A(:,99));
AC1B28 = transpose(A(:,100));
AC1B29 = transpose(A(:,101));
AC1B30 = transpose(A(:,102));
AC1B31 = transpose(A(:,103));
AC1B32 = transpose(A(:,104));
AC1B33 = transpose(A(:,105));
AC1B34 = transpose(A(:,106));
AC1B35 = transpose(A(:,107));
```



```
AC1B36 = transpose(A(:,108));
AC1B37 = transpose(A(:,109));
AC1B38 = transpose(A(:,110));
AC1B39 = transpose(A(:,111));
AC1B40 = transpose(A(:,112));
AC1B41 = transpose(A(:,113));
AC1B42 = transpose(A(:,114));
AC1B43 = transpose(A(:,115));
AC1B44 = transpose(A(:,116));
AC1B45 = transpose(A(:,117));
AC1B46 = transpose(A(:,118));
AC1B47 = transpose(A(:,119));
AC1B48 = transpose(A(:,120));
AC1B49 = transpose(A(:,121));
AC1B50 = transpose(A(:,122));
AC1B51 = transpose(A(:,123));
AC1B52 = transpose(A(:,124));
AC1B53 = transpose(A(:,125));
AC1B54 = transpose(A(:,126));
AC1B55 = transpose(A(:,127));
AC1B56 = transpose(A(:,128));
AC1B57 = transpose(A(:,129));
AC1B58 = transpose(A(:,130));
AC1B59 = transpose(A(:,131));
AC1B60 = transpose(A(:,132));
AC1B61 = transpose(A(:,133));
AC1B62 = transpose(A(:,134));
AC1B63 = transpose(A(:,135));
AC1B64 = transpose(A(:,136));
```

```
AC2B1 = transpose(A(:,139));
AC2B2 = transpose(A(:,140));
AC2B3 = transpose(A(:,141));
AC2B4 = transpose(A(:,142));
AC2B5 = transpose(A(:,143));
AC2B6 = transpose(A(:,144));
AC2B7 = transpose(A(:,145));
AC2B8 = transpose(A(:,146));
AC2B9 = transpose(A(:,147));
AC2B10 = transpose(A(:,148));
AC2B11 = transpose(A(:,149));
AC2B12 = transpose(A(:,150));
AC2B13 = transpose(A(:,151));
AC2B14 = transpose(A(:,152));
AC2B15 = transpose(A(:,153));
AC2B16 = transpose(A(:,154));
AC2B17 = transpose(A(:,155));
AC2B18 = transpose(A(:,156));
AC2B19 = transpose(A(:,157));
AC2B20 = transpose(A(:,158));
AC2B21 = transpose(A(:,159));
AC2B22 = transpose(A(:,160));
AC2B23 = transpose(A(:,161));
AC2B24 = transpose(A(:,162));
AC2B25 = transpose(A(:,163));
AC2B26 = transpose(A(:,164));
AC2B27 = transpose(A(:,165));
```

```
AC2B28 = transpose(A(:,166));
AC2B29 = transpose(A(:,167));
AC2B30 = transpose(A(:,168));
AC2B31 = transpose(A(:,169));
AC2B32 = transpose(A(:,170));
AC2B33 = transpose(A(:,171));
AC2B34 = transpose(A(:,172));
AC2B35 = transpose(A(:,173));
AC2B36 = transpose(A(:,174));
AC2B37 = transpose(A(:,175));
AC2B38 = transpose(A(:,176));
AC2B39 = transpose(A(:,177));
AC2B40 = transpose(A(:,178));
AC2B41 = transpose(A(:,179));
AC2B42 = transpose(A(:,180));
AC2B43 = transpose(A(:,181));
AC2B44 = transpose(A(:,182));
AC2B45 = transpose(A(:,183));
AC2B46 = transpose(A(:,184));
AC2B47 = transpose(A(:,185));
AC2B48 = transpose(A(:,186));
AC2B49 = transpose(A(:,187));
AC2B50 = transpose(A(:,188));
AC2B51 = transpose(A(:,189));
AC2B52 = transpose(A(:,190));
AC2B53 = transpose(A(:,191));
AC2B54 = transpose(A(:,192));
AC2B55 = transpose(A(:,193));
AC2B56 = transpose(A(:,194));
AC2B57 = transpose(A(:,195));
AC2B58 = transpose(A(:,196));
AC2B59 = transpose(A(:,197));
AC2B60 = transpose(A(:,198));
AC2B61 = transpose(A(:,199));
AC2B62 = transpose(A(:,200));
AC2B63 = transpose(A(:,201));
AC2B64 = transpose(A(:,202));
```

```
AC3B1 = transpose(A(:,205));
AC3B2 = transpose(A(:,206));
AC3B3 = transpose(A(:,207));
AC3B4 = transpose(A(:,208));
AC3B5 = transpose(A(:,209));
AC3B6 = transpose(A(:,210));
AC3B7 = transpose(A(:,211));
AC3B8 = transpose(A(:,212));
AC3B9 = transpose(A(:,213));
AC3B10 = transpose(A(:,214));
AC3B11 = transpose(A(:,215));
AC3B12 = transpose(A(:,216));
AC3B13 = transpose(A(:,217));
AC3B14 = transpose(A(:,218));
AC3B15 = transpose(A(:,219));
AC3B16 = transpose(A(:,220));
AC3B17 = transpose(A(:,221));
AC3B18 = transpose(A(:,222));
AC3B19 = transpose(A(:,223));
```

```
AC3B20 = transpose(A(:,224));
AC3B21 = transpose(A(:,225));
AC3B22 = transpose(A(:,226));
AC3B23 = transpose(A(:,227));
AC3B24 = transpose(A(:,228));
AC3B25 = transpose(A(:,229));
AC3B26 = transpose(A(:,230));
AC3B27 = transpose(A(:,231));
AC3B28 = transpose(A(:,232));
AC3B29 = transpose(A(:,233));
AC3B30 = transpose(A(:,234));
AC3B31 = transpose(A(:,235));
AC3B32 = transpose(A(:,236));
AC3B33 = transpose(A(:,237));
AC3B34 = transpose(A(:,238));
AC3B35 = transpose(A(:,239));
AC3B36 = transpose(A(:,240));
AC3B37 = transpose(A(:,241));
AC3B38 = transpose(A(:,242));
AC3B39 = transpose(A(:,243));
AC3B40 = transpose(A(:,244));
AC3B41 = transpose(A(:,245));
AC3B42 = transpose(A(:,246));
AC3B43 = transpose(A(:,247));
AC3B44 = transpose(A(:,248));
AC3B45 = transpose(A(:,249));
AC3B46 = transpose(A(:,250));
AC3B47 = transpose(A(:,251));
AC3B48 = transpose(A(:,252));
AC3B49 = transpose(A(:,253));
AC3B50 = transpose(A(:,254));
AC3B51 = transpose(A(:,255));
AC3B52 = transpose(A(:,256));
AC3B53 = transpose(A(:,257));
AC3B54 = transpose(A(:,258));
AC3B55 = transpose(A(:,259));
AC3B56 = transpose(A(:,260));
AC3B57 = transpose(A(:,261));
AC3B58 = transpose(A(:,262));
AC3B59 = transpose(A(:,263));
AC3B60 = transpose(A(:,264));
AC3B61 = transpose(A(:,265));
AC3B62 = transpose(A(:,266));
AC3B63 = transpose(A(:,267));
AC3B64 = transpose(A(:,268));
```

```
AC4B1 = transpose(A(:,271));
AC4B2 = transpose(A(:,272));
AC4B3 = transpose(A(:,273));
AC4B4 = transpose(A(:,274));
AC4B5 = transpose(A(:,275));
AC4B6 = transpose(A(:,276));
AC4B7 = transpose(A(:,277));
AC4B8 = transpose(A(:,278));
AC4B9 = transpose(A(:,279));
AC4B10 = transpose(A(:,280));
AC4B11 = transpose(A(:,281));
```

```
AC4B12 = transpose(A(:,282));
AC4B13 = transpose(A(:,283));
AC4B14 = transpose(A(:,284));
AC4B15 = transpose(A(:,285));
AC4B16 = transpose(A(:,286));
AC4B17 = transpose(A(:,287));
AC4B18 = transpose(A(:,288));
AC4B19 = transpose(A(:,289));
AC4B20 = transpose(A(:,290));
AC4B21 = transpose(A(:,291));
AC4B22 = transpose(A(:,292));
AC4B23 = transpose(A(:,293));
AC4B24 = transpose(A(:,294));
AC4B25 = transpose(A(:,295));
AC4B26 = transpose(A(:,296));
AC4B27 = transpose(A(:,297));
AC4B28 = transpose(A(:,298));
AC4B29 = transpose(A(:,299));
AC4B30 = transpose(A(:,300));
AC4B31 = transpose(A(:,301));
AC4B32 = transpose(A(:,302));
AC4B33 = transpose(A(:,303));
AC4B34 = transpose(A(:,304));
AC4B35 = transpose(A(:,305));
AC4B36 = transpose(A(:,306));
AC4B37 = transpose(A(:,307));
AC4B38 = transpose(A(:,308));
AC4B39 = transpose(A(:,309));
AC4B40 = transpose(A(:,310));
AC4B41 = transpose(A(:,311));
AC4B42 = transpose(A(:,312));
AC4B43 = transpose(A(:,313));
AC4B44 = transpose(A(:,314));
AC4B45 = transpose(A(:,315));
AC4B46 = transpose(A(:,316));
AC4B47 = transpose(A(:,317));
AC4B48 = transpose(A(:,318));
AC4B49 = transpose(A(:,319));
AC4B50 = transpose(A(:,320));
AC4B51 = transpose(A(:,321));
AC4B52 = transpose(A(:,322));
AC4B53 = transpose(A(:,323));
AC4B54 = transpose(A(:,324));
AC4B55 = transpose(A(:,325));
AC4B56 = transpose(A(:,326));
AC4B57 = transpose(A(:,327));
AC4B58 = transpose(A(:,328));
AC4B59 = transpose(A(:,329));
AC4B60 = transpose(A(:,330));
AC4B61 = transpose(A(:,331));
AC4B62 = transpose(A(:,332));
AC4B63 = transpose(A(:,333));
AC4B64 = transpose(A(:,334));
```

```

AC1_avg = (AC1B1 + AC1B2+ AC1B3 + AC1B4 + AC1B5 + AC1B6 + AC1B7 + AC1B8 +
AC1B9 + AC1B10 + AC1B11 + AC1B12+ AC1B13 + AC1B14 + AC1B15 + AC1B16 + AC1B17
+ AC1B18 + AC1B19 + AC1B20 + AC1B21 + AC1B22+ AC1B23 + AC1B24 + AC1B25 +
AC1B26 + AC1B27 + AC1B28 + AC1B29 + AC1B30 + AC1B31 + AC1B32+ AC1B33 + AC1B34
+ AC1B35 + AC1B36 + AC1B37 + AC1B38 + AC1B39 + AC1B40 + AC1B41 + AC1B42+
AC1B43 + AC1B44 + AC1B45 + AC1B46 + AC1B47 + AC1B48 + AC1B49 + AC1B50 +
AC1B51 + AC1B52+ AC1B53 + AC1B54 + AC1B55 + AC1B56 + AC1B57 + AC1B58 + AC1B59
+ AC1B60 + AC1B61 + AC1B62 + AC1B63 + AC1B64)/64;
AC2_avg = (AC2B1 + AC2B2+ AC2B3 + AC2B4 + AC2B5 + AC2B6 + AC2B7 + AC2B8 +
AC2B9 + AC2B10 + AC2B11 + AC2B12+ AC2B13 + AC2B14 + AC2B15 + AC2B16 + AC2B17
+ AC2B18 + AC2B19 + AC2B20 + AC2B21 + AC2B22+ AC2B23 + AC2B24 + AC2B25 +
AC2B26 + AC2B27 + AC2B28 + AC2B29 + AC2B30 + AC2B31 + AC2B32+ AC2B33 + AC2B34
+ AC2B35 + AC2B36 + AC2B37 + AC2B38 + AC2B39 + AC2B40 + AC2B41 + AC2B42+
AC2B43 + AC2B44 + AC2B45 + AC2B46 + AC2B47 + AC2B48 + AC2B49 + AC2B50 +
AC2B51 + AC2B52+ AC2B53 + AC2B54 + AC2B55 + AC2B56 + AC2B57 + AC2B58 + AC2B59
+ AC2B60 + AC2B61 + AC2B62 + AC2B63 + AC2B64)/64;
AC3_avg = (AC3B1 + AC3B2+ AC3B3 + AC3B4 + AC3B5 + AC3B6 + AC3B7 + AC3B8 +
AC3B9 + AC3B10 + AC3B11 + AC3B12+ AC3B13 + AC3B14 + AC3B15 + AC3B16 + AC3B17
+ AC3B18 + AC3B19 + AC3B20 + AC3B21 + AC3B22+ AC3B23 + AC3B24 + AC3B25 +
AC3B26 + AC3B27 + AC3B28 + AC3B29 + AC3B30 + AC3B31 + AC3B32+ AC3B33 + AC3B34
+ AC3B35 + AC3B36 + AC3B37 + AC3B38 + AC3B39 + AC3B40 + AC3B41 + AC3B42+
AC3B43 + AC3B44 + AC3B45 + AC3B46 + AC3B47 + AC3B48 + AC3B49 + AC3B50 +
AC3B51 + AC3B52+ AC3B53 + AC3B54 + AC3B55 + AC3B56+ AC3B57 + AC3B58 + AC3B59
+ AC3B60 + AC3B61 + AC3B62 + AC3B63 + AC3B64)/64;
AC4_avg = (AC4B1 + AC4B2+ AC4B3 + AC4B4 + AC4B5 + AC4B6 + AC4B7 + AC4B8 +
AC4B9 + AC4B10 + AC4B11 + AC4B12+ AC4B13 + AC4B14 + AC4B15 + AC4B16 + AC4B17
+ AC4B18 + AC4B19 + AC4B20 + AC4B21 + AC4B22+ AC4B23 + AC4B24 + AC4B25 +
AC4B26 + AC4B27 + AC4B28 + AC4B29 + AC4B30 + AC4B31 + AC4B32+ AC4B33 + AC4B34
+ AC4B35 + AC4B36 + AC4B37 + AC4B38 + AC4B39 + AC4B40 + AC4B41 + AC4B42+
AC4B43 + AC4B44 + AC4B45 + AC4B46 + AC4B47 + AC4B48 + AC4B49 + AC4B50 +
AC4B51 + AC4B52+ AC4B53 + AC4B54 + AC4B55 + AC4B56 + AC4B57 + AC4B58 + AC4B59
+ AC4B60 + AC4B61 + AC4B62 + AC4B63 + AC4B64)/64;

```

```

figure(1)
plot(time,AC1_avg,time,AC2_avg,time,AC3_avg,time,AC4_avg);
title('Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC1', 'AC2', 'AC3', 'AC4'}, 'Location', 'northwest');

```

```

figure(2)
plot(time,AC1_avg,time,AC2_avg);
title('Governor Side Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC1', 'AC2'}, 'Location', 'northwest');

```

```

figure(3)
plot(time,AC3_avg,time,AC4_avg);
title('Motor Side Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC3', 'AC4'}, 'Location', 'northwest');

```

```

figure(4)
plot(time,AC3_avg,time,AC1_avg);

```

```
title('Vertical Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC3', 'AC1'}, 'Location', 'northwest');

figure(5)
plot(time, AC2_avg, time, AC4_avg);
title('Horizontal Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC2', 'AC4'}, 'Location', 'northwest');
```

## D.15. Unheated Start-Stop Test Accelerometer Fast Fourier Analysis

```
clear;
close all;
clc;
%accelerometer script
%71-AC1 force
%72-AC1 std
%73-136 AC1 bins
%137 AC2 force
%138 AC2 std
%139-202 AC2 Bins
%203-AC3 force
%204-AC3 std
%205-268 AC3 Bins
%269- AC4 Force
%270-AC4 std
%271-334 AC4 bins
A = importdata('2020_04_13_start_stop_no_heat.dat');
time = [0:1:44499]/10;

B(1,1) = sum(transpose(A(:,73)))/44500;
B(2,1) = sum(transpose(A(:,74)))/44500;
B(3,1) = sum(transpose(A(:,75)))/44500;
B(4,1) = sum(transpose(A(:,76)))/44500;
B(5,1) = sum(transpose(A(:,77)))/44500;
B(6,1) = sum(transpose(A(:,78)))/44500;
B(7,1) = sum(transpose(A(:,79)))/44500;
B(8,1) = sum(transpose(A(:,80)))/44500;
B(9,1) = sum(transpose(A(:,81)))/44500;
B(10,1) = sum(transpose(A(:,82)))/44500;
B(11,1) = sum(transpose(A(:,83)))/44500;
B(12,1) = sum(transpose(A(:,84)))/44500;
B(13,1) = sum(transpose(A(:,85)))/44500;
B(14,1) = sum(transpose(A(:,86)))/44500;
B(15,1) = sum(transpose(A(:,87)))/44500;
B(16,1) = sum(transpose(A(:,88)))/44500;
B(17,1) = sum(transpose(A(:,89)))/44500;
B(18,1) = sum(transpose(A(:,90)))/44500;
B(19,1) = sum(transpose(A(:,91)))/44500;
B(20,1) = sum(transpose(A(:,92)))/44500;
B(21,1) = sum(transpose(A(:,93)))/44500;
B(22,1) = sum(transpose(A(:,94)))/44500;
B(23,1) = sum(transpose(A(:,95)))/44500;
B(24,1) = sum(transpose(A(:,96)))/44500;
B(25,1) = sum(transpose(A(:,97)))/44500;
B(26,1) = sum(transpose(A(:,98)))/44500;
B(27,1) = sum(transpose(A(:,99)))/44500;
B(28,1) = sum(transpose(A(:,100)))/44500;
B(29,1) = sum(transpose(A(:,101)))/44500;
B(30,1) = sum(transpose(A(:,102)))/44500;
B(31,1) = sum(transpose(A(:,103)))/44500;
B(32,1) = sum(transpose(A(:,104)))/44500;
B(33,1) = sum(transpose(A(:,105)))/44500;
B(34,1) = sum(transpose(A(:,106)))/44500;
B(35,1) = sum(transpose(A(:,107)))/44500;
```

```

B(36,1) = sum(transpose(A(:,108)))/44500;
B(37,1) = sum(transpose(A(:,109)))/44500;
B(38,1) = sum(transpose(A(:,110)))/44500;
B(39,1) = sum(transpose(A(:,111)))/44500;
B(40,1) = sum(transpose(A(:,112)))/44500;
B(41,1) = sum(transpose(A(:,113)))/44500;
B(42,1) = sum(transpose(A(:,114)))/44500;
B(43,1) = sum(transpose(A(:,115)))/44500;
B(44,1) = sum(transpose(A(:,116)))/44500;
B(45,1) = sum(transpose(A(:,117)))/44500;
B(46,1) = sum(transpose(A(:,118)))/44500;
B(47,1) = sum(transpose(A(:,119)))/44500;
B(48,1) = sum(transpose(A(:,120)))/44500;
B(49,1) = sum(transpose(A(:,121)))/44500;
B(50,1) = sum(transpose(A(:,122)))/44500;
B(51,1) = sum(transpose(A(:,123)))/44500;
B(52,1) = sum(transpose(A(:,124)))/44500;
B(53,1) = sum(transpose(A(:,125)))/44500;
B(54,1) = sum(transpose(A(:,126)))/44500;
B(55,1) = sum(transpose(A(:,127)))/44500;
B(56,1) = sum(transpose(A(:,128)))/44500;
B(57,1) = sum(transpose(A(:,129)))/44500;
B(58,1) = sum(transpose(A(:,130)))/44500;
B(59,1) = sum(transpose(A(:,131)))/44500;
B(60,1) = sum(transpose(A(:,132)))/44500;
B(61,1) = sum(transpose(A(:,133)))/44500;
B(62,1) = sum(transpose(A(:,134)))/44500;
B(63,1) = sum(transpose(A(:,135)))/44500;
B(64,1) = sum(transpose(A(:,136)))/44500;

```

