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Case Study on Coupling Crack on a Centrifugal Pump

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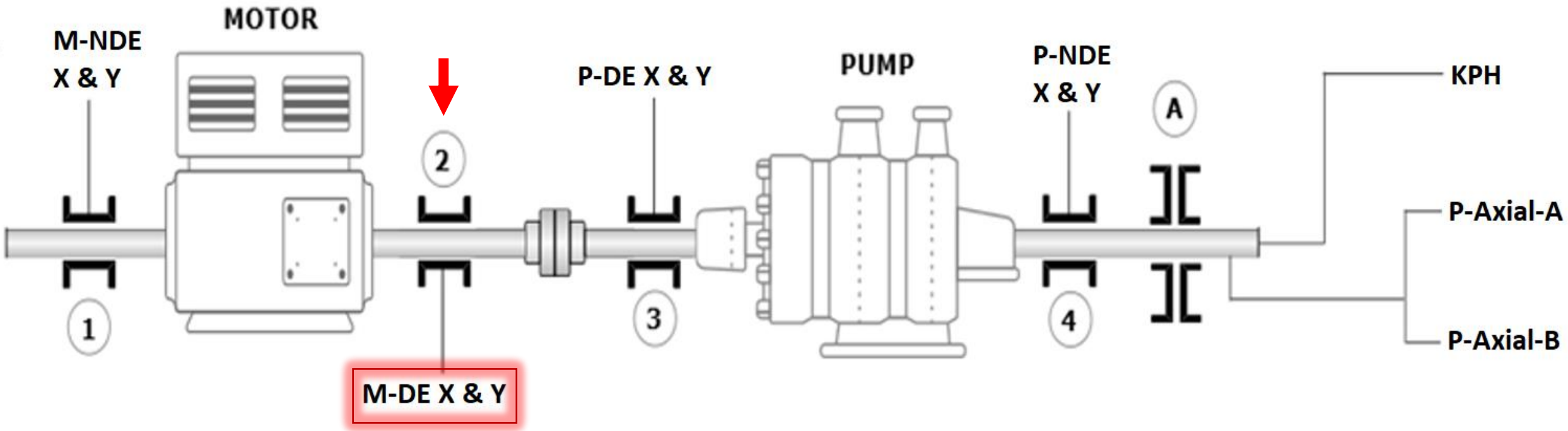
Abstract

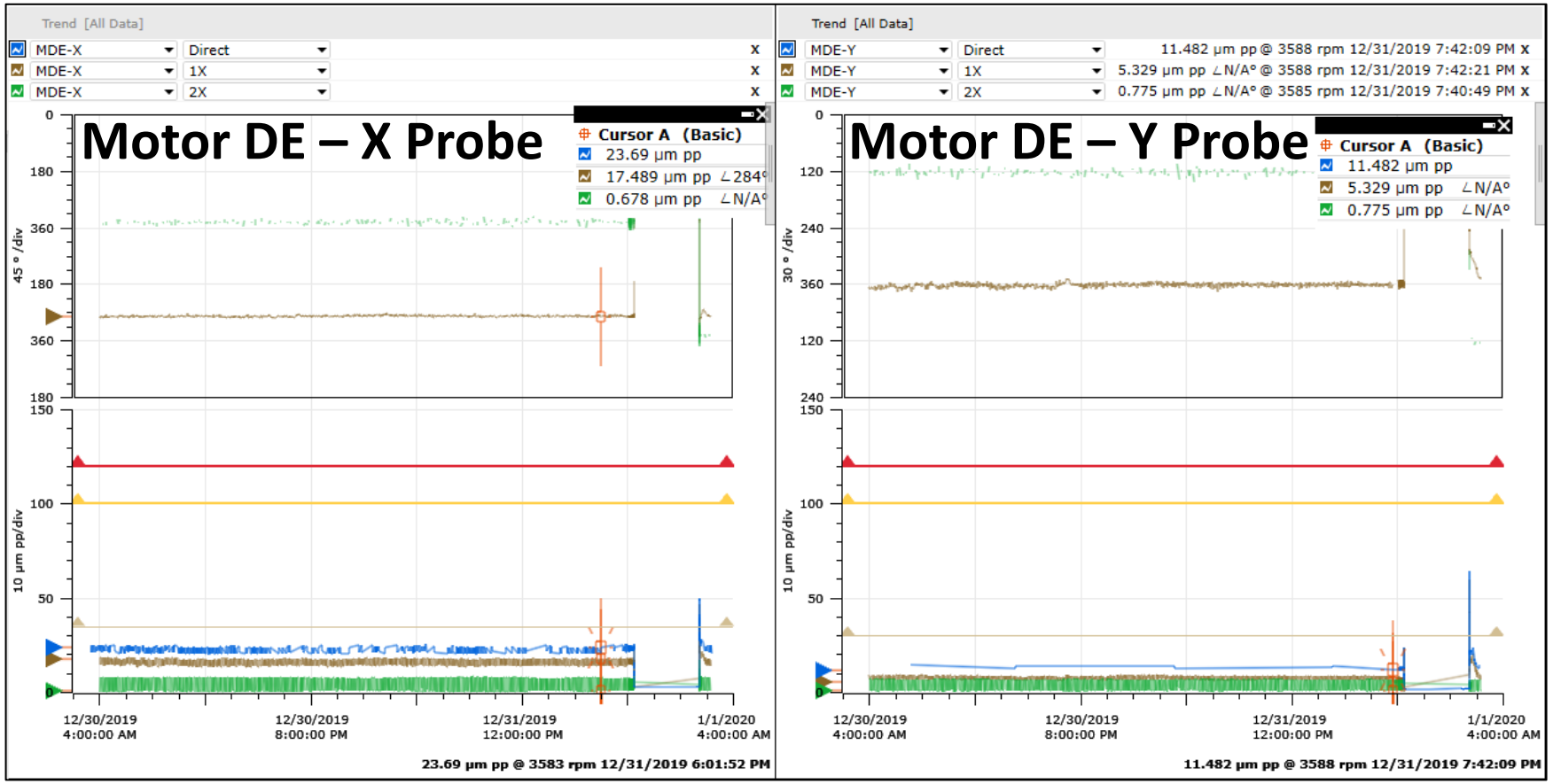
- This case study is focused on accurately identifying the root cause of the observed change in the rotor natural frequency by analyzing the vibration excursions on a motor driving a centrifugal pump through a flexible coupling.
- The unit tripped on high vibration at Motor DE bearing probes, This trip event had no records on the online monitoring server due to communication loss between the software and the Pump Monitoring Software.
- However, the machinery protection system was able to trip the unit successfully. The communication loss issue was resolved, and the unit started back up and kept running for approximately 20 minutes until it tripped again on the same Motor DE bearing vibration probes.

