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Bonus - Case Study #6

Dynamic Vibration Absorber

Distributing energy in line with the First Law of Thermodynamics

PROfessional services for PROactive maintenance

CASE STUDIES

The integration of the **MIRCE Science Theory** and **JPS Reliability Reality** is illustrated through the following 6 case studies:

1. Electrical Motor Terminal Connection Defect
2. Standby Fan Motor Defect
3. Variable Frequency Drive Deterioration
4. Vibrating Screen Gearbox Bearing Defect
5. 4 Point Contact Bearing 23RPM Defect
6. **Dynamic Vibration Absorber**

- Each slide we will discuss how the defect was detected and what actions were/were not put in place to protect the functionability of the system

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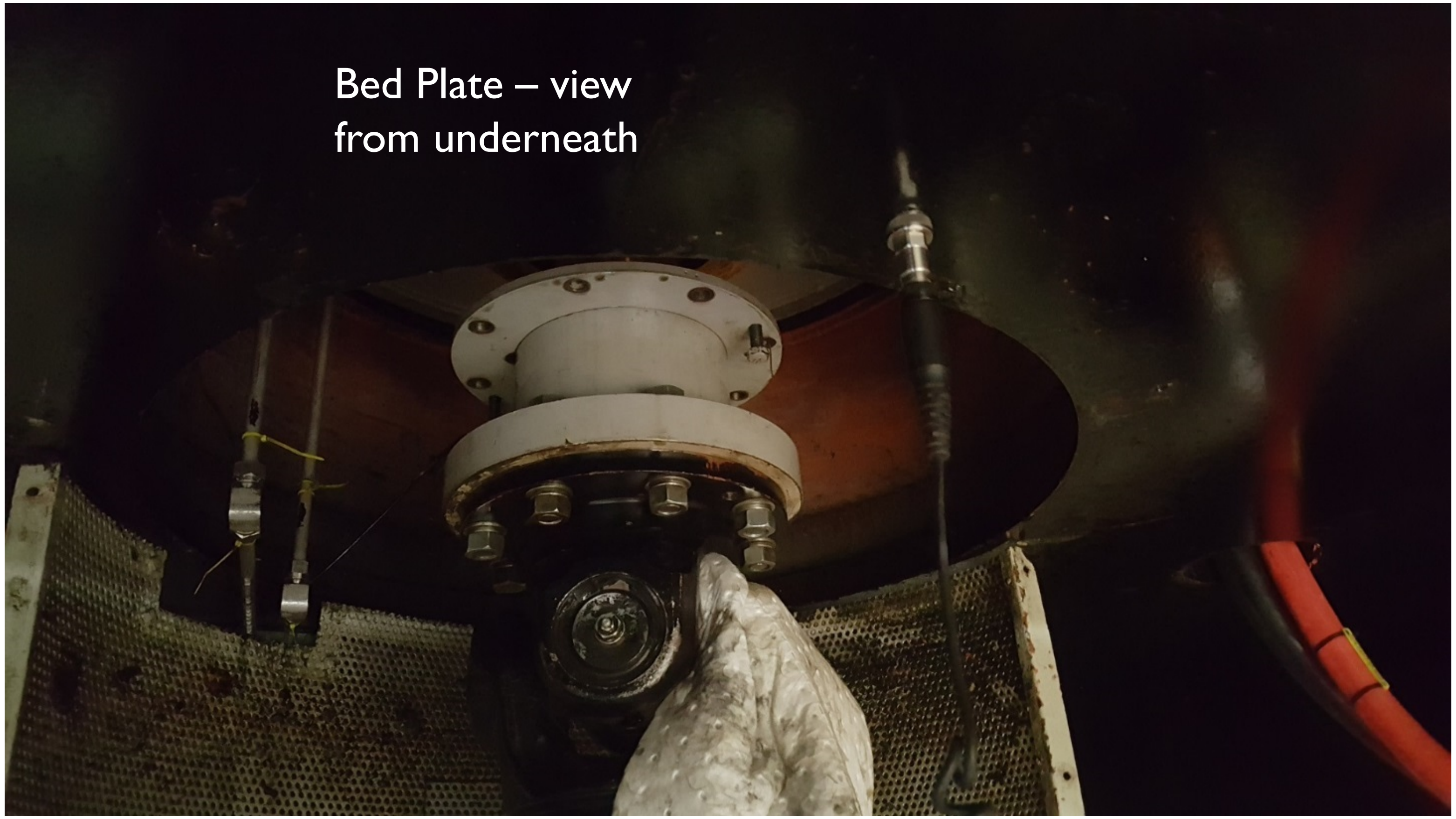
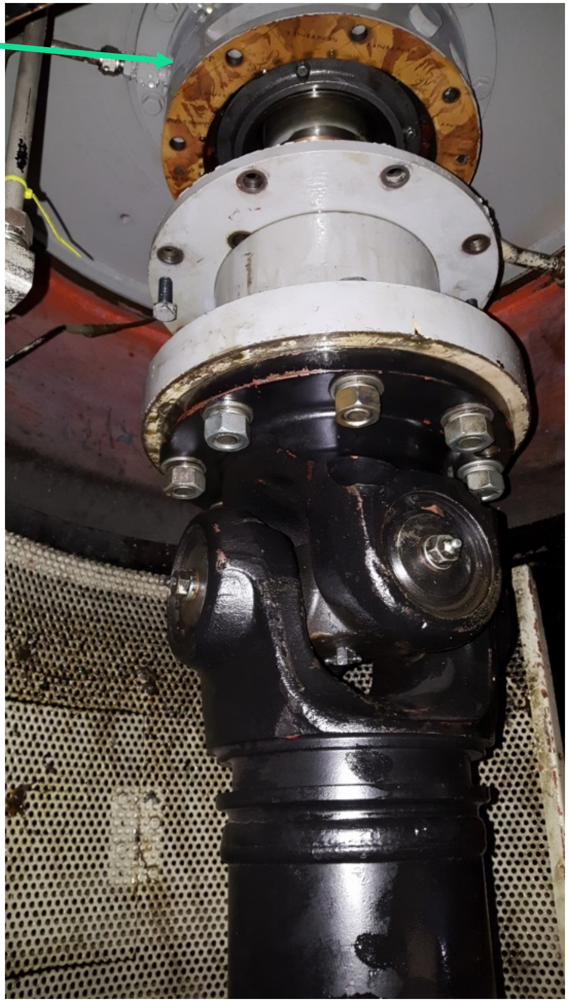
HISTORY & BACKGROUND

- High lift pumps at the pumping station facility have historically suffered from low reliability and required many expensive overhauls with new bearing sets (Babbitt/White Metal)
- Various attempts to resolve the root cause have not been successful