```

C(1,1) = sum(transpose(A(:,139)))/44500;
C(2,1) = sum(transpose(A(:,140)))/44500;
C(3,1) = sum(transpose(A(:,141)))/44500;
C(4,1) = sum(transpose(A(:,142)))/44500;
C(5,1) = sum(transpose(A(:,143)))/44500;
C(6,1) = sum(transpose(A(:,144)))/44500;
C(7,1) = sum(transpose(A(:,145)))/44500;
C(8,1) = sum(transpose(A(:,146)))/44500;
C(9,1) = sum(transpose(A(:,147)))/44500;
C(10,1) = sum(transpose(A(:,148)))/44500;
C(11,1) = sum(transpose(A(:,149)))/44500;
C(12,1) = sum(transpose(A(:,150)))/44500;
C(13,1) = sum(transpose(A(:,151)))/44500;
C(14,1) = sum(transpose(A(:,152)))/44500;
C(15,1) = sum(transpose(A(:,153)))/44500;
C(16,1) = sum(transpose(A(:,154)))/44500;
C(17,1) = sum(transpose(A(:,155)))/44500;
C(18,1) = sum(transpose(A(:,156)))/44500;
C(19,1) = sum(transpose(A(:,157)))/44500;
C(20,1) = sum(transpose(A(:,158)))/44500;
C(21,1) = sum(transpose(A(:,159)))/44500;
C(22,1) = sum(transpose(A(:,160)))/44500;
C(23,1) = sum(transpose(A(:,161)))/44500;
C(24,1) = sum(transpose(A(:,162)))/44500;
C(25,1) = sum(transpose(A(:,163)))/44500;
C(26,1) = sum(transpose(A(:,164)))/44500;
C(27,1) = sum(transpose(A(:,165)))/44500;

```



```

C(28,1) = sum(transpose(A(:,166)))/44500;
C(29,1) = sum(transpose(A(:,167)))/44500;
C(30,1) = sum(transpose(A(:,168)))/44500;
C(31,1) = sum(transpose(A(:,169)))/44500;
C(32,1) = sum(transpose(A(:,170)))/44500;
C(33,1) = sum(transpose(A(:,171)))/44500;
C(34,1) = sum(transpose(A(:,172)))/44500;
C(35,1) = sum(transpose(A(:,173)))/44500;
C(36,1) = sum(transpose(A(:,174)))/44500;
C(37,1) = sum(transpose(A(:,175)))/44500;
C(38,1) = sum(transpose(A(:,176)))/44500;
C(39,1) = sum(transpose(A(:,177)))/44500;
C(40,1) = sum(transpose(A(:,178)))/44500;
C(41,1) = sum(transpose(A(:,179)))/44500;
C(42,1) = sum(transpose(A(:,180)))/44500;
C(43,1) = sum(transpose(A(:,181)))/44500;
C(44,1) = sum(transpose(A(:,182)))/44500;
C(45,1) = sum(transpose(A(:,183)))/44500;
C(46,1) = sum(transpose(A(:,184)))/44500;
C(47,1) = sum(transpose(A(:,185)))/44500;
C(48,1) = sum(transpose(A(:,186)))/44500;
C(49,1) = sum(transpose(A(:,187)))/44500;
C(50,1) = sum(transpose(A(:,188)))/44500;
C(51,1) = sum(transpose(A(:,189)))/44500;
C(52,1) = sum(transpose(A(:,190)))/44500;
C(53,1) = sum(transpose(A(:,191)))/44500;
C(54,1) = sum(transpose(A(:,192)))/44500;
C(55,1) = sum(transpose(A(:,193)))/44500;
C(56,1) = sum(transpose(A(:,194)))/44500;
C(57,1) = sum(transpose(A(:,195)))/44500;
C(58,1) = sum(transpose(A(:,196)))/44500;
C(59,1) = sum(transpose(A(:,197)))/44500;
C(60,1) = sum(transpose(A(:,198)))/44500;
C(61,1) = sum(transpose(A(:,199)))/44500;
C(62,1) = sum(transpose(A(:,200)))/44500;
C(63,1) = sum(transpose(A(:,201)))/44500;
C(64,1) = sum(transpose(A(:,202)))/44500;

```

```

D(1,1) = sum(transpose(A(:,205)))/44500;
D(2,1) = sum(transpose(A(:,206)))/44500;
D(3,1) = sum(transpose(A(:,207)))/44500;
D(4,1) = sum(transpose(A(:,208)))/44500;
D(5,1) = sum(transpose(A(:,209)))/44500;
D(6,1) = sum(transpose(A(:,210)))/44500;
D(7,1) = sum(transpose(A(:,211)))/44500;
D(8,1) = sum(transpose(A(:,212)))/44500;
D(9,1) = sum(transpose(A(:,213)))/44500;
D(10,1) = sum(transpose(A(:,214)))/44500;
D(11,1) = sum(transpose(A(:,215)))/44500;
D(12,1) = sum(transpose(A(:,216)))/44500;
D(13,1) = sum(transpose(A(:,217)))/44500;
D(14,1) = sum(transpose(A(:,218)))/44500;
D(15,1) = sum(transpose(A(:,219)))/44500;
D(16,1) = sum(transpose(A(:,220)))/44500;
D(17,1) = sum(transpose(A(:,221)))/44500;
D(18,1) = sum(transpose(A(:,222)))/44500;
D(19,1) = sum(transpose(A(:,223)))/44500;

```

```

D(20,1) = sum(transpose(A(:,224)))/44500;
D(21,1) = sum(transpose(A(:,225)))/44500;
D(22,1) = sum(transpose(A(:,226)))/44500;
D(23,1) = sum(transpose(A(:,227)))/44500;
D(24,1) = sum(transpose(A(:,228)))/44500;
D(25,1) = sum(transpose(A(:,229)))/44500;
D(26,1) = sum(transpose(A(:,230)))/44500;
D(27,1) = sum(transpose(A(:,231)))/44500;
D(28,1) = sum(transpose(A(:,232)))/44500;
D(29,1) = sum(transpose(A(:,233)))/44500;
D(30,1) = sum(transpose(A(:,234)))/44500;
D(31,1) = sum(transpose(A(:,235)))/44500;
D(32,1) = sum(transpose(A(:,236)))/44500;
D(33,1) = sum(transpose(A(:,237)))/44500;
D(34,1) = sum(transpose(A(:,238)))/44500;
D(35,1) = sum(transpose(A(:,239)))/44500;
D(36,1) = sum(transpose(A(:,240)))/44500;
D(37,1) = sum(transpose(A(:,241)))/44500;
D(38,1) = sum(transpose(A(:,242)))/44500;
D(39,1) = sum(transpose(A(:,243)))/44500;
D(40,1) = sum(transpose(A(:,244)))/44500;
D(41,1) = sum(transpose(A(:,245)))/44500;
D(42,1) = sum(transpose(A(:,246)))/44500;
D(43,1) = sum(transpose(A(:,247)))/44500;
D(44,1) = sum(transpose(A(:,248)))/44500;
D(45,1) = sum(transpose(A(:,249)))/44500;
D(46,1) = sum(transpose(A(:,250)))/44500;
D(47,1) = sum(transpose(A(:,251)))/44500;
D(48,1) = sum(transpose(A(:,252)))/44500;
D(49,1) = sum(transpose(A(:,253)))/44500;
D(50,1) = sum(transpose(A(:,254)))/44500;
D(51,1) = sum(transpose(A(:,255)))/44500;
D(52,1) = sum(transpose(A(:,256)))/44500;
D(53,1) = sum(transpose(A(:,257)))/44500;
D(54,1) = sum(transpose(A(:,258)))/44500;
D(55,1) = sum(transpose(A(:,259)))/44500;
D(56,1) = sum(transpose(A(:,260)))/44500;
D(57,1) = sum(transpose(A(:,261)))/44500;
D(58,1) = sum(transpose(A(:,262)))/44500;
D(59,1) = sum(transpose(A(:,263)))/44500;
D(60,1) = sum(transpose(A(:,264)))/44500;
D(61,1) = sum(transpose(A(:,265)))/44500;
D(62,1) = sum(transpose(A(:,266)))/44500;
D(63,1) = sum(transpose(A(:,267)))/44500;
D(64,1) = sum(transpose(A(:,268)))/44500;

```

```

E(1,1) = sum(transpose(A(:,271)))/44500;
E(2,1) = sum(transpose(A(:,272)))/44500;
E(3,1) = sum(transpose(A(:,273)))/44500;
E(4,1) = sum(transpose(A(:,274)))/44500;
E(5,1) = sum(transpose(A(:,275)))/44500;
E(6,1) = sum(transpose(A(:,276)))/44500;
E(7,1) = sum(transpose(A(:,277)))/44500;
E(8,1) = sum(transpose(A(:,278)))/44500;
E(9,1) = sum(transpose(A(:,279)))/44500;
E(10,1) = sum(transpose(A(:,280)))/44500;
E(11,1) = sum(transpose(A(:,281)))/44500;

```

```
E(12,1) = sum(transpose(A(:,282)))/44500;
E(13,1) = sum(transpose(A(:,283)))/44500;
E(14,1) = sum(transpose(A(:,284)))/44500;
E(15,1) = sum(transpose(A(:,285)))/44500;
E(16,1) = sum(transpose(A(:,286)))/44500;
E(17,1) = sum(transpose(A(:,287)))/44500;
E(18,1) = sum(transpose(A(:,288)))/44500;
E(19,1) = sum(transpose(A(:,289)))/44500;
E(20,1) = sum(transpose(A(:,290)))/44500;
E(21,1) = sum(transpose(A(:,291)))/44500;
E(22,1) = sum(transpose(A(:,292)))/44500;
E(23,1) = sum(transpose(A(:,293)))/44500;
E(24,1) = sum(transpose(A(:,294)))/44500;
E(25,1) = sum(transpose(A(:,295)))/44500;
E(26,1) = sum(transpose(A(:,296)))/44500;
E(27,1) = sum(transpose(A(:,297)))/44500;
E(28,1) = sum(transpose(A(:,298)))/44500;
E(29,1) = sum(transpose(A(:,299)))/44500;
E(30,1) = sum(transpose(A(:,300)))/44500;
E(31,1) = sum(transpose(A(:,301)))/44500;
E(32,1) = sum(transpose(A(:,302)))/44500;
E(33,1) = sum(transpose(A(:,303)))/44500;
E(34,1) = sum(transpose(A(:,304)))/44500;
E(35,1) = sum(transpose(A(:,305)))/44500;
E(36,1) = sum(transpose(A(:,306)))/44500;
E(37,1) = sum(transpose(A(:,307)))/44500;
E(38,1) = sum(transpose(A(:,308)))/44500;
E(39,1) = sum(transpose(A(:,309)))/44500;
E(40,1) = sum(transpose(A(:,310)))/44500;
E(41,1) = sum(transpose(A(:,311)))/44500;
E(42,1) = sum(transpose(A(:,312)))/44500;
E(43,1) = sum(transpose(A(:,313)))/44500;
E(44,1) = sum(transpose(A(:,314)))/44500;
E(45,1) = sum(transpose(A(:,315)))/44500;
E(46,1) = sum(transpose(A(:,316)))/44500;
E(47,1) = sum(transpose(A(:,317)))/44500;
E(48,1) = sum(transpose(A(:,318)))/44500;
E(49,1) = sum(transpose(A(:,319)))/44500;
E(50,1) = sum(transpose(A(:,320)))/44500;
E(51,1) = sum(transpose(A(:,321)))/44500;
E(52,1) = sum(transpose(A(:,322)))/44500;
E(53,1) = sum(transpose(A(:,323)))/44500;
E(54,1) = sum(transpose(A(:,324)))/44500;
E(55,1) = sum(transpose(A(:,325)))/44500;
E(56,1) = sum(transpose(A(:,326)))/44500;
E(57,1) = sum(transpose(A(:,327)))/44500;
E(58,1) = sum(transpose(A(:,328)))/44500;
E(59,1) = sum(transpose(A(:,329)))/44500;
E(60,1) = sum(transpose(A(:,330)))/44500;
E(61,1) = sum(transpose(A(:,331)))/44500;
E(62,1) = sum(transpose(A(:,332)))/44500;
E(63,1) = sum(transpose(A(:,333)))/44500;
E(64,1) = sum(transpose(A(:,334)))/44500;
```

```
fax_bins = [0:31.25:1999];
```

```
figure(1)
plot(fax_bins, abs(fft(B)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC1 Acceleration Profile');
```

```
figure(2)
plot(fax_bins, abs(fft(C)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC2 Acceleration Profile');
```

```
figure(3)
plot(fax_bins, abs(fft(D)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC3 Acceleration Profile');
```

```
figure(4)
plot(fax_bins, abs(fft(E)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC4 Acceleration Profile');
```

## D.16. 71.1 °C Start-Stop Test Data Analysis

```
clear;
close all;
clc;

A = importdata('2020_04_14_160F_start_stop.dat');

TCM1 = transpose(A(:,3));
TCM1_F = (TCM1 * (9/5)) + 32;
TCM2 = transpose(A(:,6));
TCM2_F = (TCM2 * (9/5)) + 32;
TCM3 = transpose(A(:,9));
TCM3_F = (TCM3 * (9/5)) + 32;
TCM4 = transpose(A(:,12));
TCM4_F = (TCM4 * (9/5)) + 32;
TCMT = transpose(A(:,15));
TCMT_F = (TCMT * (9/5)) + 32;
TCMMT = transpose(A(:,18));
TCMMT_F = (TCMMT * (9/5)) + 32;
TCMMB = transpose(A(:,21));
TCMMB_F = (TCMMB * (9/5)) + 32;
TCMB = transpose(A(:,24));
TCMB_F = (TCMB * (9/5)) + 32;
TCG1 = transpose(A(:,27));
TCG1_F = (TCG1 * (9/5)) + 32;
TCG2 = transpose(A(:,30));
TCG2_F = (TCG2 * (9/5)) + 32;
TCG3 = transpose(A(:,33));
TCG3_F = (TCG3 * (9/5)) + 32;
TCG4 = transpose(A(:,36));
TCG4_F = (TCG4 * (9/5)) + 32;
TCGB = transpose(A(:,39));
TCGB_F = (TCGB * (9/5)) + 32;
TCGMB = transpose(A(:,42));
TCGMB_F = (TCGMB * (9/5)) + 32;
TCGMT = transpose(A(:,45));
TCGMT_F = (TCGMT * (9/5)) + 32;
TCGT = transpose(A(:,48));
TCGT_F = (TCGT * (9/5)) + 32;
Speed = transpose(A(:,66));
Torque = transpose(A(:,70));
motor_bearing_average = (TCM1 + TCM3 + TCM4)/3;
motor_bearing_average_F = (motor_bearing_average * (9/5)) + 32;
governor_bearing_average = (TCG1 + TCG2 + TCG3 + TCG4)/4;
governor_bearing_average_F = (governor_bearing_average * (9/5)) + 32;
time = [0:1:67139];
real_time = time/10;

figure(1);
plot(real_time,TCM1,real_time,TCM2,real_time,TCM3,real_time,TCM4)
title('Motor Side Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'M1', 'M2', 'M3', 'M4', }, 'Location', 'southeast');
```

```

figure(2);
plot(real_time,TCG1,real_time,TCG2,real_time,TCG3,real_time,TCG4)
title('Governor Side Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'G1','G2','G3','G4'},'Location','southeast');

figure(3);
plot(real_time,TCMT,real_time,TCMMT,real_time,TCMMB,real_time,TCMB)
title('Motor Side Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperatre (°C)');
legend({'Top','Middle-Top','Middle-
Bottom','Bottom'},'Location','eastoutside');

figure(4);
plot(real_time,TCGT,real_time,TCGMT,real_time,TCGMB,real_time,TCGB)
title('Governor Side Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperatre (°C)');
legend({'Top','Middle-Top','Middle-
Bottom','Bottom'},'Location','eastoutside');

figure(5);
plot(real_time,Speed)
title('Turbine Speed');
xlabel('Time (s)');
ylabel('Shaft Speed (RPM)');

figure(6);
plot(real_time,Torque)
title('Torque vs. Time');
xlabel('Time (s)');
ylabel('Torque (Nm)');

figure(7);
plot(real_time,motor_bearing_average)
title('Averaged Motor Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(8);
plot(real_time,governor_bearing_average)
title('Averaged Governor Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(9);
plot(real_time,governor_bearing_average,real_time,motor_bearing_average)
title('Bearing Averaged Temperature Comparison')
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'Averaged Governor Bearing Temperature','Averaged Motor Bearing
Temperature'},'Location','southeast');

```

```

figure(10);
plot(real_time,TCMT)
title('Top Motor Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(11);
plot(real_time,TCGT)
title('Top Governor Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(12);
plot(real_time,TCMT,real_time,TCGT)
title('Top Oil Level Temperature Comparison')
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'TCMT','TCGT'},'Location','southeast');

figure(13);
plot(real_time,TCMT,real_time,motor_bearing_average)
title('Motor Side Oil and Bearing Comparison');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'TCMT','Bearing Average'},'Location','southeast');

figure(14);
plot(real_time,TCGT,real_time,governor_bearing_average)
title('Governor Side Oil and Bearing Comparison');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'TCGT','Bearing Average'},'Location','southeast');

figure(15);
plot(real_time,TCGT_F,real_time,governor_bearing_average_F)
title('Governor Side Oil and Bearing Temperature Comparison');
xlabel('Time (s)');
ylabel('Temperature (°F)');
legend({'Top Governor Side Oil Well TC','Governor Side Bearing
Average'},'Location','southeast');

figure(16);
plot(real_time,TCMT_F,real_time,motor_bearing_average_F)
title('Motor Side Oil and Bearing Temperature Comparison');
xlabel('Time (s)');
ylabel('Temperature (°F)');
legend({'Top Motor Side Oil Well TC','Motor Side Bearing
Average'},'Location','southeast');

figure(17);
plot(real_time,motor_bearing_average_F,real_time,governor_bearing_average_F)
title('Bearing Averaged Temperature Comparison');
xlabel('Time (s)');
ylabel('Temperature (°F)');

```

```
legend({'Motor Side Bearing Average', 'Governor Side Bearing  
Average'}, 'Location', 'southeast');
```



## D.17. 71.1 °C Start-Stop Test Accelerometer Analysis

```
clear;
close all;
clc;
%accelerometer script
%71-AC1 force
%72-AC1 std
%73-136 AC1 bins
%137 AC2 force
%138 AC2 std
%139-202 AC2 Bins
%203-AC3 force
%204-AC3 std
%205-268 AC3 Bins
%269- AC4 Force
%270-AC4 std
%271-334 AC4 bins
A = importdata('2020_04_14_160F_start_stop.dat');
time = [0:1:67139]/10;
```

```
AC1B1 = transpose(A(:,73));
AC1B2 = transpose(A(:,74));
AC1B3 = transpose(A(:,75));
AC1B4 = transpose(A(:,76));
AC1B5 = transpose(A(:,77));
AC1B6 = transpose(A(:,78));
AC1B7 = transpose(A(:,79));
AC1B8 = transpose(A(:,80));
AC1B9 = transpose(A(:,81));
AC1B10 = transpose(A(:,82));
AC1B11 = transpose(A(:,83));
AC1B12 = transpose(A(:,84));
AC1B13 = transpose(A(:,85));
AC1B14 = transpose(A(:,86));
AC1B15 = transpose(A(:,87));
AC1B16 = transpose(A(:,88));
AC1B17 = transpose(A(:,89));
AC1B18 = transpose(A(:,90));
AC1B19 = transpose(A(:,91));
AC1B20 = transpose(A(:,92));
AC1B21 = transpose(A(:,93));
AC1B22 = transpose(A(:,94));
AC1B23 = transpose(A(:,95));
AC1B24 = transpose(A(:,96));
AC1B25 = transpose(A(:,97));
AC1B26 = transpose(A(:,98));
AC1B27 = transpose(A(:,99));
AC1B28 = transpose(A(:,100));
AC1B29 = transpose(A(:,101));
AC1B30 = transpose(A(:,102));
AC1B31 = transpose(A(:,103));
AC1B32 = transpose(A(:,104));
AC1B33 = transpose(A(:,105));
AC1B34 = transpose(A(:,106));
AC1B35 = transpose(A(:,107));
```

```
AC1B36 = transpose(A(:,108));
AC1B37 = transpose(A(:,109));
AC1B38 = transpose(A(:,110));
AC1B39 = transpose(A(:,111));
AC1B40 = transpose(A(:,112));
AC1B41 = transpose(A(:,113));
AC1B42 = transpose(A(:,114));
AC1B43 = transpose(A(:,115));
AC1B44 = transpose(A(:,116));
AC1B45 = transpose(A(:,117));
AC1B46 = transpose(A(:,118));
AC1B47 = transpose(A(:,119));
AC1B48 = transpose(A(:,120));
AC1B49 = transpose(A(:,121));
AC1B50 = transpose(A(:,122));
AC1B51 = transpose(A(:,123));
AC1B52 = transpose(A(:,124));
AC1B53 = transpose(A(:,125));
AC1B54 = transpose(A(:,126));
AC1B55 = transpose(A(:,127));
AC1B56 = transpose(A(:,128));
AC1B57 = transpose(A(:,129));
AC1B58 = transpose(A(:,130));
AC1B59 = transpose(A(:,131));
AC1B60 = transpose(A(:,132));
AC1B61 = transpose(A(:,133));
AC1B62 = transpose(A(:,134));
AC1B63 = transpose(A(:,135));
AC1B64 = transpose(A(:,136));
```

