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GURU GOBIND SINGH REFINERY
HPCL-MITTAL ENERGY LTD

Case Study:

High vibration problem resolution in centrifugal pump through design change

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Case study abstract

The case study is about single stage API BB2 pump. Pump operates at the temperature of 355 degree C (671 degree F), rated for pumping 442 m3/hr of Hydro-treated VGO (Vacuum Gas Oil) and is driven by a steam turbine.

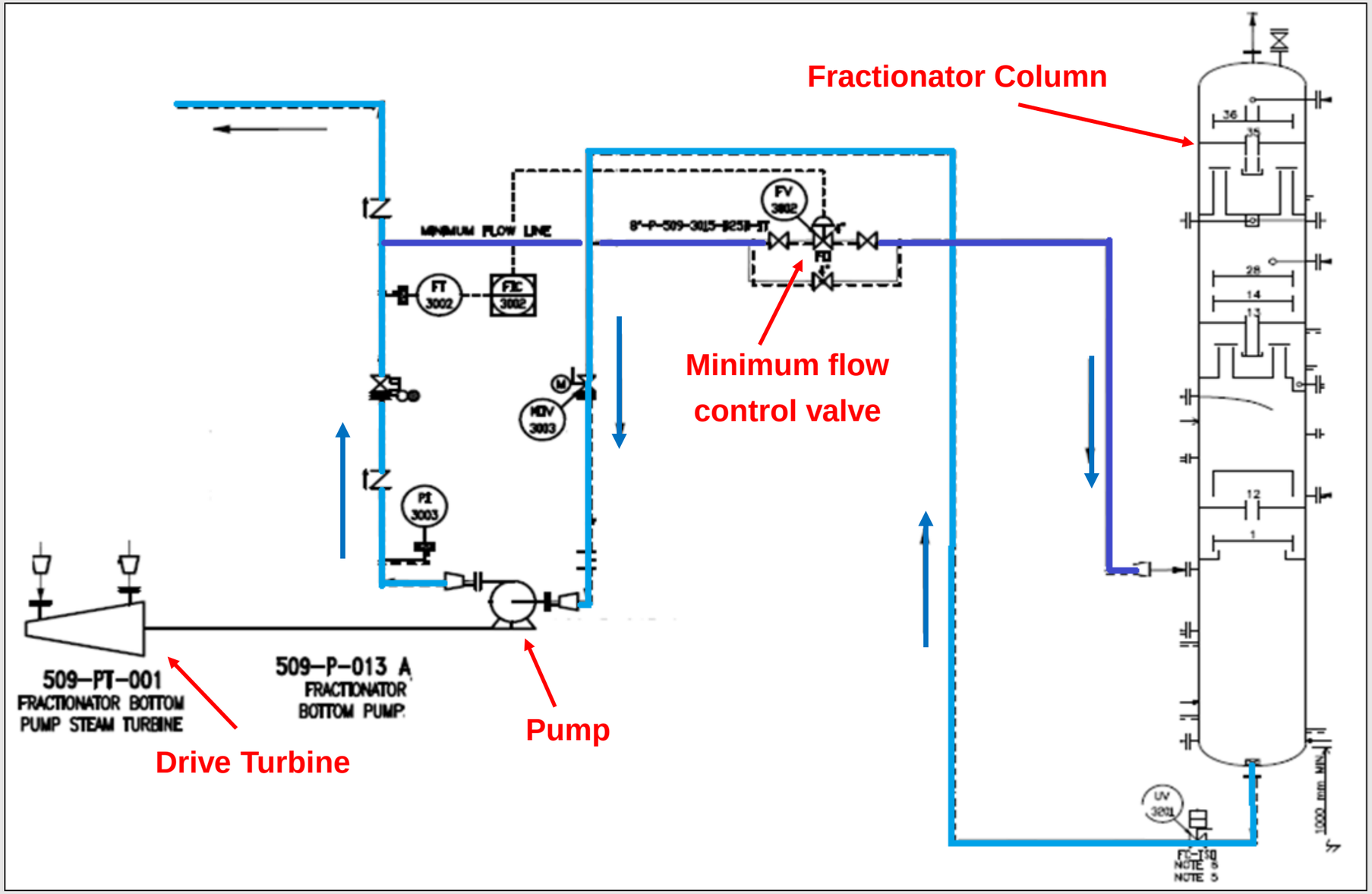
Pump bearing housing at Drive End (DE) side started exhibiting intermittent high vibrations during commissioning phase. This resulted in repeated failure of DE bearing and damage to bearing housing.

Root cause was analyzed as uneven expansion of pump casing during pump warm-up, which misaligns the DE side floating bearing within bearing housing and restrict its axial displacement (bearing used is of deep groove design). As a consequence, thermal growth of pump shaft was restricted and it was rotating in deflected shape, rubbing within throat bushes.