BEARING LOCATION



Tilting pad bearing location



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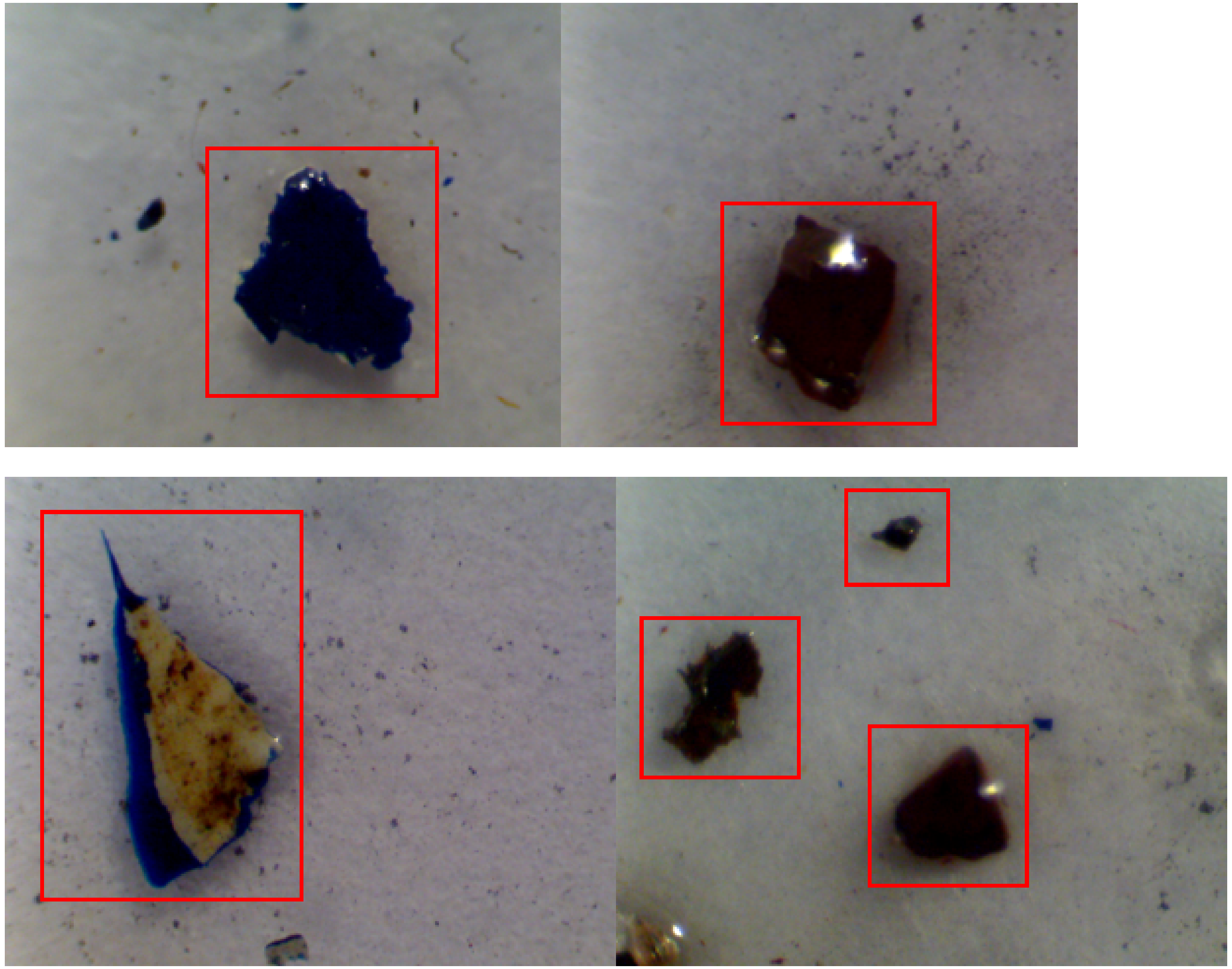
BEARING INSPECTION: OIL

- Microscopic inspection of the oil, debris is present



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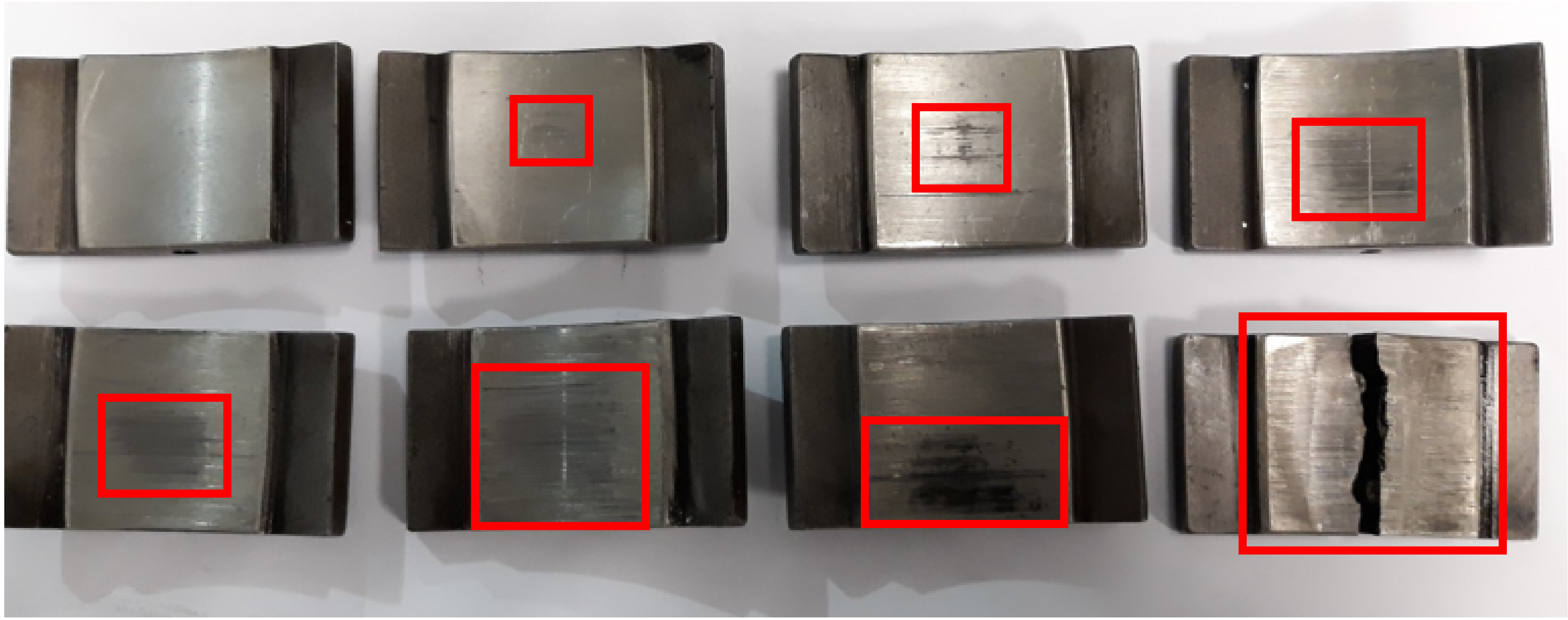
BEARING INSPECTION: TILTING PAD

- The pads vary from no contact to full contact and cracking of the tilting pad, indicating eccentric (non-orbital) motion



