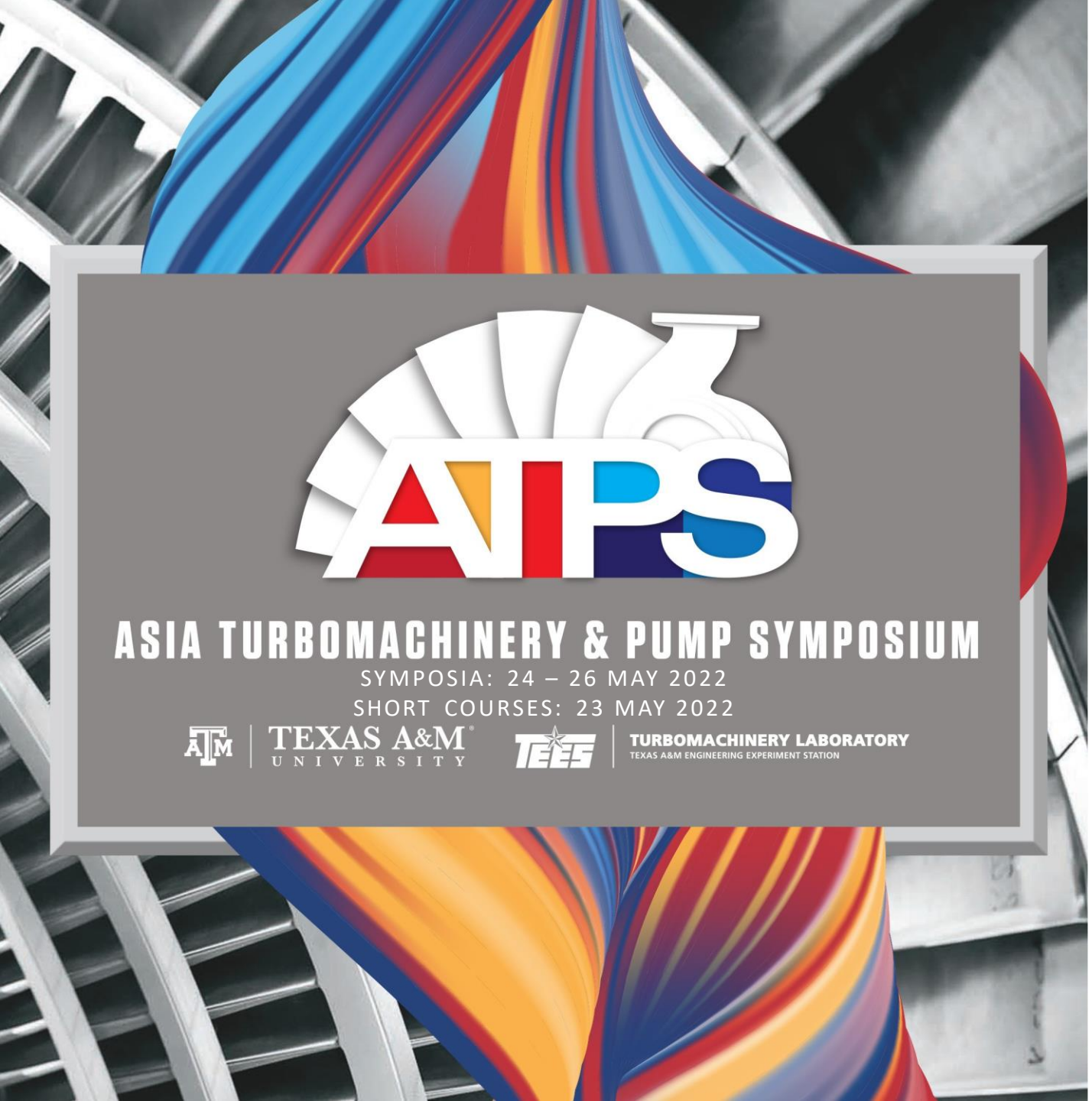


Relation between wear ring clearances & non-synchronous vibrations in BFW centrifugal pump

Waqar Ahmad–Engro Fertilizers

engro fertilizers

Presenter/Author Bios:

Waqar Ahmad is working as a Machinery Engineer in machine reliability section of Engro Fertilizers-Pakistan.

He has 5 year working experience in fertilizer industry as machinery Engineer. He is certified engineer in vibration analysis-2, machinery lubrication analysis-2 & GE machinery dynamic analysis course.

His responsibilities majorly include reliability improvement of the plant machineries, through periodic & condition-based monitoring of machines.

Waqar received his BSc Mechanical Engg. degree from NUST Islamabad in 2015.

Abstract:

A de-superheating boiler feed water pump was facing high vibration issue for last 19 years.

Pump had been overhauled multiple times in past, but the issue was not resolved. Dominant frequency appearing in vibration spectrum was 1.58 X order, which was not matching with any of the pump component frequency. Furthermore, maintenance history of the pump prior to year 2005 & complete machine manual was not available.