Machine Layout



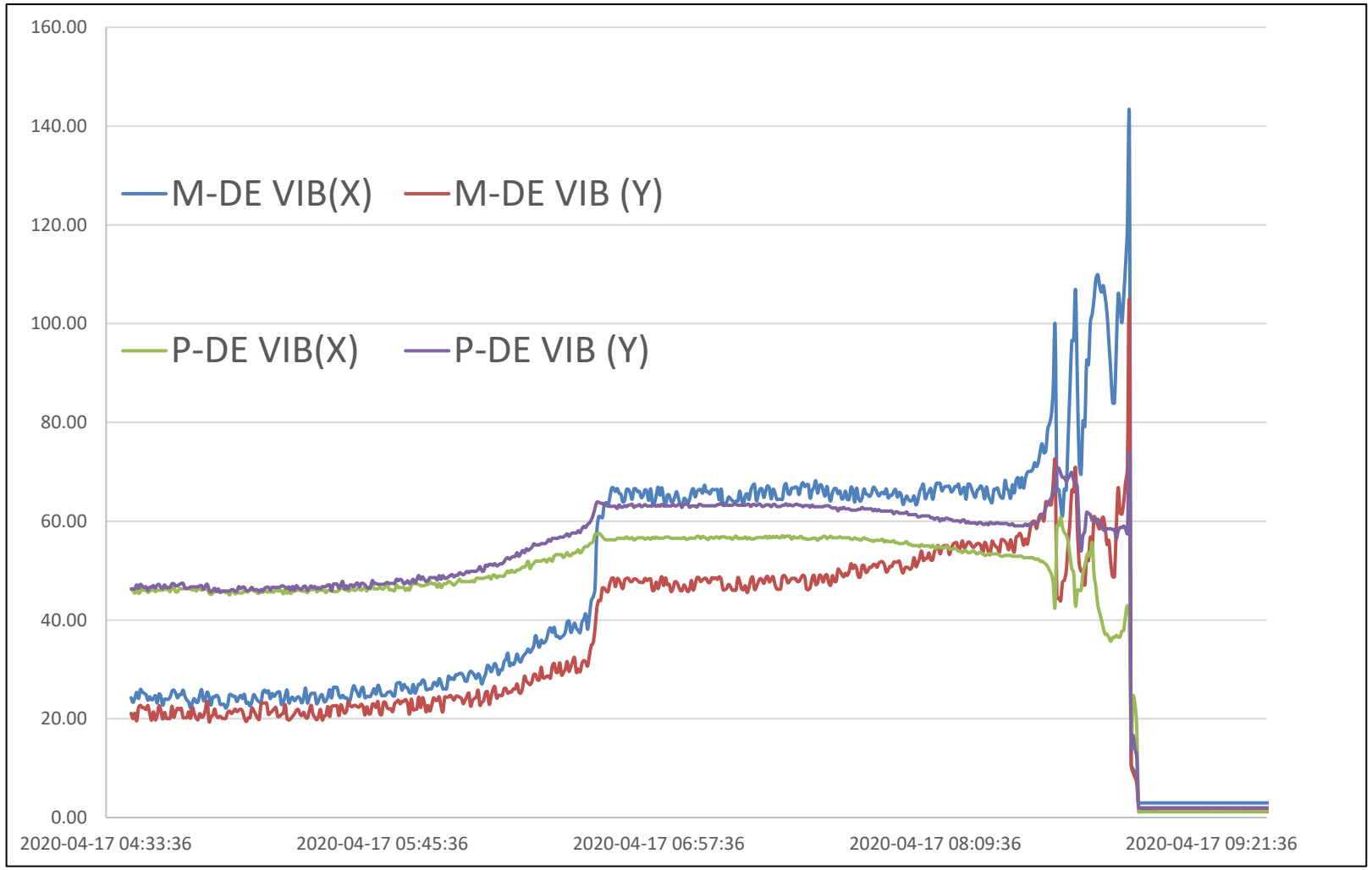
Train consists of 5000KW/60HZ (3588 RPM) induction electric motor driving a centrifugal pump through a flexible shim-pack coupling.

Previous Data Analysis prior to communication loss



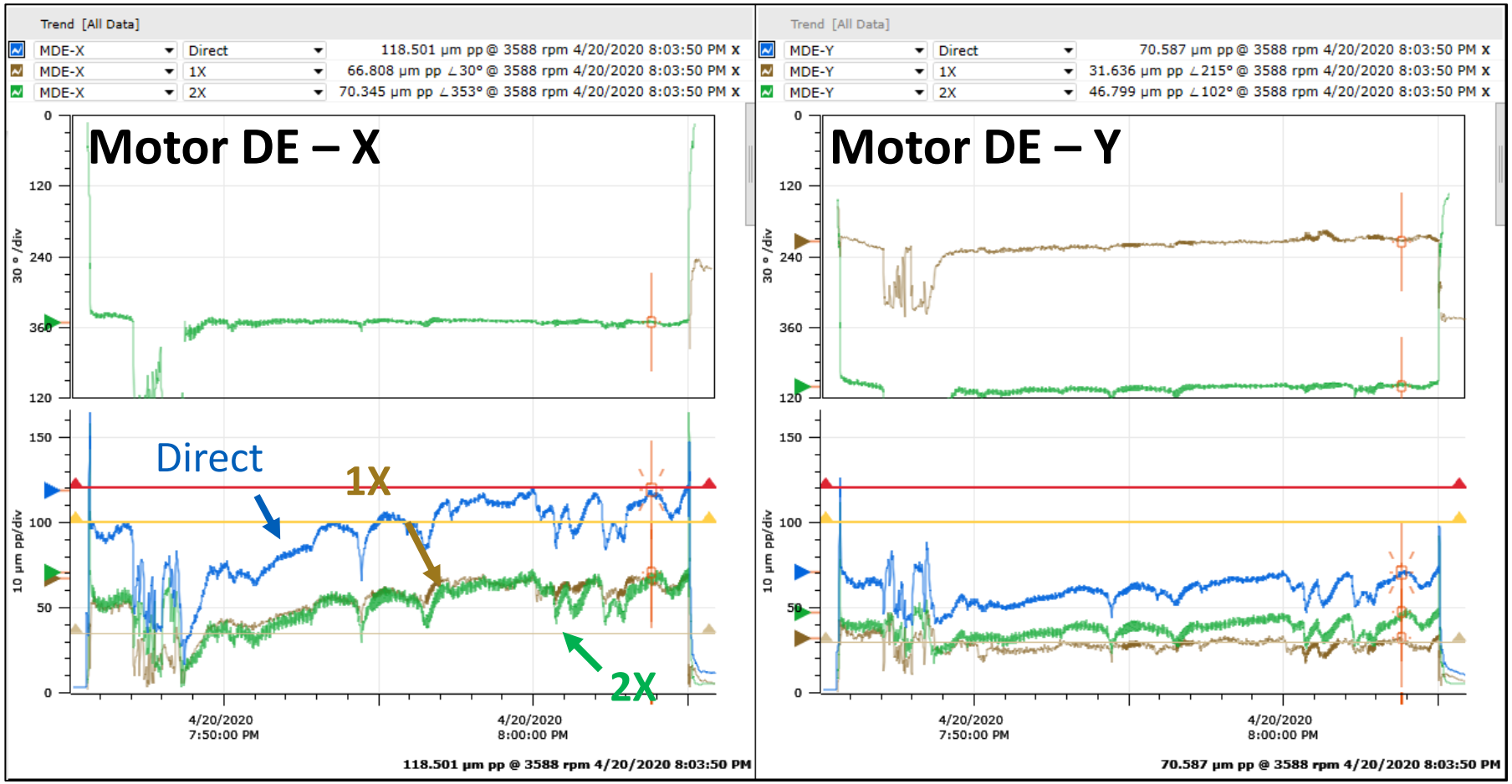
- Motor DE vibration probes shows acceptable vibration levels before the high vibration event.
- Unfortunately, no vibration data were available for approximately 4 months before the high vibration event.