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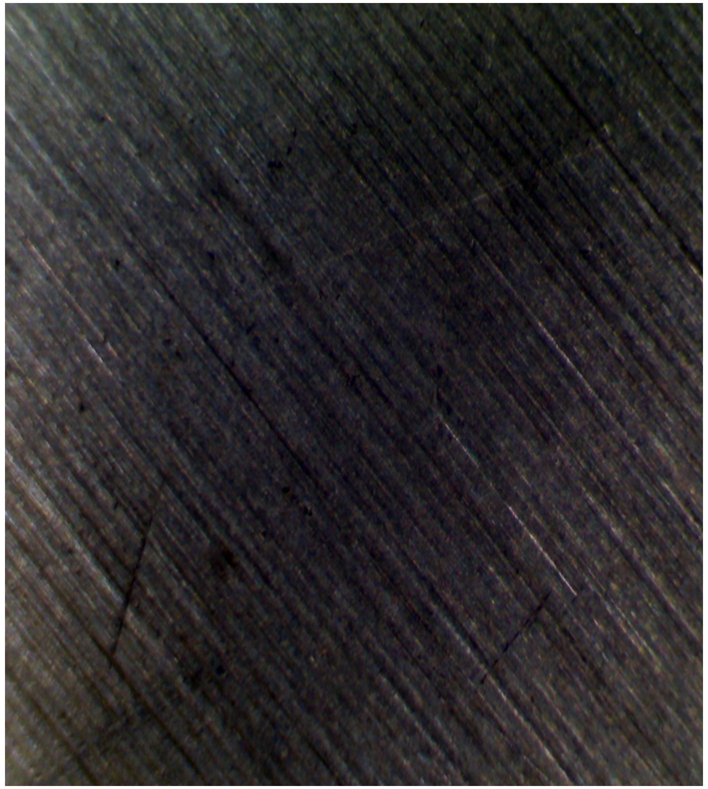
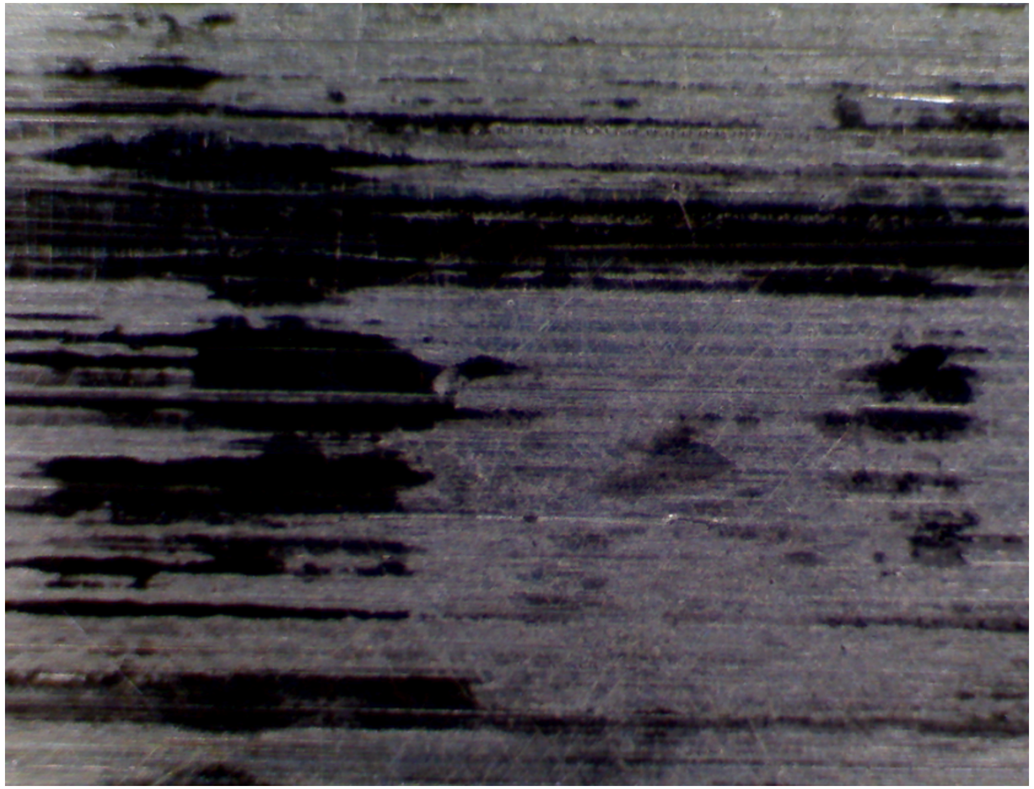
BEARING INSPECTION: TILTING PAD

- Microscopic image of a pad with no wiping, and an image of a pad with wiping damage





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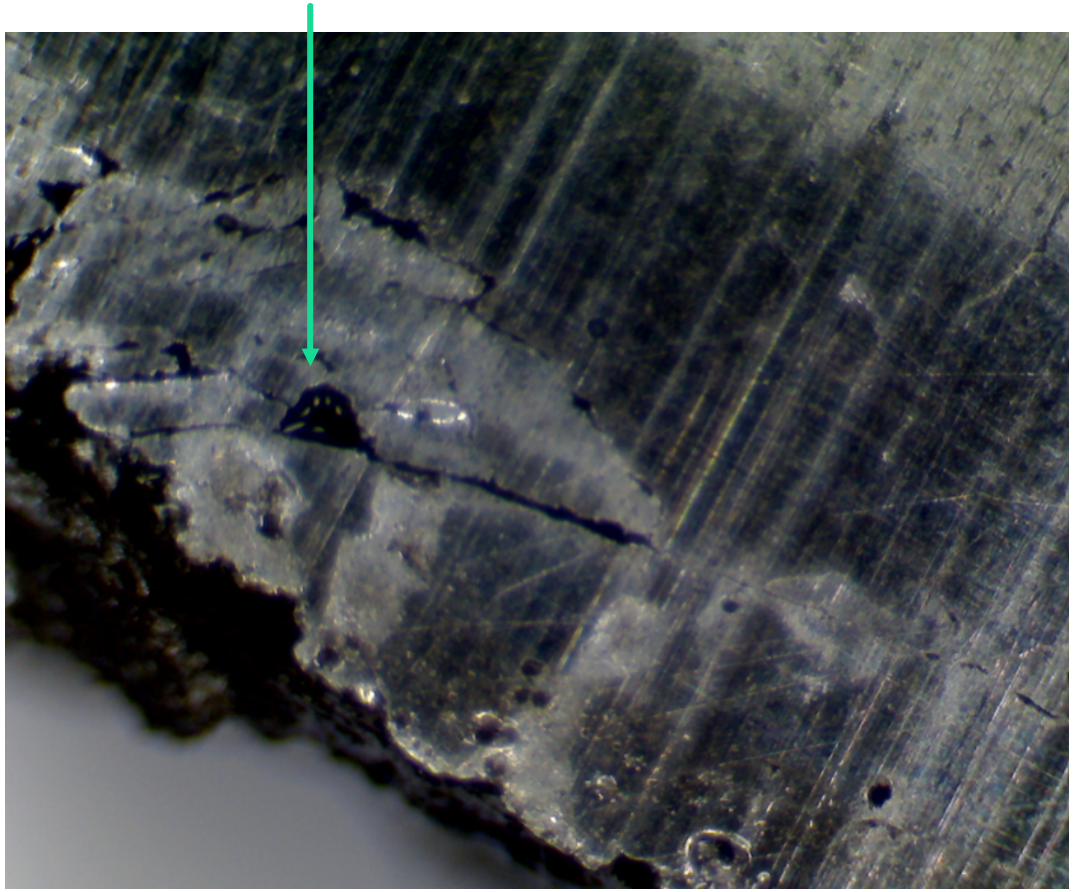
BEARING INSPECTION: TILTING PAD