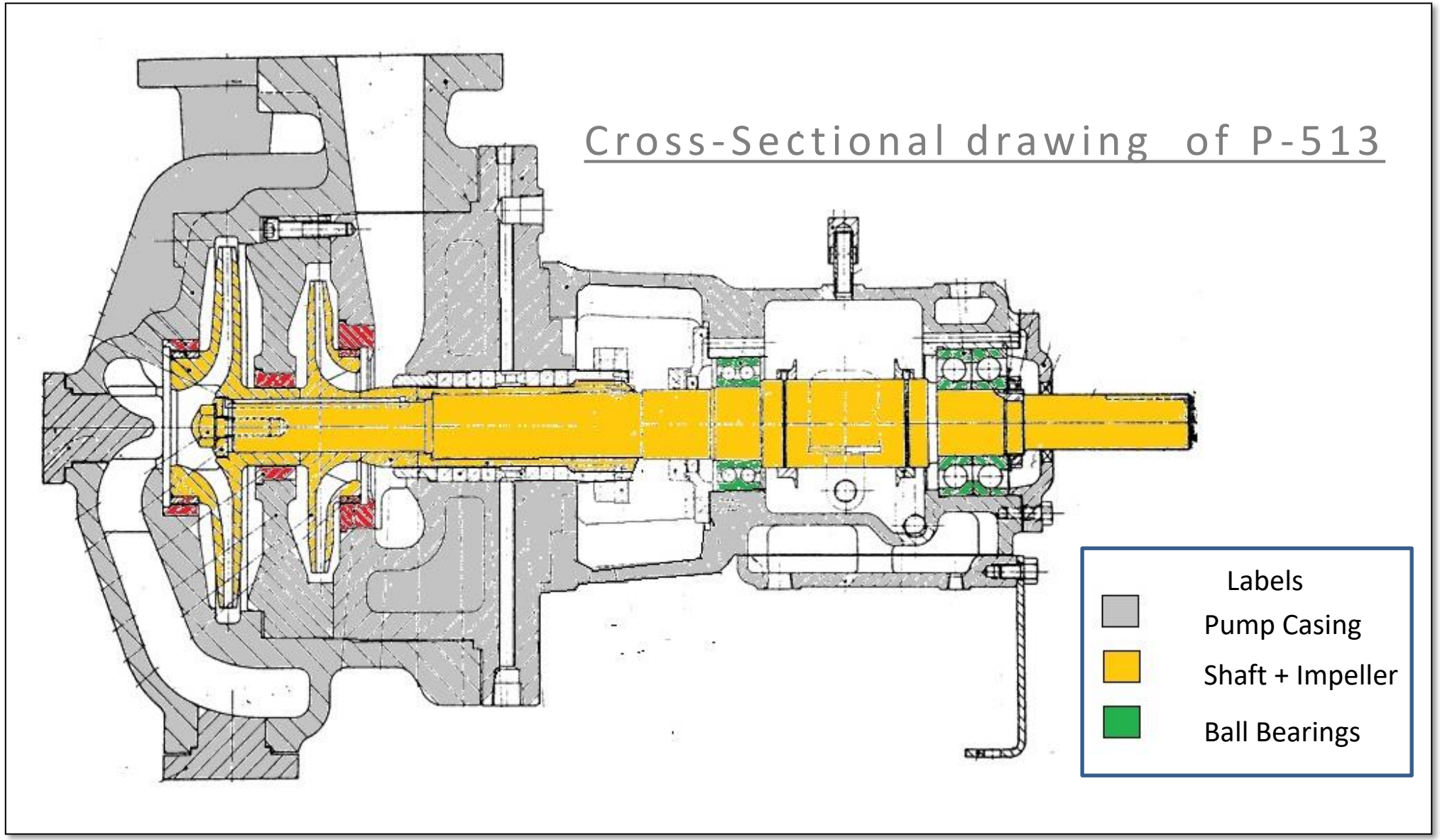
Detailed study was conducted to resolve the pump vibration issue.

Background:

There are 2 plants at Engro fertilizer site i.e., plant-1(old) and plant-2(new). At our plant-1 utilities, de-superheating boiler feed water pump is installed with following specifications.

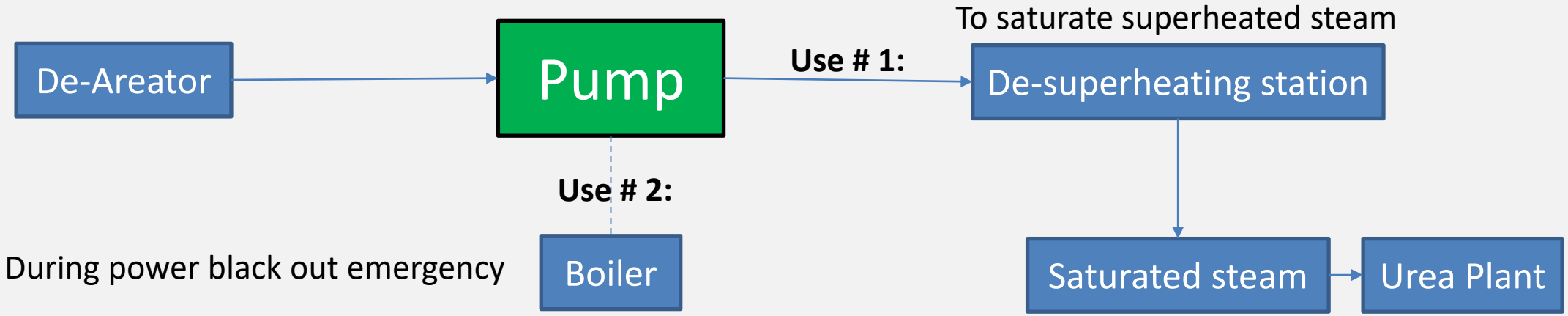
Specification of Pump:	
Service	Boiler Feed Water
Configuration	Horizontally Overhung
Designated code-API-610	OH-1
Capacity	68 M3 HR
Horsepower	17.5 HP
RPM	2960
Suction Pressure	22 PSIG
Discharge Pressure	220 PSIG
Differential Pressure	200 PSIG
Year of commissioning	1967

Background:


Cross-Sectional drawing of P-513
Labels
Pump Casing
Shaft + Impeller
Ball Bearings

Background:

This pump takes suction from this de-aerator drum. Afterward, It has 2 applications. First, it supplies quenching water to the de-superheating stations. Second, it is utilized in the initial filling of BFW for steam generation during power black-out emergency situation.



This pump remained problematic for last 19 years. In absence of this pump, the purpose of steam de-superheating was being achieved through main BFW pumps (total # 4, 3 operational & 1 standby, differential pressure 825 psig & 70 m3/hr.), while for emergency blackout situation, BFW for initial filling is supplied from plant-2 utilities.