DCS vibration trend during steady State at the vibration trip event



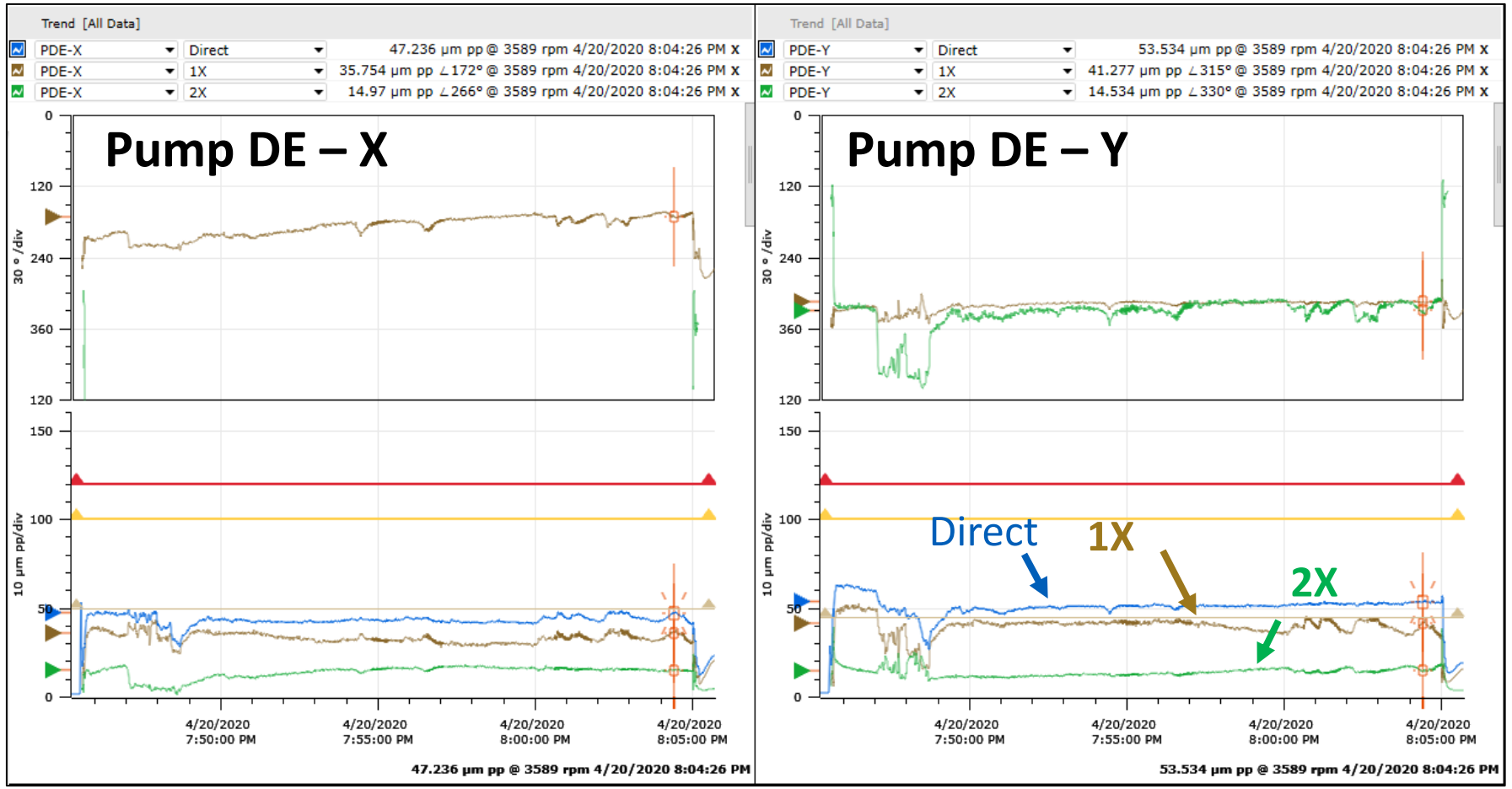
- DCS vibration trend show the gradual increase in vibration levels until tripping the unit on motor DE.
- This trip event had no records on the online monitoring server due to communication loss between the software and the pump monitoring system.

Motor Drive-End Trends after resolving the communication issue



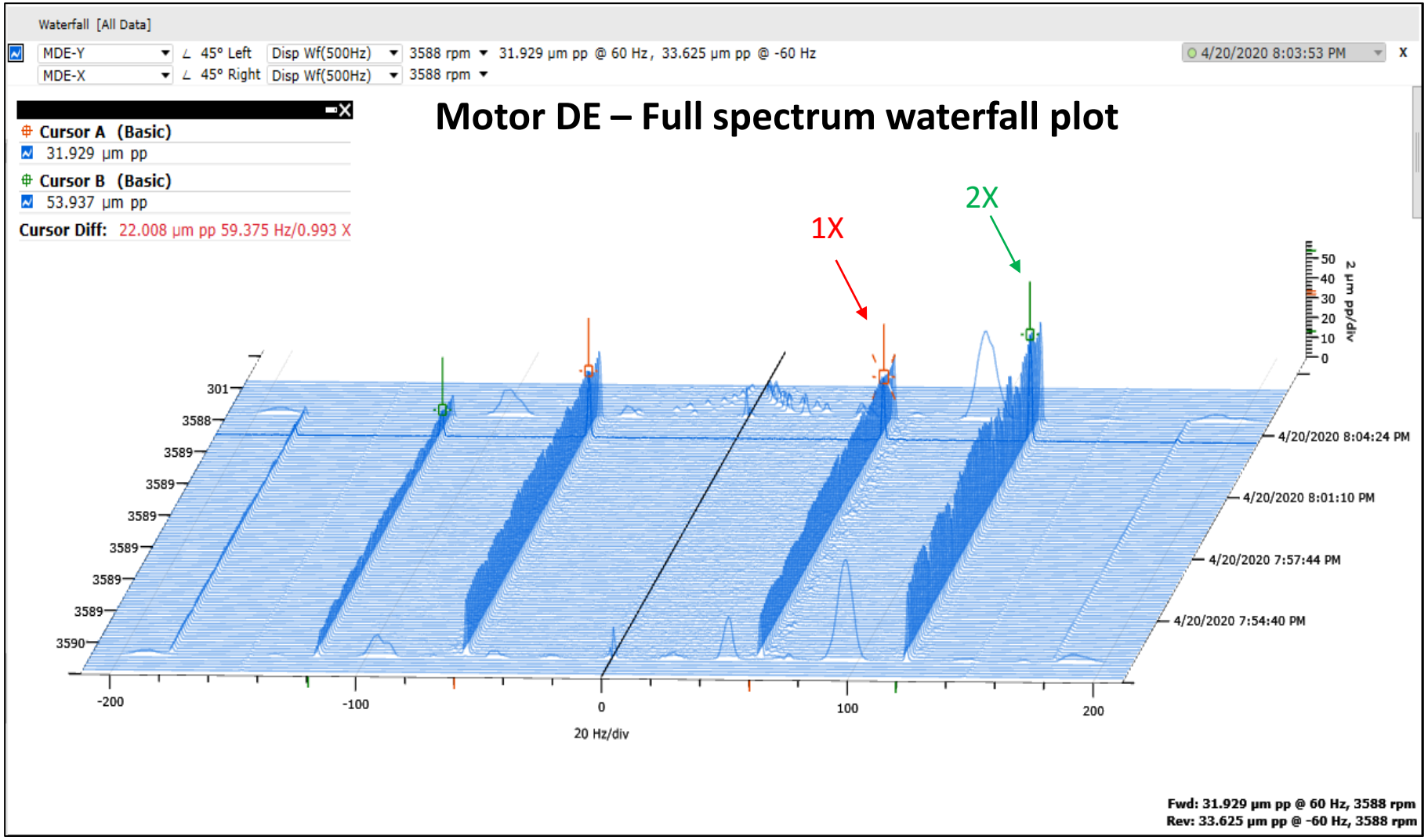
- Motor DE bearing X & Y probes vibration trends recorded on the following startup shows the dominant 1X & 2X filtered peaks raising the overall value. Also, it reveals a rapid fluctuation behavior until tripping the unit again.