- Microscopic image of the cracked pad surface displaying fatigue cracking



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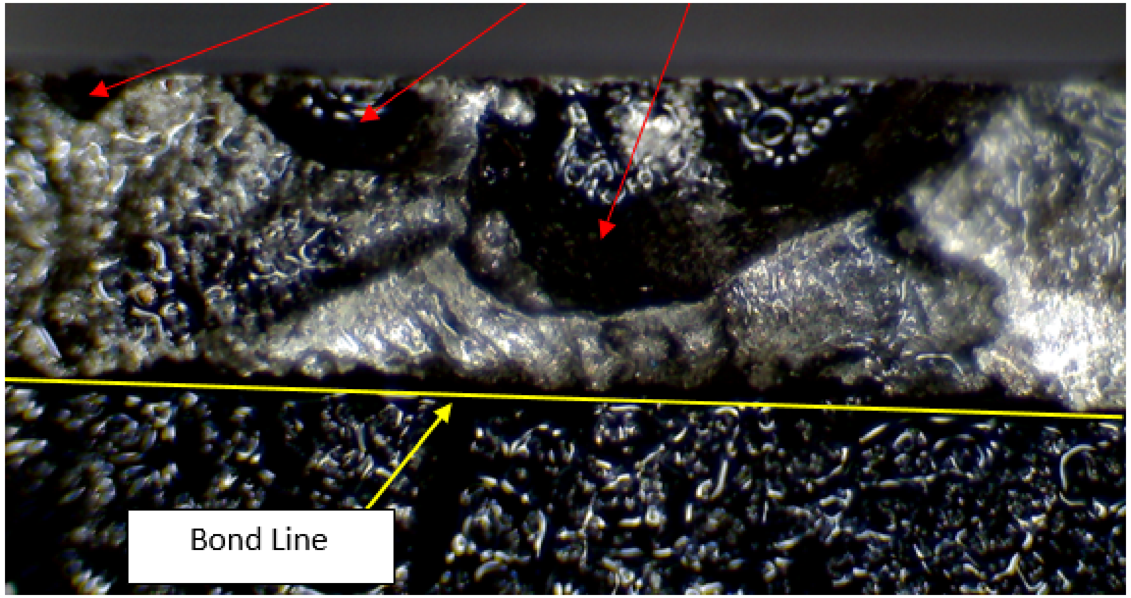
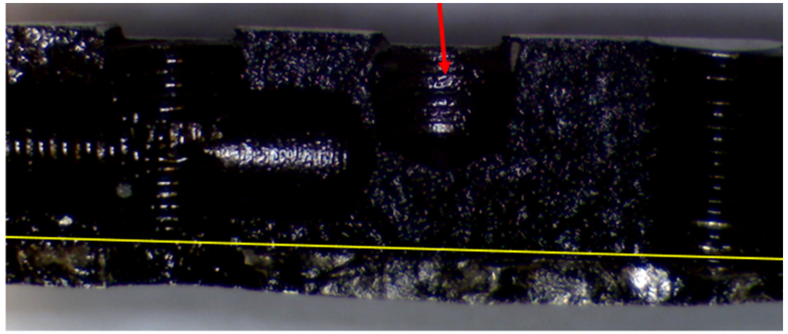
BEARING INSPECTION: TILTING PAD

- Microscopic cross sectional image of the cracked pad
- Bond line intact



- Failure is at the weakest point, the pivot point



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VIBRATION ANALYSIS

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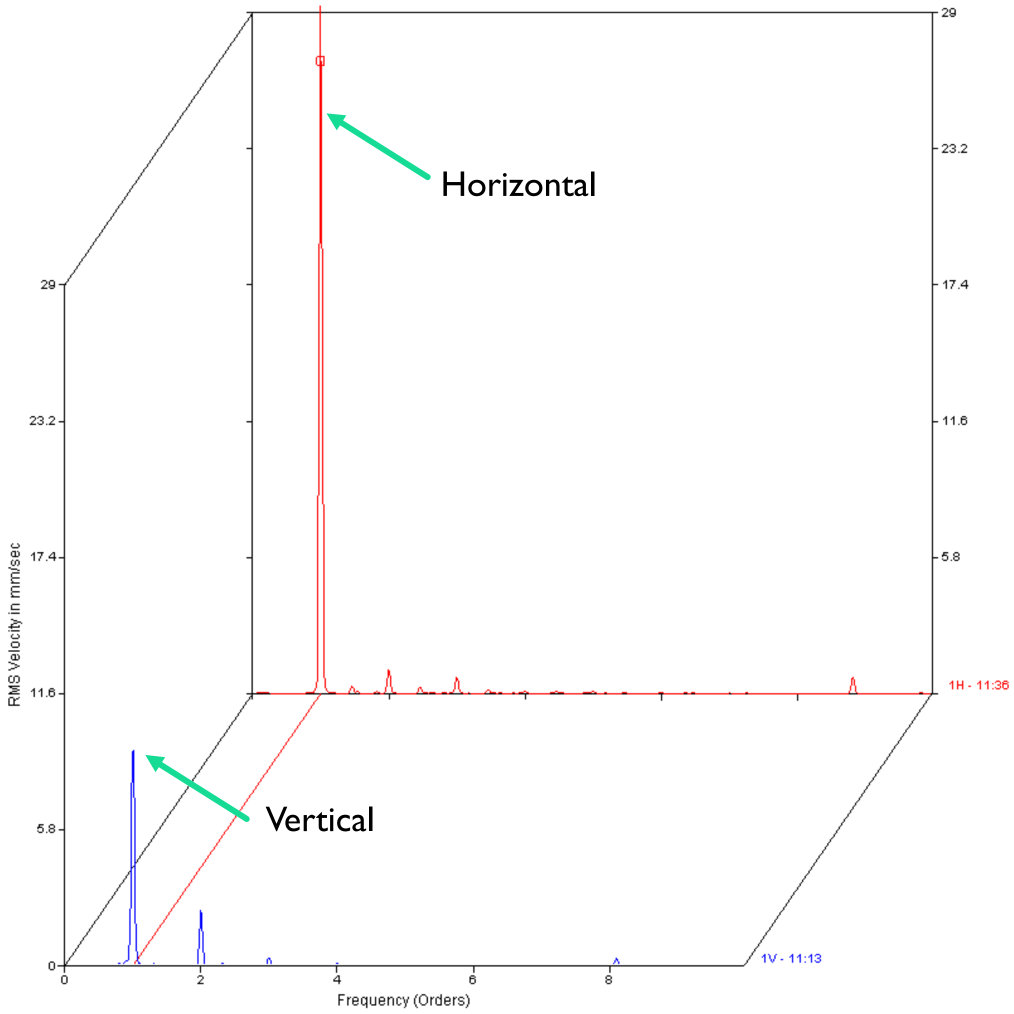
VELOCITY SPECTRA

