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UNEXPECTED VIBRATIONS IN GEARBOX CAUSED BY SYSTEM INTEGRATION ISSUES

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Authors bios

Gianluca is currently Design Engineer in the Shaft Line Integration Team for GE Oil & Gas, in Florence, Italy. He is responsible for the requisition tasks and the integrated rotor-dynamic studies. He supports also NPI projects, manufacturing and test department for full speed full load string tests. He has a degree in Mechanical Engineering, specialization in Robotics, and a former work experience in the Defense and Railways Industries.

Gaspare is currently Engineering Leader of Power Transmission for GE Oil & Gas, in Florence, Italy. He is responsible for technical selection of flexible/rigid couplings, auxiliary equipment and gears design, with particular focus on the train rotor-dynamic behavior, torsional and lateral. He has a degree in Mechanical Engineering and before joining GE he had a research assignment at University College London. He is currently member of API613 Task Force and the ATPS Advisor Committee.

Short Abstract

This case study deals with a 24MW turbo-compressor unit composed of a gas turbine, a speed reduction gearbox with a lube oil pump mounted on its low speed shaft and two compressors in series. The unit was subject to high radial vibrations at the gearbox low speed shaft during initial running phase.

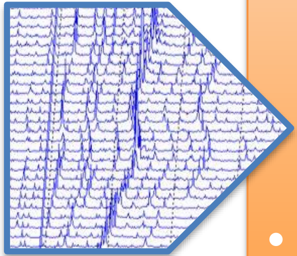
Technical investigation identified the root cause as lube oil pump working in aeration condition owing to a wrong pressure set point. Aeration, in turns, excited a torsional natural mode of the train.

This case study highlights some of the implications of mechanical integration of machines and auxiliary systems, where the modification of operating parameters may lead to unwanted outcomes which may affect availability and integrity of the unit.

1. Problem Statement

Unit/Process:

24MW Turbo-compressor unit for CO_2 service



Problem:

- No-load string test: Vibration at alarm level on Gearbox Low Speed Shaft (LSS)
- Alarm level throughout the initial phase (≈45min. from train start-up)

Potential issues:

- Failed string test
- Reduced availability at site
- Train integrity

Scope of this Case Study:

Underline the importance of system integration of machines and auxiliary systems and some of their implications on unit availability and integrity

