ASIA TURBOMACHINERY & PUMP SYMPOSIUM
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Dry Screw Compressor Trip on Axial Displacement during Cold Start

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Abstract

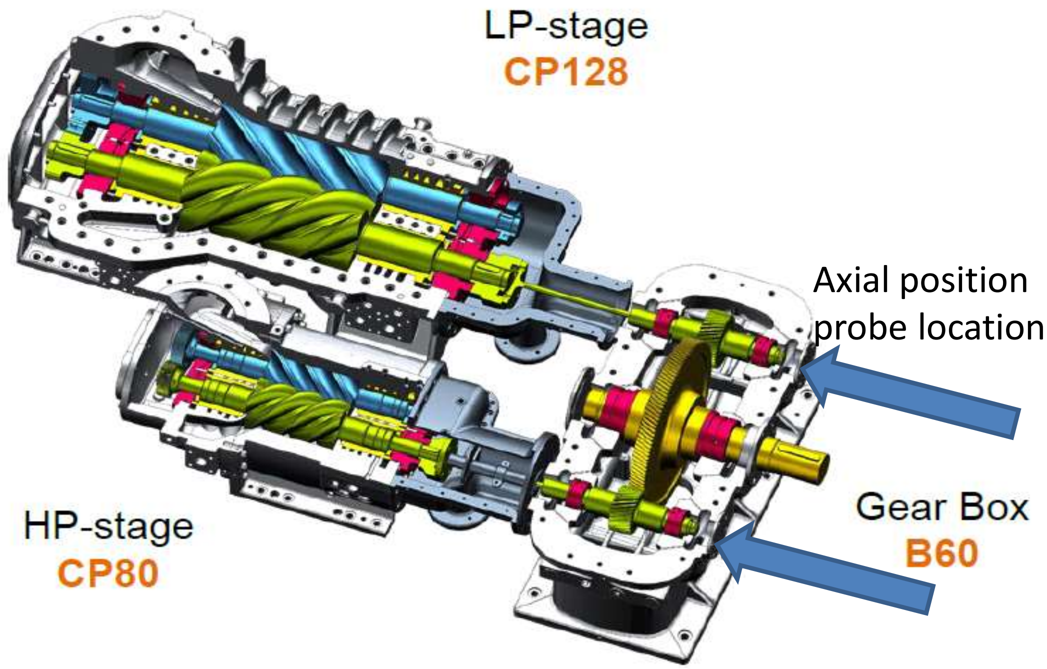
- Dry Screw Compressor experienced HH axial displacement trip within 15 minutes after every cold start-up since the MMS system upgrade in 2016.
- Failed attempt to successfully restart this compressor after every planned maintenance activity has caused disruption to Operations Process planning.
- Trip recurrence data indicated rotor thermal growth beyond trip limits. Once the compressor trips, the axial probe position needs to be adjusted to allow a successful re-start of the compressor.
- Further analysis of rotor thermal growth ascertained that during the first few minutes the effect of rotor thermal expansion was more dominant than that of the gearbox casing, which only occurred about two hours later.
- Correlation between the trip recurrence and the compressor thrust bearing type (fixed pad) was also evaluated as part of the investigation.
- Wear allowance of the thrust bearing and the rotor to casing clearance were evaluated in order to determine the trip effects to the overall train integrity.
- Reevaluation of the protection mechanism of the machine was done and changes made to remove the trip on axial.
- This case study presents details of the problems, background and the engineering assessment to achieve viable and fit-for-purpose solution.