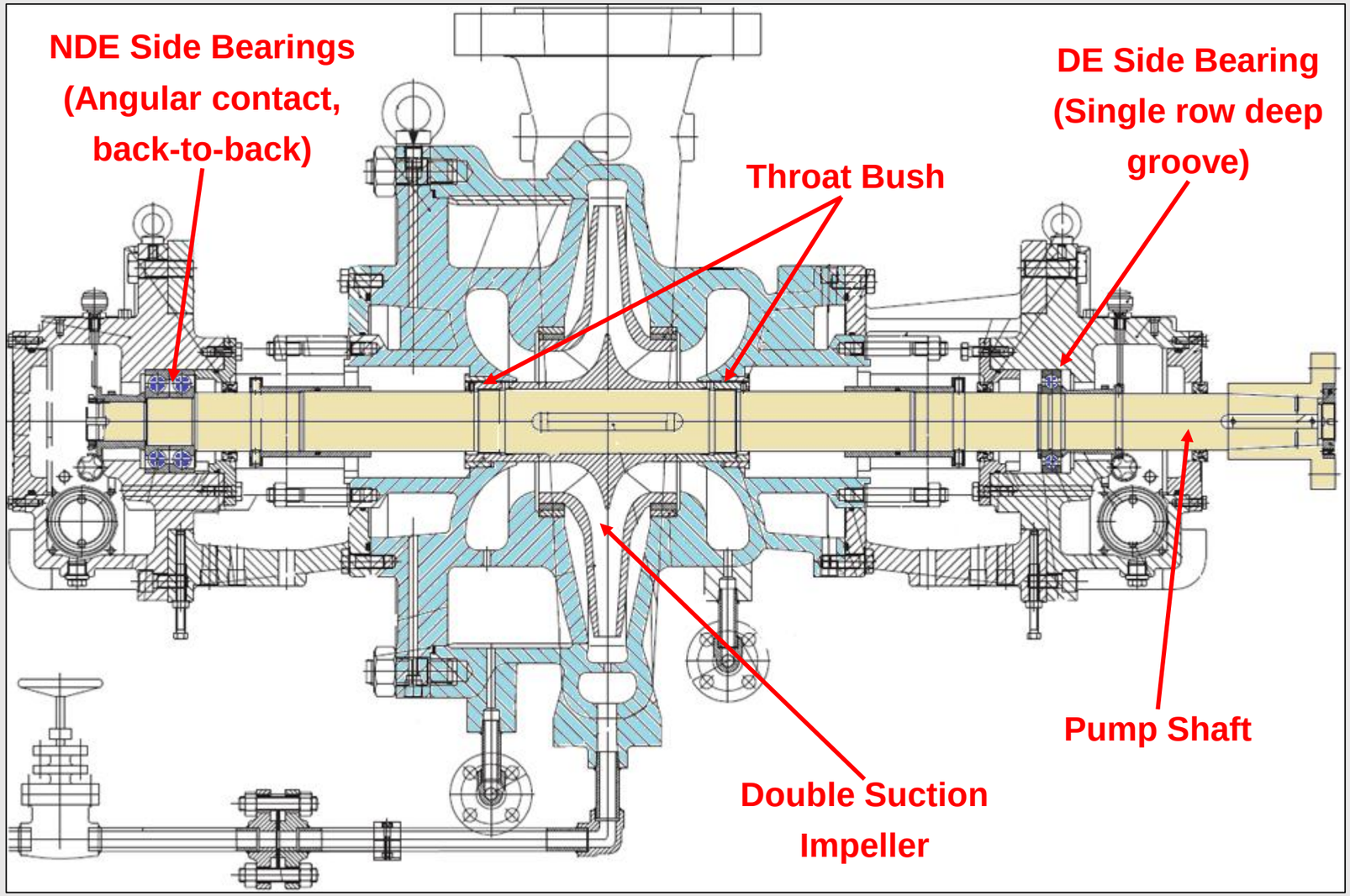
Problem was resolved by replacing the bearing design with NU type Cylindrical roller bearing, which allows higher amount of axial displacement.

This case highlights a balanced approach towards the site investigations, root cause analysis and corrective actions implementation. It also provides hints to address thermal growths issues when equipment operates at very high temperature.