2. Train Configuration and Data

Gas Turbine
100% speed: 3600 rpm
Max power: 24450 kW

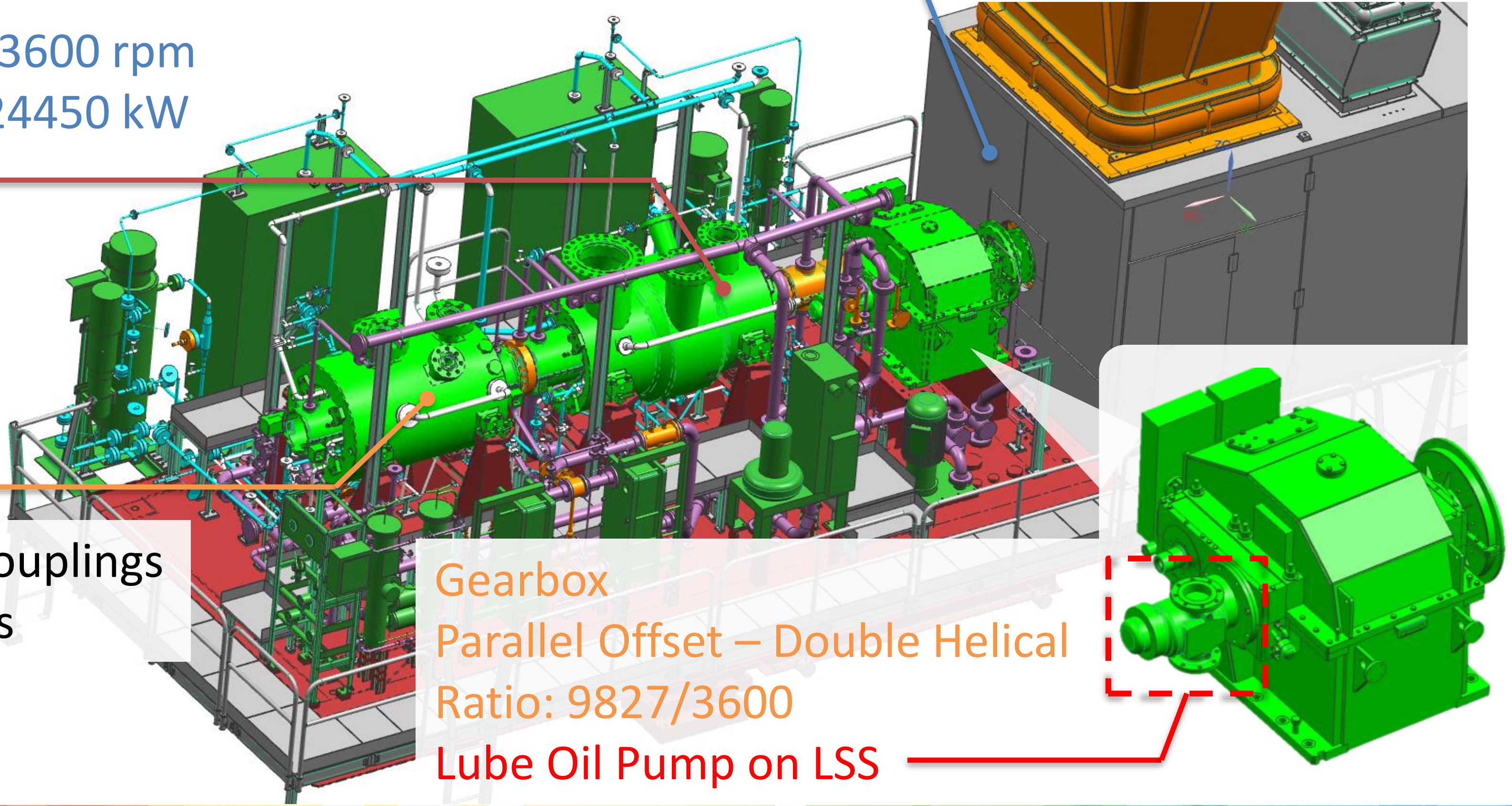
Centrifugal Compressor

Centrifugal Compressor

Dry flexible couplings b/w machines

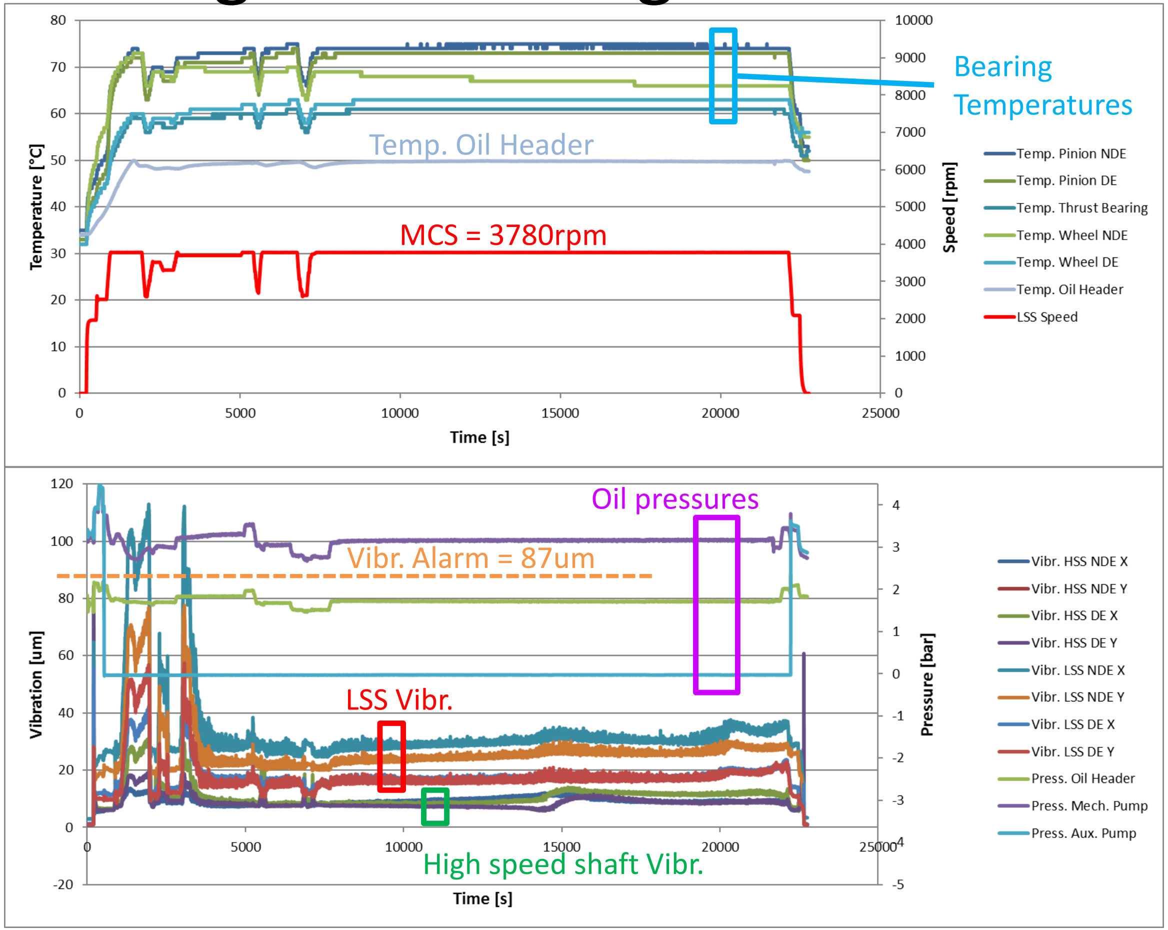
Gearbox
Parallel Offset – Double Helical
Ratio: 9827/3600