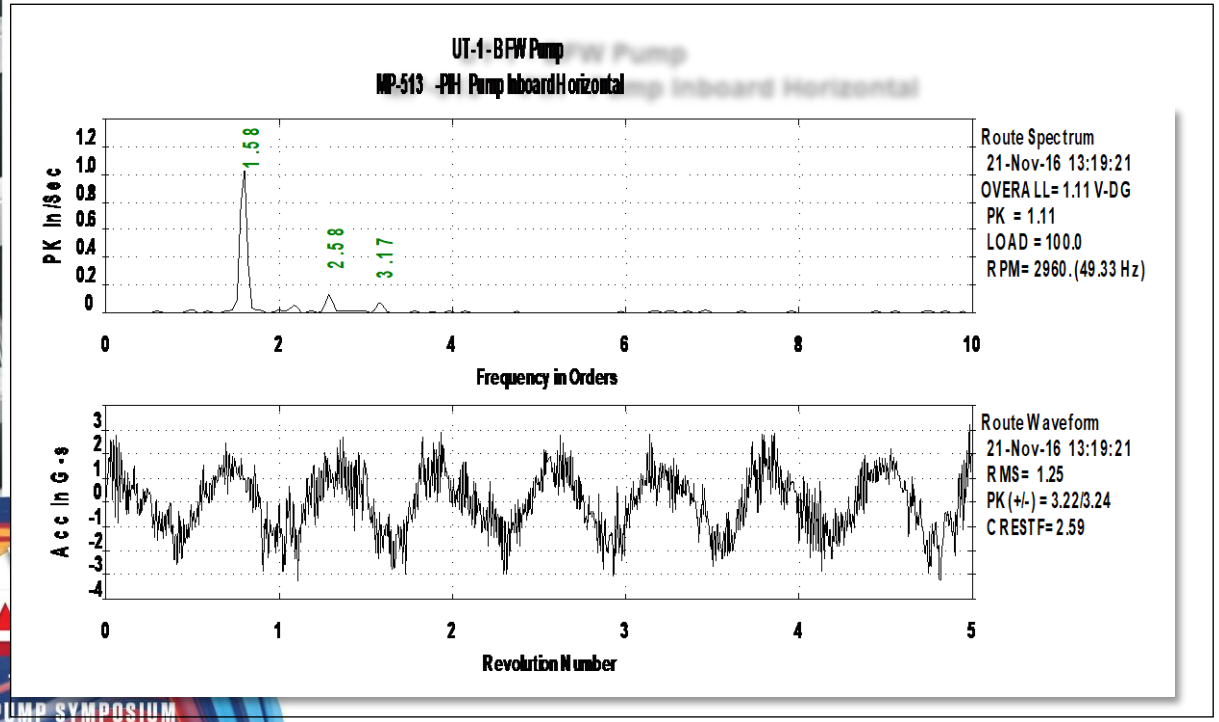
Problem Statement:

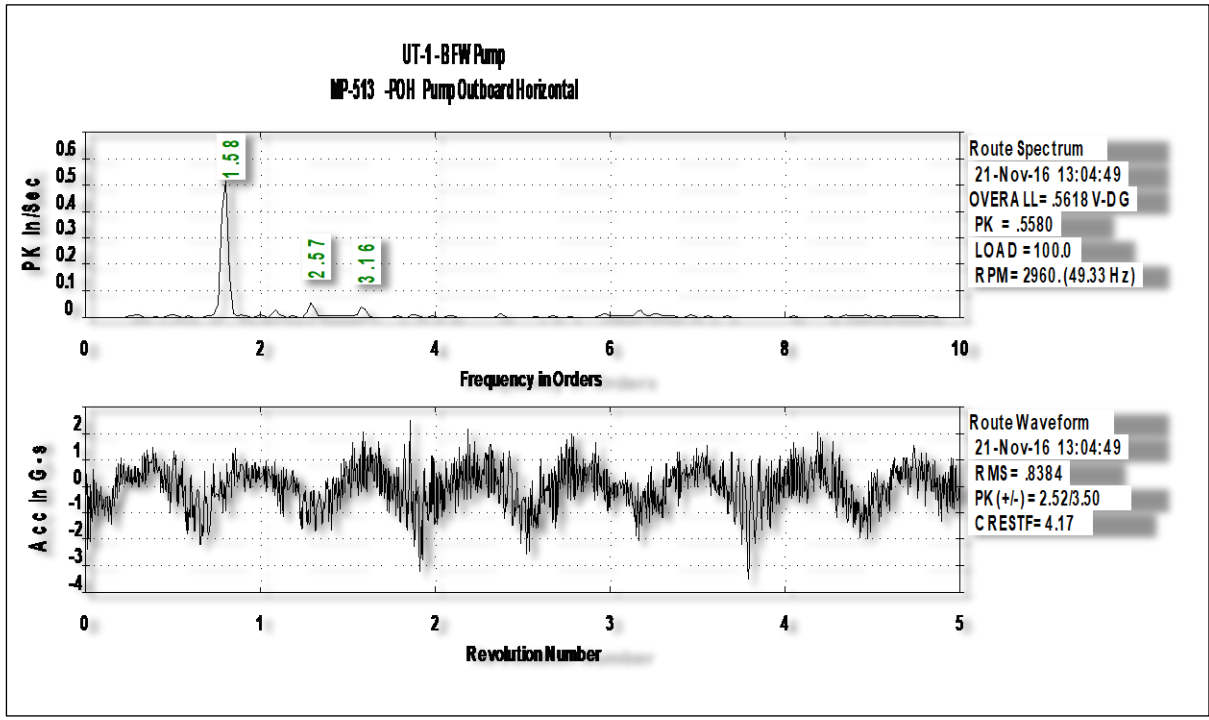
- De-superheating boiler feed water pump had high vibration issue for past 19 years
- Vibration was found high at I/B horizontal up to 1.1 inch/sec & at O/B horizontal up to 0.6 inch/sec pk
- Dominant vibration frequency in spectrum was 1.58X order
- Frequent I/B bearing failures with vibrations increasing even further
- Multiple overhauls performed in the past to resolve this problem, but the issue persisted
- Pump is operated on recommended differential pressure range (180 to 200 psi) mentioned in pump data sheet, but vibration remained high.
- Maintenance history of pump was not available prior to year 2005
- This machine is old and commissioned in 1967. Machine manual and performance curve are not available