Process Flow Diagram



Pump construction features



Pump Type: Centrifugal, single stage

Driver: Turbine

No of pumps: 2 (Turbine/ Motor driven)

Pumping temp: 355 oC

Differential pressure: 22.1 Kg/cm2g

No. of stages: 1

Impeller config.: Double suction closed

DE bearing: 6213J

NDE bearing: 7311BECBM (Back-Back)

Seal Plan: 11, 53B

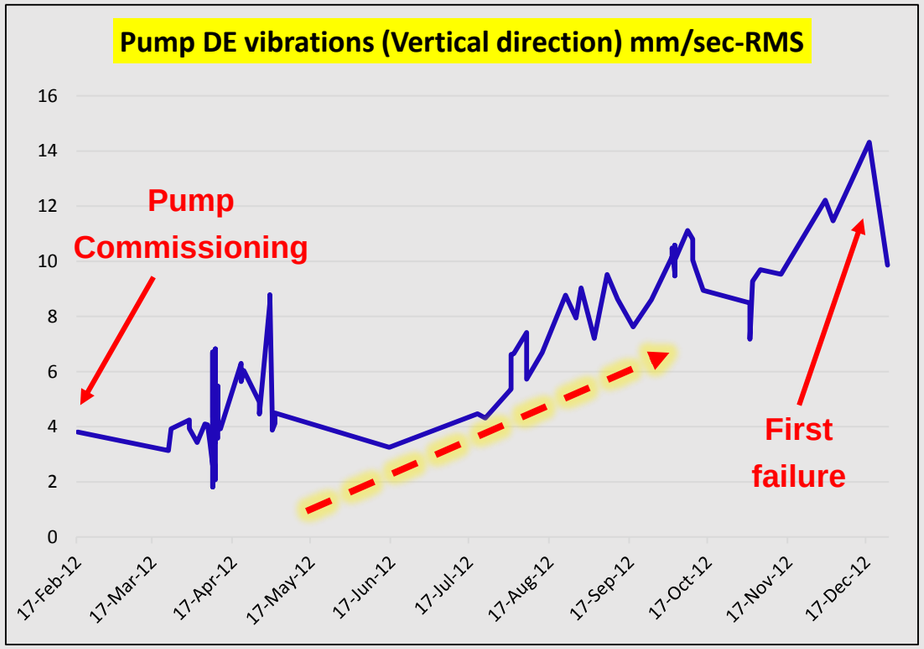
Vibrations monitoring: Offline

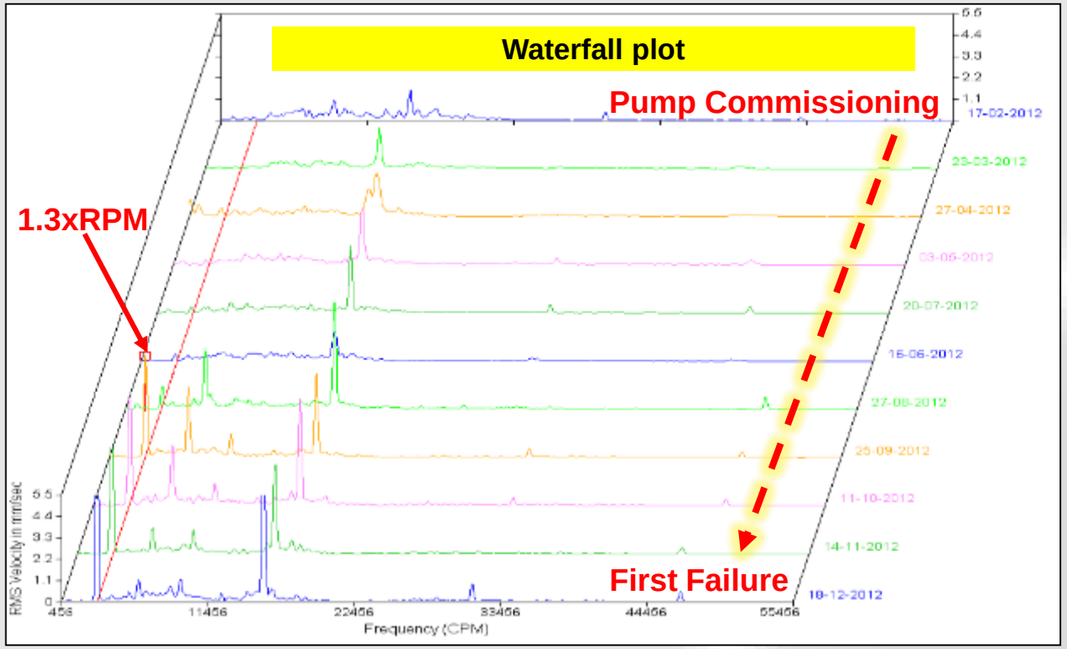
Sequence of events leading to first failure

- Pump commissioned on 17th February 2012. Vibrations measured during commissioning were in the range of 4 mm/sec-rms.
- Abnormal symptoms in the pump were observed first time within 2 months of commissioning when vibrations in the range of 8mm/sec-rms were recorded at pump drive end vertical direction - which subsequently got reduced to normal values. Vibrations are measured weekly using offline analyzer.
- October 2012 - vibrations at DE were recorded continuously higher and increasing. Vibrations spectrum indicated 1.3xRPM frequency as dominating frequency with fluctuating nature.