Agenda

1. Machine Detail
2. Problem Statement / Observations
3. Trend
4. Analysis
5. Solution
6. Broader learnings

Machine Details

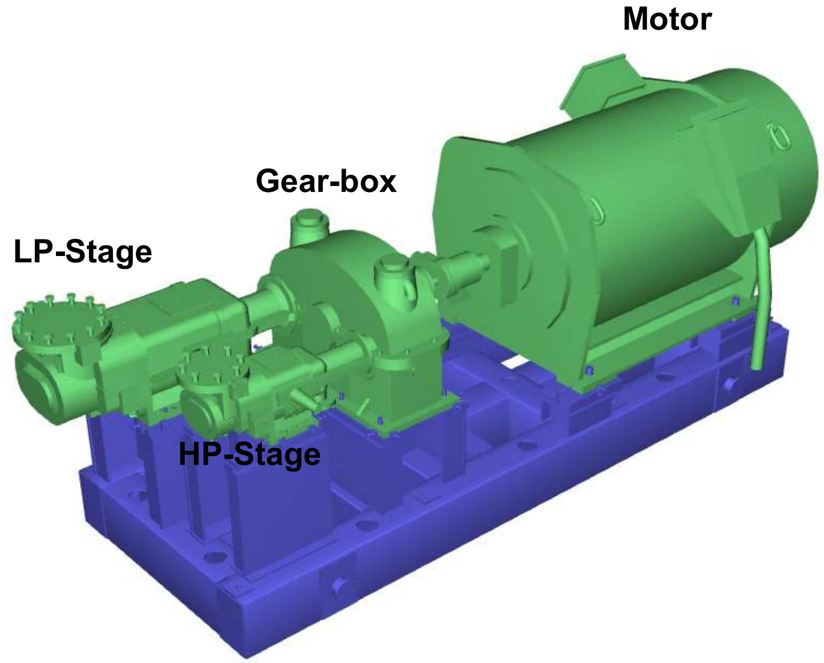
- Propane recovery dry screw compressor
- Motor + step up gearbox driven stage machine, rigidly coupled
- Preventive maintenance Interval: every 10 months for strainer cleaning
- Fixed pad thrust bearing on the compressor male rotor.
- 1 axial probe per stage of compressor mounted on pinion rotor NDE side.



Machine Details

- The following upgrades were carried out on Compressor train during recent turnaround
  - ➢ HP-stage compressor upgraded to CP80 model as SKUES10 model is no more supported by MAN
  - ➢ Gear box upgrade due to change in compressor speed which is required for upgraded HP stage model CP80
  - ➢ Stage-1 & 2 Discharge muffler upgrade from Normal screen type to Lamda type design to mitigate fouling concerns
  - ➢ Duplex suction strainer installation for LP compressor to eliminate downtime required for strainer cleaning
  - ➢ BN3500 Upgrade and conversion to Proximity probe

- Compressor tested post above mentioned upgrades and observed with Gear box Bull Gear (Low speed) shaft high vibration up to ~92µm (expected <30µm)