Lube Oil Pump on LSS



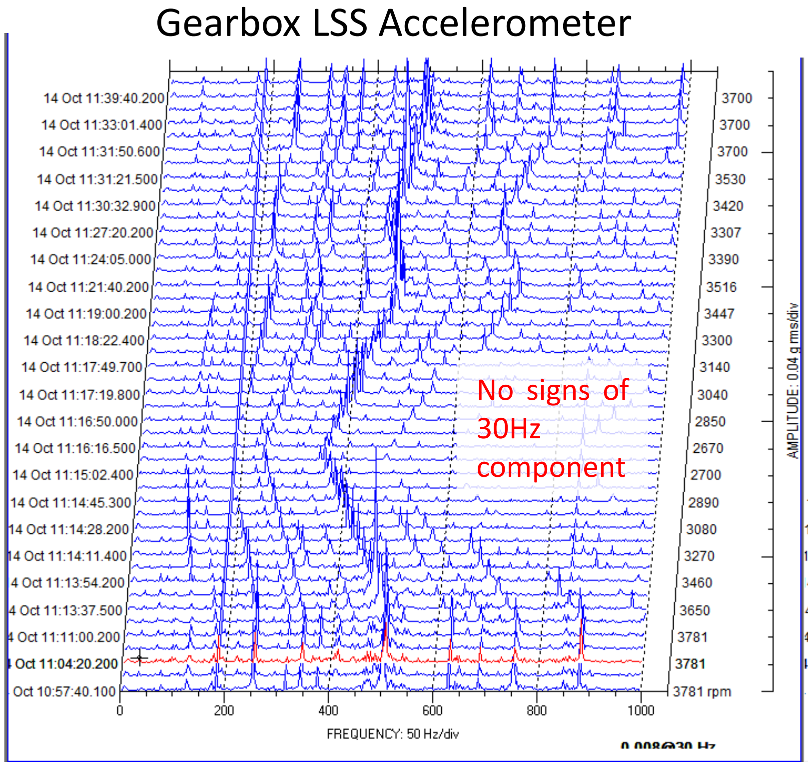
3. No-Load String Test: Findings – I

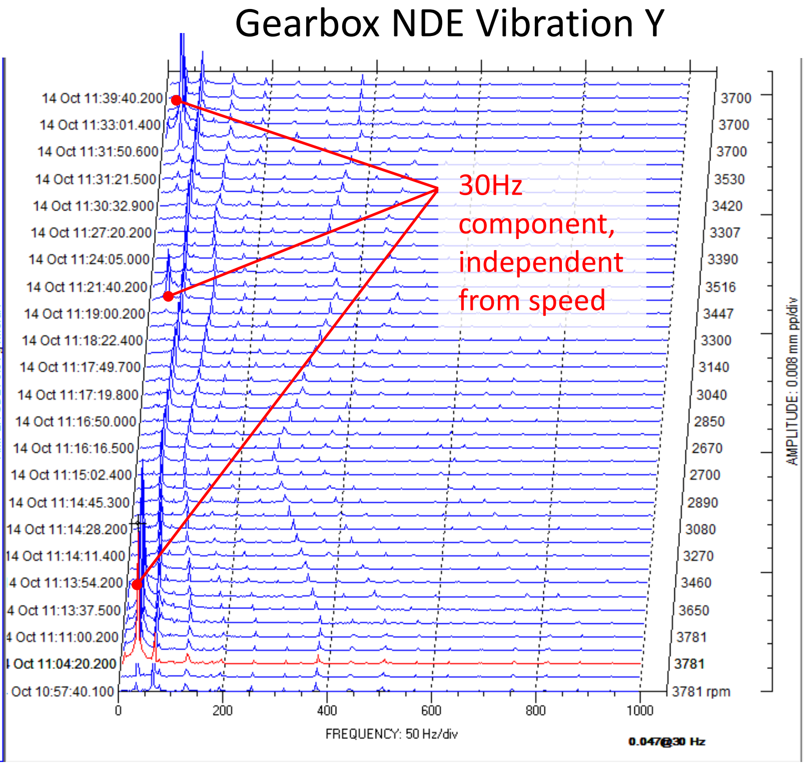
- LSS vibration above Alarm limit @ Max Continuous Speed (MCS)
- Event extinguished approx. 75min. after train start-up
- Bearing temperatures: no issues, as expected
- Lube oil supply: no issues, as expected
- Lube Oil Pump on Gearbox reported to work in a noisy way



AIPS

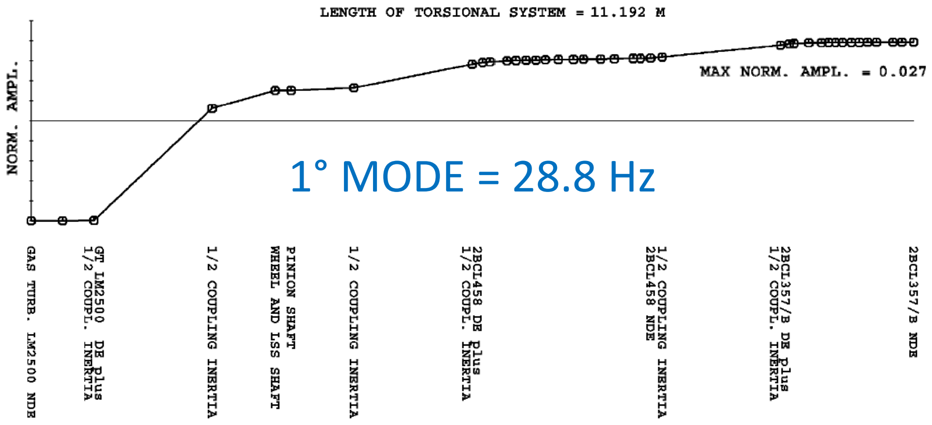
4. No-Load String Test: Findings – II





~30Hz component on LSS vibr. probe, independent from speed, not detected by GB casing accelerometer: <u>disturbance of torsional nature</u>

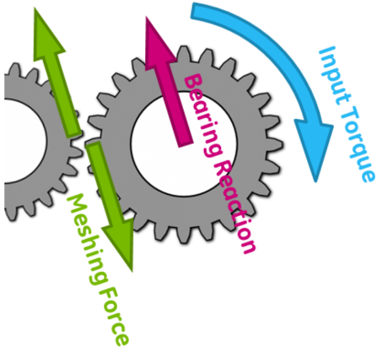
5. Torsional disturbance VS Gearbox response

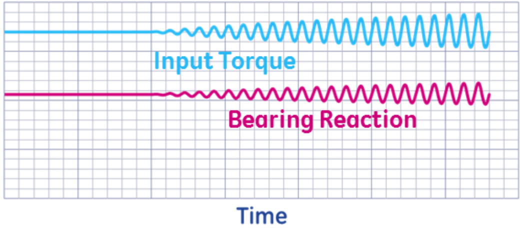


Gearbox radial vibration response at 1st Torsional Natural Frequency (TNF) was induced by torsional-lateral cross coupled effect, due to the kinematics of the geared system