Vibration trend – Pump DE (vertical)

(From commissioning to first failure)

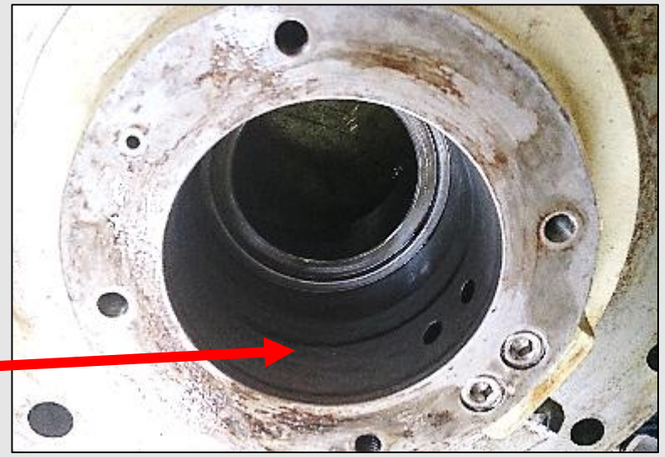




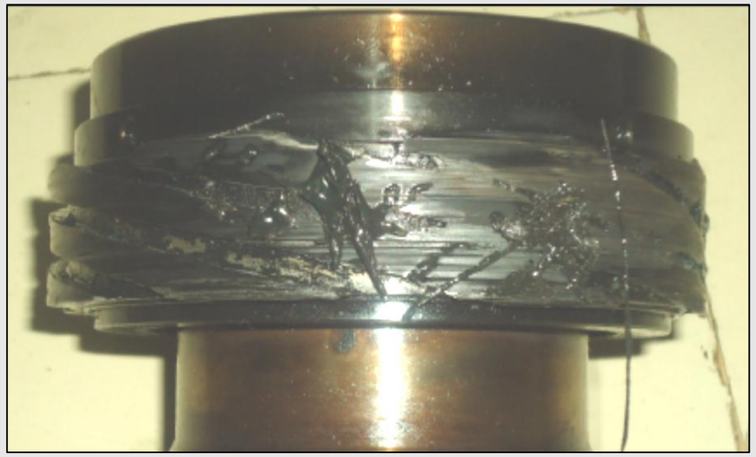
Observations during maintenance

1. DE bearing failed and got seized, mechanical seal failed
2. Rubbing in bearing housing, throat bush
3. High run-out in Shaft bearing and coupling area
4. Suction and discharge piping were observed misalignment w.r.t. pump nozzles

Bearing housing rub marks



Failed mechanical Seal



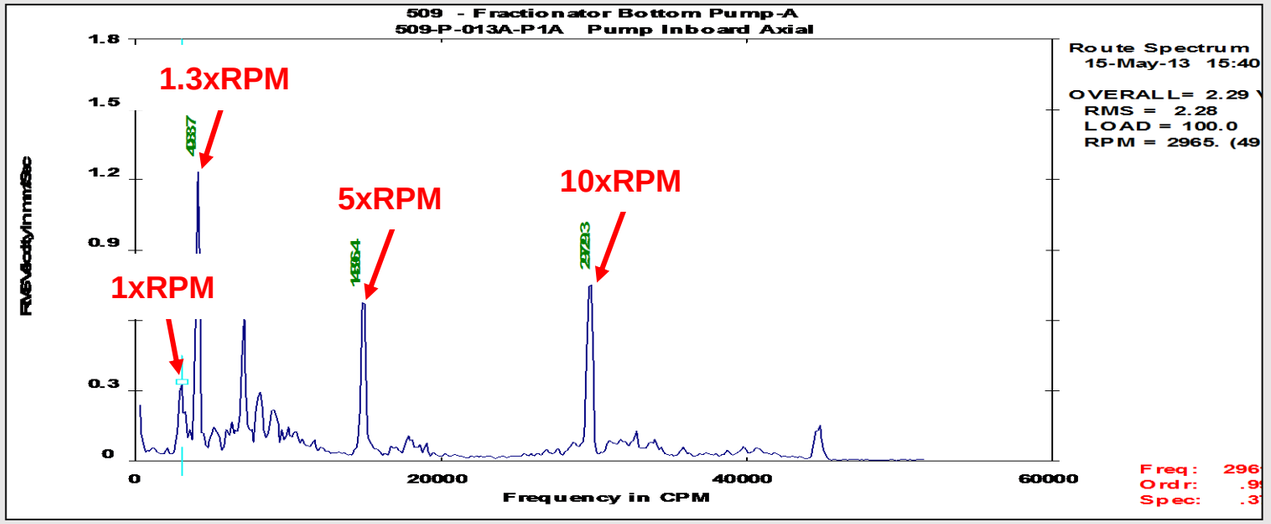
Improvement actions implemented (during year 2013 and 2014):

1. Relocating pump warm-up line from pump top to bottom and defining a slow warm-up rate for uniform expansion.
2. Ensuring minimum flow through pump by fixed minimum opening of recirculation valve
3. Pump concentricity and assembly checks along with mechanical run test at alternate vendor shop-floor.