- Forcing function 1 Order
- Directional vibration
- Vibration changes with speed

Dial Number	RPM	1 Order	Overall
0	662.51	30.25	35
1	679.34	26.94	28.96
2	694.75	20.98	21.22
3	707.68	15.87	18.00
4	721.29	12.77	15.02
5	740.79	11.63	13.69



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ADDING MASS TO THE SYSTEM

- The addition of weight moved the resonant frequency down to speed range 2
- The weight (additional mass 10Kg) dampened the vibration motion and lowered the resonant frequencies
- Conformation of a resonant condition

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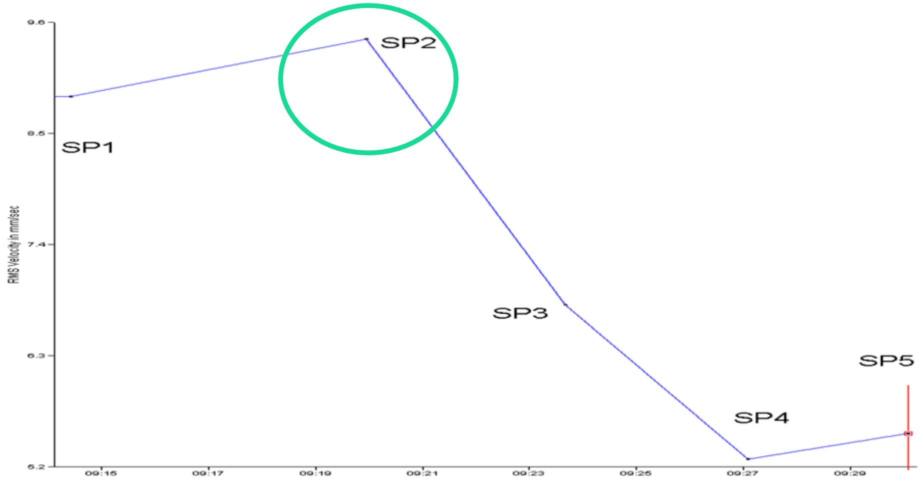
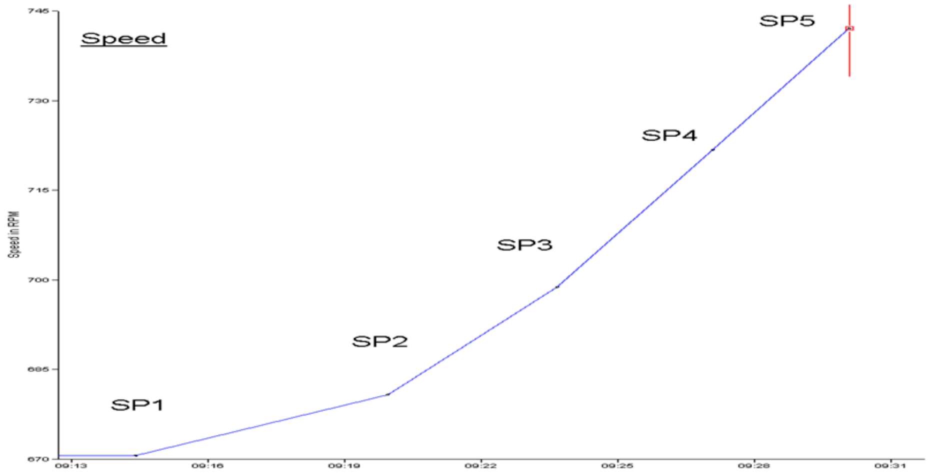
OVERALL VIBRATION VS SPEED: MASS ADDED

- The peak vibration is now occurring at speed set point 2
- As the speed increases the vibration reduces
- This type of vibration and speed relationship indicates a resonant issue