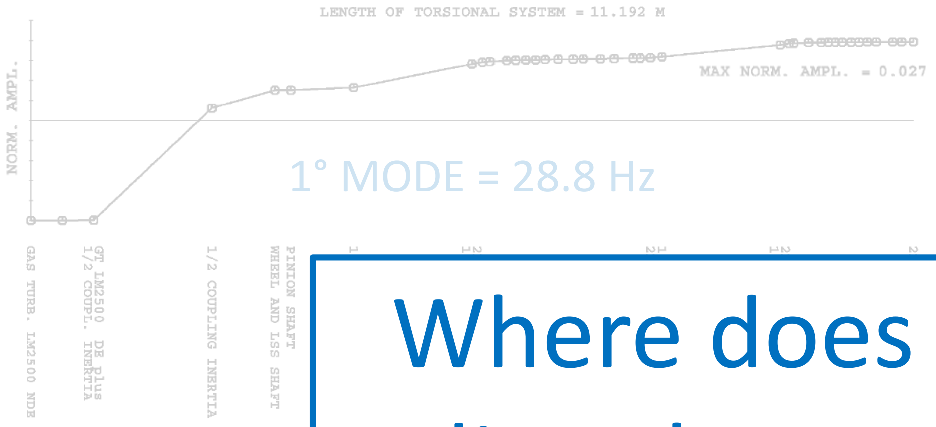
Torsional-lateral cross coupling

- Kinematic phenomenon
- Lateral vibration is the effect of torsional vibration
- The radial component of the meshing forces represents the shaft excitation source





6. Torsional disturbance VS Gearbox response



Gearbox radial vibration response at 1st Torsional Natural Frequency (TNF) was induced by torsional-lateral cross kinematics of

Where does the Torsional disturbance come from?

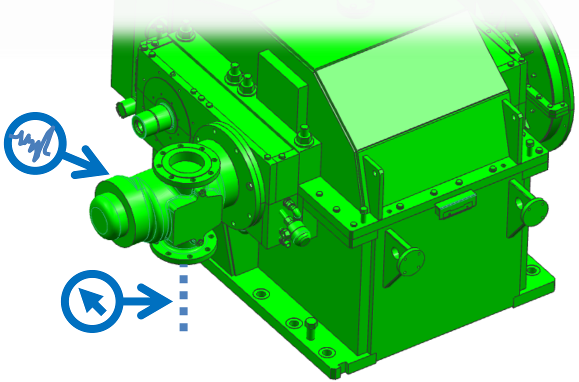
Torsional-late

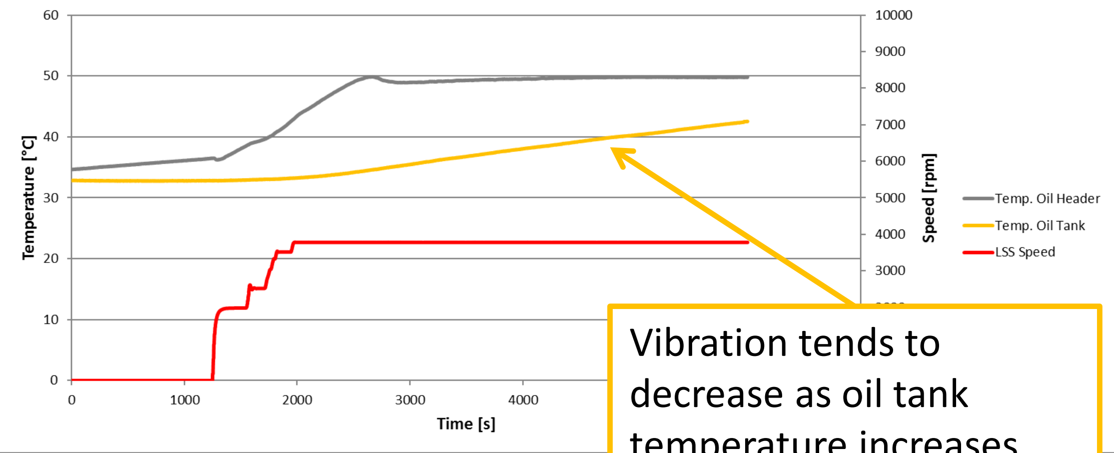
- Kinematic phenomenon
- Lateral vibration is the effect of torsional vibration
- The radial component of the meshing forces represents the shaft excitation source

7. Disturbances from the mechanical pump – I

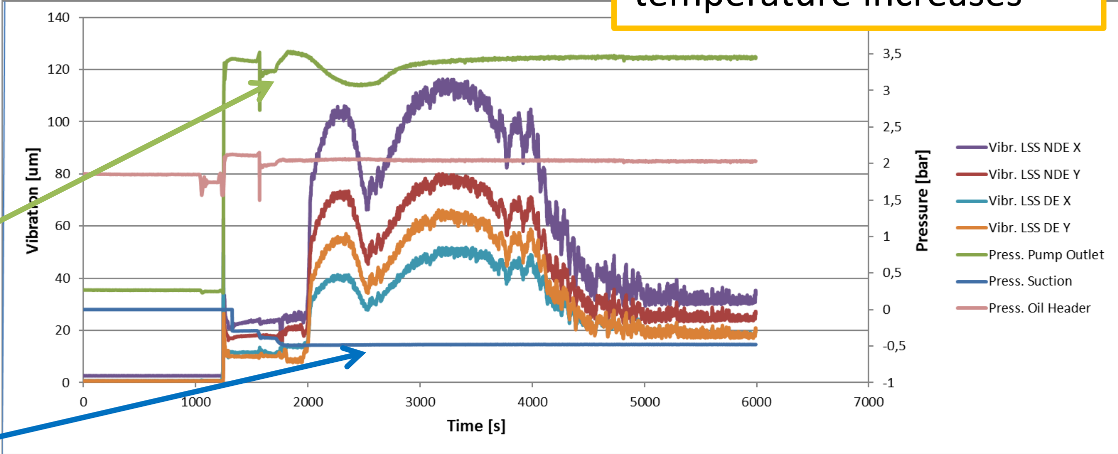
Additional No-Load test with:

- Accelerometer on pump casing
- Pressure gauge on pump suction





Vibration tends to decrease as oil tank temperature increases

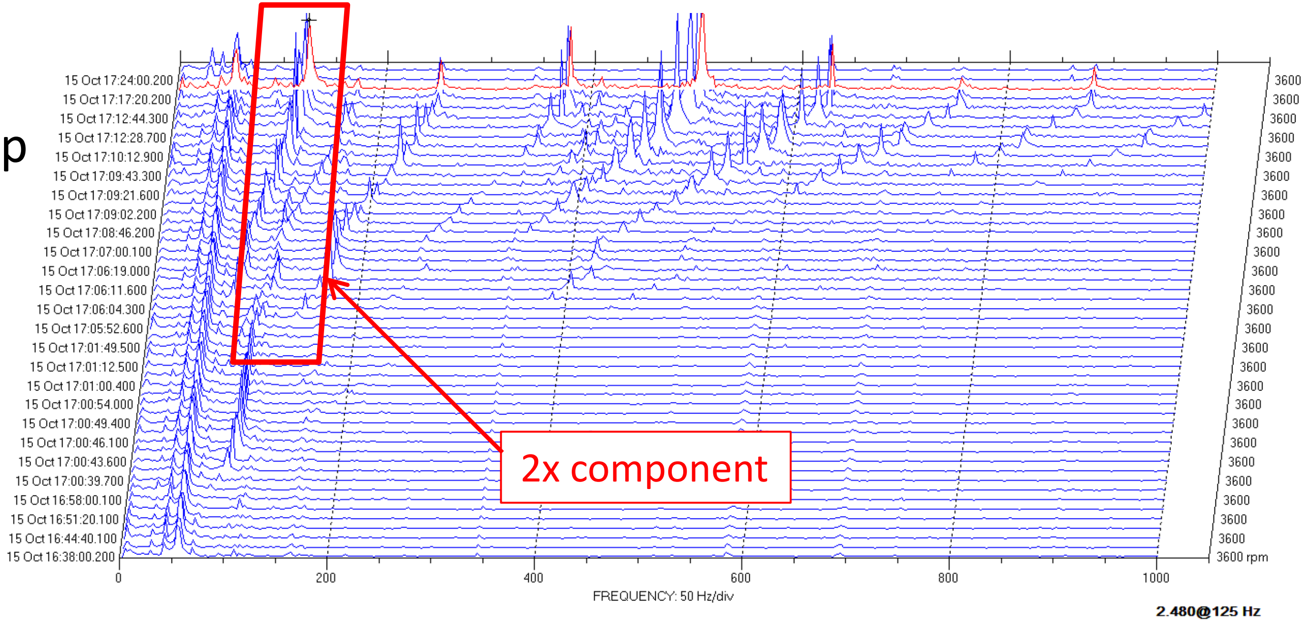


Outlet pressure (~3.5 bar) much lower than pump design pressure (6.5 bar)

High pressure drop at pump suction

8. Disturbances from the mechanical pump – II

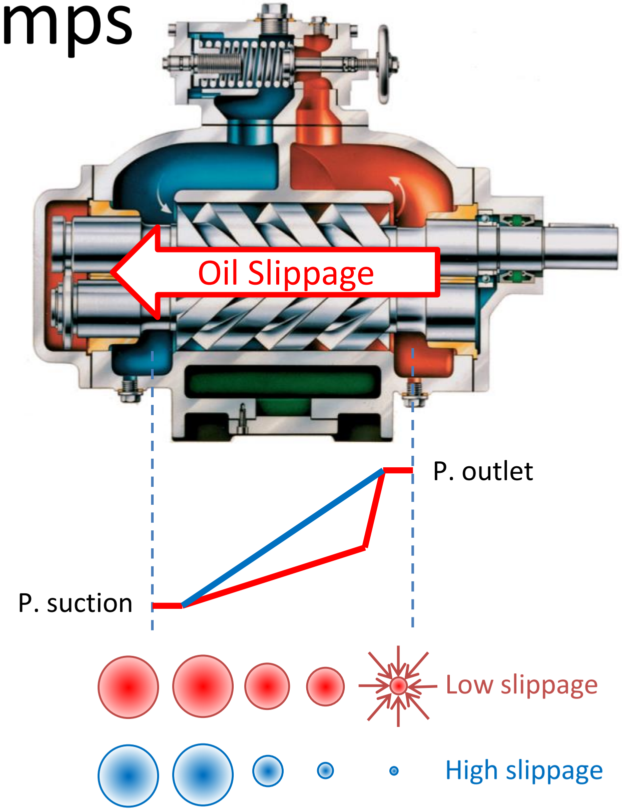
- Strong 2X component detected by accelerometer on pump casing
- Noisy functioning
- Low suction pressure
- Outlet pressure set below pump design pressure
- Dependence on oil temperature



Pump working in Aeration

9. Aeration in screw pumps

- Aeration is caused by air normally present in oil (dissolved + emulsified air)
- Pressure drop at suction leads to formation of air bubbles
- Non-smooth pressure profile throughout the compression chamber leads to abrupt compression and implosion of air bubble
- Pumps are designed with some clearance to allow oil slippage and smooth pressure profile
- Aeration is tolerable by the pump, but leads to noise and vibrations -> the torsional component of vibration excited the system's 1st TNF



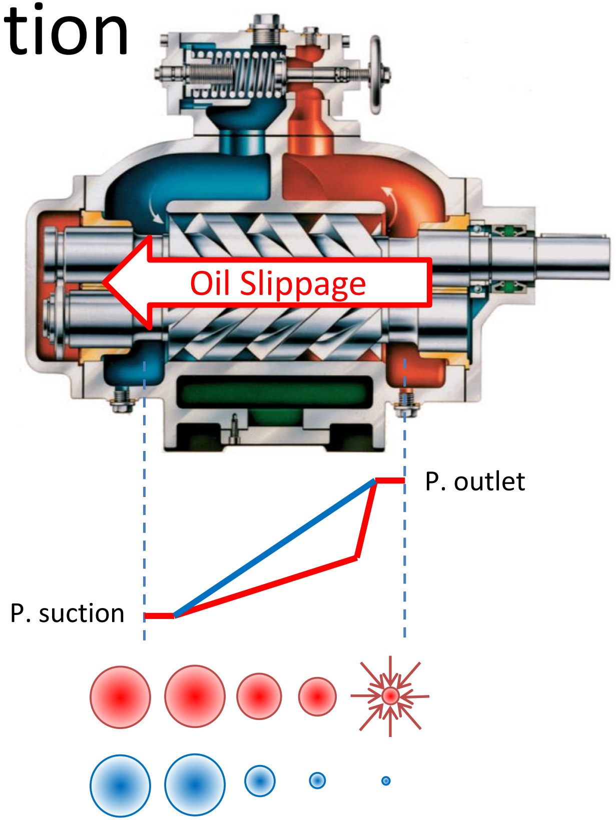
NOTE: Aeration (air bubbles) ≠ Cavitation (vacuum bubbles)