Pump Drive-End Trends after resolving the communication issue



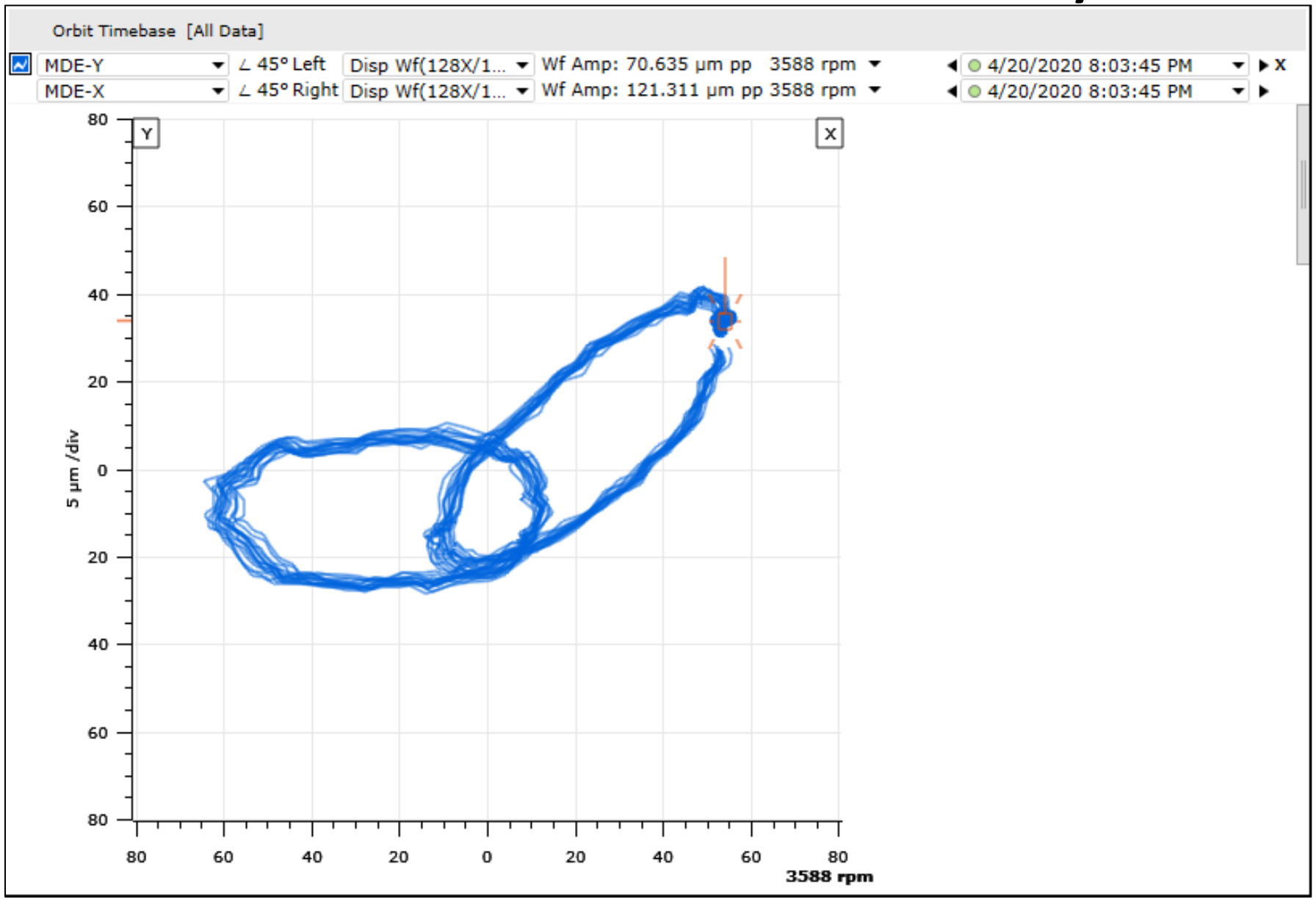
- Pump DE bearing side reveals the dominated 2X peak and the fluctuation behavior, however, the overall values were low.

Motor Drive-End Spectrum Analysis



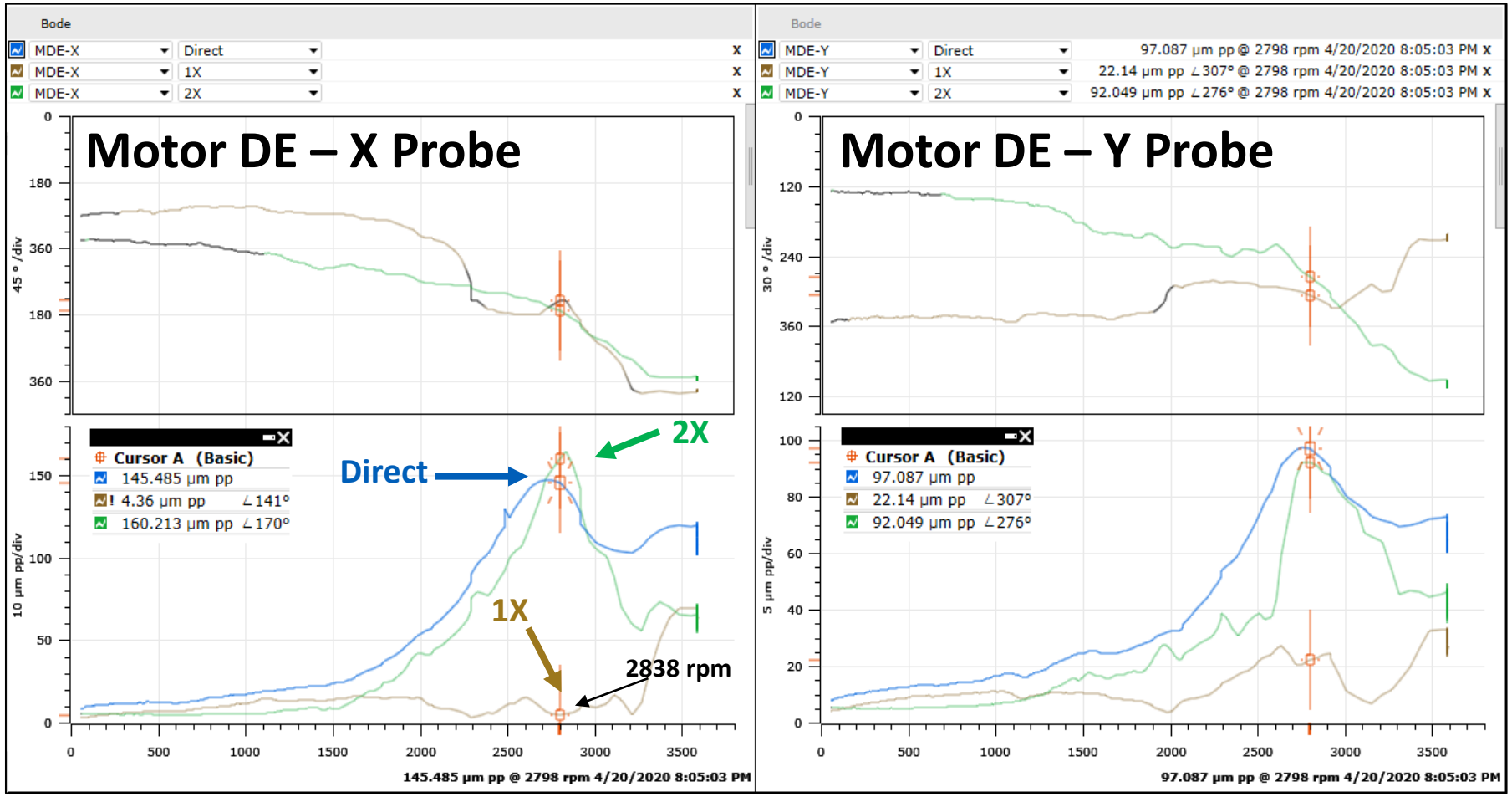
- Motor DE bearing Full-Spectrum waterfall plot during steady-state reveals the dominated 1X & 2X peaks.