```
AC2B1 = transpose(A(:,139));
AC2B2 = transpose(A(:,140));
AC2B3 = transpose(A(:,141));
AC2B4 = transpose(A(:,142));
AC2B5 = transpose(A(:,143));
AC2B6 = transpose(A(:,144));
AC2B7 = transpose(A(:,145));
AC2B8 = transpose(A(:,146));
AC2B9 = transpose(A(:,147));
AC2B10 = transpose(A(:,148));
AC2B11 = transpose(A(:,149));
AC2B12 = transpose(A(:,150));
AC2B13 = transpose(A(:,151));
AC2B14 = transpose(A(:,152));
AC2B15 = transpose(A(:,153));
AC2B16 = transpose(A(:,154));
AC2B17 = transpose(A(:,155));
AC2B18 = transpose(A(:,156));
AC2B19 = transpose(A(:,157));
AC2B20 = transpose(A(:,158));
AC2B21 = transpose(A(:,159));
AC2B22 = transpose(A(:,160));
AC2B23 = transpose(A(:,161));
AC2B24 = transpose(A(:,162));
AC2B25 = transpose(A(:,163));
AC2B26 = transpose(A(:,164));
AC2B27 = transpose(A(:,165));
```

```
AC2B28 = transpose(A(:,166));
AC2B29 = transpose(A(:,167));
AC2B30 = transpose(A(:,168));
AC2B31 = transpose(A(:,169));
AC2B32 = transpose(A(:,170));
AC2B33 = transpose(A(:,171));
AC2B34 = transpose(A(:,172));
AC2B35 = transpose(A(:,173));
AC2B36 = transpose(A(:,174));
AC2B37 = transpose(A(:,175));
AC2B38 = transpose(A(:,176));
AC2B39 = transpose(A(:,177));
AC2B40 = transpose(A(:,178));
AC2B41 = transpose(A(:,179));
AC2B42 = transpose(A(:,180));
AC2B43 = transpose(A(:,181));
AC2B44 = transpose(A(:,182));
AC2B45 = transpose(A(:,183));
AC2B46 = transpose(A(:,184));
AC2B47 = transpose(A(:,185));
AC2B48 = transpose(A(:,186));
AC2B49 = transpose(A(:,187));
AC2B50 = transpose(A(:,188));
AC2B51 = transpose(A(:,189));
AC2B52 = transpose(A(:,190));
AC2B53 = transpose(A(:,191));
AC2B54 = transpose(A(:,192));
AC2B55 = transpose(A(:,193));
AC2B56 = transpose(A(:,194));
AC2B57 = transpose(A(:,195));
AC2B58 = transpose(A(:,196));
AC2B59 = transpose(A(:,197));
AC2B60 = transpose(A(:,198));
AC2B61 = transpose(A(:,199));
AC2B62 = transpose(A(:,200));
AC2B63 = transpose(A(:,201));
AC2B64 = transpose(A(:,202));
```

```
AC3B1 = transpose(A(:,205));
AC3B2 = transpose(A(:,206));
AC3B3 = transpose(A(:,207));
AC3B4 = transpose(A(:,208));
AC3B5 = transpose(A(:,209));
AC3B6 = transpose(A(:,210));
AC3B7 = transpose(A(:,211));
AC3B8 = transpose(A(:,212));
AC3B9 = transpose(A(:,213));
AC3B10 = transpose(A(:,214));
AC3B11 = transpose(A(:,215));
AC3B12 = transpose(A(:,216));
AC3B13 = transpose(A(:,217));
AC3B14 = transpose(A(:,218));
AC3B15 = transpose(A(:,219));
AC3B16 = transpose(A(:,220));
AC3B17 = transpose(A(:,221));
AC3B18 = transpose(A(:,222));
AC3B19 = transpose(A(:,223));
```

```
AC3B20 = transpose(A(:,224));
AC3B21 = transpose(A(:,225));
AC3B22 = transpose(A(:,226));
AC3B23 = transpose(A(:,227));
AC3B24 = transpose(A(:,228));
AC3B25 = transpose(A(:,229));
AC3B26 = transpose(A(:,230));
AC3B27 = transpose(A(:,231));
AC3B28 = transpose(A(:,232));
AC3B29 = transpose(A(:,233));
AC3B30 = transpose(A(:,234));
AC3B31 = transpose(A(:,235));
AC3B32 = transpose(A(:,236));
AC3B33 = transpose(A(:,237));
AC3B34 = transpose(A(:,238));
AC3B35 = transpose(A(:,239));
AC3B36 = transpose(A(:,240));
AC3B37 = transpose(A(:,241));
AC3B38 = transpose(A(:,242));
AC3B39 = transpose(A(:,243));
AC3B40 = transpose(A(:,244));
AC3B41 = transpose(A(:,245));
AC3B42 = transpose(A(:,246));
AC3B43 = transpose(A(:,247));
AC3B44 = transpose(A(:,248));
AC3B45 = transpose(A(:,249));
AC3B46 = transpose(A(:,250));
AC3B47 = transpose(A(:,251));
AC3B48 = transpose(A(:,252));
AC3B49 = transpose(A(:,253));
AC3B50 = transpose(A(:,254));
AC3B51 = transpose(A(:,255));
AC3B52 = transpose(A(:,256));
AC3B53 = transpose(A(:,257));
AC3B54 = transpose(A(:,258));
AC3B55 = transpose(A(:,259));
AC3B56 = transpose(A(:,260));
AC3B57 = transpose(A(:,261));
AC3B58 = transpose(A(:,262));
AC3B59 = transpose(A(:,263));
AC3B60 = transpose(A(:,264));
AC3B61 = transpose(A(:,265));
AC3B62 = transpose(A(:,266));
AC3B63 = transpose(A(:,267));
AC3B64 = transpose(A(:,268));
```

```
AC4B1 = transpose(A(:,271));
AC4B2 = transpose(A(:,272));
AC4B3 = transpose(A(:,273));
AC4B4 = transpose(A(:,274));
AC4B5 = transpose(A(:,275));
AC4B6 = transpose(A(:,276));
AC4B7 = transpose(A(:,277));
AC4B8 = transpose(A(:,278));
AC4B9 = transpose(A(:,279));
AC4B10 = transpose(A(:,280));
AC4B11 = transpose(A(:,281));
```

```
AC4B12 = transpose(A(:,282));
AC4B13 = transpose(A(:,283));
AC4B14 = transpose(A(:,284));
AC4B15 = transpose(A(:,285));
AC4B16 = transpose(A(:,286));
AC4B17 = transpose(A(:,287));
AC4B18 = transpose(A(:,288));
AC4B19 = transpose(A(:,289));
AC4B20 = transpose(A(:,290));
AC4B21 = transpose(A(:,291));
AC4B22 = transpose(A(:,292));
AC4B23 = transpose(A(:,293));
AC4B24 = transpose(A(:,294));
AC4B25 = transpose(A(:,295));
AC4B26 = transpose(A(:,296));
AC4B27 = transpose(A(:,297));
AC4B28 = transpose(A(:,298));
AC4B29 = transpose(A(:,299));
AC4B30 = transpose(A(:,300));
AC4B31 = transpose(A(:,301));
AC4B32 = transpose(A(:,302));
AC4B33 = transpose(A(:,303));
AC4B34 = transpose(A(:,304));
AC4B35 = transpose(A(:,305));
AC4B36 = transpose(A(:,306));
AC4B37 = transpose(A(:,307));
AC4B38 = transpose(A(:,308));
AC4B39 = transpose(A(:,309));
AC4B40 = transpose(A(:,310));
AC4B41 = transpose(A(:,311));
AC4B42 = transpose(A(:,312));
AC4B43 = transpose(A(:,313));
AC4B44 = transpose(A(:,314));
AC4B45 = transpose(A(:,315));
AC4B46 = transpose(A(:,316));
AC4B47 = transpose(A(:,317));
AC4B48 = transpose(A(:,318));
AC4B49 = transpose(A(:,319));
AC4B50 = transpose(A(:,320));
AC4B51 = transpose(A(:,321));
AC4B52 = transpose(A(:,322));
AC4B53 = transpose(A(:,323));
AC4B54 = transpose(A(:,324));
AC4B55 = transpose(A(:,325));
AC4B56 = transpose(A(:,326));
AC4B57 = transpose(A(:,327));
AC4B58 = transpose(A(:,328));
AC4B59 = transpose(A(:,329));
AC4B60 = transpose(A(:,330));
AC4B61 = transpose(A(:,331));
AC4B62 = transpose(A(:,332));
AC4B63 = transpose(A(:,333));
AC4B64 = transpose(A(:,334));
```

```

AC1_avg = (AC1B1 + AC1B2+ AC1B3 + AC1B4 + AC1B5 + AC1B6 + AC1B7 + AC1B8 +
AC1B9 + AC1B10 + AC1B11 + AC1B12+ AC1B13 + AC1B14 + AC1B15 + AC1B16 + AC1B17
+ AC1B18 + AC1B19 + AC1B20 + AC1B21 + AC1B22+ AC1B23 + AC1B24 + AC1B25 +
AC1B26 + AC1B27 + AC1B28 + AC1B29 + AC1B30 + AC1B31 + AC1B32+ AC1B33 + AC1B34
+ AC1B35 + AC1B36 + AC1B37 + AC1B38 + AC1B39 + AC1B40 + AC1B41 + AC1B42+
AC1B43 + AC1B44 + AC1B45 + AC1B46 + AC1B47 + AC1B48 + AC1B49 + AC1B50 +
AC1B51 + AC1B52+ AC1B53 + AC1B54 + AC1B55 + AC1B56 + AC1B57 + AC1B58 + AC1B59
+ AC1B60 + AC1B61 + AC1B62 + AC1B63 + AC1B64)/64;
AC2_avg = (AC2B1 + AC2B2+ AC2B3 + AC2B4 + AC2B5 + AC2B6 + AC2B7 + AC2B8 +
AC2B9 + AC2B10 + AC2B11 + AC2B12+ AC2B13 + AC2B14 + AC2B15 + AC2B16 + AC2B17
+ AC2B18 + AC2B19 + AC2B20 + AC2B21 + AC2B22+ AC2B23 + AC2B24 + AC2B25 +
AC2B26 + AC2B27 + AC2B28 + AC2B29 + AC2B30 + AC2B31 + AC2B32+ AC2B33 + AC2B34
+ AC2B35 + AC2B36 + AC2B37 + AC2B38 + AC2B39 + AC2B40 + AC2B41 + AC2B42+
AC2B43 + AC2B44 + AC2B45 + AC2B46 + AC2B47 + AC2B48 + AC2B49 + AC2B50 +
AC2B51 + AC2B52+ AC2B53 + AC2B54 + AC2B55 + AC2B56 + AC2B57 + AC2B58 + AC2B59
+ AC2B60 + AC2B61 + AC2B62 + AC2B63 + AC2B64)/64;
AC3_avg = (AC3B1 + AC3B2+ AC3B3 + AC3B4 + AC3B5 + AC3B6 + AC3B7 + AC3B8 +
AC3B9 + AC3B10 + AC3B11 + AC3B12+ AC3B13 + AC3B14 + AC3B15 + AC3B16 + AC3B17
+ AC3B18 + AC3B19 + AC3B20 + AC3B21 + AC3B22+ AC3B23 + AC3B24 + AC3B25 +
AC3B26 + AC3B27 + AC3B28 + AC3B29 + AC3B30 + AC3B31 + AC3B32+ AC3B33 + AC3B34
+ AC3B35 + AC3B36 + AC3B37 + AC3B38 + AC3B39 + AC3B40 + AC3B41 + AC3B42+
AC3B43 + AC3B44 + AC3B45 + AC3B46 + AC3B47 + AC3B48 + AC3B49 + AC3B50 +
AC3B51 + AC3B52+ AC3B53 + AC3B54 + AC3B55 + AC3B56+ AC3B57 + AC3B58 + AC3B59
+ AC3B60 + AC3B61 + AC3B62 + AC3B63 + AC3B64)/64;
AC4_avg = (AC4B1 + AC4B2+ AC4B3 + AC4B4 + AC4B5 + AC4B6 + AC4B7 + AC4B8 +
AC4B9 + AC4B10 + AC4B11 + AC4B12+ AC4B13 + AC4B14 + AC4B15 + AC4B16 + AC4B17
+ AC4B18 + AC4B19 + AC4B20 + AC4B21 + AC4B22+ AC4B23 + AC4B24 + AC4B25 +
AC4B26 + AC4B27 + AC4B28 + AC4B29 + AC4B30 + AC4B31 + AC4B32+ AC4B33 + AC4B34
+ AC4B35 + AC4B36 + AC4B37 + AC4B38 + AC4B39 + AC4B40 + AC4B41 + AC4B42+
AC4B43 + AC4B44 + AC4B45 + AC4B46 + AC4B47 + AC4B48 + AC4B49 + AC4B50 +
AC4B51 + AC4B52+ AC4B53 + AC4B54 + AC4B55 + AC4B56 + AC4B57 + AC4B58 + AC4B59
+ AC4B60 + AC4B61 + AC4B62 + AC4B63 + AC4B64)/64;

```

```

figure(1)
plot(time,AC1_avg,time,AC2_avg,time,AC3_avg,time,AC4_avg);
title('Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC1', 'AC2', 'AC3', 'AC4'}, 'Location', 'northwest');

```

```

figure(2)
plot(time,AC1_avg,time,AC2_avg);
title('Governor Side Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC1', 'AC2'}, 'Location', 'northwest');

```

```

figure(3)
plot(time,AC3_avg,time,AC4_avg);
title('Motor Side Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC3', 'AC4'}, 'Location', 'northwest');

```

```

figure(4)
plot(time,AC3_avg,time,AC1_avg);

```

```
title('Vertical Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC3', 'AC1'}, 'Location', 'northwest');

figure(5)
plot(time, AC2_avg, time, AC4_avg);
title('Horizontal Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC2', 'AC4'}, 'Location', 'northwest');
```

## D.18. 71.1 °C Start-Stop Test Accelerometer Fast Fourier Transform

```
clear;
close all;
clc;
%accelerometer script
%71-AC1 force
%72-AC1 std
%73-136 AC1 bins
%137 AC2 force
%138 AC2 std
%139-202 AC2 Bins
%203-AC3 force
%204-AC3 std
%205-268 AC3 Bins
%269- AC4 Force
%270-AC4 std
%271-334 AC4 bins
A = importdata('2020_04_14_160F_start_stop.dat');
time = [0:1:67139]/10;
```

```
B(1,1) = sum(transpose(A(:,73)))/67140;
B(2,1) = sum(transpose(A(:,74)))/67140;
B(3,1) = sum(transpose(A(:,75)))/67140;
B(4,1) = sum(transpose(A(:,76)))/67140;
B(5,1) = sum(transpose(A(:,77)))/67140;
B(6,1) = sum(transpose(A(:,78)))/67140;
B(7,1) = sum(transpose(A(:,79)))/67140;
B(8,1) = sum(transpose(A(:,80)))/67140;
B(9,1) = sum(transpose(A(:,81)))/67140;
B(10,1) = sum(transpose(A(:,82)))/67140;
B(11,1) = sum(transpose(A(:,83)))/67140;
B(12,1) = sum(transpose(A(:,84)))/67140;
B(13,1) = sum(transpose(A(:,85)))/67140;
B(14,1) = sum(transpose(A(:,86)))/67140;
B(15,1) = sum(transpose(A(:,87)))/67140;
B(16,1) = sum(transpose(A(:,88)))/67140;
B(17,1) = sum(transpose(A(:,89)))/67140;
B(18,1) = sum(transpose(A(:,90)))/67140;
B(19,1) = sum(transpose(A(:,91)))/67140;
B(20,1) = sum(transpose(A(:,92)))/67140;
B(21,1) = sum(transpose(A(:,93)))/67140;
B(22,1) = sum(transpose(A(:,94)))/67140;
B(23,1) = sum(transpose(A(:,95)))/67140;
B(24,1) = sum(transpose(A(:,96)))/67140;
B(25,1) = sum(transpose(A(:,97)))/67140;
B(26,1) = sum(transpose(A(:,98)))/67140;
B(27,1) = sum(transpose(A(:,99)))/67140;
B(28,1) = sum(transpose(A(:,100)))/67140;
B(29,1) = sum(transpose(A(:,101)))/67140;
B(30,1) = sum(transpose(A(:,102)))/67140;
B(31,1) = sum(transpose(A(:,103)))/67140;
B(32,1) = sum(transpose(A(:,104)))/67140;
B(33,1) = sum(transpose(A(:,105)))/67140;
B(34,1) = sum(transpose(A(:,106)))/67140;
```



```
B(35,1) = sum(transpose(A(:,107)))/67140;
B(36,1) = sum(transpose(A(:,108)))/67140;
B(37,1) = sum(transpose(A(:,109)))/67140;
B(38,1) = sum(transpose(A(:,110)))/67140;
B(39,1) = sum(transpose(A(:,111)))/67140;
B(40,1) = sum(transpose(A(:,112)))/67140;
B(41,1) = sum(transpose(A(:,113)))/67140;
B(42,1) = sum(transpose(A(:,114)))/67140;
B(43,1) = sum(transpose(A(:,115)))/67140;
B(44,1) = sum(transpose(A(:,116)))/67140;
B(45,1) = sum(transpose(A(:,117)))/67140;
B(46,1) = sum(transpose(A(:,118)))/67140;
B(47,1) = sum(transpose(A(:,119)))/67140;
B(48,1) = sum(transpose(A(:,120)))/67140;
B(49,1) = sum(transpose(A(:,121)))/67140;
B(50,1) = sum(transpose(A(:,122)))/67140;
B(51,1) = sum(transpose(A(:,123)))/67140;
B(52,1) = sum(transpose(A(:,124)))/67140;
B(53,1) = sum(transpose(A(:,125)))/67140;
B(54,1) = sum(transpose(A(:,126)))/67140;
B(55,1) = sum(transpose(A(:,127)))/67140;
B(56,1) = sum(transpose(A(:,128)))/67140;
B(57,1) = sum(transpose(A(:,129)))/67140;
B(58,1) = sum(transpose(A(:,130)))/67140;
B(59,1) = sum(transpose(A(:,131)))/67140;
B(60,1) = sum(transpose(A(:,132)))/67140;
B(61,1) = sum(transpose(A(:,133)))/67140;
B(62,1) = sum(transpose(A(:,134)))/67140;
B(63,1) = sum(transpose(A(:,135)))/67140;
B(64,1) = sum(transpose(A(:,136)))/67140;
```

```
C(1,1) = sum(transpose(A(:,139)))/67140;
C(2,1) = sum(transpose(A(:,140)))/67140;
C(3,1) = sum(transpose(A(:,141)))/67140;
C(4,1) = sum(transpose(A(:,142)))/67140;
C(5,1) = sum(transpose(A(:,143)))/67140;
C(6,1) = sum(transpose(A(:,144)))/67140;
C(7,1) = sum(transpose(A(:,145)))/67140;
C(8,1) = sum(transpose(A(:,146)))/67140;
C(9,1) = sum(transpose(A(:,147)))/67140;
C(10,1) = sum(transpose(A(:,148)))/67140;
C(11,1) = sum(transpose(A(:,149)))/67140;
C(12,1) = sum(transpose(A(:,150)))/67140;
C(13,1) = sum(transpose(A(:,151)))/67140;
C(14,1) = sum(transpose(A(:,152)))/67140;
C(15,1) = sum(transpose(A(:,153)))/67140;
C(16,1) = sum(transpose(A(:,154)))/67140;
C(17,1) = sum(transpose(A(:,155)))/67140;
C(18,1) = sum(transpose(A(:,156)))/67140;
C(19,1) = sum(transpose(A(:,157)))/67140;
C(20,1) = sum(transpose(A(:,158)))/67140;
C(21,1) = sum(transpose(A(:,159)))/67140;
C(22,1) = sum(transpose(A(:,160)))/67140;
C(23,1) = sum(transpose(A(:,161)))/67140;
C(24,1) = sum(transpose(A(:,162)))/67140;
C(25,1) = sum(transpose(A(:,163)))/67140;
C(26,1) = sum(transpose(A(:,164)))/67140;
```