Trouble Shooting:

Vibration Analysis data was reviewed, and it revealed predominant vibration at **1.58X(non-synchronous).** Pointing out to 3 possible issues as per vibration literature

- ✓Bearing fault frequencies (Bearings Nos & fault frequencies are provided in slide 11)
- ✓Transmitting vibration from neighboring machines
- ✓Resonance frequencies





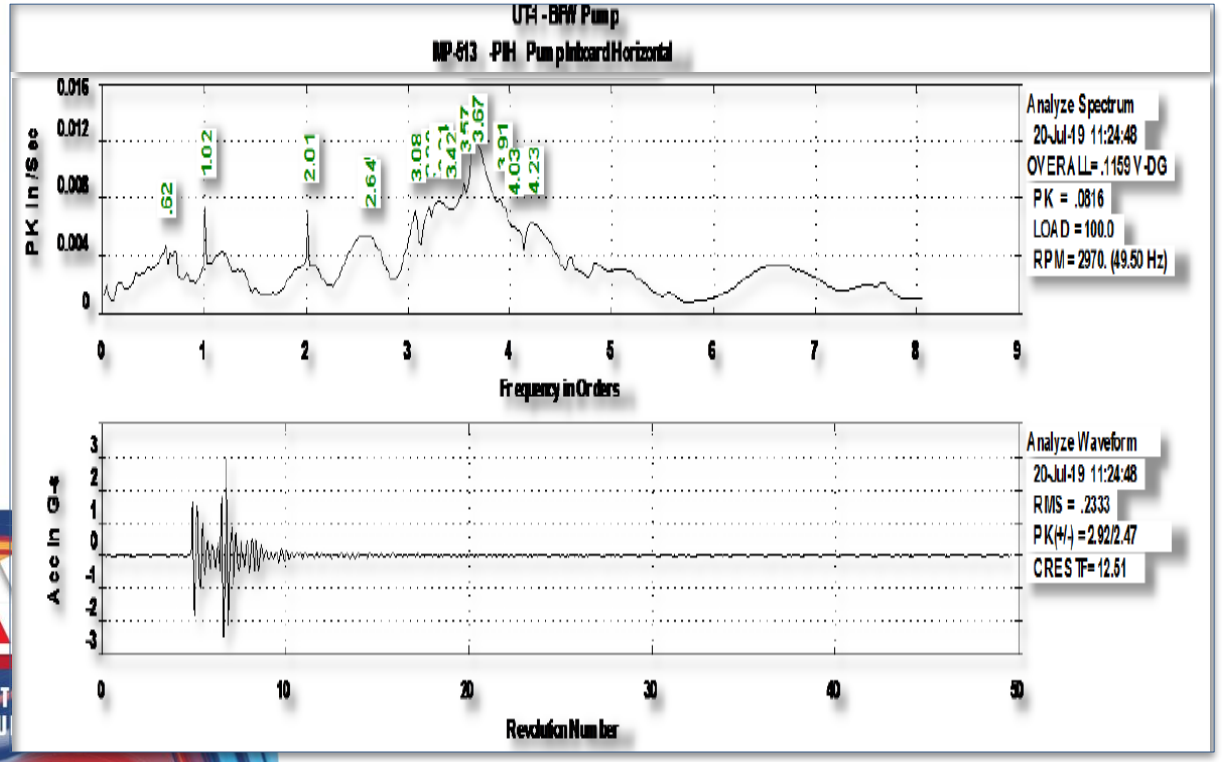
Bump Test

Note:

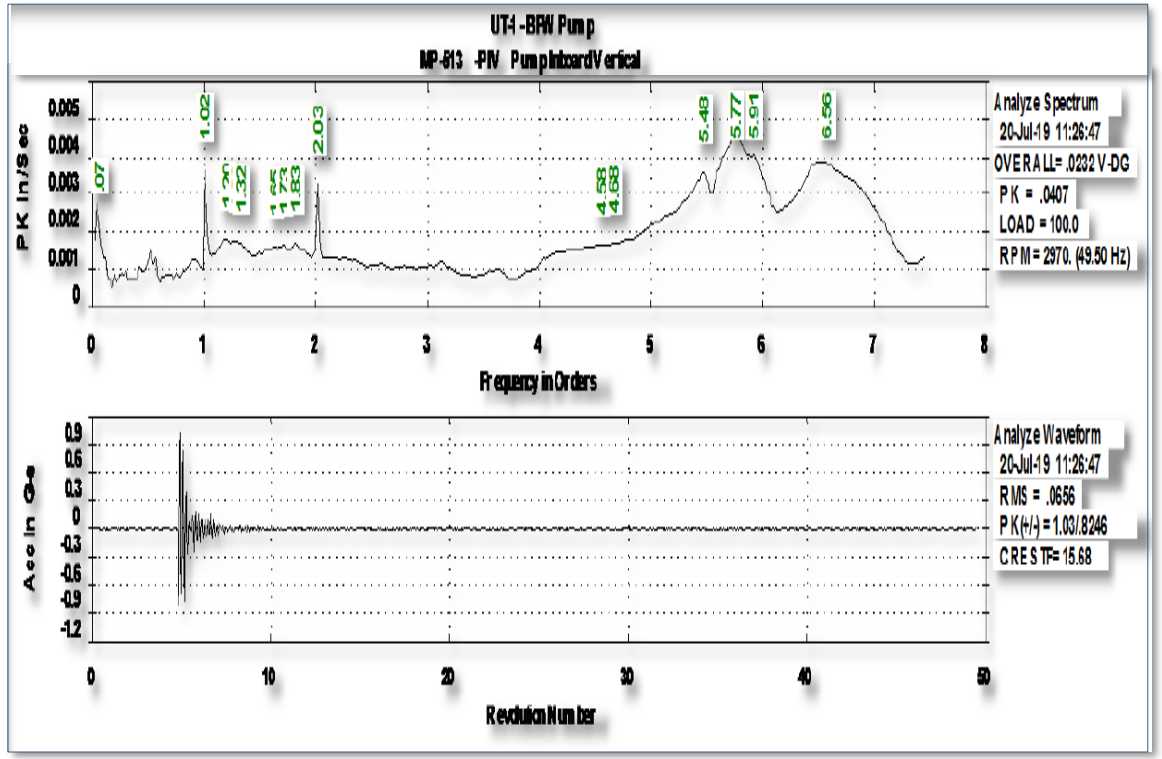
Bump test revealed resonant frequency at 3.6X & 5.7X order.