Cavitation is much more severe phenomenon resulting in pump damage

10. Factors influencing Aeration

Aeration reduction

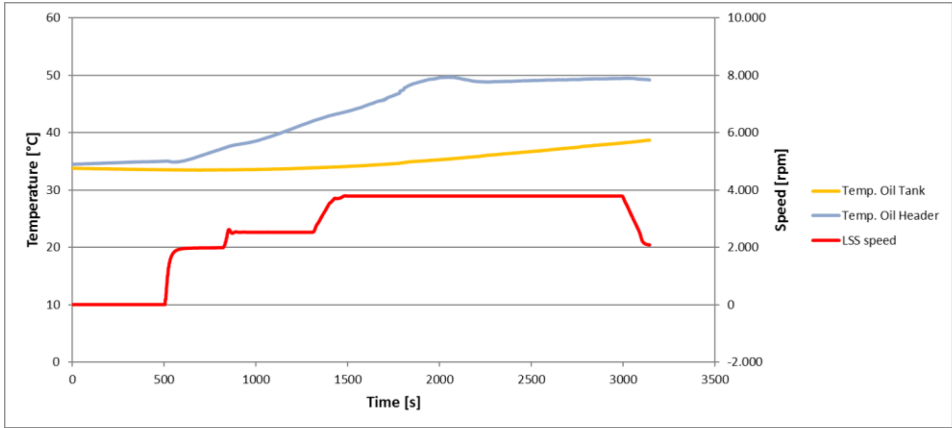
- Reduce pressure drop at suction (reduces bubble formation and volume)
- Increase pump internal slippage: this lead to pump volumetric efficiency reduction
- Increase outlet pressure (facilitates slippage)
- Increase oil operating temperature (decreases viscosity and facilitates slippage)

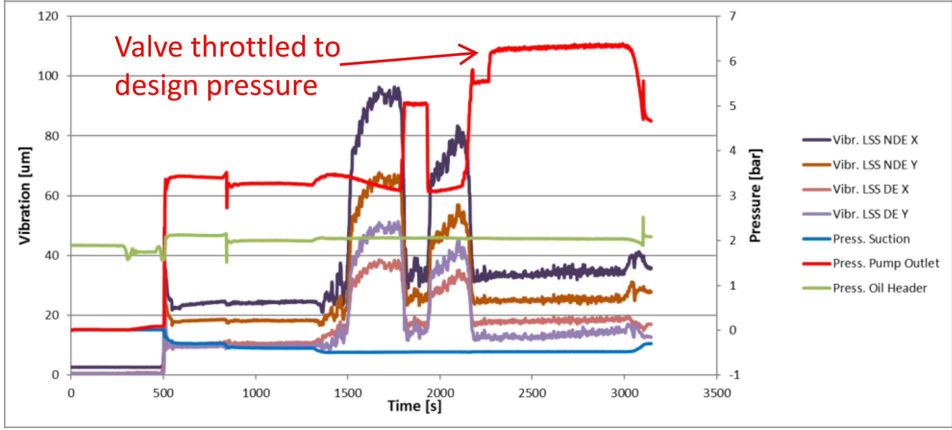


11. Corrective actions on train – I

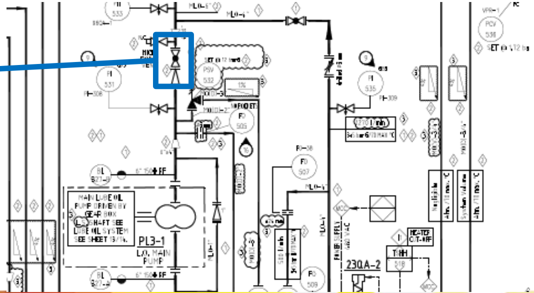
Root cause: Pump designed/optimized for discharge nominal pressure of 6.5 bar, as required at the beginning of the project. Lube oil system pressure set-point was then reduced to 3.5 bar afterwards, without reviewing pump design (6.5 < 3.5)

Solution: Mitigate aeration by increasing outlet pressure set-point (other actions not feasible at site, as they needed major reworking of materials)