```

C(27,1) = sum(transpose(A(:,165)))/67140;
C(28,1) = sum(transpose(A(:,166)))/67140;
C(29,1) = sum(transpose(A(:,167)))/67140;
C(30,1) = sum(transpose(A(:,168)))/67140;
C(31,1) = sum(transpose(A(:,169)))/67140;
C(32,1) = sum(transpose(A(:,170)))/67140;
C(33,1) = sum(transpose(A(:,171)))/67140;
C(34,1) = sum(transpose(A(:,172)))/67140;
C(35,1) = sum(transpose(A(:,173)))/67140;
C(36,1) = sum(transpose(A(:,174)))/67140;
C(37,1) = sum(transpose(A(:,175)))/67140;
C(38,1) = sum(transpose(A(:,176)))/67140;
C(39,1) = sum(transpose(A(:,177)))/67140;
C(40,1) = sum(transpose(A(:,178)))/67140;
C(41,1) = sum(transpose(A(:,179)))/67140;
C(42,1) = sum(transpose(A(:,180)))/67140;
C(43,1) = sum(transpose(A(:,181)))/67140;
C(44,1) = sum(transpose(A(:,182)))/67140;
C(45,1) = sum(transpose(A(:,183)))/67140;
C(46,1) = sum(transpose(A(:,184)))/67140;
C(47,1) = sum(transpose(A(:,185)))/67140;
C(48,1) = sum(transpose(A(:,186)))/67140;
C(49,1) = sum(transpose(A(:,187)))/67140;
C(50,1) = sum(transpose(A(:,188)))/67140;
C(51,1) = sum(transpose(A(:,189)))/67140;
C(52,1) = sum(transpose(A(:,190)))/67140;
C(53,1) = sum(transpose(A(:,191)))/67140;
C(54,1) = sum(transpose(A(:,192)))/67140;
C(55,1) = sum(transpose(A(:,193)))/67140;
C(56,1) = sum(transpose(A(:,194)))/67140;
C(57,1) = sum(transpose(A(:,195)))/67140;
C(58,1) = sum(transpose(A(:,196)))/67140;
C(59,1) = sum(transpose(A(:,197)))/67140;
C(60,1) = sum(transpose(A(:,198)))/67140;
C(61,1) = sum(transpose(A(:,199)))/67140;
C(62,1) = sum(transpose(A(:,200)))/67140;
C(63,1) = sum(transpose(A(:,201)))/67140;
C(64,1) = sum(transpose(A(:,202)))/67140;

```

```

D(1,1) = sum(transpose(A(:,205)))/67140;
D(2,1) = sum(transpose(A(:,206)))/67140;
D(3,1) = sum(transpose(A(:,207)))/67140;
D(4,1) = sum(transpose(A(:,208)))/67140;
D(5,1) = sum(transpose(A(:,209)))/67140;
D(6,1) = sum(transpose(A(:,210)))/67140;
D(7,1) = sum(transpose(A(:,211)))/67140;
D(8,1) = sum(transpose(A(:,212)))/67140;
D(9,1) = sum(transpose(A(:,213)))/67140;
D(10,1) = sum(transpose(A(:,214)))/67140;
D(11,1) = sum(transpose(A(:,215)))/67140;
D(12,1) = sum(transpose(A(:,216)))/67140;
D(13,1) = sum(transpose(A(:,217)))/67140;
D(14,1) = sum(transpose(A(:,218)))/67140;
D(15,1) = sum(transpose(A(:,219)))/67140;
D(16,1) = sum(transpose(A(:,220)))/67140;
D(17,1) = sum(transpose(A(:,221)))/67140;
D(18,1) = sum(transpose(A(:,222)))/67140;

```

```

D(19,1) = sum(transpose(A(:,223)))/67140;
D(20,1) = sum(transpose(A(:,224)))/67140;
D(21,1) = sum(transpose(A(:,225)))/67140;
D(22,1) = sum(transpose(A(:,226)))/67140;
D(23,1) = sum(transpose(A(:,227)))/67140;
D(24,1) = sum(transpose(A(:,228)))/67140;
D(25,1) = sum(transpose(A(:,229)))/67140;
D(26,1) = sum(transpose(A(:,230)))/67140;
D(27,1) = sum(transpose(A(:,231)))/67140;
D(28,1) = sum(transpose(A(:,232)))/67140;
D(29,1) = sum(transpose(A(:,233)))/67140;
D(30,1) = sum(transpose(A(:,234)))/67140;
D(31,1) = sum(transpose(A(:,235)))/67140;
D(32,1) = sum(transpose(A(:,236)))/67140;
D(33,1) = sum(transpose(A(:,237)))/67140;
D(34,1) = sum(transpose(A(:,238)))/67140;
D(35,1) = sum(transpose(A(:,239)))/67140;
D(36,1) = sum(transpose(A(:,240)))/67140;
D(37,1) = sum(transpose(A(:,241)))/67140;
D(38,1) = sum(transpose(A(:,242)))/67140;
D(39,1) = sum(transpose(A(:,243)))/67140;
D(40,1) = sum(transpose(A(:,244)))/67140;
D(41,1) = sum(transpose(A(:,245)))/67140;
D(42,1) = sum(transpose(A(:,246)))/67140;
D(43,1) = sum(transpose(A(:,247)))/67140;
D(44,1) = sum(transpose(A(:,248)))/67140;
D(45,1) = sum(transpose(A(:,249)))/67140;
D(46,1) = sum(transpose(A(:,250)))/67140;
D(47,1) = sum(transpose(A(:,251)))/67140;
D(48,1) = sum(transpose(A(:,252)))/67140;
D(49,1) = sum(transpose(A(:,253)))/67140;
D(50,1) = sum(transpose(A(:,254)))/67140;
D(51,1) = sum(transpose(A(:,255)))/67140;
D(52,1) = sum(transpose(A(:,256)))/67140;
D(53,1) = sum(transpose(A(:,257)))/67140;
D(54,1) = sum(transpose(A(:,258)))/67140;
D(55,1) = sum(transpose(A(:,259)))/67140;
D(56,1) = sum(transpose(A(:,260)))/67140;
D(57,1) = sum(transpose(A(:,261)))/67140;
D(58,1) = sum(transpose(A(:,262)))/67140;
D(59,1) = sum(transpose(A(:,263)))/67140;
D(60,1) = sum(transpose(A(:,264)))/67140;
D(61,1) = sum(transpose(A(:,265)))/67140;
D(62,1) = sum(transpose(A(:,266)))/67140;
D(63,1) = sum(transpose(A(:,267)))/67140;
D(64,1) = sum(transpose(A(:,268)))/67140;

```

```

E(1,1) = sum(transpose(A(:,271)))/67140;
E(2,1) = sum(transpose(A(:,272)))/67140;
E(3,1) = sum(transpose(A(:,273)))/67140;
E(4,1) = sum(transpose(A(:,274)))/67140;
E(5,1) = sum(transpose(A(:,275)))/67140;
E(6,1) = sum(transpose(A(:,276)))/67140;
E(7,1) = sum(transpose(A(:,277)))/67140;
E(8,1) = sum(transpose(A(:,278)))/67140;
E(9,1) = sum(transpose(A(:,279)))/67140;
E(10,1) = sum(transpose(A(:,280)))/67140;

```

```
E(11,1) = sum(transpose(A(:,281)))/67140;
E(12,1) = sum(transpose(A(:,282)))/67140;
E(13,1) = sum(transpose(A(:,283)))/67140;
E(14,1) = sum(transpose(A(:,284)))/67140;
E(15,1) = sum(transpose(A(:,285)))/67140;
E(16,1) = sum(transpose(A(:,286)))/67140;
E(17,1) = sum(transpose(A(:,287)))/67140;
E(18,1) = sum(transpose(A(:,288)))/67140;
E(19,1) = sum(transpose(A(:,289)))/67140;
E(20,1) = sum(transpose(A(:,290)))/67140;
E(21,1) = sum(transpose(A(:,291)))/67140;
E(22,1) = sum(transpose(A(:,292)))/67140;
E(23,1) = sum(transpose(A(:,293)))/67140;
E(24,1) = sum(transpose(A(:,294)))/67140;
E(25,1) = sum(transpose(A(:,295)))/67140;
E(26,1) = sum(transpose(A(:,296)))/67140;
E(27,1) = sum(transpose(A(:,297)))/67140;
E(28,1) = sum(transpose(A(:,298)))/67140;
E(29,1) = sum(transpose(A(:,299)))/67140;
E(30,1) = sum(transpose(A(:,300)))/67140;
E(31,1) = sum(transpose(A(:,301)))/67140;
E(32,1) = sum(transpose(A(:,302)))/67140;
E(33,1) = sum(transpose(A(:,303)))/67140;
E(34,1) = sum(transpose(A(:,304)))/67140;
E(35,1) = sum(transpose(A(:,305)))/67140;
E(36,1) = sum(transpose(A(:,306)))/67140;
E(37,1) = sum(transpose(A(:,307)))/67140;
E(38,1) = sum(transpose(A(:,308)))/67140;
E(39,1) = sum(transpose(A(:,309)))/67140;
E(40,1) = sum(transpose(A(:,310)))/67140;
E(41,1) = sum(transpose(A(:,311)))/67140;
E(42,1) = sum(transpose(A(:,312)))/67140;
E(43,1) = sum(transpose(A(:,313)))/67140;
E(44,1) = sum(transpose(A(:,314)))/67140;
E(45,1) = sum(transpose(A(:,315)))/67140;
E(46,1) = sum(transpose(A(:,316)))/67140;
E(47,1) = sum(transpose(A(:,317)))/67140;
E(48,1) = sum(transpose(A(:,318)))/67140;
E(49,1) = sum(transpose(A(:,319)))/67140;
E(50,1) = sum(transpose(A(:,320)))/67140;
E(51,1) = sum(transpose(A(:,321)))/67140;
E(52,1) = sum(transpose(A(:,322)))/67140;
E(53,1) = sum(transpose(A(:,323)))/67140;
E(54,1) = sum(transpose(A(:,324)))/67140;
E(55,1) = sum(transpose(A(:,325)))/67140;
E(56,1) = sum(transpose(A(:,326)))/67140;
E(57,1) = sum(transpose(A(:,327)))/67140;
E(58,1) = sum(transpose(A(:,328)))/67140;
E(59,1) = sum(transpose(A(:,329)))/67140;
E(60,1) = sum(transpose(A(:,330)))/67140;
E(61,1) = sum(transpose(A(:,331)))/67140;
E(62,1) = sum(transpose(A(:,332)))/67140;
E(63,1) = sum(transpose(A(:,333)))/67140;
E(64,1) = sum(transpose(A(:,334)))/67140;
```

```
fax_bins = [0:31.25:1999];
figure(1)
```

```
plot(fax_bins, abs(fft(B)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC1 Acceleration Profile');
```

```
figure(2)
plot(fax_bins, abs(fft(C)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC2 Acceleration Profile');
```

```
figure(3)
plot(fax_bins, abs(fft(D)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC3 Acceleration Profile');
```

```
figure(4)
plot(fax_bins, abs(fft(E)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC4 Acceleration Profile');
```

## D.19. 82.2 °C Start-Stop Test Data Analysis

```
clear;
close all;
clc;

A = importdata('2020_04_20_180F_start_stop.dat');

TCM1 = transpose(A(:,3));
TCM1_F = (TCM1 * (9/5)) + 32;
TCM2 = transpose(A(:,6));
TCM2_F = (TCM2 * (9/5)) + 32;
TCM3 = transpose(A(:,9));
TCM3_F = (TCM3 * (9/5)) + 32;
TCM4 = transpose(A(:,12));
TCM4_F = (TCM4 * (9/5)) + 32;
TCMT = transpose(A(:,15));
TCMT_F = (TCMT * (9/5)) + 32;
TCMMT = transpose(A(:,18));
TCMMT_F = (TCMMT * (9/5)) + 32;
TCMMB = transpose(A(:,21));
TCMMB_F = (TCMMB * (9/5)) + 32;
TCMB = transpose(A(:,24));
TCMB_F = (TCMB * (9/5)) + 32;
TCG1 = transpose(A(:,27));
TCG1_F = (TCG1 * (9/5)) + 32;
TCG2 = transpose(A(:,30));
TCG2_F = (TCG2 * (9/5)) + 32;
TCG3 = transpose(A(:,33));
TCG3_F = (TCG3 * (9/5)) + 32;
TCG4 = transpose(A(:,36));
TCG4_F = (TCG4 * (9/5)) + 32;
TCGB = transpose(A(:,39));
TCGB_F = (TCGB * (9/5)) + 32;
TCGMB = transpose(A(:,42));
TCGMB_F = (TCGMB * (9/5)) + 32;
TCGMT = transpose(A(:,45));
TCGMT_F = (TCGMT * (9/5)) + 32;
TCGT = transpose(A(:,48));
TCGT_F = (TCGT * (9/5)) + 32;
Speed = transpose(A(:,66));
Torque = transpose(A(:,70));
motor_bearing_average = (TCM1 + TCM2 + TCM3 + TCM4)/4;
motor_bearing_average_F = (TCM1_F + TCM2_F + TCM3_F + TCM4_F)/4;
governor_bearing_average = (TCG1 + TCG2 + TCG3 + TCG4)/4;
governor_bearing_average_F = (TCG1_F + TCG2_F + TCG3_F + TCG4_F)/4;
time = [0:1:95729];
real_time = time/10;

figure(1);
plot(real_time,TCM1,real_time,TCM2,real_time,TCM3,real_time,TCM4)
title('Motor Side Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'M1', 'M2', 'M3', 'M4', }, 'Location', 'southeast');
```

```

figure(2);
plot(real_time,TCG1,real_time,TCG2,real_time,TCG3,real_time,TCG4)
title('Governor Side Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'G1','G2','G3','G4'},,'Location','southeast');

figure(3);
plot(real_time,TCMT,real_time,TCMMT,real_time,TCMMB,real_time,TCMB)
title('Motor Side Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperatre (°C)');
legend({'Top','Middle-Top','Middle-
Bottom','Bottom'},,'Location','eastoutside');

figure(4);
plot(real_time,TCGT,real_time,TCGMT,real_time,TCGMB,real_time,TCGB)
title('Governor Side Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperatre (°C)');
legend({'Top','Middle-Top','Middle-
Bottom','Bottom'},,'Location','eastoutside');

figure(5);
plot(real_time,Speed)
title('Turbine Speed');
xlabel('Time (s)');
ylabel('Shaft Speed (RPM)');

figure(6);
plot(real_time,Torque)
title('Torque vs. Time');
xlabel('Time (s)');
ylabel('Torque (Nm)');

figure(7);
plot(real_time,motor_bearing_average)
title('Averaged Motor Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(8);
plot(real_time,governor_bearing_average)
title('Averaged Governor Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(9);
plot(real_time,governor_bearing_average,real_time,motor_bearing_average)
title('Bearing Averaged Temperature Comparison')
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'Averaged Governor Bearing Temperature','Averaged Motor Bearing
Temperature'},,'Location','southeast');

```

```

figure(10);
plot(real_time,TCMT)
title('Top Motor Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(11);
plot(real_time,TCGT)
title('Top Governor Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(12);
plot(real_time,TCMT,real_time,TCGT)
title('Top Oil Level Temperature Comparison')
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'TCMT','TCGT'},'Location','southeast');

figure(13);
plot(real_time,TCMT,real_time,motor_bearing_average)
title('Motor Side Oil and Bearing Comparison');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'TCMT','Bearing Average'},'Location','southeast');

figure(14);
plot(real_time,TCGT,real_time,governor_bearing_average)
title('Governor Side Oil and Bearing Comparison');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'TCGT','Bearing Average'},'Location','southeast');

figure(15);
plot(real_time,TCGT_F,real_time,governor_bearing_average_F)
title('Governor Side Oil and Bearing Temperature Comparison');
xlabel('Time (s)');
ylabel('Temperature (°F)');
legend({'Top Governor Side Oil Well TC','Governor Side Bearing
Average'},'Location','southeast');

figure(16);
plot(real_time,TCMT_F,real_time,motor_bearing_average_F)
title('Motor Side Oil and Bearing Temperature Comparison');
xlabel('Time (s)');
ylabel('Temperature (°F)');
legend({'Top Motor Side Oil Well TC','Motor Side Bearing
Average'},'Location','southeast');

figure(17);
plot(real_time,governor_bearing_average_F,real_time,motor_bearing_average_F);
title('Bearing Averaged Temperature Comparison')
xlabel('Time (s)');
ylabel('Temperature (°F)');

```



```
legend({'Governor Side Bearing Average', 'Motor Side Bearing  
Average'}, 'Location', 'southeast');
```

## D.20. 82.2 °C Start-Stop Test Accelerometer Analysis

```
clear;
close all;
clc;
%accelerometer script
%71-AC1 force
%72-AC1 std
%73-136 AC1 bins
%137 AC2 force
%138 AC2 std
%139-202 AC2 Bins
%203-AC3 force
%204-AC3 std
%205-268 AC3 Bins
%269- AC4 Force
%270-AC4 std
%271-334 AC4 bins
A = importdata('2020_04_20_180F_start_stop.dat');
time = [0:1:95729]/10;
```

```
AC1B1 = transpose(A(:,73));
AC1B2 = transpose(A(:,74));
AC1B3 = transpose(A(:,75));
AC1B4 = transpose(A(:,76));
AC1B5 = transpose(A(:,77));
AC1B6 = transpose(A(:,78));
AC1B7 = transpose(A(:,79));
AC1B8 = transpose(A(:,80));
AC1B9 = transpose(A(:,81));
AC1B10 = transpose(A(:,82));
AC1B11 = transpose(A(:,83));
AC1B12 = transpose(A(:,84));
AC1B13 = transpose(A(:,85));
AC1B14 = transpose(A(:,86));
AC1B15 = transpose(A(:,87));
AC1B16 = transpose(A(:,88));
AC1B17 = transpose(A(:,89));
AC1B18 = transpose(A(:,90));
AC1B19 = transpose(A(:,91));
AC1B20 = transpose(A(:,92));
AC1B21 = transpose(A(:,93));
AC1B22 = transpose(A(:,94));
AC1B23 = transpose(A(:,95));
AC1B24 = transpose(A(:,96));
AC1B25 = transpose(A(:,97));
AC1B26 = transpose(A(:,98));
AC1B27 = transpose(A(:,99));
AC1B28 = transpose(A(:,100));
AC1B29 = transpose(A(:,101));
AC1B30 = transpose(A(:,102));
AC1B31 = transpose(A(:,103));
AC1B32 = transpose(A(:,104));
AC1B33 = transpose(A(:,105));
AC1B34 = transpose(A(:,106));
AC1B35 = transpose(A(:,107));
```

```
AC1B36 = transpose(A(:,108));
AC1B37 = transpose(A(:,109));
AC1B38 = transpose(A(:,110));
AC1B39 = transpose(A(:,111));
AC1B40 = transpose(A(:,112));
AC1B41 = transpose(A(:,113));
AC1B42 = transpose(A(:,114));
AC1B43 = transpose(A(:,115));
AC1B44 = transpose(A(:,116));
AC1B45 = transpose(A(:,117));
AC1B46 = transpose(A(:,118));
AC1B47 = transpose(A(:,119));
AC1B48 = transpose(A(:,120));
AC1B49 = transpose(A(:,121));
AC1B50 = transpose(A(:,122));
AC1B51 = transpose(A(:,123));
AC1B52 = transpose(A(:,124));
AC1B53 = transpose(A(:,125));
AC1B54 = transpose(A(:,126));
AC1B55 = transpose(A(:,127));
AC1B56 = transpose(A(:,128));
AC1B57 = transpose(A(:,129));
AC1B58 = transpose(A(:,130));
AC1B59 = transpose(A(:,131));
AC1B60 = transpose(A(:,132));
AC1B61 = transpose(A(:,133));
AC1B62 = transpose(A(:,134));
AC1B63 = transpose(A(:,135));
AC1B64 = transpose(A(:,136));
```