Motor Drive-End Orbit Analysis



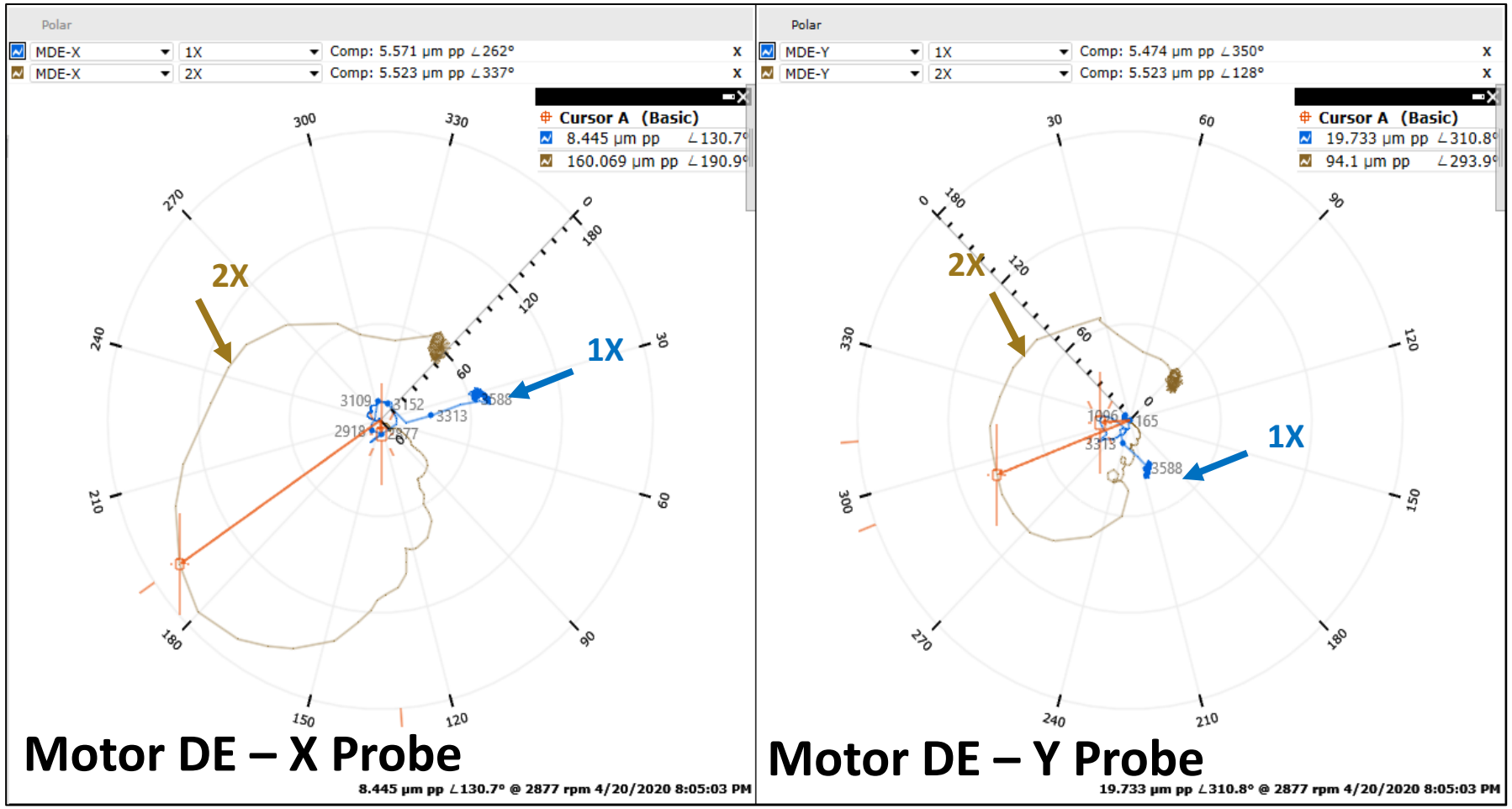
- Motor DE bearing orbit plot during steady-state reveals the dominated 1X & 2X peaks.

Transient Data Analysis – Motor DE Bode Plot



Motor DE bearing transient data analysis during shutdown throughout Bode plot show the 2X peak excitation of second critical frequency while passing half of 2nd critical speed at 2800 RPM. While 1st critical speed continues to perform normally during coasting down.