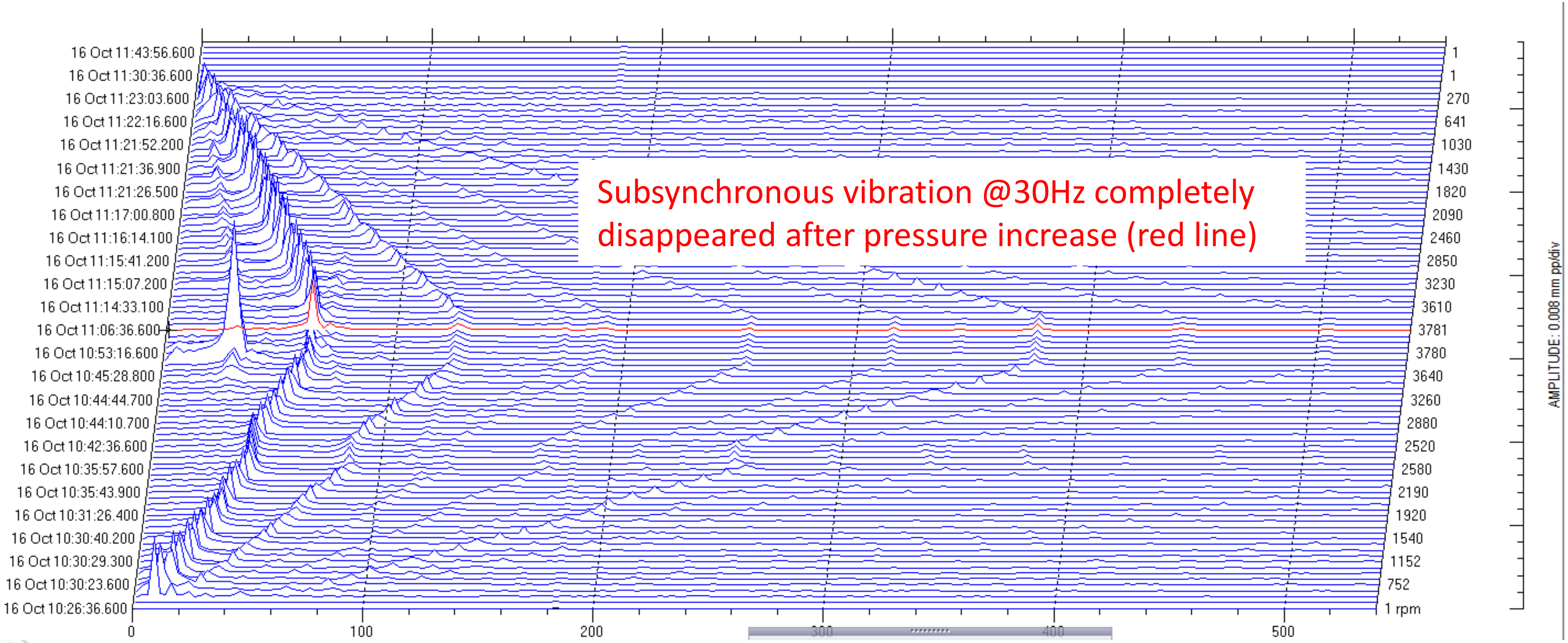


Manual valve throttled



12. Corrective actions on train – II

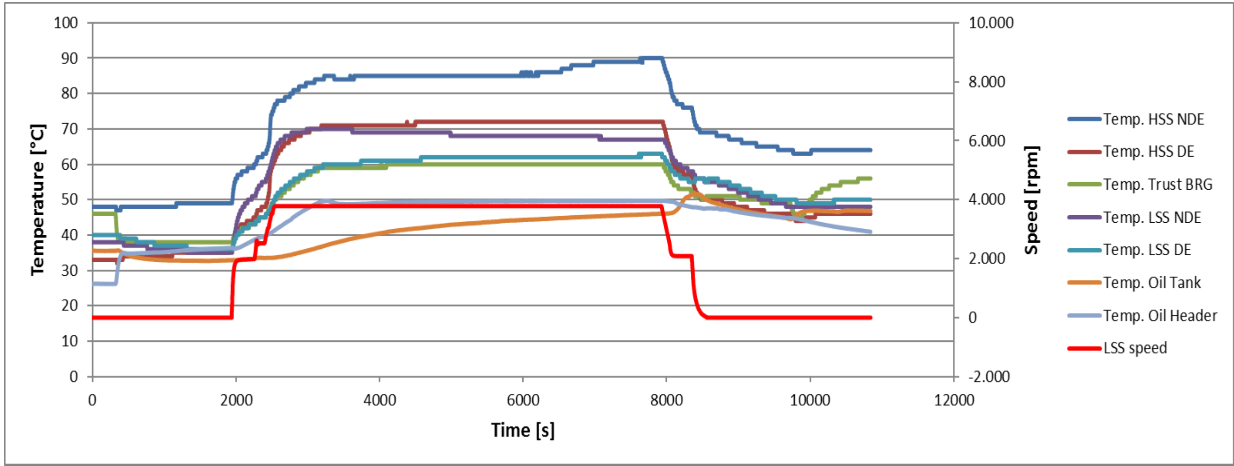
- Aeration phenomenon was extinguished
- Train torsional vibration completely disappeared

