Journal Bearing Upgrade to Solve Reliability Issues in an Accessory Gearbox.

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INTRODUCTION

• Accessory gearbox on gas turbine - generator

• Gas turbine vital for operation of Alpine field on the north slope of Alaska

• Accessory gearbox journal bearings failed on several occasions – brought gas turbine down

• Failures attributed to varying load directions

• Redesigned to replace sleeve bearings with tilting pad journal bearings
ConocoPhillips Alpine Field

- Operator: ConocoPhillips
- Located 40 miles west of Kuparuk.
- Alpine is the largest onshore oil field discovered in North America in the past 20 years.
- It began producing in late 2000.
- Its 2008 net crude oil production was 44MBD.

Data from ConocoPhillips website
Gearbox

- Motor drives gearbox to start the gas turbine
- Also driven off the gearbox:
  - Hydraulic pump
  - Oil pump
  - Fuel pump – not used
- Once started the motor disengages and the turbine drives the pumps
- Changing from driving to driven changes bearing load directions
Gearbox

**TOP VIEW**
- Drives Hydraulic Pump
- Drives Fuel Pump
- Drives Lube Oil Pump
- Input from Gas Turbine

**SIDE VIEW**
- 129 Teeth
- 39 Teeth
- 134 Teeth
- 19 Teeth

RPM:
- Drives Hydraulic Pump: 11,000 RPM
- Drives Fuel Pump: 1,620 RPM
- Drives Lube Oil Pump: 1,560 RPM
- Input from Gas Turbine: 5,359 RPM
- 19 Teeth: 11,000 RPM
Gearbox

Center distances & rotation confirmation.
Input From Starter Motor

Gearbox

Fuel Pump

Gas Turbine Coupling

Hydraulic Pump

Lube Oil Pump
Gearbox - Turbine Side
Failed Bearings
Failed Bearings

#4 Journal Bearing - As installed
Failed Bearings

#4 Journal Bearing - Looking at Upper Half
Failed Bearings

#4 Thrust Bearing - As Installed
Failed Bearings

#4 Thrust Bearing - Looking at Upper Half
Load Analysis

- Had center distances, speeds, and ratios
- Estimated pressure and helix angles
- Estimated hp
  - For pumps used aux motor sizes
  - Used motor HP for startup
- Two scenarios
  - Start up – driven by motor
  - Running – driven by turbine
Bearing Numbering

**TOP VIEW**

- Bearing 5
- Bearing 3
- Bearing 6
- Bearing 4

**SIDE VIEW**

- Shaft 4
  - #1: 39 Teeth, 5,359 RPM
  - #4: 129 Teeth
- Shaft 5
  - #5: 134 Teeth
  - #3: 19 Teeth, 11,000 RPM
  - #3: 1,560 RPM

RPM:
- Shaft 4: 1,620 RPM
- Shaft 5: 1,560 RPM

Teeth:
- Shaft 4: 129 Teeth
- Shaft 5: 134 Teeth
- Shaft 1: 39 Teeth
- Shaft 3: 19 Teeth
Load Analysis – Bearing 6

LOAD AT START-UP

1250 lbs LOAD @ TDC

22.5°

BEARING SPLIT LINE

CASE SPLIT LINE

RUNNING LOAD

190 lbs LOAD 4° OFF BDC
Load Analysis – Bearing 3

LOAD AT START-UP

228 lbs
LOAD 21°
OFF BDC.

12.5°

RUNNING LOAD

218 lbs
LOAD 33°
OFF BDC.
Failed Bearings

- Bearings from shaft 4 and 5 failed
- Shaft 4 experiences severe load angle changes
- Shaft 5 not as severe
- Decided to upgrade to Tilting Pad Journal Bearings
  - Reduce sensitivity to load angles
- Installed and running successfully
Tilting Pad Journal Bearings – Bearing 3

- Rotation
- CASE SPLIT LINE
- BEARING SPLIT LINE
- "A"
- "B"
- 218 LBS RUNNING LOAD 33\(^\circ\) OFF BDC
- 228 LBS START-UP LOAD 21\(^\circ\) OFF BDC

Dimensions:
- 2.375
- 2.757 ± .001
- 2.759 ± .001
- 2.762 ± .001
- 1.750 PAD LENGTH
- (4.062 ± .006 CASE BORE)
- (4.063 ± .006 CASE BORE)

Section "A-A"
Tilting Pad Journal Bearings – Bearing 4

218 LBS RUNNING LOAD
33° OFF BDC

228 LBS START-UP LOAD
21° OFF BDC

GEAR SIDE
2.368 (DISTANCE BETWEEN COLLARS)

SECTION “A—A”
2.762 ± .000 SEAL D/A. TYP.
2.757 ± .000 SET BORE
1.750 PAD LENGTH
4.063 ± .000 CASE BORE
2.759 ± .000 PAD BORE
1.715 ± .000

CASE SPLIT LINE
BEARING SPLIT LINE
"A"
"B"
"A"
"B"
"A"
"B"
Tilting Pad Journal Bearings – Bearing 5

- 1250 LBS START-UP LOAD @ TDC
- 190 LBS RUNNING LOAD 4" OFF BDC
- GEAR SIDE
- SECTION "A–A"
CONCLUSIONS

• Changing from a driver to a driven caused bearing load angle changes

• Tilting Pad journal bearings are not as sensitive to these load angle changes

• Bored out the case to accept the larger TPJ’s

• Installed and running successfully for a few years now – several starts

• ConocoPhillips has plans to upgrade spare box