```
AC2B1 = transpose(A(:,139));
AC2B2 = transpose(A(:,140));
AC2B3 = transpose(A(:,141));
AC2B4 = transpose(A(:,142));
AC2B5 = transpose(A(:,143));
AC2B6 = transpose(A(:,144));
AC2B7 = transpose(A(:,145));
AC2B8 = transpose(A(:,146));
AC2B9 = transpose(A(:,147));
AC2B10 = transpose(A(:,148));
AC2B11 = transpose(A(:,149));
AC2B12 = transpose(A(:,150));
AC2B13 = transpose(A(:,151));
AC2B14 = transpose(A(:,152));
AC2B15 = transpose(A(:,153));
AC2B16 = transpose(A(:,154));
AC2B17 = transpose(A(:,155));
AC2B18 = transpose(A(:,156));
AC2B19 = transpose(A(:,157));
AC2B20 = transpose(A(:,158));
AC2B21 = transpose(A(:,159));
AC2B22 = transpose(A(:,160));
AC2B23 = transpose(A(:,161));
AC2B24 = transpose(A(:,162));
AC2B25 = transpose(A(:,163));
AC2B26 = transpose(A(:,164));
AC2B27 = transpose(A(:,165));
```

```
AC2B28 = transpose(A(:,166));
AC2B29 = transpose(A(:,167));
AC2B30 = transpose(A(:,168));
AC2B31 = transpose(A(:,169));
AC2B32 = transpose(A(:,170));
AC2B33 = transpose(A(:,171));
AC2B34 = transpose(A(:,172));
AC2B35 = transpose(A(:,173));
AC2B36 = transpose(A(:,174));
AC2B37 = transpose(A(:,175));
AC2B38 = transpose(A(:,176));
AC2B39 = transpose(A(:,177));
AC2B40 = transpose(A(:,178));
AC2B41 = transpose(A(:,179));
AC2B42 = transpose(A(:,180));
AC2B43 = transpose(A(:,181));
AC2B44 = transpose(A(:,182));
AC2B45 = transpose(A(:,183));
AC2B46 = transpose(A(:,184));
AC2B47 = transpose(A(:,185));
AC2B48 = transpose(A(:,186));
AC2B49 = transpose(A(:,187));
AC2B50 = transpose(A(:,188));
AC2B51 = transpose(A(:,189));
AC2B52 = transpose(A(:,190));
AC2B53 = transpose(A(:,191));
AC2B54 = transpose(A(:,192));
AC2B55 = transpose(A(:,193));
AC2B56 = transpose(A(:,194));
AC2B57 = transpose(A(:,195));
AC2B58 = transpose(A(:,196));
AC2B59 = transpose(A(:,197));
AC2B60 = transpose(A(:,198));
AC2B61 = transpose(A(:,199));
AC2B62 = transpose(A(:,200));
AC2B63 = transpose(A(:,201));
AC2B64 = transpose(A(:,202));
```

```
AC3B1 = transpose(A(:,205));
AC3B2 = transpose(A(:,206));
AC3B3 = transpose(A(:,207));
AC3B4 = transpose(A(:,208));
AC3B5 = transpose(A(:,209));
AC3B6 = transpose(A(:,210));
AC3B7 = transpose(A(:,211));
AC3B8 = transpose(A(:,212));
AC3B9 = transpose(A(:,213));
AC3B10 = transpose(A(:,214));
AC3B11 = transpose(A(:,215));
AC3B12 = transpose(A(:,216));
AC3B13 = transpose(A(:,217));
AC3B14 = transpose(A(:,218));
AC3B15 = transpose(A(:,219));
AC3B16 = transpose(A(:,220));
AC3B17 = transpose(A(:,221));
AC3B18 = transpose(A(:,222));
AC3B19 = transpose(A(:,223));
```

```
AC3B20 = transpose(A(:,224));
AC3B21 = transpose(A(:,225));
AC3B22 = transpose(A(:,226));
AC3B23 = transpose(A(:,227));
AC3B24 = transpose(A(:,228));
AC3B25 = transpose(A(:,229));
AC3B26 = transpose(A(:,230));
AC3B27 = transpose(A(:,231));
AC3B28 = transpose(A(:,232));
AC3B29 = transpose(A(:,233));
AC3B30 = transpose(A(:,234));
AC3B31 = transpose(A(:,235));
AC3B32 = transpose(A(:,236));
AC3B33 = transpose(A(:,237));
AC3B34 = transpose(A(:,238));
AC3B35 = transpose(A(:,239));
AC3B36 = transpose(A(:,240));
AC3B37 = transpose(A(:,241));
AC3B38 = transpose(A(:,242));
AC3B39 = transpose(A(:,243));
AC3B40 = transpose(A(:,244));
AC3B41 = transpose(A(:,245));
AC3B42 = transpose(A(:,246));
AC3B43 = transpose(A(:,247));
AC3B44 = transpose(A(:,248));
AC3B45 = transpose(A(:,249));
AC3B46 = transpose(A(:,250));
AC3B47 = transpose(A(:,251));
AC3B48 = transpose(A(:,252));
AC3B49 = transpose(A(:,253));
AC3B50 = transpose(A(:,254));
AC3B51 = transpose(A(:,255));
AC3B52 = transpose(A(:,256));
AC3B53 = transpose(A(:,257));
AC3B54 = transpose(A(:,258));
AC3B55 = transpose(A(:,259));
AC3B56 = transpose(A(:,260));
AC3B57 = transpose(A(:,261));
AC3B58 = transpose(A(:,262));
AC3B59 = transpose(A(:,263));
AC3B60 = transpose(A(:,264));
AC3B61 = transpose(A(:,265));
AC3B62 = transpose(A(:,266));
AC3B63 = transpose(A(:,267));
AC3B64 = transpose(A(:,268));
```

```
AC4B1 = transpose(A(:,271));
AC4B2 = transpose(A(:,272));
AC4B3 = transpose(A(:,273));
AC4B4 = transpose(A(:,274));
AC4B5 = transpose(A(:,275));
AC4B6 = transpose(A(:,276));
AC4B7 = transpose(A(:,277));
AC4B8 = transpose(A(:,278));
AC4B9 = transpose(A(:,279));
AC4B10 = transpose(A(:,280));
AC4B11 = transpose(A(:,281));
```

```
AC4B12 = transpose(A(:,282));
AC4B13 = transpose(A(:,283));
AC4B14 = transpose(A(:,284));
AC4B15 = transpose(A(:,285));
AC4B16 = transpose(A(:,286));
AC4B17 = transpose(A(:,287));
AC4B18 = transpose(A(:,288));
AC4B19 = transpose(A(:,289));
AC4B20 = transpose(A(:,290));
AC4B21 = transpose(A(:,291));
AC4B22 = transpose(A(:,292));
AC4B23 = transpose(A(:,293));
AC4B24 = transpose(A(:,294));
AC4B25 = transpose(A(:,295));
AC4B26 = transpose(A(:,296));
AC4B27 = transpose(A(:,297));
AC4B28 = transpose(A(:,298));
AC4B29 = transpose(A(:,299));
AC4B30 = transpose(A(:,300));
AC4B31 = transpose(A(:,301));
AC4B32 = transpose(A(:,302));
AC4B33 = transpose(A(:,303));
AC4B34 = transpose(A(:,304));
AC4B35 = transpose(A(:,305));
AC4B36 = transpose(A(:,306));
AC4B37 = transpose(A(:,307));
AC4B38 = transpose(A(:,308));
AC4B39 = transpose(A(:,309));
AC4B40 = transpose(A(:,310));
AC4B41 = transpose(A(:,311));
AC4B42 = transpose(A(:,312));
AC4B43 = transpose(A(:,313));
AC4B44 = transpose(A(:,314));
AC4B45 = transpose(A(:,315));
AC4B46 = transpose(A(:,316));
AC4B47 = transpose(A(:,317));
AC4B48 = transpose(A(:,318));
AC4B49 = transpose(A(:,319));
AC4B50 = transpose(A(:,320));
AC4B51 = transpose(A(:,321));
AC4B52 = transpose(A(:,322));
AC4B53 = transpose(A(:,323));
AC4B54 = transpose(A(:,324));
AC4B55 = transpose(A(:,325));
AC4B56 = transpose(A(:,326));
AC4B57 = transpose(A(:,327));
AC4B58 = transpose(A(:,328));
AC4B59 = transpose(A(:,329));
AC4B60 = transpose(A(:,330));
AC4B61 = transpose(A(:,331));
AC4B62 = transpose(A(:,332));
AC4B63 = transpose(A(:,333));
AC4B64 = transpose(A(:,334));
```

```

AC1_avg = (AC1B1 + AC1B2+ AC1B3 + AC1B4 + AC1B5 + AC1B6 + AC1B7 + AC1B8 +
AC1B9 + AC1B10 + AC1B11 + AC1B12+ AC1B13 + AC1B14 + AC1B15 + AC1B16 + AC1B17
+ AC1B18 + AC1B19 + AC1B20 + AC1B21 + AC1B22+ AC1B23 + AC1B24 + AC1B25 +
AC1B26 + AC1B27 + AC1B28 + AC1B29 + AC1B30 + AC1B31 + AC1B32+ AC1B33 + AC1B34
+ AC1B35 + AC1B36 + AC1B37 + AC1B38 + AC1B39 + AC1B40 + AC1B41 + AC1B42+
AC1B43 + AC1B44 + AC1B45 + AC1B46 + AC1B47 + AC1B48 + AC1B49 + AC1B50 +
AC1B51 + AC1B52+ AC1B53 + AC1B54 + AC1B55 + AC1B56 + AC1B57 + AC1B58 + AC1B59
+ AC1B60 + AC1B61 + AC1B62 + AC1B63 + AC1B64)/64;
AC2_avg = (AC2B1 + AC2B2+ AC2B3 + AC2B4 + AC2B5 + AC2B6 + AC2B7 + AC2B8 +
AC2B9 + AC2B10 + AC2B11 + AC2B12+ AC2B13 + AC2B14 + AC2B15 + AC2B16 + AC2B17
+ AC2B18 + AC2B19 + AC2B20 + AC2B21 + AC2B22+ AC2B23 + AC2B24 + AC2B25 +
AC2B26 + AC2B27 + AC2B28 + AC2B29 + AC2B30 + AC2B31 + AC2B32+ AC2B33 + AC2B34
+ AC2B35 + AC2B36 + AC2B37 + AC2B38 + AC2B39 + AC2B40 + AC2B41 + AC2B42+
AC2B43 + AC2B44 + AC2B45 + AC2B46 + AC2B47 + AC2B48 + AC2B49 + AC2B50 +
AC2B51 + AC2B52+ AC2B53 + AC2B54 + AC2B55 + AC2B56 + AC2B57 + AC2B58 + AC2B59
+ AC2B60 + AC2B61 + AC2B62 + AC2B63 + AC2B64)/64;
AC3_avg = (AC3B1 + AC3B2+ AC3B3 + AC3B4 + AC3B5 + AC3B6 + AC3B7 + AC3B8 +
AC3B9 + AC3B10 + AC3B11 + AC3B12+ AC3B13 + AC3B14 + AC3B15 + AC3B16 + AC3B17
+ AC3B18 + AC3B19 + AC3B20 + AC3B21 + AC3B22+ AC3B23 + AC3B24 + AC3B25 +
AC3B26 + AC3B27 + AC3B28 + AC3B29 + AC3B30 + AC3B31 + AC3B32+ AC3B33 + AC3B34
+ AC3B35 + AC3B36 + AC3B37 + AC3B38 + AC3B39 + AC3B40 + AC3B41 + AC3B42+
AC3B43 + AC3B44 + AC3B45 + AC3B46 + AC3B47 + AC3B48 + AC3B49 + AC3B50 +
AC3B51 + AC3B52+ AC3B53 + AC3B54 + AC3B55 + AC3B56+ AC3B57 + AC3B58 + AC3B59
+ AC3B60 + AC3B61 + AC3B62 + AC3B63 + AC3B64)/64;
AC4_avg = (AC4B1 + AC4B2+ AC4B3 + AC4B4 + AC4B5 + AC4B6 + AC4B7 + AC4B8 +
AC4B9 + AC4B10 + AC4B11 + AC4B12+ AC4B13 + AC4B14 + AC4B15 + AC4B16 + AC4B17
+ AC4B18 + AC4B19 + AC4B20 + AC4B21 + AC4B22+ AC4B23 + AC4B24 + AC4B25 +
AC4B26 + AC4B27 + AC4B28 + AC4B29 + AC4B30 + AC4B31 + AC4B32+ AC4B33 + AC4B34
+ AC4B35 + AC4B36 + AC4B37 + AC4B38 + AC4B39 + AC4B40 + AC4B41 + AC4B42+
AC4B43 + AC4B44 + AC4B45 + AC4B46 + AC4B47 + AC4B48 + AC4B49 + AC4B50 +
AC4B51 + AC4B52+ AC4B53 + AC4B54 + AC4B55 + AC4B56 + AC4B57 + AC4B58 + AC4B59
+ AC4B60 + AC4B61 + AC4B62 + AC4B63 + AC4B64)/64;

```

```

figure(1)
plot(time,AC1_avg,time,AC2_avg,time,AC3_avg,time,AC4_avg);
title('Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC1', 'AC2', 'AC3', 'AC4'}, 'Location', 'northwest');

```

```

figure(2)
plot(time,AC1_avg,time,AC2_avg);
title('Governor Side Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC1', 'AC2'}, 'Location', 'northwest');

```

```

figure(3)
plot(time,AC3_avg,time,AC4_avg);
title('Motor Side Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC3', 'AC4'}, 'Location', 'northwest');

```

```

figure(4)
plot(time,AC3_avg,time,AC1_avg);

```

```
title('Vertical Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC3', 'AC1'}, 'Location', 'northwest');

figure(5)
plot(time, AC2_avg, time, AC4_avg);
title('Horizontal Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC2', 'AC4'}, 'Location', 'northwest');
```



## D.21. 82.2 °C Start-Stop Test Accelerometer Fast Fourier Transform

```
clear;
close all;
clc;
%accelerometer script
%71-AC1 force
%72-AC1 std
%73-136 AC1 bins
%137 AC2 force
%138 AC2 std
%139-202 AC2 Bins
%203-AC3 force
%204-AC3 std
%205-268 AC3 Bins
%269- AC4 Force
%270-AC4 std
%271-334 AC4 bins
A = importdata('2020_04_20_180F_start_stop.dat');
time = [0:1:95729]/10;
```

```
B(1,1) = sum(transpose(A(:,73)))/95730;
B(2,1) = sum(transpose(A(:,74)))/95730;
B(3,1) = sum(transpose(A(:,75)))/95730;
B(4,1) = sum(transpose(A(:,76)))/95730;
B(5,1) = sum(transpose(A(:,77)))/95730;
B(6,1) = sum(transpose(A(:,78)))/95730;
B(7,1) = sum(transpose(A(:,79)))/95730;
B(8,1) = sum(transpose(A(:,80)))/95730;
B(9,1) = sum(transpose(A(:,81)))/95730;
B(10,1) = sum(transpose(A(:,82)))/95730;
B(11,1) = sum(transpose(A(:,83)))/95730;
B(12,1) = sum(transpose(A(:,84)))/95730;
B(13,1) = sum(transpose(A(:,85)))/95730;
B(14,1) = sum(transpose(A(:,86)))/95730;
B(15,1) = sum(transpose(A(:,87)))/95730;
B(16,1) = sum(transpose(A(:,88)))/95730;
B(17,1) = sum(transpose(A(:,89)))/95730;
B(18,1) = sum(transpose(A(:,90)))/95730;
B(19,1) = sum(transpose(A(:,91)))/95730;
B(20,1) = sum(transpose(A(:,92)))/95730;
B(21,1) = sum(transpose(A(:,93)))/95730;
B(22,1) = sum(transpose(A(:,94)))/95730;
B(23,1) = sum(transpose(A(:,95)))/95730;
B(24,1) = sum(transpose(A(:,96)))/95730;
B(25,1) = sum(transpose(A(:,97)))/95730;
B(26,1) = sum(transpose(A(:,98)))/95730;
B(27,1) = sum(transpose(A(:,99)))/95730;
B(28,1) = sum(transpose(A(:,100)))/95730;
B(29,1) = sum(transpose(A(:,101)))/95730;
B(30,1) = sum(transpose(A(:,102)))/95730;
B(31,1) = sum(transpose(A(:,103)))/95730;
B(32,1) = sum(transpose(A(:,104)))/95730;
B(33,1) = sum(transpose(A(:,105)))/95730;
B(34,1) = sum(transpose(A(:,106)))/95730;
```

```

B(35,1) = sum(transpose(A(:,107)))/95730;
B(36,1) = sum(transpose(A(:,108)))/95730;
B(37,1) = sum(transpose(A(:,109)))/95730;
B(38,1) = sum(transpose(A(:,110)))/95730;
B(39,1) = sum(transpose(A(:,111)))/95730;
B(40,1) = sum(transpose(A(:,112)))/95730;
B(41,1) = sum(transpose(A(:,113)))/95730;
B(42,1) = sum(transpose(A(:,114)))/95730;
B(43,1) = sum(transpose(A(:,115)))/95730;
B(44,1) = sum(transpose(A(:,116)))/95730;
B(45,1) = sum(transpose(A(:,117)))/95730;
B(46,1) = sum(transpose(A(:,118)))/95730;
B(47,1) = sum(transpose(A(:,119)))/95730;
B(48,1) = sum(transpose(A(:,120)))/95730;
B(49,1) = sum(transpose(A(:,121)))/95730;
B(50,1) = sum(transpose(A(:,122)))/95730;
B(51,1) = sum(transpose(A(:,123)))/95730;
B(52,1) = sum(transpose(A(:,124)))/95730;
B(53,1) = sum(transpose(A(:,125)))/95730;
B(54,1) = sum(transpose(A(:,126)))/95730;
B(55,1) = sum(transpose(A(:,127)))/95730;
B(56,1) = sum(transpose(A(:,128)))/95730;
B(57,1) = sum(transpose(A(:,129)))/95730;
B(58,1) = sum(transpose(A(:,130)))/95730;
B(59,1) = sum(transpose(A(:,131)))/95730;
B(60,1) = sum(transpose(A(:,132)))/95730;
B(61,1) = sum(transpose(A(:,133)))/95730;
B(62,1) = sum(transpose(A(:,134)))/95730;
B(63,1) = sum(transpose(A(:,135)))/95730;
B(64,1) = sum(transpose(A(:,136)))/95730;

```

```

C(1,1) = sum(transpose(A(:,139)))/95730;
C(2,1) = sum(transpose(A(:,140)))/95730;
C(3,1) = sum(transpose(A(:,141)))/95730;
C(4,1) = sum(transpose(A(:,142)))/95730;
C(5,1) = sum(transpose(A(:,143)))/95730;
C(6,1) = sum(transpose(A(:,144)))/95730;
C(7,1) = sum(transpose(A(:,145)))/95730;
C(8,1) = sum(transpose(A(:,146)))/95730;
C(9,1) = sum(transpose(A(:,147)))/95730;
C(10,1) = sum(transpose(A(:,148)))/95730;
C(11,1) = sum(transpose(A(:,149)))/95730;
C(12,1) = sum(transpose(A(:,150)))/95730;
C(13,1) = sum(transpose(A(:,151)))/95730;
C(14,1) = sum(transpose(A(:,152)))/95730;
C(15,1) = sum(transpose(A(:,153)))/95730;
C(16,1) = sum(transpose(A(:,154)))/95730;
C(17,1) = sum(transpose(A(:,155)))/95730;
C(18,1) = sum(transpose(A(:,156)))/95730;
C(19,1) = sum(transpose(A(:,157)))/95730;
C(20,1) = sum(transpose(A(:,158)))/95730;
C(21,1) = sum(transpose(A(:,159)))/95730;
C(22,1) = sum(transpose(A(:,160)))/95730;
C(23,1) = sum(transpose(A(:,161)))/95730;
C(24,1) = sum(transpose(A(:,162)))/95730;
C(25,1) = sum(transpose(A(:,163)))/95730;
C(26,1) = sum(transpose(A(:,164)))/95730;

```