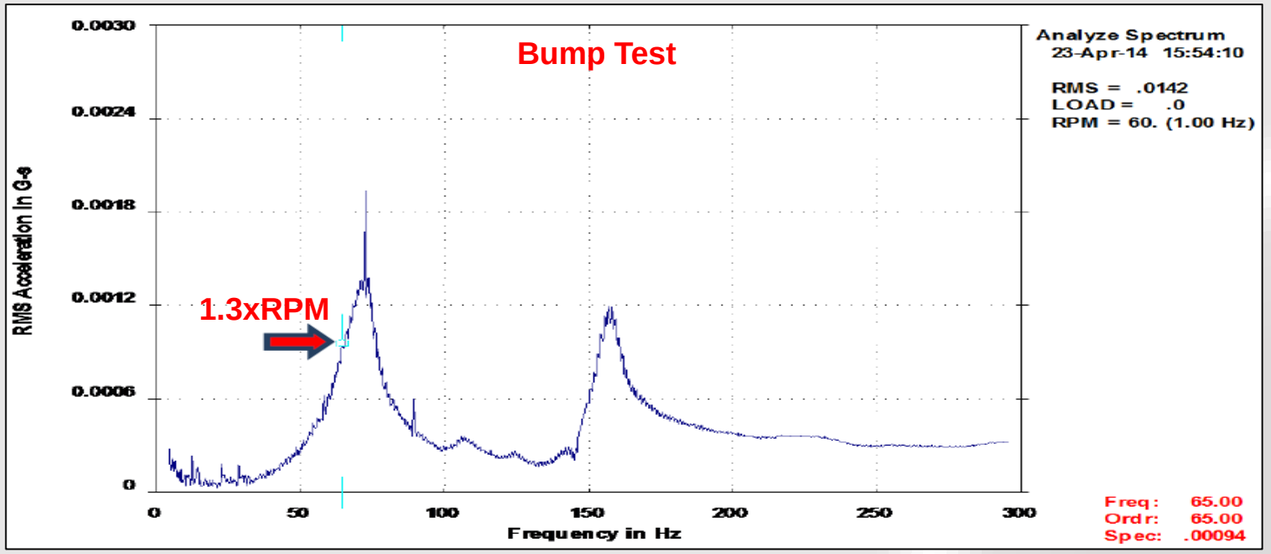
Analysis

- Visual inspection of the failed components showed rubbing at shaft throat bush area and also at wear rings.

- Fault frequencies indicated dominating 1.3xRPM frequency, which was observed to be fluctuating in nature.