It confirms that issue is not related to pump's natural frequency or resonance.

Bump test on pump



Bump test on pump foundation



Observations & Rectification:

Upon dismantling bearings condition, impeller, wear ring, throat bush clearances, fits values, alignment and rotor balancing were checked.

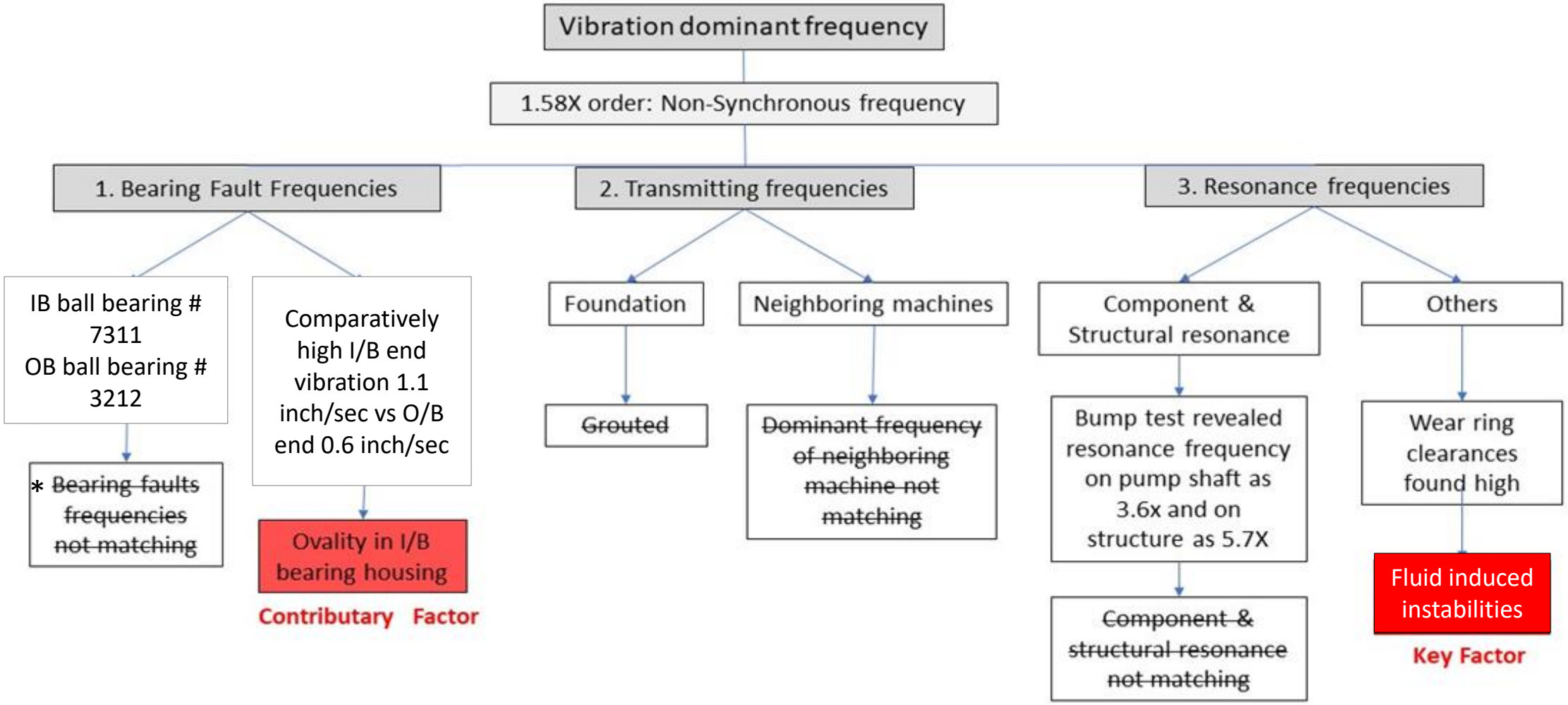
Based on which, following were the observations

1. Both(2ea) impeller wear ring clearances found high at 0.026” vs API-610 recommended value of 0.017”
2. Ovality of 0.005” was observed in I/B bearing housing
3. I/B ball bearings were polyamide caged(max operating temp limit of polyamide caged bearing is 120 ℃), while this pump service temperature is 130 ℃.
4. Balancing of rotor and machine alignment were found within acceptable range

Action taken:

1. Wear ring clearances were newly fabricated to maintain correct clearances. Moreover, wear ring were additionally fabricated and introduced in warehouse as spare item.
2. Machining of I/B bearing housing and installation of sleeve ring was done, to address ovality issue. Moreover, I/B bearing was modified with steel caged ball bearing.

Fault Tree Analysis (FTA):