```

C(27,1) = sum(transpose(A(:,165)))/95730;
C(28,1) = sum(transpose(A(:,166)))/95730;
C(29,1) = sum(transpose(A(:,167)))/95730;
C(30,1) = sum(transpose(A(:,168)))/95730;
C(31,1) = sum(transpose(A(:,169)))/95730;
C(32,1) = sum(transpose(A(:,170)))/95730;
C(33,1) = sum(transpose(A(:,171)))/95730;
C(34,1) = sum(transpose(A(:,172)))/95730;
C(35,1) = sum(transpose(A(:,173)))/95730;
C(36,1) = sum(transpose(A(:,174)))/95730;
C(37,1) = sum(transpose(A(:,175)))/95730;
C(38,1) = sum(transpose(A(:,176)))/95730;
C(39,1) = sum(transpose(A(:,177)))/95730;
C(40,1) = sum(transpose(A(:,178)))/95730;
C(41,1) = sum(transpose(A(:,179)))/95730;
C(42,1) = sum(transpose(A(:,180)))/95730;
C(43,1) = sum(transpose(A(:,181)))/95730;
C(44,1) = sum(transpose(A(:,182)))/95730;
C(45,1) = sum(transpose(A(:,183)))/95730;
C(46,1) = sum(transpose(A(:,184)))/95730;
C(47,1) = sum(transpose(A(:,185)))/95730;
C(48,1) = sum(transpose(A(:,186)))/95730;
C(49,1) = sum(transpose(A(:,187)))/95730;
C(50,1) = sum(transpose(A(:,188)))/95730;
C(51,1) = sum(transpose(A(:,189)))/95730;
C(52,1) = sum(transpose(A(:,190)))/95730;
C(53,1) = sum(transpose(A(:,191)))/95730;
C(54,1) = sum(transpose(A(:,192)))/95730;
C(55,1) = sum(transpose(A(:,193)))/95730;
C(56,1) = sum(transpose(A(:,194)))/95730;
C(57,1) = sum(transpose(A(:,195)))/95730;
C(58,1) = sum(transpose(A(:,196)))/95730;
C(59,1) = sum(transpose(A(:,197)))/95730;
C(60,1) = sum(transpose(A(:,198)))/95730;
C(61,1) = sum(transpose(A(:,199)))/95730;
C(62,1) = sum(transpose(A(:,200)))/95730;
C(63,1) = sum(transpose(A(:,201)))/95730;
C(64,1) = sum(transpose(A(:,202)))/95730;

```

```

D(1,1) = sum(transpose(A(:,205)))/95730;
D(2,1) = sum(transpose(A(:,206)))/95730;
D(3,1) = sum(transpose(A(:,207)))/95730;
D(4,1) = sum(transpose(A(:,208)))/95730;
D(5,1) = sum(transpose(A(:,209)))/95730;
D(6,1) = sum(transpose(A(:,210)))/95730;
D(7,1) = sum(transpose(A(:,211)))/95730;
D(8,1) = sum(transpose(A(:,212)))/95730;
D(9,1) = sum(transpose(A(:,213)))/95730;
D(10,1) = sum(transpose(A(:,214)))/95730;
D(11,1) = sum(transpose(A(:,215)))/95730;
D(12,1) = sum(transpose(A(:,216)))/95730;
D(13,1) = sum(transpose(A(:,217)))/95730;
D(14,1) = sum(transpose(A(:,218)))/95730;
D(15,1) = sum(transpose(A(:,219)))/95730;
D(16,1) = sum(transpose(A(:,220)))/95730;
D(17,1) = sum(transpose(A(:,221)))/95730;
D(18,1) = sum(transpose(A(:,222)))/95730;

```

```

D(19,1) = sum(transpose(A(:,223)))/95730;
D(20,1) = sum(transpose(A(:,224)))/95730;
D(21,1) = sum(transpose(A(:,225)))/95730;
D(22,1) = sum(transpose(A(:,226)))/95730;
D(23,1) = sum(transpose(A(:,227)))/95730;
D(24,1) = sum(transpose(A(:,228)))/95730;
D(25,1) = sum(transpose(A(:,229)))/95730;
D(26,1) = sum(transpose(A(:,230)))/95730;
D(27,1) = sum(transpose(A(:,231)))/95730;
D(28,1) = sum(transpose(A(:,232)))/95730;
D(29,1) = sum(transpose(A(:,233)))/95730;
D(30,1) = sum(transpose(A(:,234)))/95730;
D(31,1) = sum(transpose(A(:,235)))/95730;
D(32,1) = sum(transpose(A(:,236)))/95730;
D(33,1) = sum(transpose(A(:,237)))/95730;
D(34,1) = sum(transpose(A(:,238)))/95730;
D(35,1) = sum(transpose(A(:,239)))/95730;
D(36,1) = sum(transpose(A(:,240)))/95730;
D(37,1) = sum(transpose(A(:,241)))/95730;
D(38,1) = sum(transpose(A(:,242)))/95730;
D(39,1) = sum(transpose(A(:,243)))/95730;
D(40,1) = sum(transpose(A(:,244)))/95730;
D(41,1) = sum(transpose(A(:,245)))/95730;
D(42,1) = sum(transpose(A(:,246)))/95730;
D(43,1) = sum(transpose(A(:,247)))/95730;
D(44,1) = sum(transpose(A(:,248)))/95730;
D(45,1) = sum(transpose(A(:,249)))/95730;
D(46,1) = sum(transpose(A(:,250)))/95730;
D(47,1) = sum(transpose(A(:,251)))/95730;
D(48,1) = sum(transpose(A(:,252)))/95730;
D(49,1) = sum(transpose(A(:,253)))/95730;
D(50,1) = sum(transpose(A(:,254)))/95730;
D(51,1) = sum(transpose(A(:,255)))/95730;
D(52,1) = sum(transpose(A(:,256)))/95730;
D(53,1) = sum(transpose(A(:,257)))/95730;
D(54,1) = sum(transpose(A(:,258)))/95730;
D(55,1) = sum(transpose(A(:,259)))/95730;
D(56,1) = sum(transpose(A(:,260)))/95730;
D(57,1) = sum(transpose(A(:,261)))/95730;
D(58,1) = sum(transpose(A(:,262)))/95730;
D(59,1) = sum(transpose(A(:,263)))/95730;
D(60,1) = sum(transpose(A(:,264)))/95730;
D(61,1) = sum(transpose(A(:,265)))/95730;
D(62,1) = sum(transpose(A(:,266)))/95730;
D(63,1) = sum(transpose(A(:,267)))/95730;
D(64,1) = sum(transpose(A(:,268)))/95730;

```

```

E(1,1) = sum(transpose(A(:,271)))/95730;
E(2,1) = sum(transpose(A(:,272)))/95730;
E(3,1) = sum(transpose(A(:,273)))/95730;
E(4,1) = sum(transpose(A(:,274)))/95730;
E(5,1) = sum(transpose(A(:,275)))/95730;
E(6,1) = sum(transpose(A(:,276)))/95730;
E(7,1) = sum(transpose(A(:,277)))/95730;
E(8,1) = sum(transpose(A(:,278)))/95730;
E(9,1) = sum(transpose(A(:,279)))/95730;
E(10,1) = sum(transpose(A(:,280)))/95730;

```

```
E(11,1) = sum(transpose(A(:,281)))/95730;
E(12,1) = sum(transpose(A(:,282)))/95730;
E(13,1) = sum(transpose(A(:,283)))/95730;
E(14,1) = sum(transpose(A(:,284)))/95730;
E(15,1) = sum(transpose(A(:,285)))/95730;
E(16,1) = sum(transpose(A(:,286)))/95730;
E(17,1) = sum(transpose(A(:,287)))/95730;
E(18,1) = sum(transpose(A(:,288)))/95730;
E(19,1) = sum(transpose(A(:,289)))/95730;
E(20,1) = sum(transpose(A(:,290)))/95730;
E(21,1) = sum(transpose(A(:,291)))/95730;
E(22,1) = sum(transpose(A(:,292)))/95730;
E(23,1) = sum(transpose(A(:,293)))/95730;
E(24,1) = sum(transpose(A(:,294)))/95730;
E(25,1) = sum(transpose(A(:,295)))/95730;
E(26,1) = sum(transpose(A(:,296)))/95730;
E(27,1) = sum(transpose(A(:,297)))/95730;
E(28,1) = sum(transpose(A(:,298)))/95730;
E(29,1) = sum(transpose(A(:,299)))/95730;
E(30,1) = sum(transpose(A(:,300)))/95730;
E(31,1) = sum(transpose(A(:,301)))/95730;
E(32,1) = sum(transpose(A(:,302)))/95730;
E(33,1) = sum(transpose(A(:,303)))/95730;
E(34,1) = sum(transpose(A(:,304)))/95730;
E(35,1) = sum(transpose(A(:,305)))/95730;
E(36,1) = sum(transpose(A(:,306)))/95730;
E(37,1) = sum(transpose(A(:,307)))/95730;
E(38,1) = sum(transpose(A(:,308)))/95730;
E(39,1) = sum(transpose(A(:,309)))/95730;
E(40,1) = sum(transpose(A(:,310)))/95730;
E(41,1) = sum(transpose(A(:,311)))/95730;
E(42,1) = sum(transpose(A(:,312)))/95730;
E(43,1) = sum(transpose(A(:,313)))/95730;
E(44,1) = sum(transpose(A(:,314)))/95730;
E(45,1) = sum(transpose(A(:,315)))/95730;
E(46,1) = sum(transpose(A(:,316)))/95730;
E(47,1) = sum(transpose(A(:,317)))/95730;
E(48,1) = sum(transpose(A(:,318)))/95730;
E(49,1) = sum(transpose(A(:,319)))/95730;
E(50,1) = sum(transpose(A(:,320)))/95730;
E(51,1) = sum(transpose(A(:,321)))/95730;
E(52,1) = sum(transpose(A(:,322)))/95730;
E(53,1) = sum(transpose(A(:,323)))/95730;
E(54,1) = sum(transpose(A(:,324)))/95730;
E(55,1) = sum(transpose(A(:,325)))/95730;
E(56,1) = sum(transpose(A(:,326)))/95730;
E(57,1) = sum(transpose(A(:,327)))/95730;
E(58,1) = sum(transpose(A(:,328)))/95730;
E(59,1) = sum(transpose(A(:,329)))/95730;
E(60,1) = sum(transpose(A(:,330)))/95730;
E(61,1) = sum(transpose(A(:,331)))/95730;
E(62,1) = sum(transpose(A(:,332)))/95730;
E(63,1) = sum(transpose(A(:,333)))/95730;
E(64,1) = sum(transpose(A(:,334)))/95730;
```

```
fax_bins = [0:31.25:1999];
figure(1)
```

```
plot(fax_bins, abs(fft(B)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC1 Acceleration Profile');
```

```
figure(2)
plot(fax_bins, abs(fft(C)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC2 Acceleration Profile');
```

```
figure(3)
plot(fax_bins, abs(fft(D)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC3 Acceleration Profile');
```

```
figure(4)
plot(fax_bins, abs(fft(E)))
xlabel('Frequency (Hz)');
ylabel('Acceleration (g)');
title('AC4 Acceleration Profile');
```

## D.22. 93.3 °C Start-Stop Test Data Analysis

```
clear;
close all;
clc;

A = importdata('2020_04_16_200F_start_stop.dat');

TCM1 = transpose(A(:,3));
TCM1_F = (TCM1 * (9/5)) + 32;
TCM2 = transpose(A(:,6));
TCM2_F = (TCM2 * (9/5)) + 32;
TCM3 = transpose(A(:,9));
TCM3_F = (TCM3 * (9/5)) + 32;
TCM4 = transpose(A(:,12));
TCM4_F = (TCM4 * (9/5)) + 32;
TCMT = transpose(A(:,15));
TCMT_F = (TCMT * (9/5)) + 32;
TCMMT = transpose(A(:,18));
TCMMT_F = (TCMMT * (9/5)) + 32;
TCMMB = transpose(A(:,21));
TCMMB_F = (TCMMB * (9/5)) + 32;
TCMB = transpose(A(:,24));
TCMB_F = (TCMB * (9/5)) + 32;
TCG1 = transpose(A(:,27));
TCG1_F = (TCG1 * (9/5)) + 32;
TCG2 = transpose(A(:,30));
TCG2_F = (TCG2 * (9/5)) + 32;
TCG3 = transpose(A(:,33));
TCG3_F = (TCG3 * (9/5)) + 32;
TCG4 = transpose(A(:,36));
TCG4_F = (TCG4 * (9/5)) + 32;
TCGB = transpose(A(:,39));
TCGB_F = (TCGB * (9/5)) + 32;
TCGMB = transpose(A(:,42));
TCGMB_F = (TCGMB * (9/5)) + 32;
TCGMT = transpose(A(:,45));
TCGMT_F = (TCGMT * (9/5)) + 32;
TCGT = transpose(A(:,48));
TCGT_F = (TCGT * (9/5)) + 32;
Speed = transpose(A(:,66));
Torque = transpose(A(:,70));
motor_bearing_average = (TCM1 + TCM2 + TCM3 + TCM4)/4;
motor_bearing_average_F = (TCM1_F + TCM2_F + TCM3_F + TCM4_F)/4;
governor_bearing_average = (TCG1 + TCG2 + TCG3 + TCG4)/4;
governor_bearing_average_F = (TCG1_F + TCG2_F + TCG3_F + TCG4_F)/4;
time = [0:1:94589];
real_time = time/10;

figure(1);
plot(real_time,TCM1,real_time,TCM2,real_time,TCM3,real_time,TCM4)
title('Motor Side Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'M1', 'M2', 'M3', 'M4', }, 'Location', 'southeast');
```

```

figure(2);
plot(real_time,TCG1,real_time,TCG2,real_time,TCG3,real_time,TCG4)
title('Governor Side Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'G1','G2','G3','G4'},'Location','southeast');

figure(3);
plot(real_time,TCMT,real_time,TCMMT,real_time,TCMMB,real_time,TCMB)
title('Motor Side Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperatre (°C)');
legend({'Top','Middle-Top','Middle-
Bottom','Bottom'},'Location','eastoutside');

figure(4);
plot(real_time,TCGT,real_time,TCGMT,real_time,TCGMB,real_time,TCGB)
title('Governor Side Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperatre (°C)');
legend({'Top','Middle-Top','Middle-
Bottom','Bottom'},'Location','eastoutside');

figure(5);
plot(real_time,Speed)
title('Turbine Speed');
xlabel('Time (s)');
ylabel('Shaft Speed (RPM)');

figure(6);
plot(real_time,Torque)
title('Torque vs. Time');
xlabel('Time (s)');
ylabel('Torque (Nm)');

figure(7);
plot(real_time,motor_bearing_average)
title('Averaged Motor Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(8);
plot(real_time,governor_bearing_average)
title('Averaged Governor Bearing Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(9);
plot(real_time,governor_bearing_average,real_time,motor_bearing_average)
title('Bearing Averaged Temperature Comparison')
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'Averaged Governor Bearing Temperature','Averaged Motor Bearing
Temperature'},'Location','southeast');

```



```

figure(10);
plot(real_time,TCMT)
title('Top Motor Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(11);
plot(real_time,TCGT)
title('Top Governor Oil Well Temperature');
xlabel('Time (s)');
ylabel('Temperature (°C)');

figure(12);
plot(real_time,TCMT,real_time,TCGT)
title('Top Oil Level Temperature Comparison')
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'TCMT','TCGT'},'Location','southeast');

figure(13);
plot(real_time,TCMT,real_time,motor_bearing_average)
title('Motor Side Oil and Bearing Comparison');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'TCMT','Bearing Average'},'Location','southeast');

figure(14);
plot(real_time,TCGT,real_time,governor_bearing_average)
title('Governor Side Oil and Bearing Comparison');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'TCGT','Bearing Average'},'Location','southeast');

figure(15);
plot(real_time,TCGT_F,real_time,governor_bearing_average_F)
title('Governor Side Oil and Bearing Temperature Comparison');
xlabel('Time (s)');
ylabel('Temperature (°F)');
legend({'Top Governor Side Oil Well TC','Governor Side Bearing
Average'},'Location','southeast');

figure(16);
plot(real_time,TCMT_F,real_time,motor_bearing_average_F)
title('Motor Side Oil and Bearing Temperature Comparison');
xlabel('Time (s)');
ylabel('Temperature (°F)');
legend({'Top Motor Side Oil Well TC','Motor Side Bearing
Average'},'Location','southeast');

figure(17);
plot(real_time,motor_bearing_average_F,real_time,governor_bearing_average_F);
title('Bearing Averaged Temperature Comparison')
xlabel('Time (s)');
ylabel('Temperature (°F)');

```

```
legend({'Motor Side Bearing Average', 'Governor Side Bearing  
Average'}, 'Location', 'southeast');
```

## D.23. 93.3 °C Start-Stop Test Accelerometer Analysis

```
clear;
close all;
clc;
%accelerometer script
%71-AC1 force
%72-AC1 std
%73-136 AC1 bins
%137 AC2 force
%138 AC2 std
%139-202 AC2 Bins
%203-AC3 force
%204-AC3 std
%205-268 AC3 Bins
%269- AC4 Force
%270-AC4 std
%271-334 AC4 bins
A = importdata('2020_04_16_200F_start_stop.dat');
time = [0:1:94589]/10;
```

```
AC1B1 = transpose(A(:,73));
AC1B2 = transpose(A(:,74));
AC1B3 = transpose(A(:,75));
AC1B4 = transpose(A(:,76));
AC1B5 = transpose(A(:,77));
AC1B6 = transpose(A(:,78));
AC1B7 = transpose(A(:,79));
AC1B8 = transpose(A(:,80));
AC1B9 = transpose(A(:,81));
AC1B10 = transpose(A(:,82));
AC1B11 = transpose(A(:,83));
AC1B12 = transpose(A(:,84));
AC1B13 = transpose(A(:,85));
AC1B14 = transpose(A(:,86));
AC1B15 = transpose(A(:,87));
AC1B16 = transpose(A(:,88));
AC1B17 = transpose(A(:,89));
AC1B18 = transpose(A(:,90));
AC1B19 = transpose(A(:,91));
AC1B20 = transpose(A(:,92));
AC1B21 = transpose(A(:,93));
AC1B22 = transpose(A(:,94));
AC1B23 = transpose(A(:,95));
AC1B24 = transpose(A(:,96));
AC1B25 = transpose(A(:,97));
AC1B26 = transpose(A(:,98));
AC1B27 = transpose(A(:,99));
AC1B28 = transpose(A(:,100));
AC1B29 = transpose(A(:,101));
AC1B30 = transpose(A(:,102));
AC1B31 = transpose(A(:,103));
AC1B32 = transpose(A(:,104));
AC1B33 = transpose(A(:,105));
AC1B34 = transpose(A(:,106));
AC1B35 = transpose(A(:,107));
```

```
AC1B36 = transpose(A(:,108));
AC1B37 = transpose(A(:,109));
AC1B38 = transpose(A(:,110));
AC1B39 = transpose(A(:,111));
AC1B40 = transpose(A(:,112));
AC1B41 = transpose(A(:,113));
AC1B42 = transpose(A(:,114));
AC1B43 = transpose(A(:,115));
AC1B44 = transpose(A(:,116));
AC1B45 = transpose(A(:,117));
AC1B46 = transpose(A(:,118));
AC1B47 = transpose(A(:,119));
AC1B48 = transpose(A(:,120));
AC1B49 = transpose(A(:,121));
AC1B50 = transpose(A(:,122));
AC1B51 = transpose(A(:,123));
AC1B52 = transpose(A(:,124));
AC1B53 = transpose(A(:,125));
AC1B54 = transpose(A(:,126));
AC1B55 = transpose(A(:,127));
AC1B56 = transpose(A(:,128));
AC1B57 = transpose(A(:,129));
AC1B58 = transpose(A(:,130));
AC1B59 = transpose(A(:,131));
AC1B60 = transpose(A(:,132));
AC1B61 = transpose(A(:,133));
AC1B62 = transpose(A(:,134));
AC1B63 = transpose(A(:,135));
AC1B64 = transpose(A(:,136));
```

```
AC2B1 = transpose(A(:,139));
AC2B2 = transpose(A(:,140));
AC2B3 = transpose(A(:,141));
AC2B4 = transpose(A(:,142));
AC2B5 = transpose(A(:,143));
AC2B6 = transpose(A(:,144));
AC2B7 = transpose(A(:,145));
AC2B8 = transpose(A(:,146));
AC2B9 = transpose(A(:,147));
AC2B10 = transpose(A(:,148));
AC2B11 = transpose(A(:,149));
AC2B12 = transpose(A(:,150));
AC2B13 = transpose(A(:,151));
AC2B14 = transpose(A(:,152));
AC2B15 = transpose(A(:,153));
AC2B16 = transpose(A(:,154));
AC2B17 = transpose(A(:,155));
AC2B18 = transpose(A(:,156));
AC2B19 = transpose(A(:,157));
AC2B20 = transpose(A(:,158));
AC2B21 = transpose(A(:,159));
AC2B22 = transpose(A(:,160));
AC2B23 = transpose(A(:,161));
AC2B24 = transpose(A(:,162));
AC2B25 = transpose(A(:,163));
AC2B26 = transpose(A(:,164));
AC2B27 = transpose(A(:,165));
```