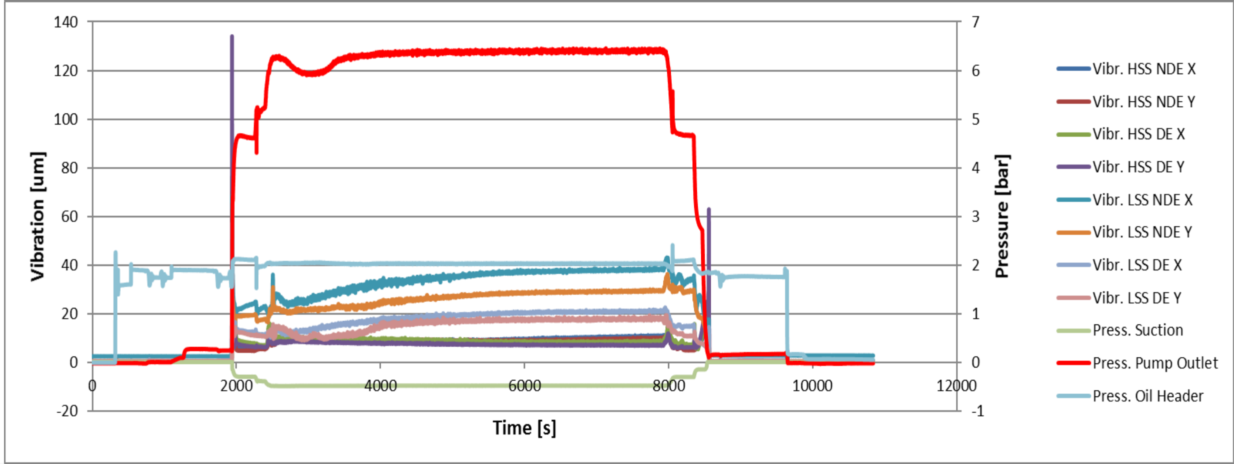


13. Final Validation

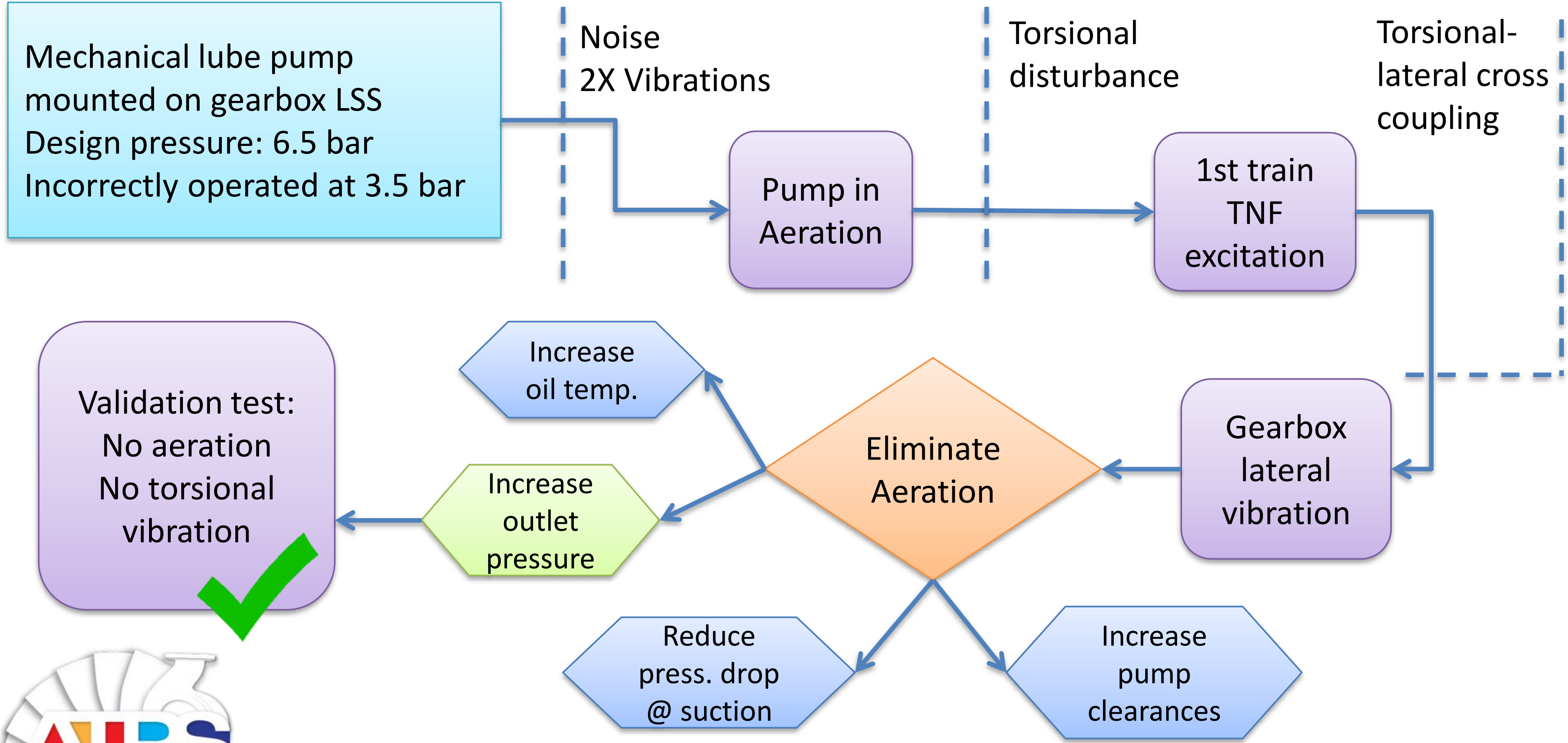
- Corrective action: orifice installed downstream of pump discharge to increase pressure set-point.
- Orifice selected to guarantee correct discharge pressure in all operating cases (different speed and different pressure drops in the system)

Final Full Speed – No Load test to validate corrective action: no high vibration, corrective action is effective





14. Case Study Keypoints



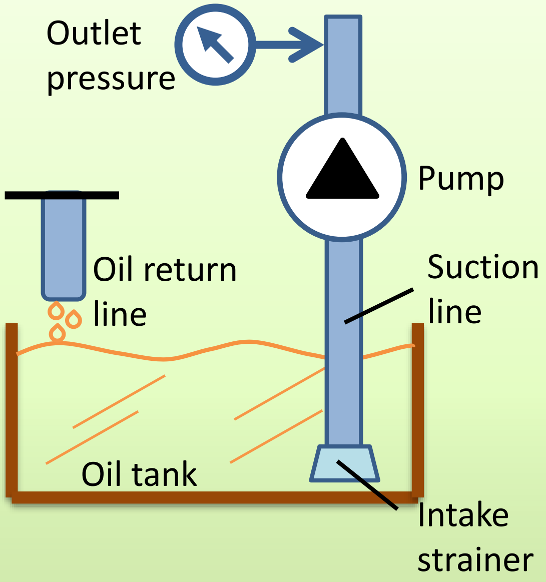
15. Lessons Learnt

Configuration Management:

pump Designer not alerted – assumption that lower pressure was ok -> Involve all affected Functions when change occurs on operating points

Design:

- Decrease Pump Volumetric Efficiency (↑ clearances). Rule of thumb: < 80% if high aeration risk is expected
- Place intake strainer far from oil return, where % of emulsified oil is higher
- Reduce pressure drop on intake and suction line as much as technically possible (ex. minimize line length)
- Higher outlet pressure reduces aeration risks
- Increase lube oil tank temperature



Thank you!