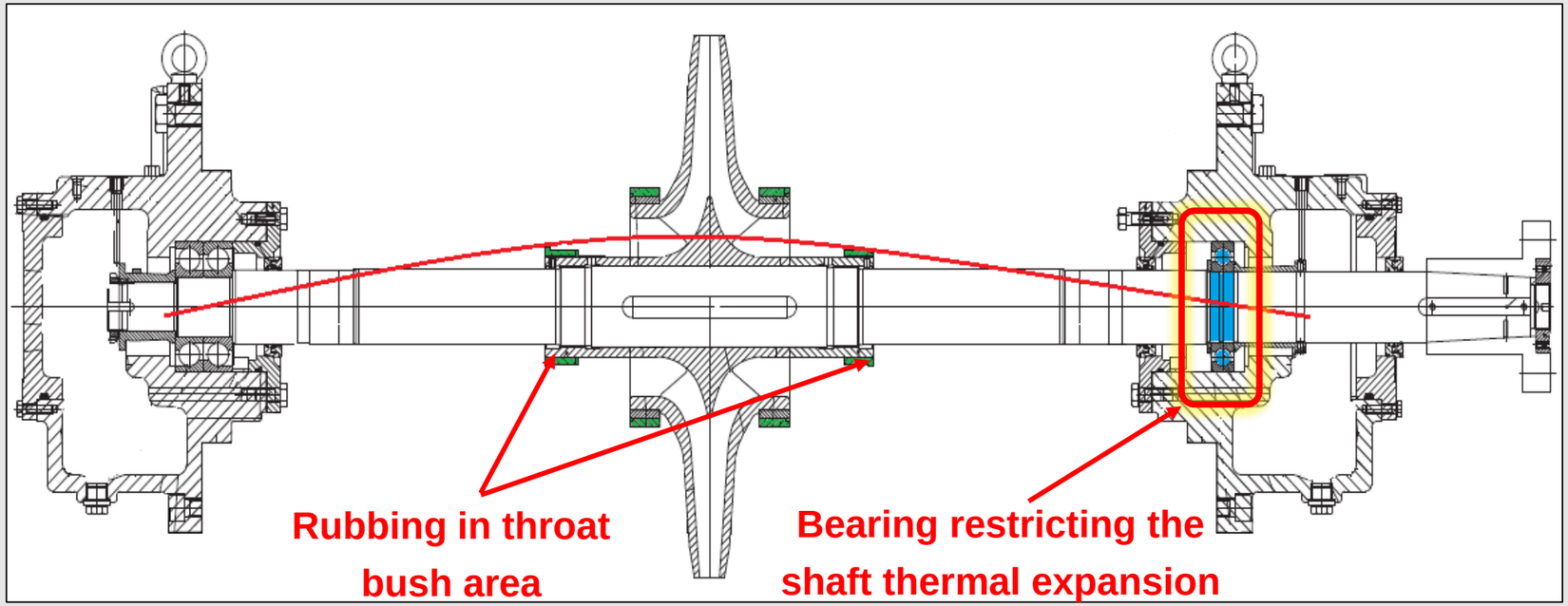
- Bump test carried out on pump shaft/impeller assembly indicated natural frequency in the range of 1.3xRPM to 1.4xRPM (~70Hz).
- Rubbing of pump shaft, while in operation, excites this natural frequency, hence 1.3xRPM vibrations are observed.



Conclusion

Wear marks of DE bearing housing (free bearing) indicated restriction in bearing axial movement, hence restriction in pump shaft expansion. *During warm-up, linear expansion measured in shaft is approx 1.0 mm.*

This results in deflecting the shaft, creating rub between shaft and throat bush as well as in wear rings. The phenomenon reflected in vibration spectrum as 1.3xRPM order vibrations.



With fluid being pumped at very high temperature (355 ^{o}C), the fits of the bearing on the shaft and inside housing becomes highly important. The fits become even more important with deep groove ball bearing (6213) at the floating end.

Solution:

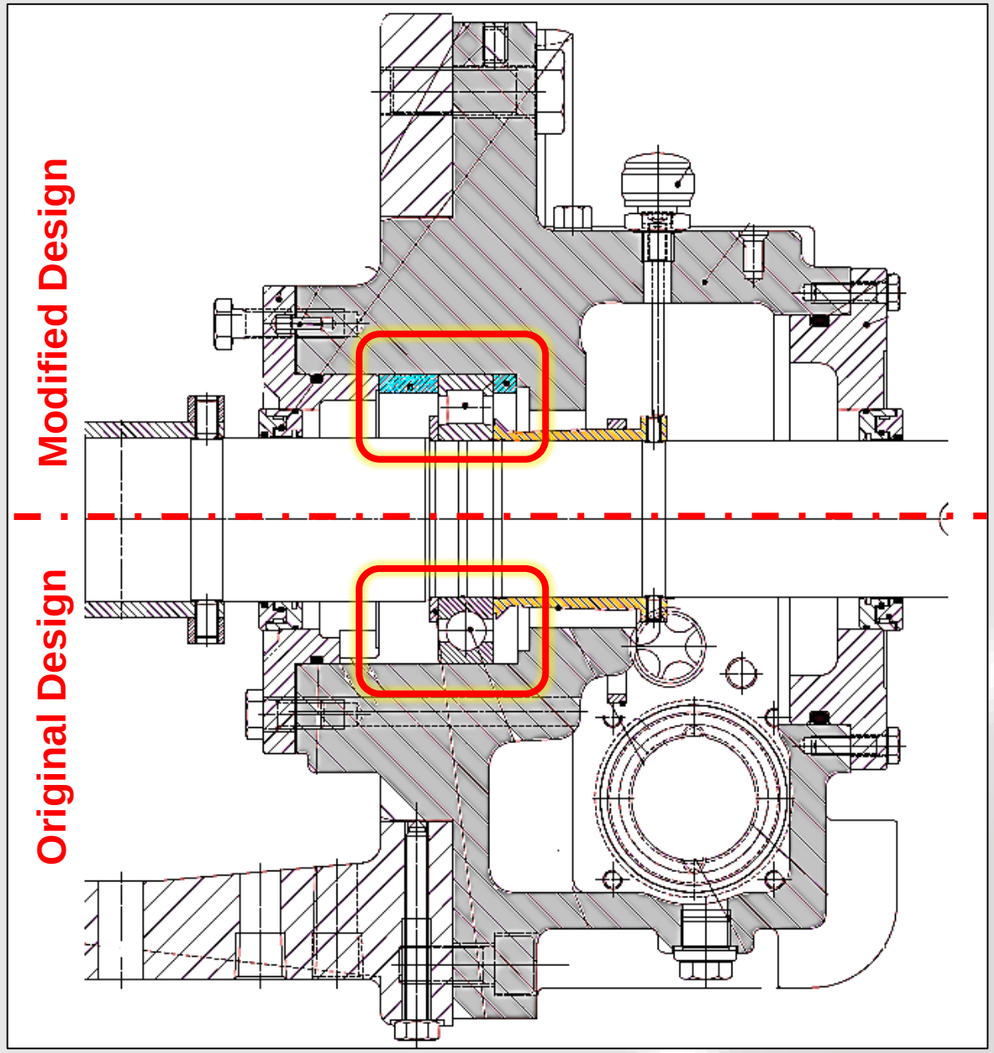
To improve free end bearing design so as to eliminate restriction to shaft expansion during pump warm up.