***Bearing fault frequencies**

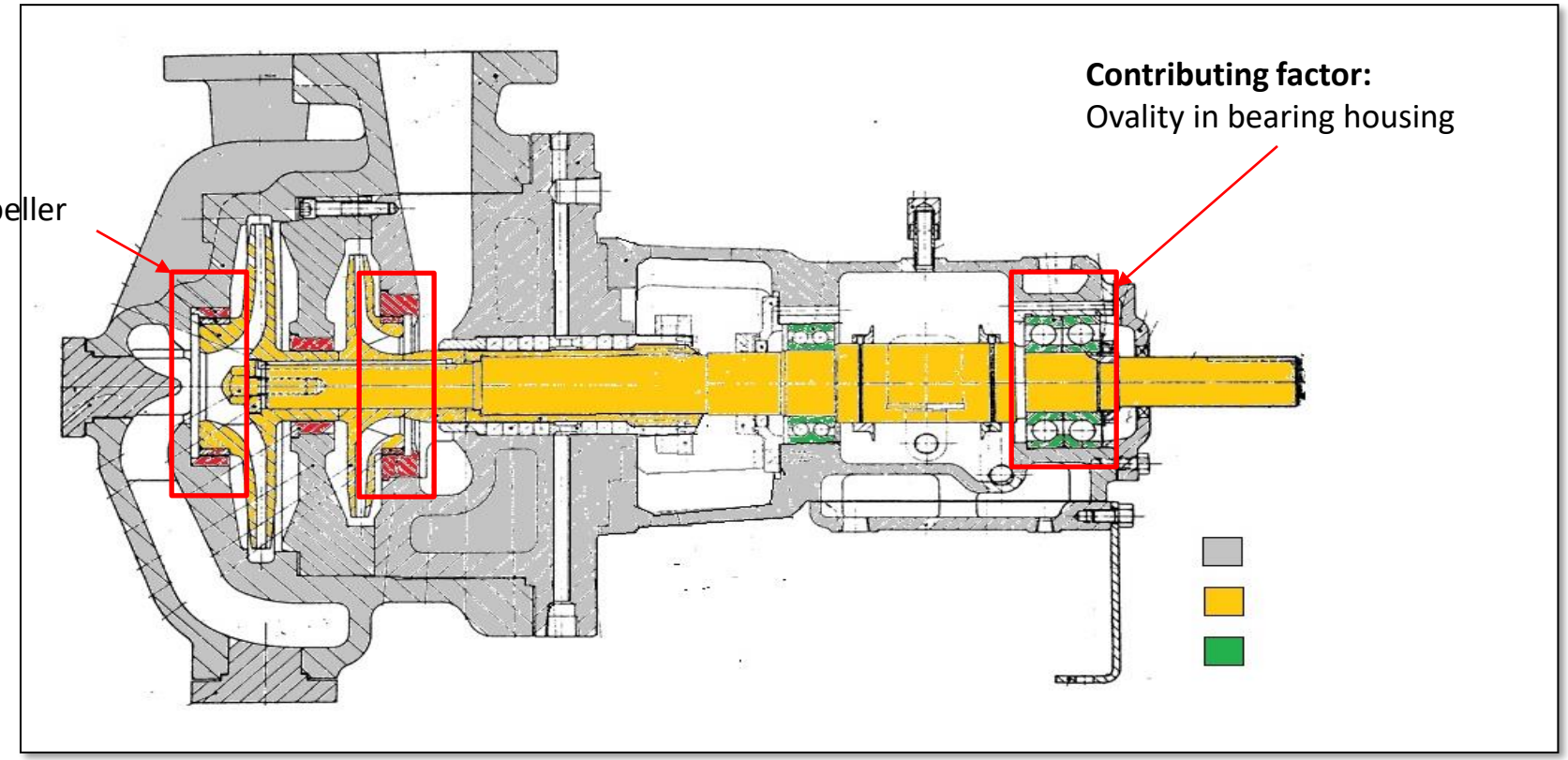
Bearing # 7311: **BPFO**: 4.8, **BPFI** 7.2**, FTF** 0.4, **BSF** 2.07

Bearing # 3212: **BPFO**: 7.78, **BPFI** 10.22, **FTF** 0.43, **BSF** 3.15

Root Cause:

Method of rule of elimination was utilized to identify the cause of the problem. Based on analysis, it revealed that dominant frequency 1.58X was appearing in vibration spectrum, due to increased impeller wear ring(both) clearances (key factor) & issue of comparatively high vibration at pump I/B end (vs O/B end) was caused by ovality in bearing housing (contributing factor).

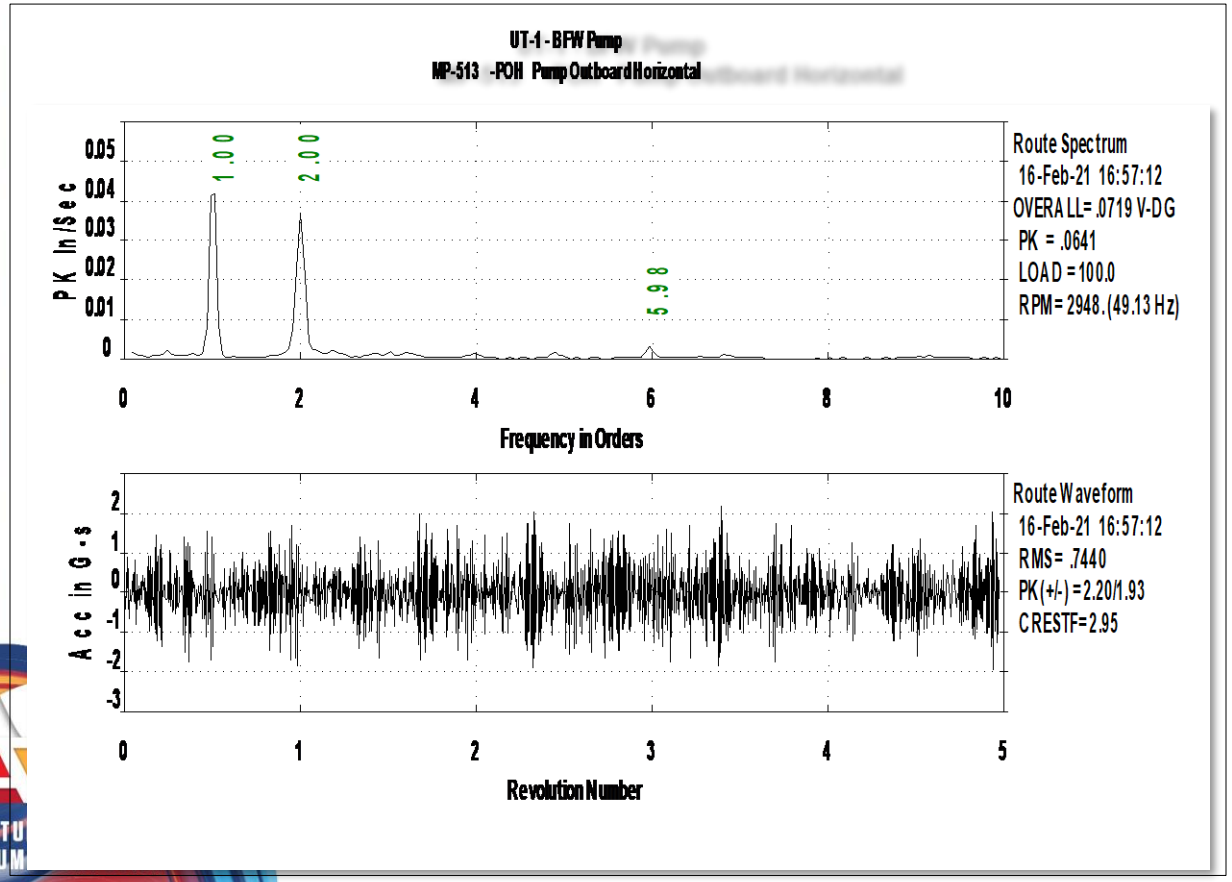
Key factor:
Increased impeller wear ring clearances