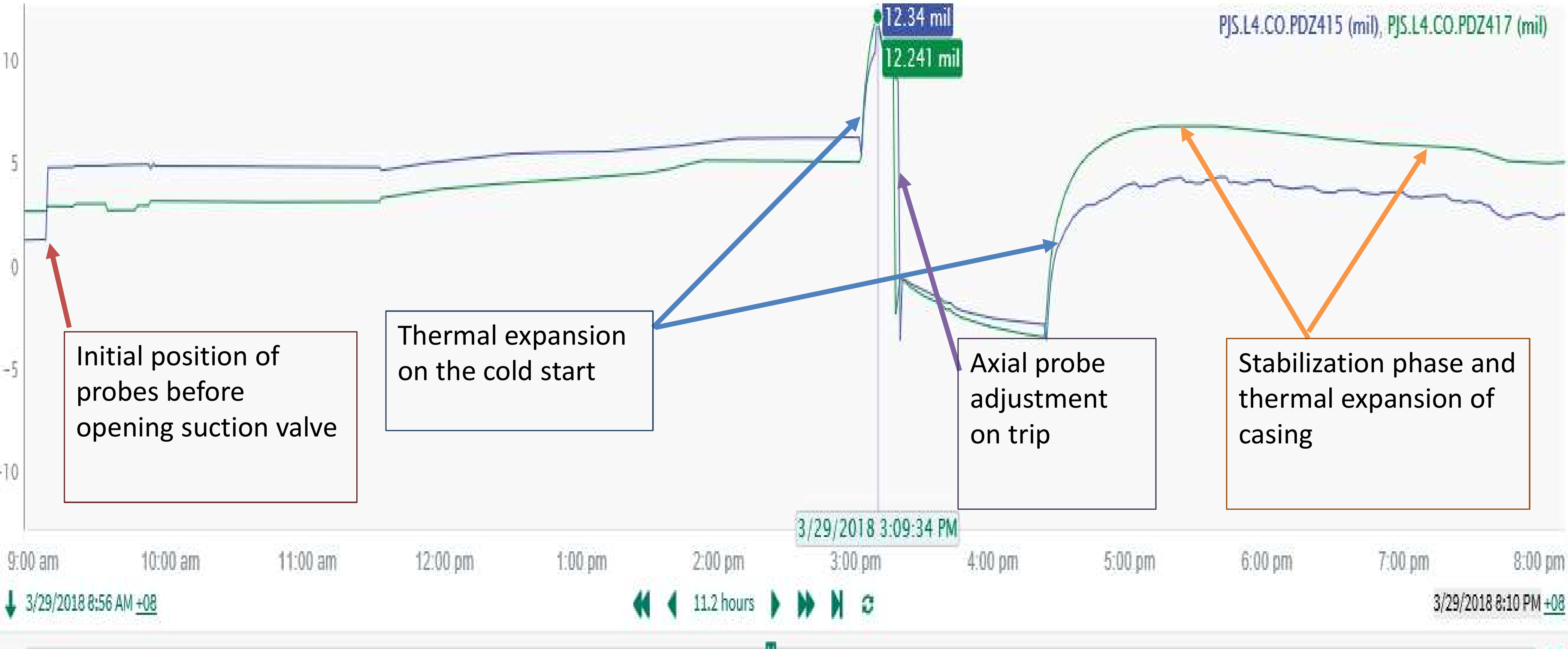
Problem Statement /Observations

- Compressor BN system installed in 2016. Prior to upgrade, only casing vibration.
- Since upgrade, upon every cold start, the compressor trips on high axial position.
- Due to space constraint on the compressor, the axial position probes for the compressor were installed on the gearbox pinion rotor NDE side.
- Thrust position alarm and trip: Alarm ±8 mils, trip ±12 mils.
- Thrust position increase during start up is >12 mils at steady rate for the first 15 mins, causing trip of the compressor.

Problem Statement /Observations

- Axial probe adjustment done to enable the start of the machine, post trip.
- The axial position value stabilizes in 1 hour and then starts reducing from then on for a few hours.
- Similar increase in thrust position value seen in last 3 start up since upgrade in 2016.
- Thrust position increase seen on both compressor stages but NOT on the bull gear rotor.