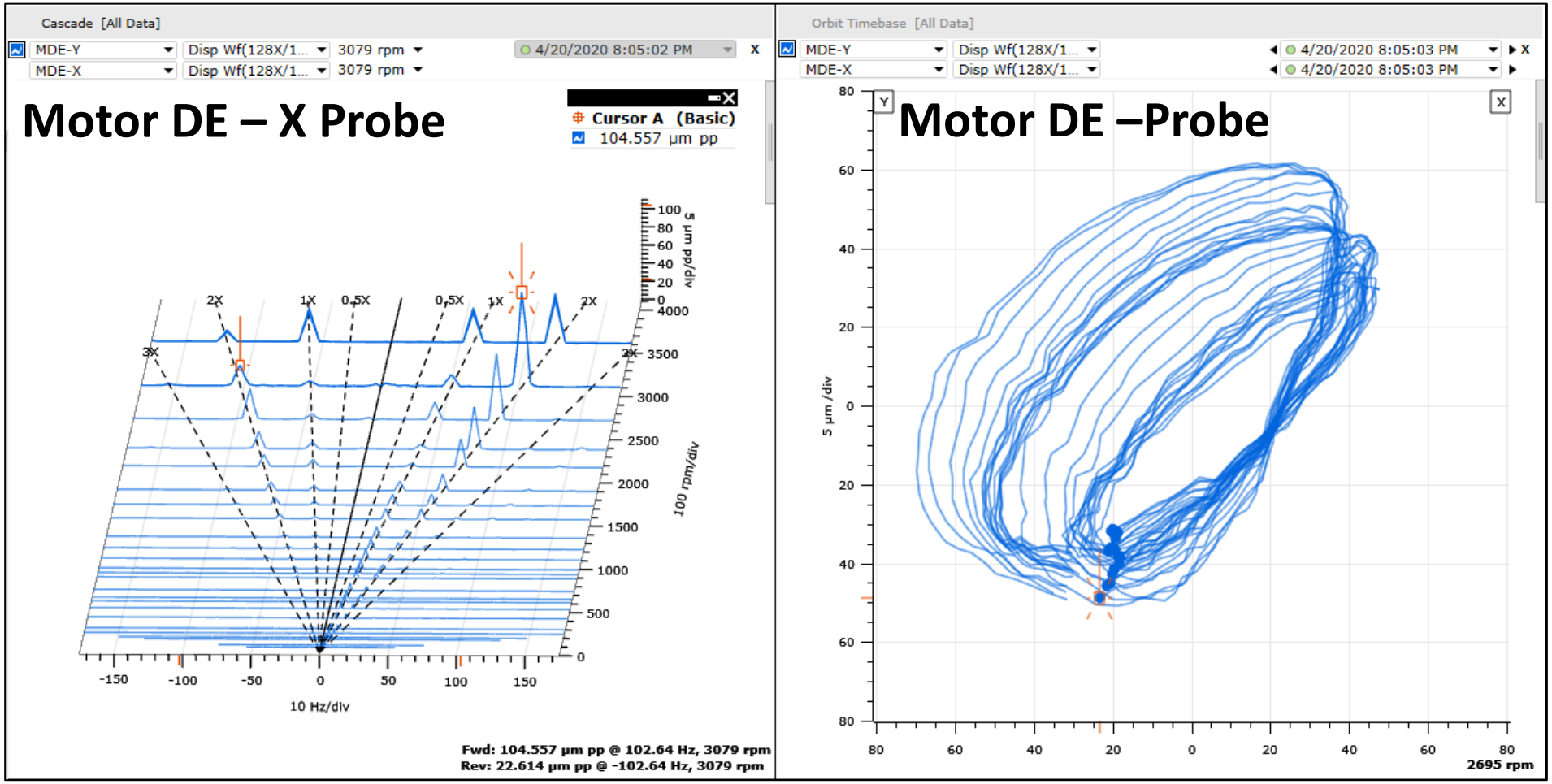
Transient Data Analysis – Motor DE Polar Plot



- Motor DE bearing Polar plot shows the 2X peak excitation of second critical frequency while passing half of 2nd critical speed at 2800 RPM. While the 1st critical speed continues to perform normally during coasting down.

Transient Data Analysis – Motor DE Cascade and Orbit Plot

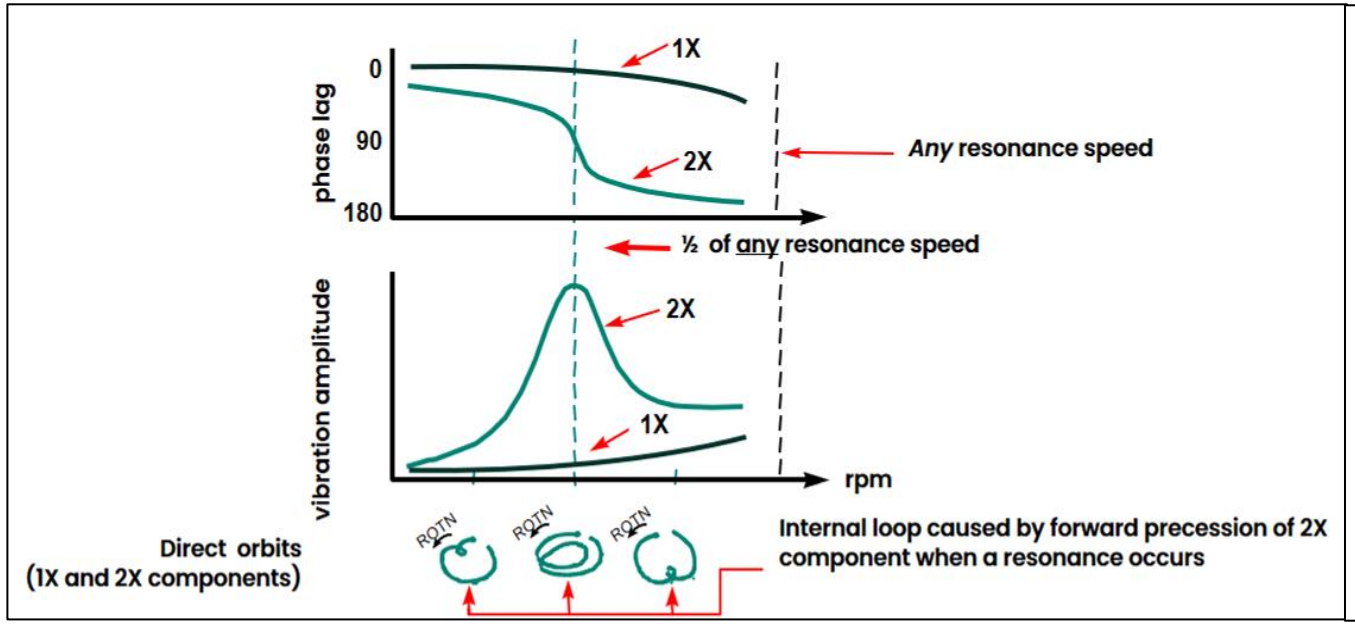
-Motor DE bearing synchronous Direct Orbit & Full Cascade plot while coasting down at 3231 RPM