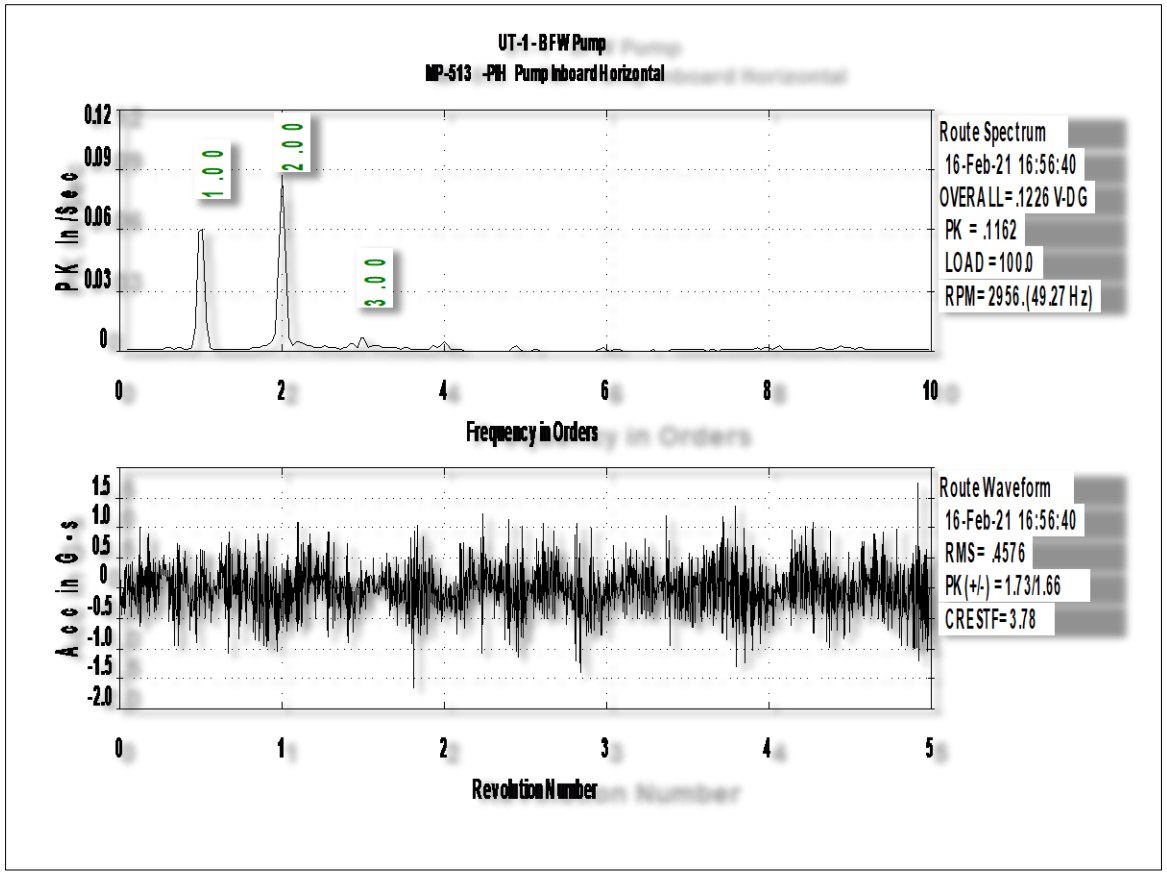


Results :

Machine was started on 16 Feb-2021, after performing corrective actions. Vibration values of pump were reduced from 1.1 inch/sec to 0.10 inch/sec pk at same operating parameters. Dominant frequency of 1.58x order present in previous spectrums was completely vanished. Currently, vibrations of machine are running normal.

Spectrums after overhaul





Lesson Learnt:

- Increased wear ring clearances can produce fluid induced instabilities that leads to high vibration at non-synchronous frequencies

- Maintenance history of the pump to be properly recorded, otherwise it cause problem in troubleshooting of machine faults

- Explore using of nonmetallic wear rings in centrifugal pump to keep clearances even below API recommended clearances. Non-metallic wear ring with reduced clearances bears more radial load, reduces chances of pump seizure and improves pump efficiency by Lomakin effect.

- In addition to this, complex issue of vibration can sometimes be resolved by following basic rule of maintenance repair, such as adjustment of wear ring clearance to proper limit

References:

https://www.maintenance.org/topic/crude-oil-pump-with-1-3x-to-1-4x-running-speed-but-not-high-all-the-time

https://www.maintenance.org/topic/is-it-rotating-cavitation?reply=39959094296389904 6#1811088793

https://www.pumpsandsystems.com/power-wear-rings-part-two-efficiency

API-610 centrifugal pump 11th edition 2010

Vibration Analysis Training Manual– Category II by Mobius institute- Chapter 6 page 27

Thank You

ASIA TURBOMACHINERY & PUMP SYMPOSIUM

Pump Data Sheet

APPROVED
FOR CONSTRUCTION - FLUOR CORP.
JAN 23 1967

SPECIFICATION SHEET
CENTRIFUGAL PUMP
THE FLUOR CORPORATION, LTD.