Problem resolution

Drive End side 6213J (deep groove ball) bearing replaced with NU213 ECJ/C3 (cylindrical roller) bearing after due consideration of minimum load, axial displacement requirements and concurrence of pump manufacturer

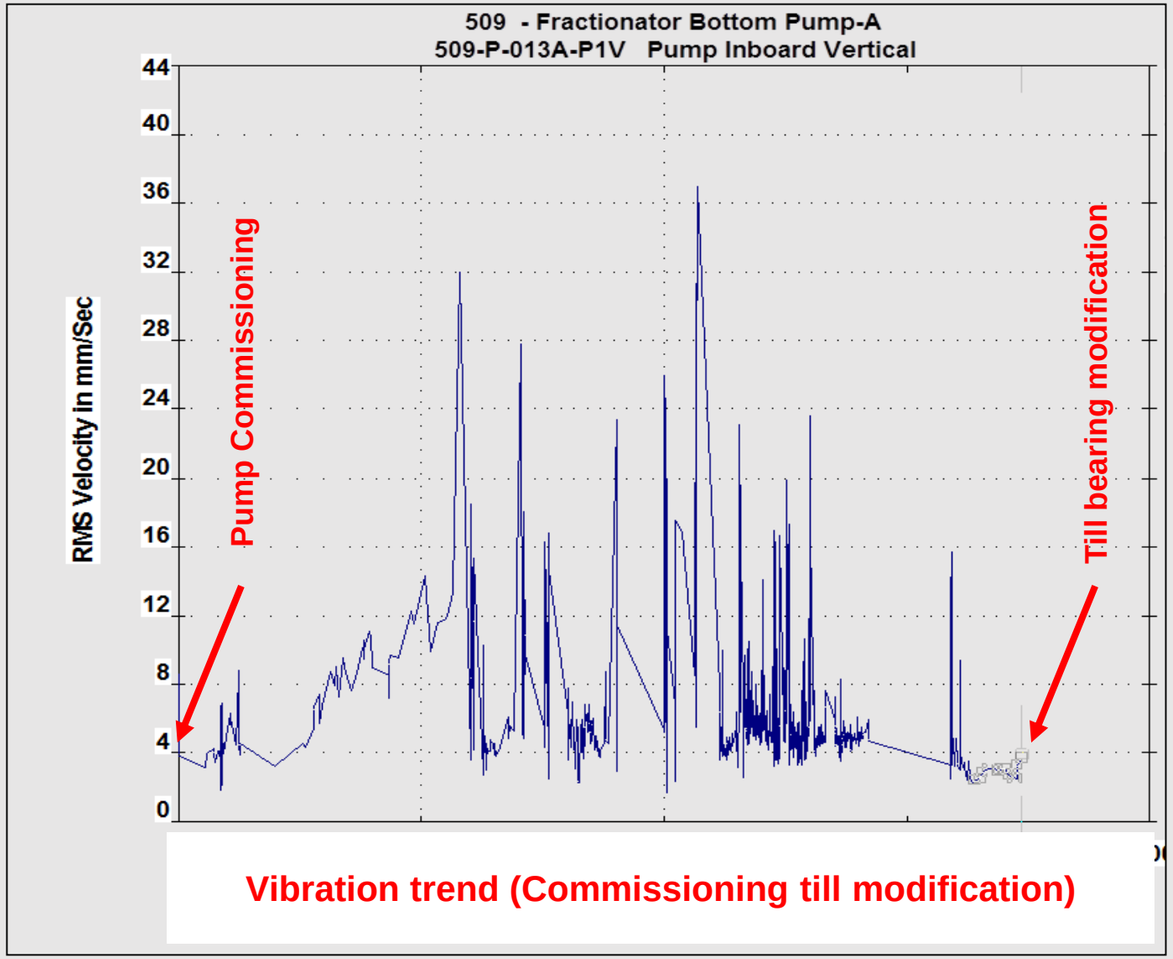
Considerations

- Minimum load – Meets minimum load requirement (confirmed by pump OEM)
- Axial Displacement – Can withstand upto 1.4 mm displacement whereas actual displacement is 1.0 mm
- Fits and location – Can accommodate within same bearing housing by installing spacer rings