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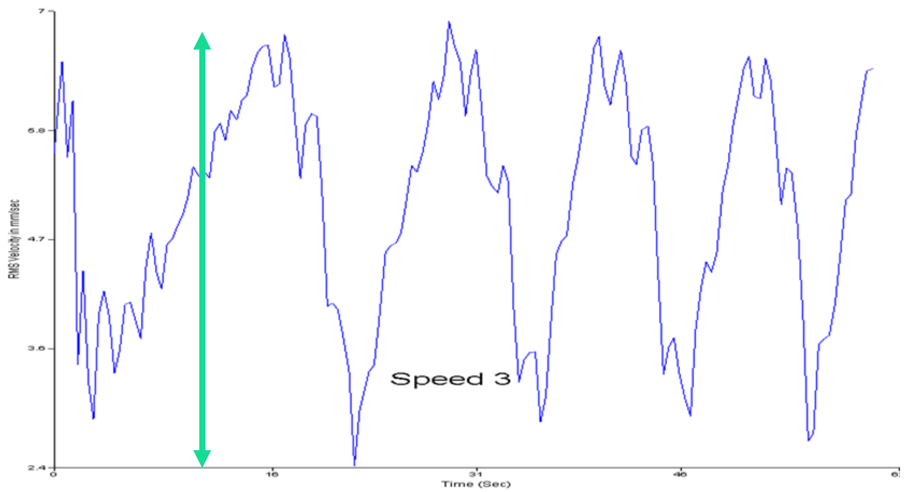
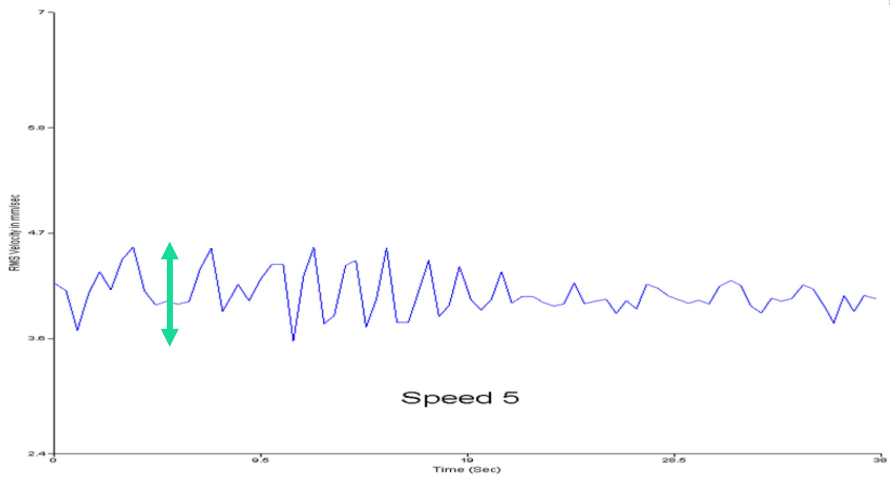
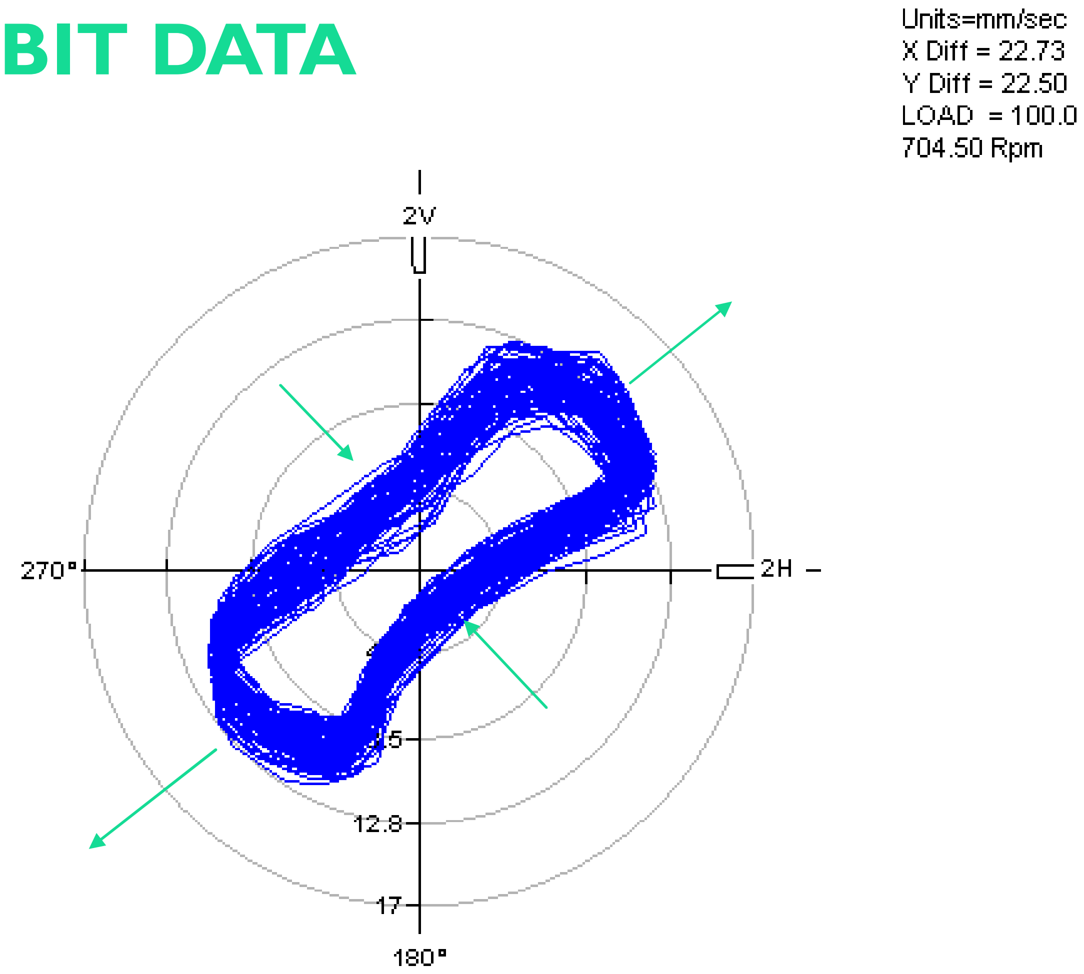
VIBRATION VS SPEED: STRIP CHART

- Speed 3 high fluctuation, indicating a critical speed / resonance / beat frequency
- Speed 5 lower levels and more constant