Trends



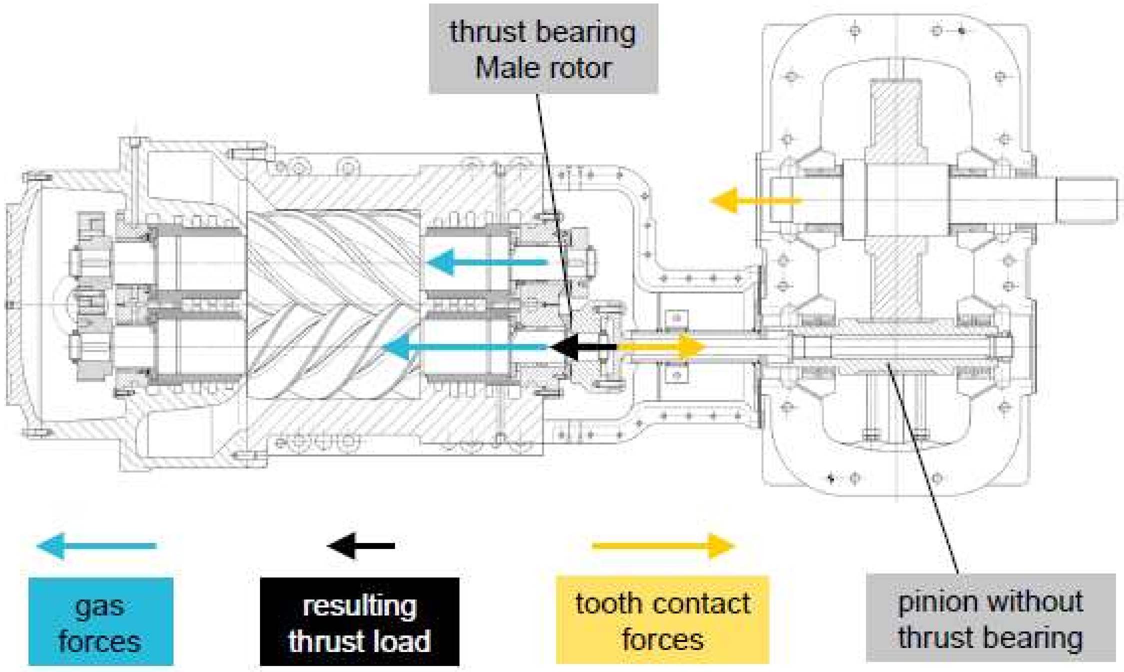
12.34 mil
12.241 mil
PJS.L4.CO.PDZ415 (mil), PJS.L4.CO.PDZ417 (mil)
10
5
0
-5
-10
Initial position of probes before opening suction valve
Thermal expansion on the cold start
Axial probe adjustment on trip
Stabilization phase and thermal expansion of casing
3/29/2018 3:09:34 PM
9:00 am
10:00 am
11:00 am
12:00 pm
1:00 pm
2:00 pm
3:00 pm
4:00 pm
5:00 pm
6:00 pm
7:00 pm
8:00 pm
3/29/2018 8:56 AM +08
11.2 hours
3/29/2018 8:10 PM +08

Analysis

- Similar trend observed on every cold start and similar increase is observed on the stage 1 & stage 2 compressor axial position.
- During the increase of thrust position value, the thrust bearing temperatures for both stage 1 & 2 are steady and well within acceptable limits.
- Compressor radial and vibration parameters are also normal during this period.
- Above data shows that the thrust position increase during start up is not indicative of any damage to the thrust bearings or the rotors.

Analysis

- Thrust position increase associated with combined thermal expansion of the pinion and torsion bar (rigid coupling).
- The location of the thrust bearing is shown. In the picture on the right, the screw thermal growth is towards the left and the pinion + torsion bar growth is towards right.



Analysis

- The combined length of the torsion bar + the pinion rotor is about 700mm.
- During start up, the temperature increase of the rotor is about 30DegC.
- The thermal expansion of the rotor for a temperature rise of 30 DegC was calculated (from ambient temp to operating temp).
- During the initial few minutes of run, only the rotor thermally expands. Casing thermal expansion is slower.
- Axial probe mounted on the casing end cover and hence, sees only rotor growth for first few minutes of run.

Analysis

Rotor thermal expansion calculation:
Only rotor thermal expansion considered for the first 15 mins of operation. It is expected that the casing thermal would be more gradual.

$\mathbf{\Delta L = \alpha L_o \Delta T}$

ΔL – thermal expansion of rotor (in mm)
α - Coefficient of thermal expansion of rotor material (12.7×10^{-6} for pinion + torsion bar material – 31CrMoV9
L_o – Length of pinion rotor + torsion bar (in mm)
ΔT – (rotor temperature ~60 degC – ambient temperature ~26 degC)

$\mathbf{\Delta L = \alpha L_o \Delta T =}$ $12.7 \times 10^{-6} \times 700 \times 34$

ΔL = 0.3 mm = 12 mils

Analysis

- Thermal expansion of the rotor is equal to the trip limit on axial position!
- Axial position cannot be exact zero before start and is normally 2-3 mils due to minor movement of the shaft within clearance.
- With current protection system, tripping the compressor within few minutes of start is unavoidable.