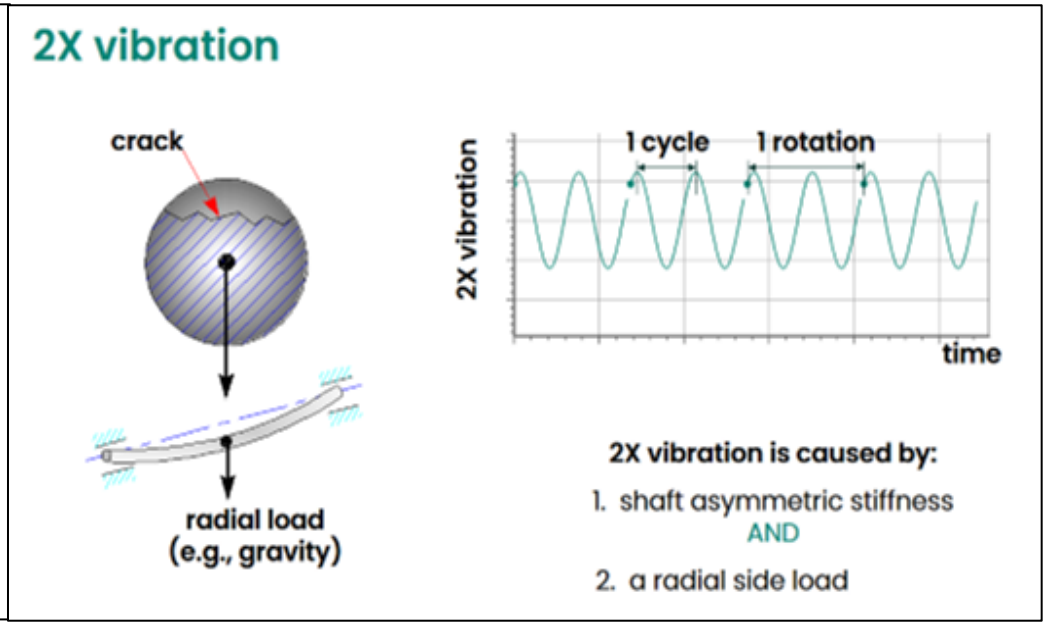


Conclusion

- Transient data analysis throughout Bode, Polar & Full spectrum Cascade plots revealed that the 2X component exhibited abnormal behavior. While the rotor was coasting down and before passing the 1st critical speed (which is ~2300 RPM as per Motor datasheet and previously recorded data), the 2X component was excited, reaching 160 μm PP at 2800 RPM. It appears that this 2X vibration at 2800 rpm is half of the second natural frequency of 5600 CPM as evidenced from the shutdown 2X polar plot. Thus, it is believed that the observed 2X peak belongs to excitation of the 2nd critical speed. Note that this unusual behavior was not found on previous runs.
- This phenomena represents a rotor running at a speed close to half of resonant frequency with presence of asymmetric stiffness with a radial force.

Back to Basics:
Shaft Crack Detection Rule

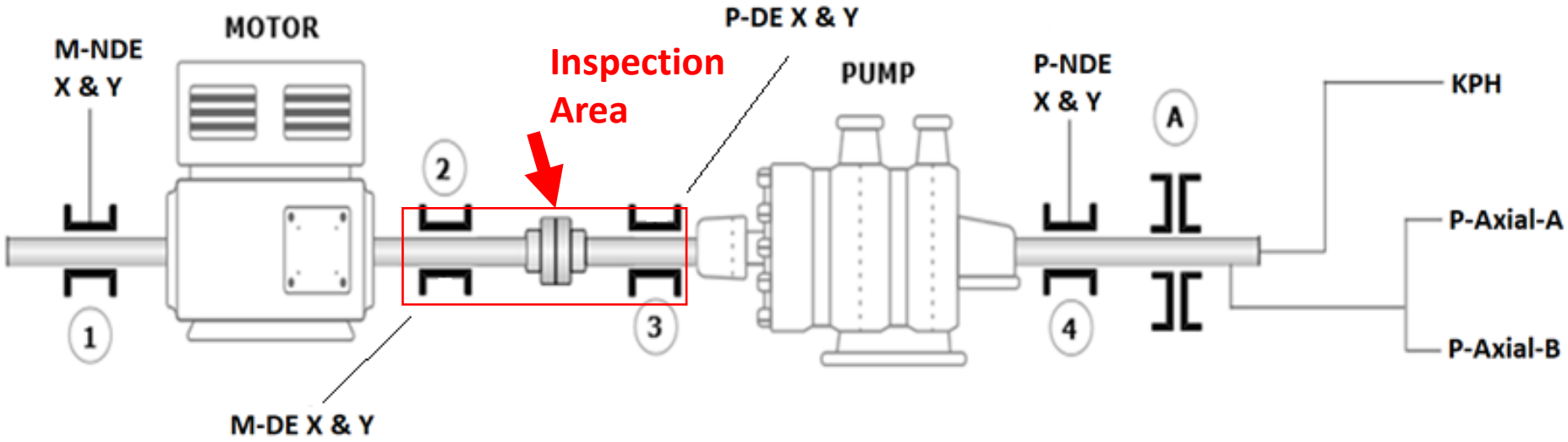




- A rotor system with an asymmetric shaft and a radial side load force, rotating at a speed near half "½" of any resonant frequency, may experience high 2X vibration amplitude and 2X phase shift.
- Other 2X vibration effects on a cracked shaft will result in a more rapid growth of the crack. This Includes increased reversal stresses & low or high cycle fatigue.

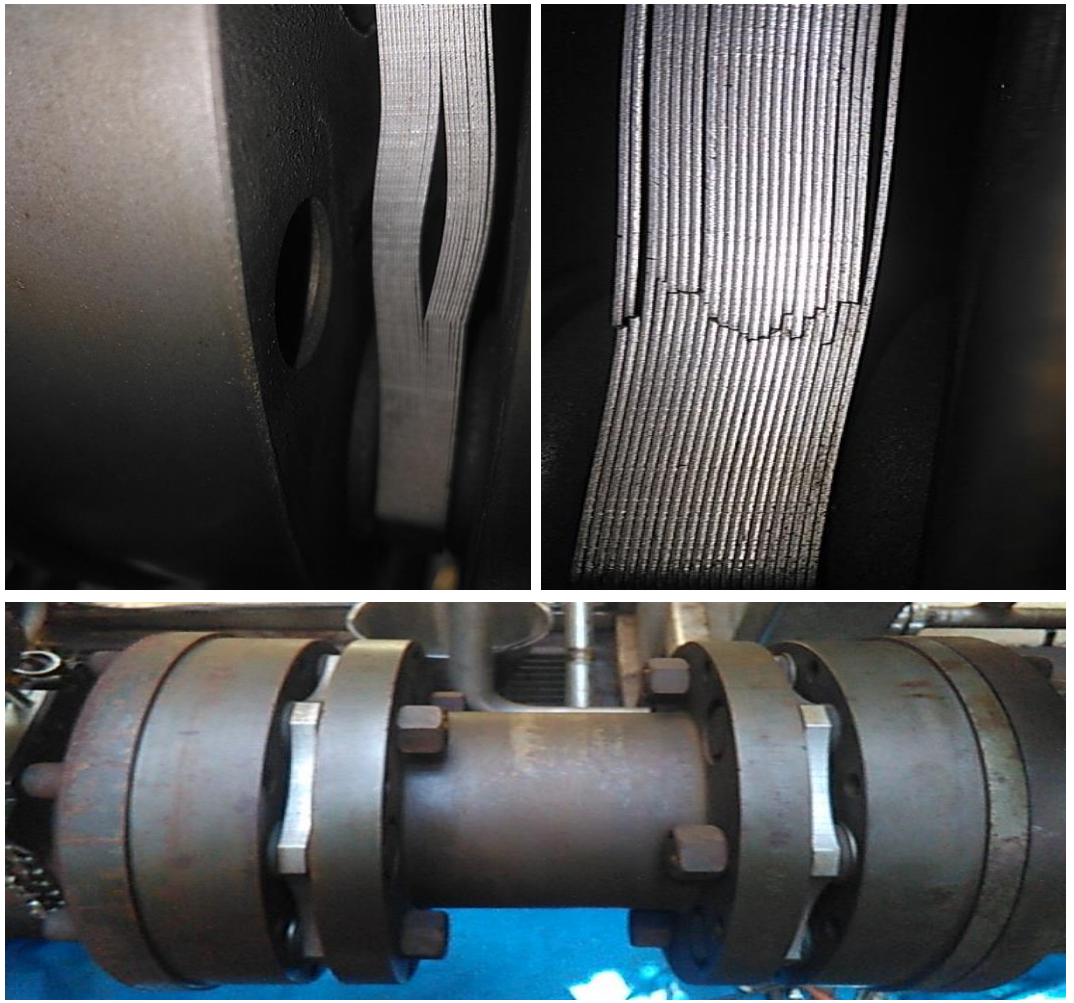
Recommendation

- It was concluded that the rotor is experiencing crack symptoms; hence it was recommended to:
  - Inspect the coupling between motor and pump for any sign of coupling shims damage or shaft crack.