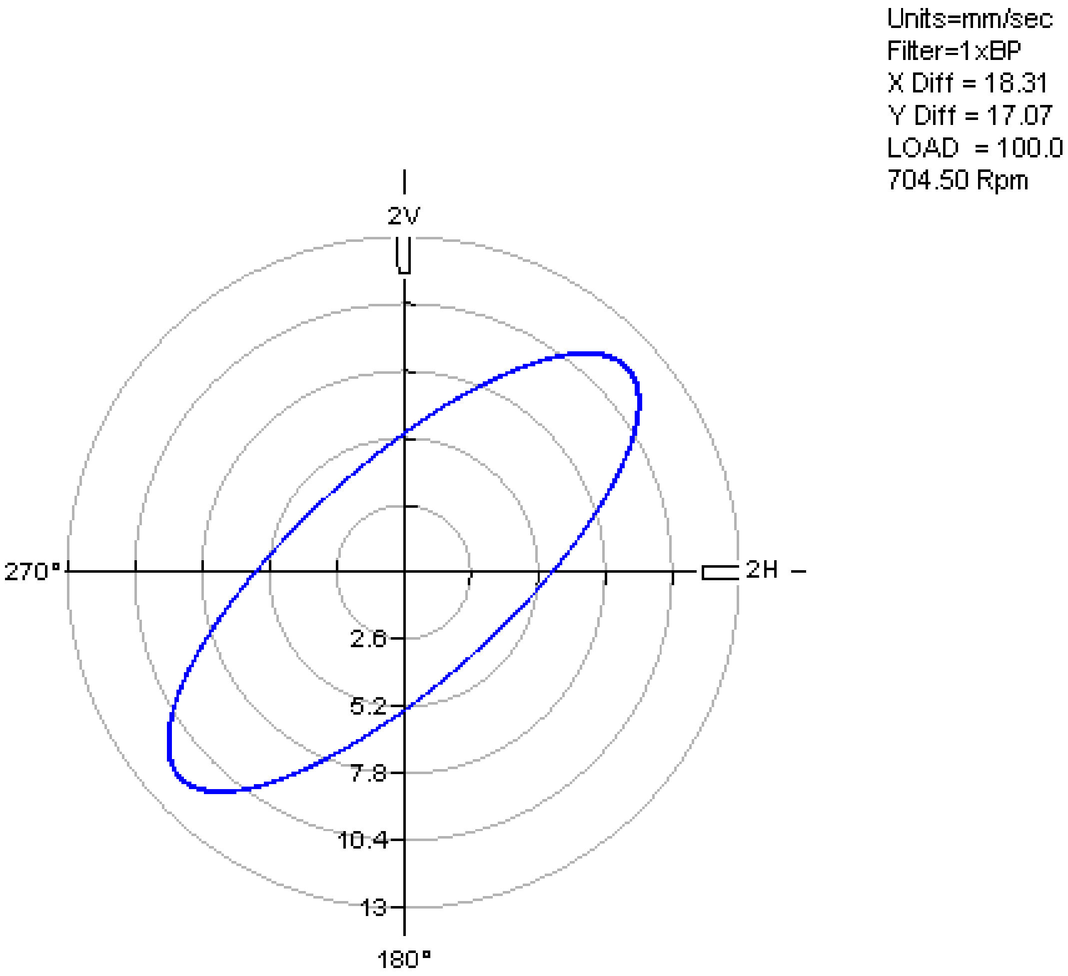




ORBIT DATA



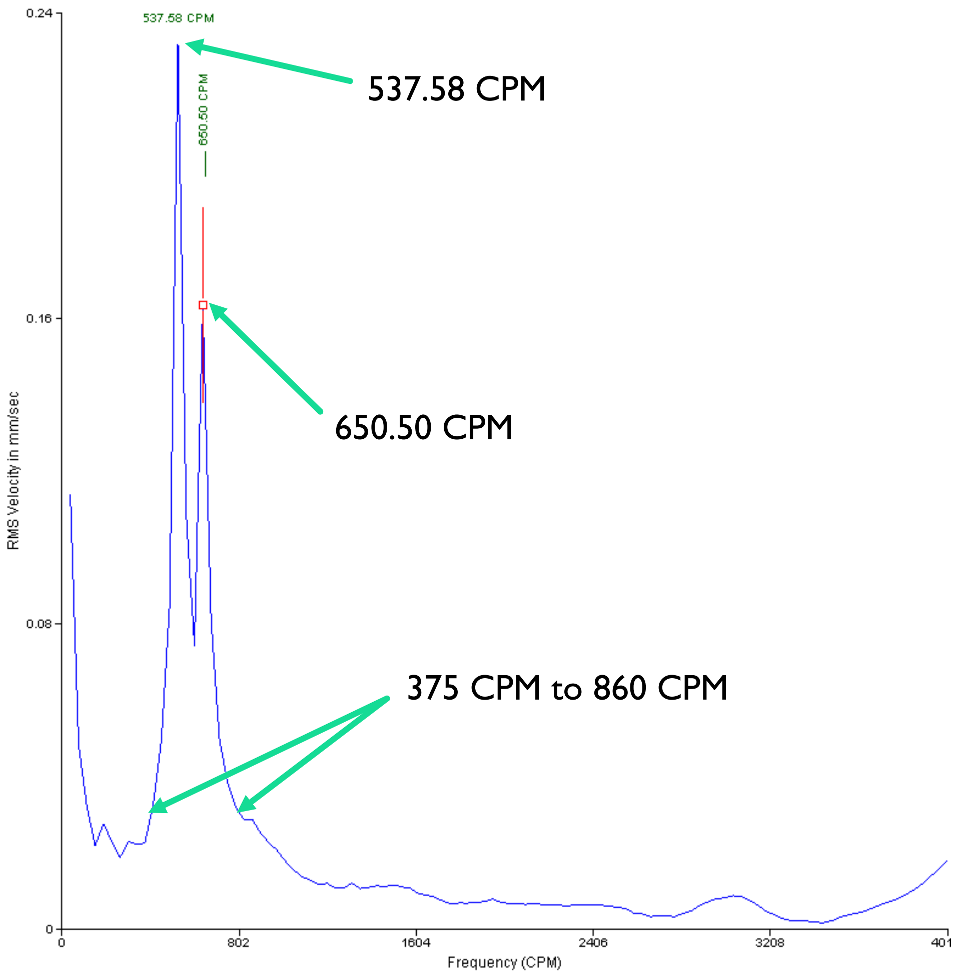
Raw Data



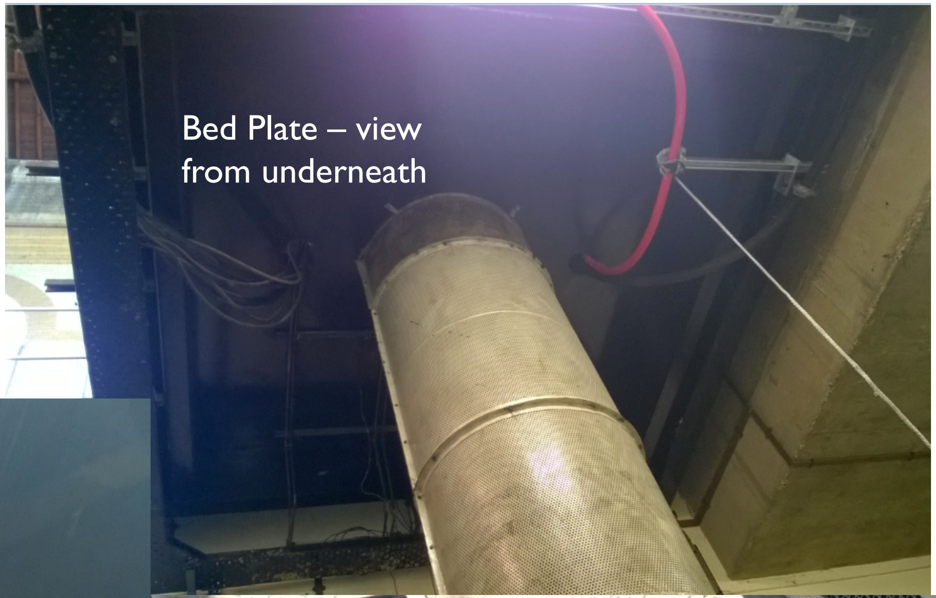
1 Order Filtered

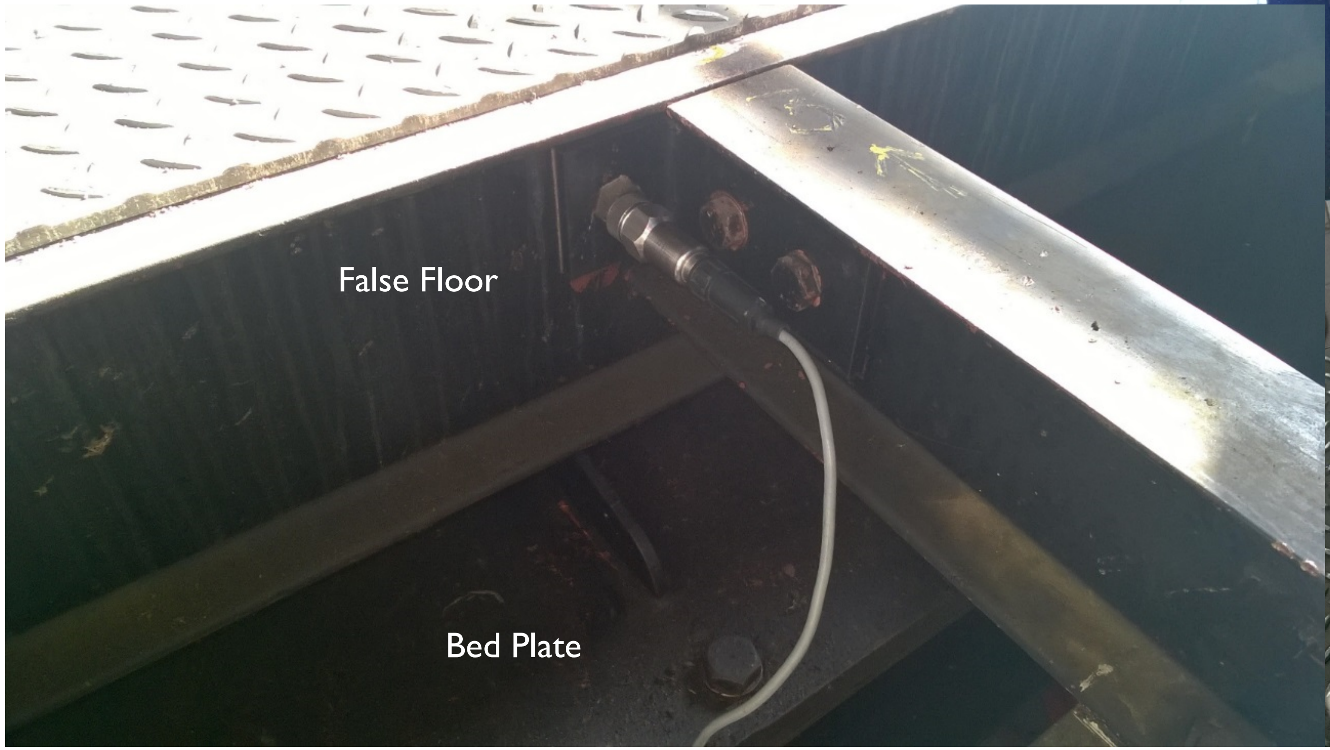
RESONANCE TEST 'BUMP TEST'