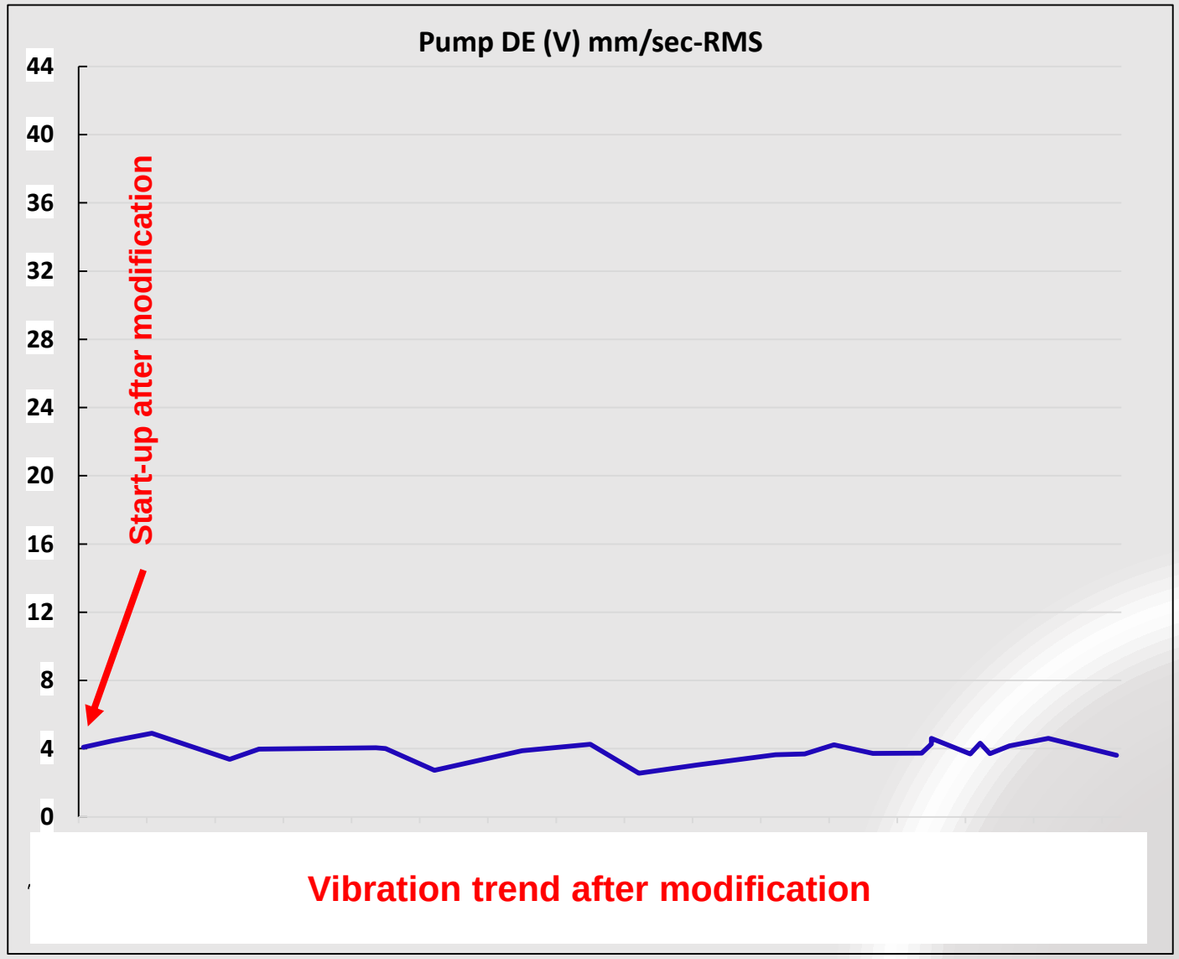


Results

After change in bearing type, pump is running satisfactorily with vibrations well within limits in the range of 3 - 5 mm/sec-rms. No fluctuating peaks are observed even after considerable number of pump start-stop events



Vibration trend (Commissioning till modification)



Vibration trend after modification

Thanks!
Questions?