```
AC2B28 = transpose(A(:,166));
AC2B29 = transpose(A(:,167));
AC2B30 = transpose(A(:,168));
AC2B31 = transpose(A(:,169));
AC2B32 = transpose(A(:,170));
AC2B33 = transpose(A(:,171));
AC2B34 = transpose(A(:,172));
AC2B35 = transpose(A(:,173));
AC2B36 = transpose(A(:,174));
AC2B37 = transpose(A(:,175));
AC2B38 = transpose(A(:,176));
AC2B39 = transpose(A(:,177));
AC2B40 = transpose(A(:,178));
AC2B41 = transpose(A(:,179));
AC2B42 = transpose(A(:,180));
AC2B43 = transpose(A(:,181));
AC2B44 = transpose(A(:,182));
AC2B45 = transpose(A(:,183));
AC2B46 = transpose(A(:,184));
AC2B47 = transpose(A(:,185));
AC2B48 = transpose(A(:,186));
AC2B49 = transpose(A(:,187));
AC2B50 = transpose(A(:,188));
AC2B51 = transpose(A(:,189));
AC2B52 = transpose(A(:,190));
AC2B53 = transpose(A(:,191));
AC2B54 = transpose(A(:,192));
AC2B55 = transpose(A(:,193));
AC2B56 = transpose(A(:,194));
AC2B57 = transpose(A(:,195));
AC2B58 = transpose(A(:,196));
AC2B59 = transpose(A(:,197));
AC2B60 = transpose(A(:,198));
AC2B61 = transpose(A(:,199));
AC2B62 = transpose(A(:,200));
AC2B63 = transpose(A(:,201));
AC2B64 = transpose(A(:,202));
```

```
AC3B1 = transpose(A(:,205));
AC3B2 = transpose(A(:,206));
AC3B3 = transpose(A(:,207));
AC3B4 = transpose(A(:,208));
AC3B5 = transpose(A(:,209));
AC3B6 = transpose(A(:,210));
AC3B7 = transpose(A(:,211));
AC3B8 = transpose(A(:,212));
AC3B9 = transpose(A(:,213));
AC3B10 = transpose(A(:,214));
AC3B11 = transpose(A(:,215));
AC3B12 = transpose(A(:,216));
AC3B13 = transpose(A(:,217));
AC3B14 = transpose(A(:,218));
AC3B15 = transpose(A(:,219));
AC3B16 = transpose(A(:,220));
AC3B17 = transpose(A(:,221));
AC3B18 = transpose(A(:,222));
AC3B19 = transpose(A(:,223));
```

```
AC3B20 = transpose(A(:,224));
AC3B21 = transpose(A(:,225));
AC3B22 = transpose(A(:,226));
AC3B23 = transpose(A(:,227));
AC3B24 = transpose(A(:,228));
AC3B25 = transpose(A(:,229));
AC3B26 = transpose(A(:,230));
AC3B27 = transpose(A(:,231));
AC3B28 = transpose(A(:,232));
AC3B29 = transpose(A(:,233));
AC3B30 = transpose(A(:,234));
AC3B31 = transpose(A(:,235));
AC3B32 = transpose(A(:,236));
AC3B33 = transpose(A(:,237));
AC3B34 = transpose(A(:,238));
AC3B35 = transpose(A(:,239));
AC3B36 = transpose(A(:,240));
AC3B37 = transpose(A(:,241));
AC3B38 = transpose(A(:,242));
AC3B39 = transpose(A(:,243));
AC3B40 = transpose(A(:,244));
AC3B41 = transpose(A(:,245));
AC3B42 = transpose(A(:,246));
AC3B43 = transpose(A(:,247));
AC3B44 = transpose(A(:,248));
AC3B45 = transpose(A(:,249));
AC3B46 = transpose(A(:,250));
AC3B47 = transpose(A(:,251));
AC3B48 = transpose(A(:,252));
AC3B49 = transpose(A(:,253));
AC3B50 = transpose(A(:,254));
AC3B51 = transpose(A(:,255));
AC3B52 = transpose(A(:,256));
AC3B53 = transpose(A(:,257));
AC3B54 = transpose(A(:,258));
AC3B55 = transpose(A(:,259));
AC3B56 = transpose(A(:,260));
AC3B57 = transpose(A(:,261));
AC3B58 = transpose(A(:,262));
AC3B59 = transpose(A(:,263));
AC3B60 = transpose(A(:,264));
AC3B61 = transpose(A(:,265));
AC3B62 = transpose(A(:,266));
AC3B63 = transpose(A(:,267));
AC3B64 = transpose(A(:,268));
```

```
AC4B1 = transpose(A(:,271));
AC4B2 = transpose(A(:,272));
AC4B3 = transpose(A(:,273));
AC4B4 = transpose(A(:,274));
AC4B5 = transpose(A(:,275));
AC4B6 = transpose(A(:,276));
AC4B7 = transpose(A(:,277));
AC4B8 = transpose(A(:,278));
AC4B9 = transpose(A(:,279));
AC4B10 = transpose(A(:,280));
AC4B11 = transpose(A(:,281));
```

```
AC4B12 = transpose(A(:,282));
AC4B13 = transpose(A(:,283));
AC4B14 = transpose(A(:,284));
AC4B15 = transpose(A(:,285));
AC4B16 = transpose(A(:,286));
AC4B17 = transpose(A(:,287));
AC4B18 = transpose(A(:,288));
AC4B19 = transpose(A(:,289));
AC4B20 = transpose(A(:,290));
AC4B21 = transpose(A(:,291));
AC4B22 = transpose(A(:,292));
AC4B23 = transpose(A(:,293));
AC4B24 = transpose(A(:,294));
AC4B25 = transpose(A(:,295));
AC4B26 = transpose(A(:,296));
AC4B27 = transpose(A(:,297));
AC4B28 = transpose(A(:,298));
AC4B29 = transpose(A(:,299));
AC4B30 = transpose(A(:,300));
AC4B31 = transpose(A(:,301));
AC4B32 = transpose(A(:,302));
AC4B33 = transpose(A(:,303));
AC4B34 = transpose(A(:,304));
AC4B35 = transpose(A(:,305));
AC4B36 = transpose(A(:,306));
AC4B37 = transpose(A(:,307));
AC4B38 = transpose(A(:,308));
AC4B39 = transpose(A(:,309));
AC4B40 = transpose(A(:,310));
AC4B41 = transpose(A(:,311));
AC4B42 = transpose(A(:,312));
AC4B43 = transpose(A(:,313));
AC4B44 = transpose(A(:,314));
AC4B45 = transpose(A(:,315));
AC4B46 = transpose(A(:,316));
AC4B47 = transpose(A(:,317));
AC4B48 = transpose(A(:,318));
AC4B49 = transpose(A(:,319));
AC4B50 = transpose(A(:,320));
AC4B51 = transpose(A(:,321));
AC4B52 = transpose(A(:,322));
AC4B53 = transpose(A(:,323));
AC4B54 = transpose(A(:,324));
AC4B55 = transpose(A(:,325));
AC4B56 = transpose(A(:,326));
AC4B57 = transpose(A(:,327));
AC4B58 = transpose(A(:,328));
AC4B59 = transpose(A(:,329));
AC4B60 = transpose(A(:,330));
AC4B61 = transpose(A(:,331));
AC4B62 = transpose(A(:,332));
AC4B63 = transpose(A(:,333));
AC4B64 = transpose(A(:,334));
```

```

AC1_avg = (AC1B1 + AC1B2+ AC1B3 + AC1B4 + AC1B5 + AC1B6 + AC1B7 + AC1B8 +
AC1B9 + AC1B10 + AC1B11 + AC1B12+ AC1B13 + AC1B14 + AC1B15 + AC1B16 + AC1B17
+ AC1B18 + AC1B19 + AC1B20 + AC1B21 + AC1B22+ AC1B23 + AC1B24 + AC1B25 +
AC1B26 + AC1B27 + AC1B28 + AC1B29 + AC1B30 + AC1B31 + AC1B32+ AC1B33 + AC1B34
+ AC1B35 + AC1B36 + AC1B37 + AC1B38 + AC1B39 + AC1B40 + AC1B41 + AC1B42+
AC1B43 + AC1B44 + AC1B45 + AC1B46 + AC1B47 + AC1B48 + AC1B49 + AC1B50 +
AC1B51 + AC1B52+ AC1B53 + AC1B54 + AC1B55 + AC1B56 + AC1B57 + AC1B58 + AC1B59
+ AC1B60 + AC1B61 + AC1B62 + AC1B63 + AC1B64)/64;
AC2_avg = (AC2B1 + AC2B2+ AC2B3 + AC2B4 + AC2B5 + AC2B6 + AC2B7 + AC2B8 +
AC2B9 + AC2B10 + AC2B11 + AC2B12+ AC2B13 + AC2B14 + AC2B15 + AC2B16 + AC2B17
+ AC2B18 + AC2B19 + AC2B20 + AC2B21 + AC2B22+ AC2B23 + AC2B24 + AC2B25 +
AC2B26 + AC2B27 + AC2B28 + AC2B29 + AC2B30 + AC2B31 + AC2B32+ AC2B33 + AC2B34
+ AC2B35 + AC2B36 + AC2B37 + AC2B38 + AC2B39 + AC2B40 + AC2B41 + AC2B42+
AC2B43 + AC2B44 + AC2B45 + AC2B46 + AC2B47 + AC2B48 + AC2B49 + AC2B50 +
AC2B51 + AC2B52+ AC2B53 + AC2B54 + AC2B55 + AC2B56 + AC2B57 + AC2B58 + AC2B59
+ AC2B60 + AC2B61 + AC2B62 + AC2B63 + AC2B64)/64;
AC3_avg = (AC3B1 + AC3B2+ AC3B3 + AC3B4 + AC3B5 + AC3B6 + AC3B7 + AC3B8 +
AC3B9 + AC3B10 + AC3B11 + AC3B12+ AC3B13 + AC3B14 + AC3B15 + AC3B16 + AC3B17
+ AC3B18 + AC3B19 + AC3B20 + AC3B21 + AC3B22+ AC3B23 + AC3B24 + AC3B25 +
AC3B26 + AC3B27 + AC3B28 + AC3B29 + AC3B30 + AC3B31 + AC3B32+ AC3B33 + AC3B34
+ AC3B35 + AC3B36 + AC3B37 + AC3B38 + AC3B39 + AC3B40 + AC3B41 + AC3B42+
AC3B43 + AC3B44 + AC3B45 + AC3B46 + AC3B47 + AC3B48 + AC3B49 + AC3B50 +
AC3B51 + AC3B52+ AC3B53 + AC3B54 + AC3B55 + AC3B56+ AC3B57 + AC3B58 + AC3B59
+ AC3B60 + AC3B61 + AC3B62 + AC3B63 + AC3B64)/64;
AC4_avg = (AC4B1 + AC4B2+ AC4B3 + AC4B4 + AC4B5 + AC4B6 + AC4B7 + AC4B8 +
AC4B9 + AC4B10 + AC4B11 + AC4B12+ AC4B13 + AC4B14 + AC4B15 + AC4B16 + AC4B17
+ AC4B18 + AC4B19 + AC4B20 + AC4B21 + AC4B22+ AC4B23 + AC4B24 + AC4B25 +
AC4B26 + AC4B27 + AC4B28 + AC4B29 + AC4B30 + AC4B31 + AC4B32+ AC4B33 + AC4B34
+ AC4B35 + AC4B36 + AC4B37 + AC4B38 + AC4B39 + AC4B40 + AC4B41 + AC4B42+
AC4B43 + AC4B44 + AC4B45 + AC4B46 + AC4B47 + AC4B48 + AC4B49 + AC4B50 +
AC4B51 + AC4B52+ AC4B53 + AC4B54 + AC4B55 + AC4B56 + AC4B57 + AC4B58 + AC4B59
+ AC4B60 + AC4B61 + AC4B62 + AC4B63 + AC4B64)/64;

```

```

figure(1)
plot(time,AC1_avg,time,AC2_avg,time,AC3_avg,time,AC4_avg);
title('Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC1', 'AC2', 'AC3', 'AC4'}, 'Location', 'northwest');

```

```

figure(2)
plot(time,AC1_avg,time,AC2_avg);
title('Governor Side Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC1', 'AC2'}, 'Location', 'northwest');

```

```

figure(3)
plot(time,AC3_avg,time,AC4_avg);
title('Motor Side Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC3', 'AC4'}, 'Location', 'northwest');

```

```

figure(4)
plot(time,AC3_avg,time,AC1_avg);

```



```
title('Vertical Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC3', 'AC1'}, 'Location', 'northwest');

figure(5)
plot(time, AC2_avg, time, AC4_avg);
title('Horizontal Accelerometer Outputs');
xlabel('Time (s)');
ylabel('Acceleration (g)');
legend({'AC2', 'AC4'}, 'Location', 'northwest');
```

## D.24. 93.3 °C Start-Stop Test Accelerometer Fast Fourier Transform

```
clear;
close all;
clc;
%accelerometer script
%71-AC1 force
%72-AC1 std
%73-136 AC1 bins
%137 AC2 force
%138 AC2 std
%139-202 AC2 Bins
%203-AC3 force
%204-AC3 std
%205-268 AC3 Bins
%269- AC4 Force
%270-AC4 std
%271-334 AC4 bins
A = importdata('2020_04_16_200F_start_stop.dat');
time = [0:1:94589]/10;
```

```
B(1,1) = sum(transpose(A(:,73)))/94590;
B(2,1) = sum(transpose(A(:,74)))/94590;
B(3,1) = sum(transpose(A(:,75)))/94590;
B(4,1) = sum(transpose(A(:,76)))/94590;
B(5,1) = sum(transpose(A(:,77)))/94590;
B(6,1) = sum(transpose(A(:,78)))/94590;
B(7,1) = sum(transpose(A(:,79)))/94590;
B(8,1) = sum(transpose(A(:,80)))/94590;
B(9,1) = sum(transpose(A(:,81)))/94590;
B(10,1) = sum(transpose(A(:,82)))/94590;
B(11,1) = sum(transpose(A(:,83)))/94590;
B(12,1) = sum(transpose(A(:,84)))/94590;
B(13,1) = sum(transpose(A(:,85)))/94590;
B(14,1) = sum(transpose(A(:,86)))/94590;
B(15,1) = sum(transpose(A(:,87)))/94590;
B(16,1) = sum(transpose(A(:,88)))/94590;
B(17,1) = sum(transpose(A(:,89)))/94590;
B(18,1) = sum(transpose(A(:,90)))/94590;
B(19,1) = sum(transpose(A(:,91)))/94590;
B(20,1) = sum(transpose(A(:,92)))/94590;
B(21,1) = sum(transpose(A(:,93)))/94590;
B(22,1) = sum(transpose(A(:,94)))/94590;
B(23,1) = sum(transpose(A(:,95)))/94590;
B(24,1) = sum(transpose(A(:,96)))/94590;
B(25,1) = sum(transpose(A(:,97)))/94590;
B(26,1) = sum(transpose(A(:,98)))/94590;
B(27,1) = sum(transpose(A(:,99)))/94590;
B(28,1) = sum(transpose(A(:,100)))/94590;
B(29,1) = sum(transpose(A(:,101)))/94590;
B(30,1) = sum(transpose(A(:,102)))/94590;
B(31,1) = sum(transpose(A(:,103)))/94590;
B(32,1) = sum(transpose(A(:,104)))/94590;
B(33,1) = sum(transpose(A(:,105)))/94590;
B(34,1) = sum(transpose(A(:,106)))/94590;
```

```

B(35,1) = sum(transpose(A(:,107)))/94590;
B(36,1) = sum(transpose(A(:,108)))/94590;
B(37,1) = sum(transpose(A(:,109)))/94590;
B(38,1) = sum(transpose(A(:,110)))/94590;
B(39,1) = sum(transpose(A(:,111)))/94590;
B(40,1) = sum(transpose(A(:,112)))/94590;
B(41,1) = sum(transpose(A(:,113)))/94590;
B(42,1) = sum(transpose(A(:,114)))/94590;
B(43,1) = sum(transpose(A(:,115)))/94590;
B(44,1) = sum(transpose(A(:,116)))/94590;
B(45,1) = sum(transpose(A(:,117)))/94590;
B(46,1) = sum(transpose(A(:,118)))/94590;
B(47,1) = sum(transpose(A(:,119)))/94590;
B(48,1) = sum(transpose(A(:,120)))/94590;
B(49,1) = sum(transpose(A(:,121)))/94590;
B(50,1) = sum(transpose(A(:,122)))/94590;
B(51,1) = sum(transpose(A(:,123)))/94590;
B(52,1) = sum(transpose(A(:,124)))/94590;
B(53,1) = sum(transpose(A(:,125)))/94590;
B(54,1) = sum(transpose(A(:,126)))/94590;
B(55,1) = sum(transpose(A(:,127)))/94590;
B(56,1) = sum(transpose(A(:,128)))/94590;
B(57,1) = sum(transpose(A(:,129)))/94590;
B(58,1) = sum(transpose(A(:,130)))/94590;
B(59,1) = sum(transpose(A(:,131)))/94590;
B(60,1) = sum(transpose(A(:,132)))/94590;
B(61,1) = sum(transpose(A(:,133)))/94590;
B(62,1) = sum(transpose(A(:,134)))/94590;
B(63,1) = sum(transpose(A(:,135)))/94590;
B(64,1) = sum(transpose(A(:,136)))/94590;

```

```

C(1,1) = sum(transpose(A(:,139)))/94590;
C(2,1) = sum(transpose(A(:,140)))/94590;
C(3,1) = sum(transpose(A(:,141)))/94590;
C(4,1) = sum(transpose(A(:,142)))/94590;
C(5,1) = sum(transpose(A(:,143)))/94590;
C(6,1) = sum(transpose(A(:,144)))/94590;
C(7,1) = sum(transpose(A(:,145)))/94590;
C(8,1) = sum(transpose(A(:,146)))/94590;
C(9,1) = sum(transpose(A(:,147)))/94590;
C(10,1) = sum(transpose(A(:,148)))/94590;
C(11,1) = sum(transpose(A(:,149)))/94590;
C(12,1) = sum(transpose(A(:,150)))/94590;
C(13,1) = sum(transpose(A(:,151)))/94590;
C(14,1) = sum(transpose(A(:,152)))/94590;
C(15,1) = sum(transpose(A(:,153)))/94590;
C(16,1) = sum(transpose(A(:,154)))/94590;
C(17,1) = sum(transpose(A(:,155)))/94590;
C(18,1) = sum(transpose(A(:,156)))/94590;
C(19,1) = sum(transpose(A(:,157)))/94590;
C(20,1) = sum(transpose(A(:,158)))/94590;
C(21,1) = sum(transpose(A(:,159)))/94590;
C(22,1) = sum(transpose(A(:,160)))/94590;
C(23,1) = sum(transpose(A(:,161)))/94590;
C(24,1) = sum(transpose(A(:,162)))/94590;
C(25,1) = sum(transpose(A(:,163)))/94590;
C(26,1) = sum(transpose(A(:,164)))/94590;

```

```

C(27,1) = sum(transpose(A(:,165)))/94590;
C(28,1) = sum(transpose(A(:,166)))/94590;
C(29,1) = sum(transpose(A(:,167)))/94590;
C(30,1) = sum(transpose(A(:,168)))/94590;
C(31,1) = sum(transpose(A(:,169)))/94590;
C(32,1) = sum(transpose(A(:,170)))/94590;
C(33,1) = sum(transpose(A(:,171)))/94590;
C(34,1) = sum(transpose(A(:,172)))/94590;
C(35,1) = sum(transpose(A(:,173)))/94590;
C(36,1) = sum(transpose(A(:,174)))/94590;
C(37,1) = sum(transpose(A(:,175)))/94590;
C(38,1) = sum(transpose(A(:,176)))/94590;
C(39,1) = sum(transpose(A(:,177)))/94590;
C(40,1) = sum(transpose(A(:,178)))/94590;
C(41,1) = sum(transpose(A(:,179)))/94590;
C(42,1) = sum(transpose(A(:,180)))/94590;
C(43,1) = sum(transpose(A(:,181)))/94590;
C(44,1) = sum(transpose(A(:,182)))/94590;
C(45,1) = sum(transpose(A(:,183)))/94590;
C(46,1) = sum(transpose(A(:,184)))/94590;
C(47,1) = sum(transpose(A(:,185)))/94590;
C(48,1) = sum(transpose(A(:,186)))/94590;
C(49,1) = sum(transpose(A(:,187)))/94590;
C(50,1) = sum(transpose(A(:,188)))/94590;
C(51,1) = sum(transpose(A(:,189)))/94590;
C(52,1) = sum(transpose(A(:,190)))/94590;
C(53,1) = sum(transpose(A(:,191)))/94590;
C(54,1) = sum(transpose(A(:,192)))/94590;
C(55,1) = sum(transpose(A(:,193)))/94590;
C(56,1) = sum(transpose(A(:,194)))/94590;
C(57,1) = sum(transpose(A(:,195)))/94590;
C(58,1) = sum(transpose(A(:,196)))/94590;
C(59,1) = sum(transpose(A(:,197)))/94590;
C(60,1) = sum(transpose(A(:,198)))/94590;
C(61,1) = sum(transpose(A(:,199)))/94590;
C(62,1) = sum(transpose(A(:,200)))/94590;
C(63,1) = sum(transpose(A(:,201)))/94590;
C(64,1) = sum(transpose(A(:,202)))/94590;

```