4-607

SHEET NO. P-512 REV. 1
JOB NO. 4253 DATE 7-22-66
BY H.E.S CHK'D.

FOR ESSO WEST PAKISTAN FERTILIZER CO. ITEM NO. P-513
SITE DAHARKI, W. PAKISTAN UNIT CONDENSATE TREATMENT
SERVICE DESUPERHEATING WATER PUMP MOTOR DRIVE ✓ TURBINE DRIVE —
PUMP MFR. WORTHINGTON SIZE & TYPE 1½ HNB-103 NO. REQ'D. ONE

OPERATING CONDITIONS

LIQUID	CONDENSATE	US GPM @ P.T. NORMAL	DES. 30
		DISCH. PRESS. PSIG	222
PUMP. TEMP. °F	250	SUCT. PRESS. PSIG	22
SP. GR. @ P.T.	0.94	DIFF. PRESS. PSI	200
VAP. PRESS. @ P.T. PSIA	25	DIFF. HEAD FEET	492
VISC. @ P.T. - SSU		NPSH AVAIL. @ P.T. - FEET	7
CORR./EROS. DUE TO		HHP	3.5

PERFORMANCE

PROPOSAL CURVE NO.	MCN-8663
NPSH REQ'D - (WATER) - FT.	3.95
NO. OF STAGES	2
RPM	2900
DES. EFF.	30%
BHP	17.5
MAX. BHP DES. IMP.	26.4
MAX. HEAD DES. IMP. - FT.	512
MIN. CONTINUOUS GPM (BY MFR)	13.5
ROTATION FACING COUPLING END	CCW
WATER COOLING	REQ'D
BEARINGS	YES
STUFF. BOX	YES
PEDESTAL	NO
GLAND	NO
TOTAL WATER REQ'D. GPM	4
PACKING COOLING	NONE
FLUSHING	PRODUCT RECIRCULATION FROM DISCH. TO MECH. SEAL FACES
AUX. PIPING	FLUSHING BY WORTHINGTON.

CONSTRUCTION & MATERIALS

CASING - MOUNTING (CENTERLINE X) (FOOT) (BRACKET) (VERTICAL)
SPLIT (AXIAL) (RADIAL X)
TYPE (SINGLE VOLUTE) (DOUBLE VOLUTE) (DIFFUSER)
TAPPED OPENINGS (VENT) (DRAIN X) (GAGE CONNS.)

NOZZLES	SIZE	ASA RATING	FACING	POSITION
SUCTION	3"	300#	RF	TOP
DISCHARGE	1½"	300#	RF	TOP

IMPELLER DIA. DES. 6½" - 9¾" MAX. 9½" - 11¾" TYPE ENCLOSED
BEARINGS-RADIAL BALL THRUST BALL LUBE OIL RING
COUPLING & GUARD THOMAS DEP-C & YRC WITH SPACER DISCS BASEPLATE DRAIN PAN
PACKING NONE
MECH. SEAL CODE 8STUM MFR. JOHN CRANE TYPE 21 XPIDI
CASING ORIGINAL PRESSURE 200 PSIG @ 72°F.
MATERIAL CODE - CASINGS (ASTM A-216-GRADE WCB) INTERNALS I (ASTM A 276-T6)

I - CAST IRON	INTERNALS CODE	I	B	S	C	x
B - BRONZE	IMPELLER	I	B	S	C	ASTM A 743-GRADE CA-15
S - STEEL	INNER CASE PARTS	I	I	S	C	
C - 11-13% CHROME	SLEEVE (PACKED)	Ch	Ch	Af	Af	—
A - ALLOY	SLEEVE (SEAL)	C	C	C	C	AISI 420
h - HARDENED	WEAR PARTS	I	B	C	C	ASTM A 743-GRADE CA-40
f - FACED	SHAFT	S	S	S	S	SAE 4140
x -	GLAND PLATE					11-13½ CHROME

SHOP TESTS	REQUIRED	WITNESSED
RUNNING PERF.	YES	YES
NPSH	NO	NO
HYDROSTATIC 560 PSIG		NO
MAX. ALLOW. W.P. 600 PSIG		850 °F.
WEIGHTS: PUMP AND BASE 1140 LBS		
MOTOR TURBINE		

MOTOR DRIVER BY FLUOR.
ITEM NO. P-513M MTD. BY FLUOR.
METRIC HP 20 RPM 3000 FRAME
MFR.
TYPE INSUL.
ENCL. TEMP. RISE °C
VOLTS/PHASE/CYCLES
BEARINGS LUBE
FULL LOAD AMPS.

TURBINE DRIVER BY
ITEM NO. MTD. BY
HP RPM MAT'L
MFR. & TYPE
INLET STEAM PSIG TEMP. °F
EXHAUST
STEAM RATE - F.L. #/BHP/HR
BEARINGS LUBE

NOZZLES	SIZE	ASA RATING	FACING	POSITION
INLET				
EXHAUST				

MFR. FINAL DATA (AS BUILT)
ACTUAL IMPELLER DIA.
TEST CURVE NO.
OUTLINE DWG. NO.
PUMP SECT. DWG. NO.
SEAL DIM. DWG. NO.
PUMP SERIAL NO.

API SPEC. 610 & APPENDICES I & II GOVERN UNLESS OTHERWISE STATED.
EXCEPTIONS (ITEMIZE): NO CORTEC-BEARING MATERIALS SHALL BE PROVIDED IN CONTACT WITH PUMPED FLUID DUE TO PRESENCE OF H_2S & CO_2.

PUMP PRICE	REVISIONS:
EXTRAS	1 - 1/10/67 REVISED PER PURCHASE
DRIVER PRICE	
STARTER PRICE	
ESTIMATED FREIGHT	
TOTAL EVALUATED PRICE	
SHIPMENT PROMISED	
MEETS SPEC. (YES) (NO)	

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10-60