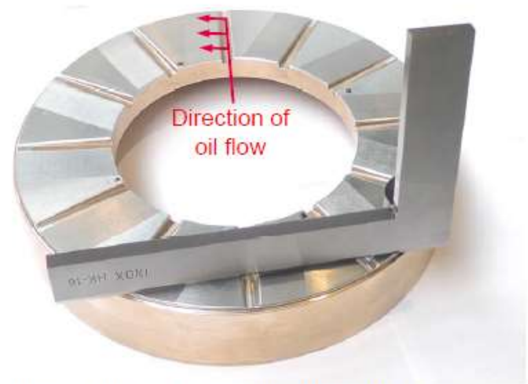
Solution

- Following solutions explored to mitigate this problem:
  - Increase in trip limits
  - Trip on thrust bearing temperature
  - Removal of trip on axial position while keeping its alarm active

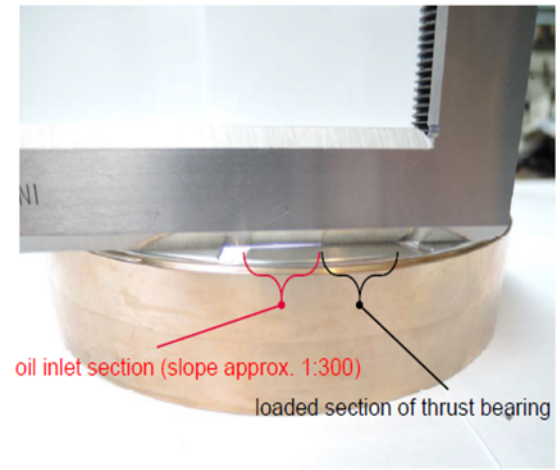
- Of the above proposed solutions, solution 3 was implemented.
- Trip on thrust position was removed and replaced with high-high alarm.

Solution

- Increase in trip limits (not implemented):
  - Current trip limit is more than the thrust bearing clearance and thrust pad allowable wear.
  - Tapered land type fixed pad thrust bearing with allowable wear of 1.18 mils only. Screw clearance 4 mils.
  - Current alarm/ trip values already much more than allowable wear, hence increase of trip not logical.



Picture 1: thurst bearing male rotor overview



Picture 2: thrust bearing detail

Solution

- Trip on thrust bearing temperature (not implemented):
  - OEM recommendation to provide trip on temperature.
  - Thrust bearing temperature probe available in this machine is 1oo1.
  - As such, temperature probes are considered unreliable for tripping as per ExxonMobil standard & hence trip is not provided on temperature.
  - High and high-high alarm provided on thrust bearing temperature conservatively to enable operations response.

Solution

- Removal of trip on axial position while keeping its alarm active (implemented solution):
  - OEM recommendation to remove trip on axial position.
  - When axial position probe is adjusted on trip, the reference position is disturbed and hence the reading is not truly representative.
  - Also, values and variation are way more than the allowable wear and hence the position value is actually irrelevant.
  - Hence, trip removed and replaced with high-high alarm.
  - Combination of thrust position and temperature alarms now in place.

Conclusion

- Axial position trip can be used to protect rotor from touching the casing instead of monitoring / protecting tapered land type thrust bearings.
- For this configuration of machine, it is unlikely that the rotor would touch the casing before the bearing is damaged.
- Axial position for bearing protection might make sense for other bearing configurations for tilting pad or rolling element bearings.
- In conclusion, for this machine and bearing configuration, axial position trip is not suitable and not recommended.

Broader learnings

- EM critical machinery monitoring and protection guidelines mandate provision of trip on axial position. Learning is: there are some exceptions to the standard rules.
- Trip on thrust position not relevant in fixed pad thrust bearing machines with rigid couplings.
- Thermal expansion factor to be considered while selecting critical machinery protection on thrust position.

Thank you

Any questions please?

Back Up slides

Thermal growth calculation