```

D(1,1) = sum(transpose(A(:,205)))/94590;
D(2,1) = sum(transpose(A(:,206)))/94590;
D(3,1) = sum(transpose(A(:,207)))/94590;
D(4,1) = sum(transpose(A(:,208)))/94590;
D(5,1) = sum(transpose(A(:,209)))/94590;
D(6,1) = sum(transpose(A(:,210)))/94590;
D(7,1) = sum(transpose(A(:,211)))/94590;
D(8,1) = sum(transpose(A(:,212)))/94590;
D(9,1) = sum(transpose(A(:,213)))/94590;
D(10,1) = sum(transpose(A(:,214)))/94590;
D(11,1) = sum(transpose(A(:,215)))/94590;
D(12,1) = sum(transpose(A(:,216)))/94590;
D(13,1) = sum(transpose(A(:,217)))/94590;
D(14,1) = sum(transpose(A(:,218)))/94590;
D(15,1) = sum(transpose(A(:,219)))/94590;
D(16,1) = sum(transpose(A(:,220)))/94590;
D(17,1) = sum(transpose(A(:,221)))/94590;
D(18,1) = sum(transpose(A(:,222)))/94590;

```

```

D(19,1) = sum(transpose(A(:,223)))/94590;
D(20,1) = sum(transpose(A(:,224)))/94590;
D(21,1) = sum(transpose(A(:,225)))/94590;
D(22,1) = sum(transpose(A(:,226)))/94590;
D(23,1) = sum(transpose(A(:,227)))/94590;
D(24,1) = sum(transpose(A(:,228)))/94590;
D(25,1) = sum(transpose(A(:,229)))/94590;
D(26,1) = sum(transpose(A(:,230)))/94590;
D(27,1) = sum(transpose(A(:,231)))/94590;
D(28,1) = sum(transpose(A(:,232)))/94590;
D(29,1) = sum(transpose(A(:,233)))/94590;
D(30,1) = sum(transpose(A(:,234)))/94590;
D(31,1) = sum(transpose(A(:,235)))/94590;
D(32,1) = sum(transpose(A(:,236)))/94590;
D(33,1) = sum(transpose(A(:,237)))/94590;
D(34,1) = sum(transpose(A(:,238)))/94590;
D(35,1) = sum(transpose(A(:,239)))/94590;
D(36,1) = sum(transpose(A(:,240)))/94590;
D(37,1) = sum(transpose(A(:,241)))/94590;
D(38,1) = sum(transpose(A(:,242)))/94590;
D(39,1) = sum(transpose(A(:,243)))/94590;
D(40,1) = sum(transpose(A(:,244)))/94590;
D(41,1) = sum(transpose(A(:,245)))/94590;
D(42,1) = sum(transpose(A(:,246)))/94590;
D(43,1) = sum(transpose(A(:,247)))/94590;
D(44,1) = sum(transpose(A(:,248)))/94590;
D(45,1) = sum(transpose(A(:,249)))/94590;
D(46,1) = sum(transpose(A(:,250)))/94590;
D(47,1) = sum(transpose(A(:,251)))/94590;
D(48,1) = sum(transpose(A(:,252)))/94590;
D(49,1) = sum(transpose(A(:,253)))/94590;
D(50,1) = sum(transpose(A(:,254)))/94590;
D(51,1) = sum(transpose(A(:,255)))/94590;
D(52,1) = sum(transpose(A(:,256)))/94590;
D(53,1) = sum(transpose(A(:,257)))/94590;
D(54,1) = sum(transpose(A(:,258)))/94590;
D(55,1) = sum(transpose(A(:,259)))/94590;
D(56,1) = sum(transpose(A(:,260)))/94590;
D(57,1) = sum(transpose(A(:,261)))/94590;
D(58,1) = sum(transpose(A(:,262)))/94590;
D(59,1) = sum(transpose(A(:,263)))/94590;
D(60,1) = sum(transpose(A(:,264)))/94590;
D(61,1) = sum(transpose(A(:,265)))/94590;
D(62,1) = sum(transpose(A(:,266)))/94590;
D(63,1) = sum(transpose(A(:,267)))/94590;
D(64,1) = sum(transpose(A(:,268)))/94590;

```

```

E(1,1) = sum(transpose(A(:,271)))/94590;
E(2,1) = sum(transpose(A(:,272)))/94590;
E(3,1) = sum(transpose(A(:,273)))/94590;
E(4,1) = sum(transpose(A(:,274)))/94590;
E(5,1) = sum(transpose(A(:,275)))/94590;
E(6,1) = sum(transpose(A(:,276)))/94590;
E(7,1) = sum(transpose(A(:,277)))/94590;
E(8,1) = sum(transpose(A(:,278)))/94590;
E(9,1) = sum(transpose(A(:,279)))/94590;
E(10,1) = sum(transpose(A(:,280)))/94590;

```

```
E(11,1) = sum(transpose(A(:,281)))/94590;
E(12,1) = sum(transpose(A(:,282)))/94590;
E(13,1) = sum(transpose(A(:,283)))/94590;
E(14,1) = sum(transpose(A(:,284)))/94590;
E(15,1) = sum(transpose(A(:,285)))/94590;
E(16,1) = sum(transpose(A(:,286)))/94590;
E(17,1) = sum(transpose(A(:,287)))/94590;
E(18,1) = sum(transpose(A(:,288)))/94590;
E(19,1) = sum(transpose(A(:,289)))/94590;
E(20,1) = sum(transpose(A(:,290)))/94590;
E(21,1) = sum(transpose(A(:,291)))/94590;
E(22,1) = sum(transpose(A(:,292)))/94590;
E(23,1) = sum(transpose(A(:,293)))/94590;
E(24,1) = sum(transpose(A(:,294)))/94590;
E(25,1) = sum(transpose(A(:,295)))/94590;
E(26,1) = sum(transpose(A(:,296)))/94590;
E(27,1) = sum(transpose(A(:,297)))/94590;
E(28,1) = sum(transpose(A(:,298)))/94590;
E(29,1) = sum(transpose(A(:,299)))/94590;
E(30,1) = sum(transpose(A(:,300)))/94590;
E(31,1) = sum(transpose(A(:,301)))/94590;
E(32,1) = sum(transpose(A(:,302)))/94590;
E(33,1) = sum(transpose(A(:,303)))/94590;
E(34,1) = sum(transpose(A(:,304)))/94590;
E(35,1) = sum(transpose(A(:,305)))/94590;
E(36,1) = sum(transpose(A(:,306)))/94590;
E(37,1) = sum(transpose(A(:,307)))/94590;
E(38,1) = sum(transpose(A(:,308)))/94590;
E(39,1) = sum(transpose(A(:,309)))/94590;
E(40,1) = sum(transpose(A(:,310)))/94590;
E(41,1) = sum(transpose(A(:,311)))/94590;
E(42,1) = sum(transpose(A(:,312)))/94590;
E(43,1) = sum(transpose(A(:,313)))/94590;
E(44,1) = sum(transpose(A(:,314)))/94590;
E(45,1) = sum(transpose(A(:,315)))/94590;
E(46,1) = sum(transpose(A(:,316)))/94590;
E(47,1) = sum(transpose(A(:,317)))/94590;
E(48,1) = sum(transpose(A(:,318)))/94590;
E(49,1) = sum(transpose(A(:,319)))/94590;
E(50,1) = sum(transpose(A(:,320)))/94590;
E(51,1) = sum(transpose(A(:,321)))/94590;
E(52,1) = sum(transpose(A(:,322)))/94590;
E(53,1) = sum(transpose(A(:,323)))/94590;
E(54,1) = sum(transpose(A(:,324)))/94590;
E(55,1) = sum(transpose(A(:,325)))/94590;
E(56,1) = sum(transpose(A(:,326)))/94590;
E(57,1) = sum(transpose(A(:,327)))/94590;
E(58,1) = sum(transpose(A(:,328)))/94590;
E(59,1) = sum(transpose(A(:,329)))/94590;
E(60,1) = sum(transpose(A(:,330)))/94590;
E(61,1) = sum(transpose(A(:,331)))/94590;
E(62,1) = sum(transpose(A(:,332)))/94590;
E(63,1) = sum(transpose(A(:,333)))/94590;
E(64,1) = sum(transpose(A(:,334)))/94590;
```

```
fax_bins = [0:31.25:1999];
figure(1)
```

```
plot(fax_bins, abs(fft(B)))  
xlabel('Frequency (Hz)');  
ylabel('Acceleration (g)');  
title('AC1 Acceleration Profile');
```

```
figure(2)  
plot(fax_bins, abs(fft(C)))  
xlabel('Frequency (Hz)');  
ylabel('Acceleration (g)');  
title('AC2 Acceleration Profile');
```

```
figure(3)  
plot(fax_bins, abs(fft(D)))  
xlabel('Frequency (Hz)');  
ylabel('Acceleration (g)');  
title('AC3 Acceleration Profile');
```

```
figure(4)  
plot(fax_bins, abs(fft(E)))  
xlabel('Frequency (Hz)');  
ylabel('Acceleration (g)');  
title('AC4 Acceleration Profile');
```

## D.25. Start-Stop Comparison Plotter

```
clear;
close all;
clc;

A = importdata('2020_04_13_start_stop_no_heat.dat');
B = importdata('2020_04_14_160F_start_stop.dat');
C = importdata('2020_04_20_180F_start_stop.dat');
D = importdata('2020_04_16_200F_start_stop.dat');

TCM1_NH = transpose(A(:,3));
TCM2_NH = transpose(A(:,6));
TCM3_NH = transpose(A(:,9));
TCM4_NH = transpose(A(:,12));
TCMT_NH = transpose(A(:,15));
TCMMT_NH = transpose(A(:,18));
TCMMB_NH = transpose(A(:,21));
TCMB_NH = transpose(A(:,24));
TCG1_NH = transpose(A(:,27));
TCG2_NH = transpose(A(:,30));
TCG3_NH = transpose(A(:,33));
TCG4_NH = transpose(A(:,36));
TCGB_NH = transpose(A(:,39));
TCGMB_NH = transpose(A(:,42));
TCGMT_NH = transpose(A(:,45));
TCGT_NH = transpose(A(:,48));
Speed_NH = transpose(A(:,66));
torque_NH = transpose(A(:,70));
motor_bearing_NH_avg = (TCM1_NH + TCM2_NH + TCM3_NH + TCM4_NH)/4;
motor_bearing_NH_avg_F = (motor_bearing_NH_avg * (9/5)) + 32;
governor_bearing_NH_avg = (TCG1_NH + TCG2_NH + TCG3_NH + TCG4_NH)/4;
governor_bearing_NH_avg_F = (governor_bearing_NH_avg * (9/5)) + 32;
time_NH = [0:1:44499];
real_time_NH = time_NH/10;

TCM1_160 = transpose(B(:,3));
TCM2_160 = transpose(B(:,6));
TCM3_160 = transpose(B(:,9));
TCM4_160 = transpose(B(:,12));
TCMT_160 = transpose(B(:,15));
TCMMT_160 = transpose(B(:,18));
TCMMB_160 = transpose(B(:,21));
TCMB_160 = transpose(B(:,24));
TCG1_160 = transpose(B(:,27));
TCG2_160 = transpose(B(:,30));
TCG3_160 = transpose(B(:,33));
TCG4_160 = transpose(B(:,36));
TCGB_160 = transpose(B(:,39));
TCGMB_160 = transpose(B(:,42));
TCGMT_160 = transpose(B(:,45));
TCGT_160 = transpose(B(:,48));
Speed_160 = transpose(B(:,66));
torque_160 = transpose(B(:,70));
motor_bearing_160_avg = (TCM1_160 + TCM3_160 + TCM4_160)/3;
motor_bearing_160_avg_F = (motor_bearing_160_avg * (9/5)) + 32;
```



```

governor_bearing_160_avg = (TCG1_160 + TCG2_160 + TCG3_160 + TCG4_160)/4;
governor_bearing_160_avg_F = (governor_bearing_160_avg * (9/5)) + 32;
time_160 = [0:1:67139];
real_time_160 = time_160/10;

```

```

TCM1_180 = transpose(C(:,3));
TCM2_180 = transpose(C(:,6));
TCM3_180 = transpose(C(:,9));
TCM4_180 = transpose(C(:,12));
TCMT_180 = transpose(C(:,15));
TCMMT_180 = transpose(C(:,18));
TCMMB_180 = transpose(C(:,21));
TCMB_180 = transpose(C(:,24));
TCG1_180 = transpose(C(:,27));
TCG2_180 = transpose(C(:,30));
TCG3_180 = transpose(C(:,33));
TCG4_180 = transpose(C(:,36));
TCGB_180 = transpose(C(:,39));
TCGMB_180 = transpose(C(:,42));
TCGMT_180 = transpose(C(:,45));
TCGT_180 = transpose(C(:,48));
Speed_180 = transpose(C(:,66));
torque_180 = transpose(C(:,70));
motor_bearing_180_avg = (TCM1_180 + TCM2_180 + TCM3_180 + TCM4_180)/4;
motor_bearing_180_avg_F = (motor_bearing_180_avg * (9/5)) + 32;
governor_bearing_180_avg = (TCG1_180 + TCG2_180 + TCG3_180 + TCG4_180)/4;
governor_bearing_180_avg_F = (governor_bearing_180_avg * (9/5)) + 32;
time_180 = [0:1:95729];
real_time_180 = time_180/10;

```

```

TCM1_200 = transpose(D(:,3));
TCM2_200 = transpose(D(:,6));
TCM3_200 = transpose(D(:,9));
TCM4_200 = transpose(D(:,12));
TCMT_200 = transpose(D(:,15));
TCMMT_200 = transpose(D(:,18));
TCMMB_200 = transpose(D(:,21));
TCMB_200 = transpose(D(:,24));
TCG1_200 = transpose(D(:,27));
TCG2_200 = transpose(D(:,30));
TCG3_200 = transpose(D(:,33));
TCG4_200 = transpose(D(:,36));
TCGB_200 = transpose(D(:,39));
TCGMB_200 = transpose(D(:,42));
TCGMT_200 = transpose(D(:,45));
TCGT_200 = transpose(D(:,48));
Speed_200 = transpose(D(:,66));
torque_200 = transpose(D(:,70));
motor_bearing_200_avg = (TCM1_200 + TCM2_200 + TCM3_200 + TCM4_200)/4;
motor_bearing_200_avg_F = (motor_bearing_200_avg * (9/5)) + 32;
governor_bearing_200_avg = (TCG1_200 + TCG2_200 + TCG3_200 + TCG4_200)/4;
governor_bearing_200_avg_F = (governor_bearing_200_avg * (9/5)) + 32;
time_200 = [0:1:94589];
real_time_200 = time_200/10;

```

```

time_comparison = [0:1:44465];

```

```

real_time_comparison = time_comparison/10;

motor_bearing_200_avg_comparison = motor_bearing_200_avg(49206:93671);
motor_bearing_180_avg_comparison = motor_bearing_180_avg(35274:79739);
motor_bearing_160_avg_comparison = motor_bearing_160_avg(22104:66569);
motor_bearing_NH_avg_comparison = motor_bearing_NH_avg(35:44500);

governor_bearing_200_avg_comparison = governor_bearing_200_avg(49216:93681);
governor_bearing_180_avg_comparison = governor_bearing_180_avg(35274:79739);
governor_bearing_160_avg_comparison = governor_bearing_160_avg(22104:66569);
governor_bearing_NH_avg_comparison = governor_bearing_NH_avg(35:44500);

motor_bearing_200_avg_comparison_F = motor_bearing_200_avg_F(49206:93671);
motor_bearing_180_avg_comparison_F = motor_bearing_180_avg_F(35274:79739);
motor_bearing_160_avg_comparison_F = motor_bearing_160_avg_F(22104:66569);
motor_bearing_NH_avg_comparison_F = motor_bearing_NH_avg_F(35:44500);

governor_bearing_200_avg_comparison_F =
governor_bearing_200_avg_F(49216:93681);
governor_bearing_180_avg_comparison_F =
governor_bearing_180_avg_F(35274:79739);
governor_bearing_160_avg_comparison_F =
governor_bearing_160_avg_F(22104:66569);
governor_bearing_NH_avg_comparison_F = governor_bearing_NH_avg_F(35:44500);

torque_200_comparison = torque_200(49216:93681);
torque_180_comparison = torque_180(35274:79739);
torque_160_comparison = torque_160(22104:66569);
torque_NH_comparison = torque_NH(35:44500);

torque_200_comparison_short = torque_200(49216:57866);
torque_180_comparison_short = torque_180(35274:43924);
torque_160_comparison_short = torque_160(22104:30754);
torque_NH_comparison_short = torque_NH(35:8685);
time_comparison_torque_short = [0:1:8650];
real_time_comparison_torque_short = time_comparison_torque_short/10;

figure(1)
plot(real_time_comparison_torque_short,torque_200_comparison_short,real_time_
comparison_torque_short,torque_180_comparison_short,real_time_comparison_torq
ue_short,torque_160_comparison_short,real_time_comparison_torque_short,torque
_NH_comparison_short)
title('First Start Torque Comparison')
xlabel('Time (s)');
ylabel('Torque (Nm)');
legend({'93.3 °C Test','82.2 °C Test','71.1 °C Test','No Heat
Test'},'Location','southeast');

figure(2);
plot(real_time_comparison,torque_200_comparison,real_time_comparison,torque_1
80_comparison,real_time_comparison,torque_160_comparison,real_time_comparison
,torque_NH_comparison)
title('Start-Stop Torque Comparison');
xlabel('Time (s)');

```

```

ylabel('Torque (Nm)');
legend({'93.3 °C Test', '82.2 °C Test', '71.1 °C Test', 'No Heat
Test'}, 'Location', 'southeast');

figure(3);
plot(real_time_comparison, motor_bearing_200_avg_comparison, real_time_comparis
on, motor_bearing_180_avg_comparison, real_time_comparison, motor_bearing_160_av
g_comparison, real_time_comparison, motor_bearing_NH_avg_comparison);
title('Motor Bearing Average Temperature Comparison');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'93.3 °C Test', '82.2 °C Test', '71.1 °C Test', 'No Heat
Test'}, 'Location', 'southeast');

figure(4);
plot(real_time_comparison, governor_bearing_200_avg_comparison, real_time_compa
rison, governor_bearing_180_avg_comparison, real_time_comparison, governor_beari
ng_160_avg_comparison, real_time_comparison, governor_bearing_NH_avg_comparison
);
title('Governor Bearing Average Temperature Comparison');
xlabel('Time (s)');
ylabel('Temperature (°C)');
legend({'93.3 °C Test', '82.2 °C Test', '71.1 °C Test', 'No Heat
Test'}, 'Location', 'southeast');

figure(5);
plot(real_time_comparison, motor_bearing_200_avg_comparison_F, real_time_compari
son, motor_bearing_180_avg_comparison_F, real_time_comparison, motor_bearing_16
0_avg_comparison_F, real_time_comparison, motor_bearing_NH_avg_comparison_F);
title('Motor Bearing Average Temperature Comparison');
xlabel('Time (s)');
ylabel('Temperature (°F)');
legend({'200 °F Test', '180 °F Test', '160 °F Test', 'No Heat
Test'}, 'Location', 'southeast');

figure(6);
plot(real_time_comparison, governor_bearing_200_avg_comparison_F, real_time_com
parison, governor_bearing_180_avg_comparison_F, real_time_comparison, governor_b
earing_160_avg_comparison_F, real_time_comparison, governor_bearing_NH_avg_comp
arison_F);
title('Governor Bearing Average Temperature Comparison');
xlabel('Time (s)');
ylabel('Temperature (°F)');
legend({'200 °F Test', '180 °F Test', '160 °F Test', 'No Heat
Test'}, 'Location', 'southeast');

```