Findings

- ✓ Upon our recommendation, the site team inspected the coupling and found the shims (membrane) are bent and broken, as shown in the photos and inline with what was recommended.



Lesson Learned

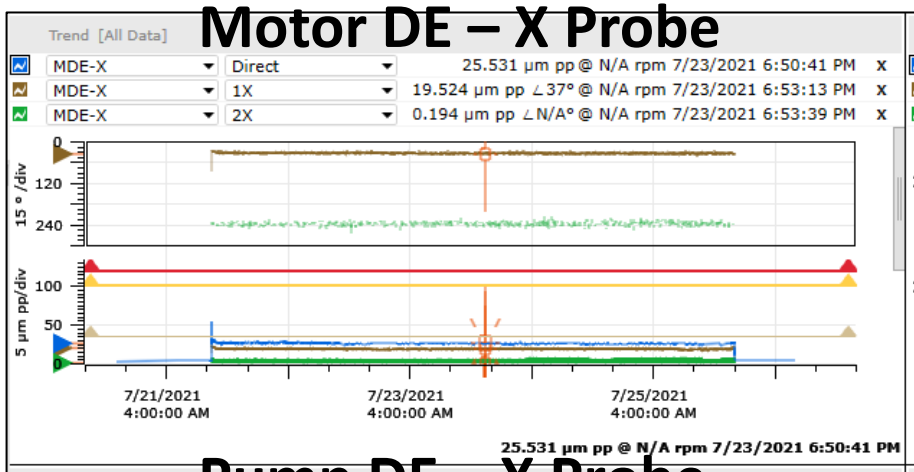
- Maintaining healthy communication status between the vibration monitoring software and the protection system is essential to early detect any rotor behavior deterioration.
- Software alarms were already implemented on the vibration monitoring software; however, due to the communication loss across the monitoring system and the remote monitoring team, this failure could not be detected earlier.

Possible causes

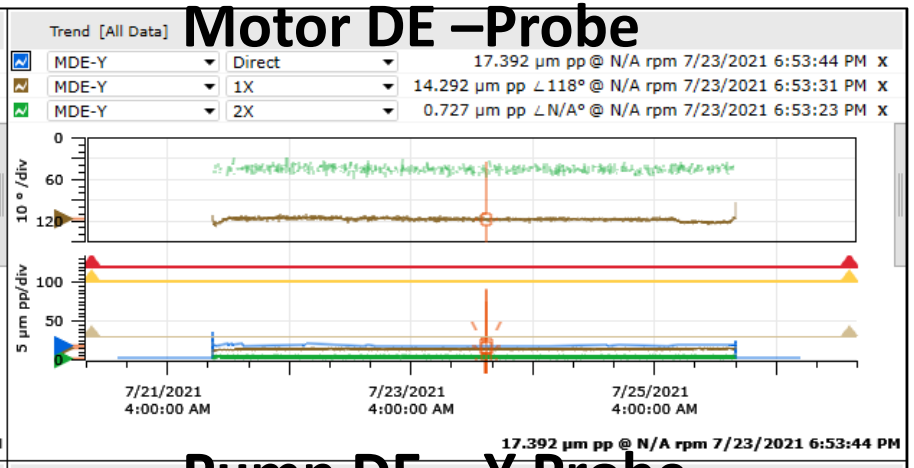
- Historically these units are found in a highly corrosive environment in addition to corrosive foundations (another case from other sister machine) which could lead to this damage.
- The high dynamic forces coming from the motor each startup and frequently due to multiple process upsets could also contribute to experiencing this type of failure. This has been observed historically which also led to multiple pump trip events during startup.
- Minimum flow setpoint for one or two pump operation was found set incorrectly and rectified accordingly.
- Based of the findings above, asset team is working through the list of causes and eliminating them.

Motor and Pump DE bearings trends after coupling replacement

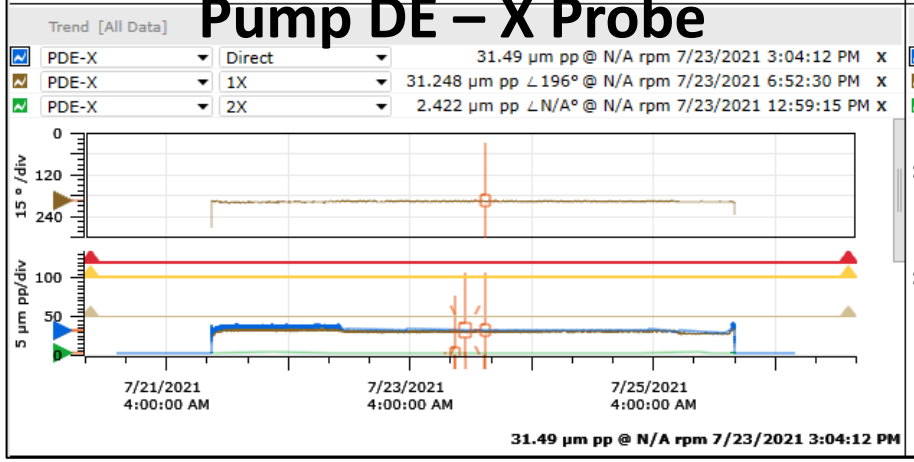
Motor DE – X Probe



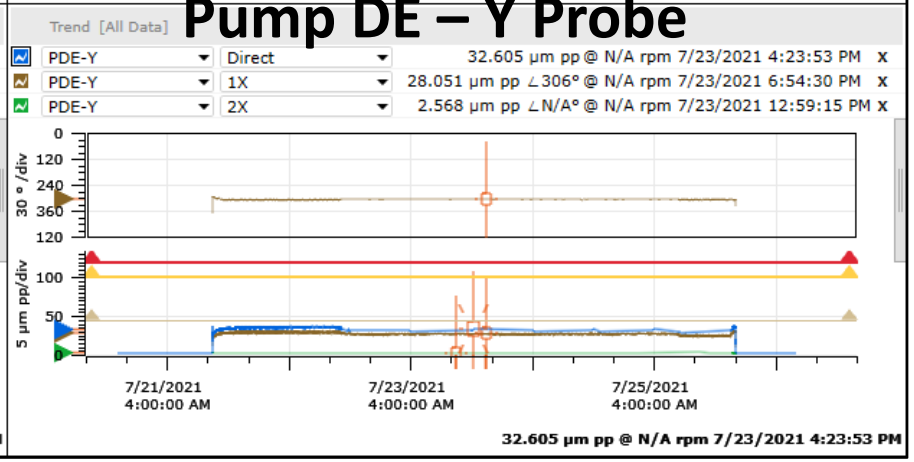
Motor DE –Probe



Pump DE – X Probe



Pump DE – Y Probe



- Coupling was replaced and the unit started again with acceptable and normal vibration levels.

END

Questions?