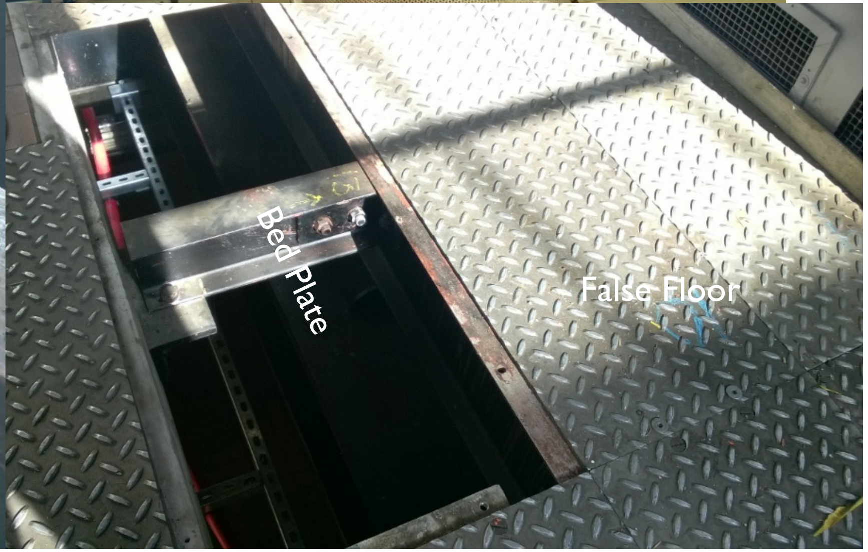
- Bump test indicating a structural resonance



FLOOR STRUCTURE







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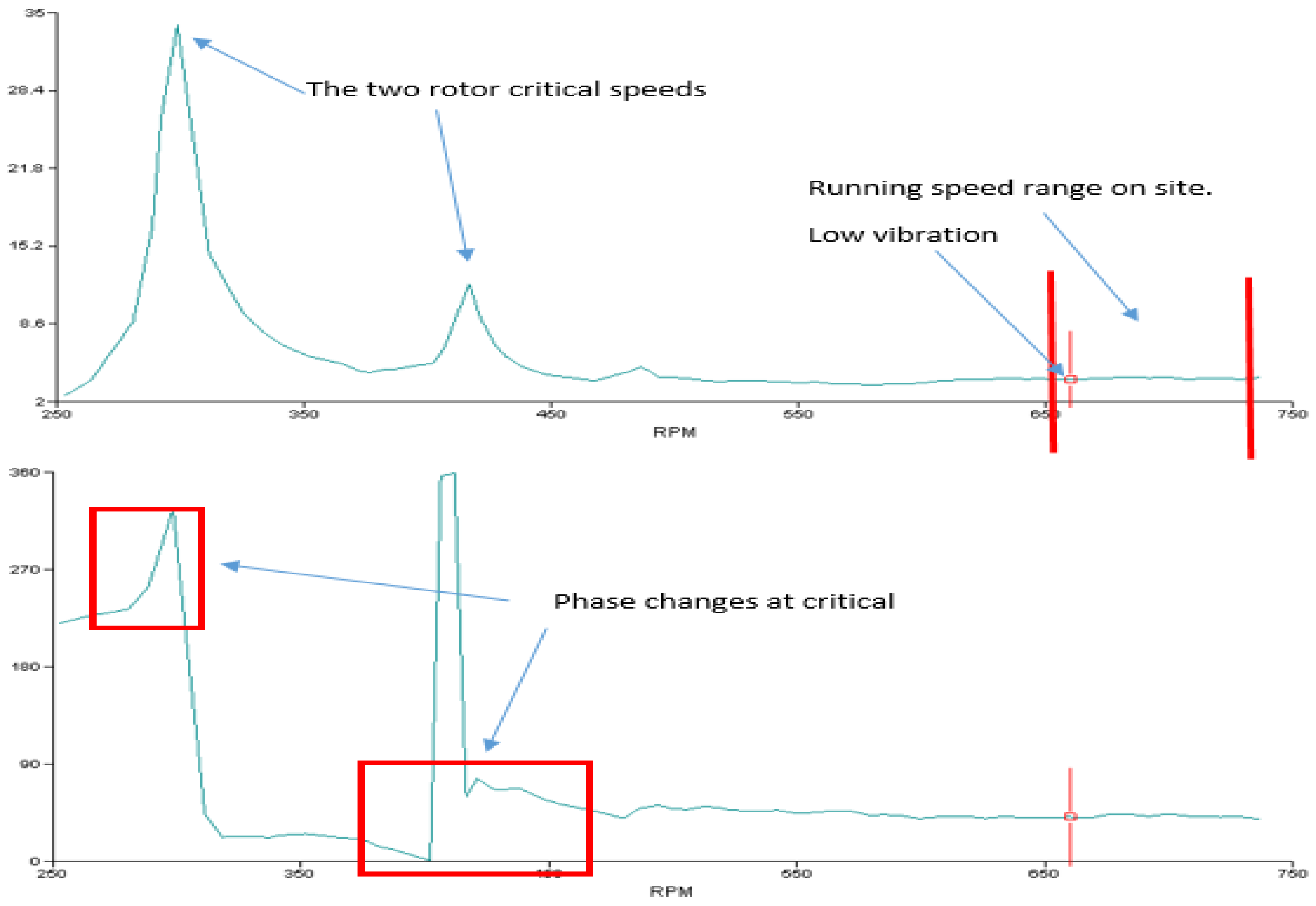
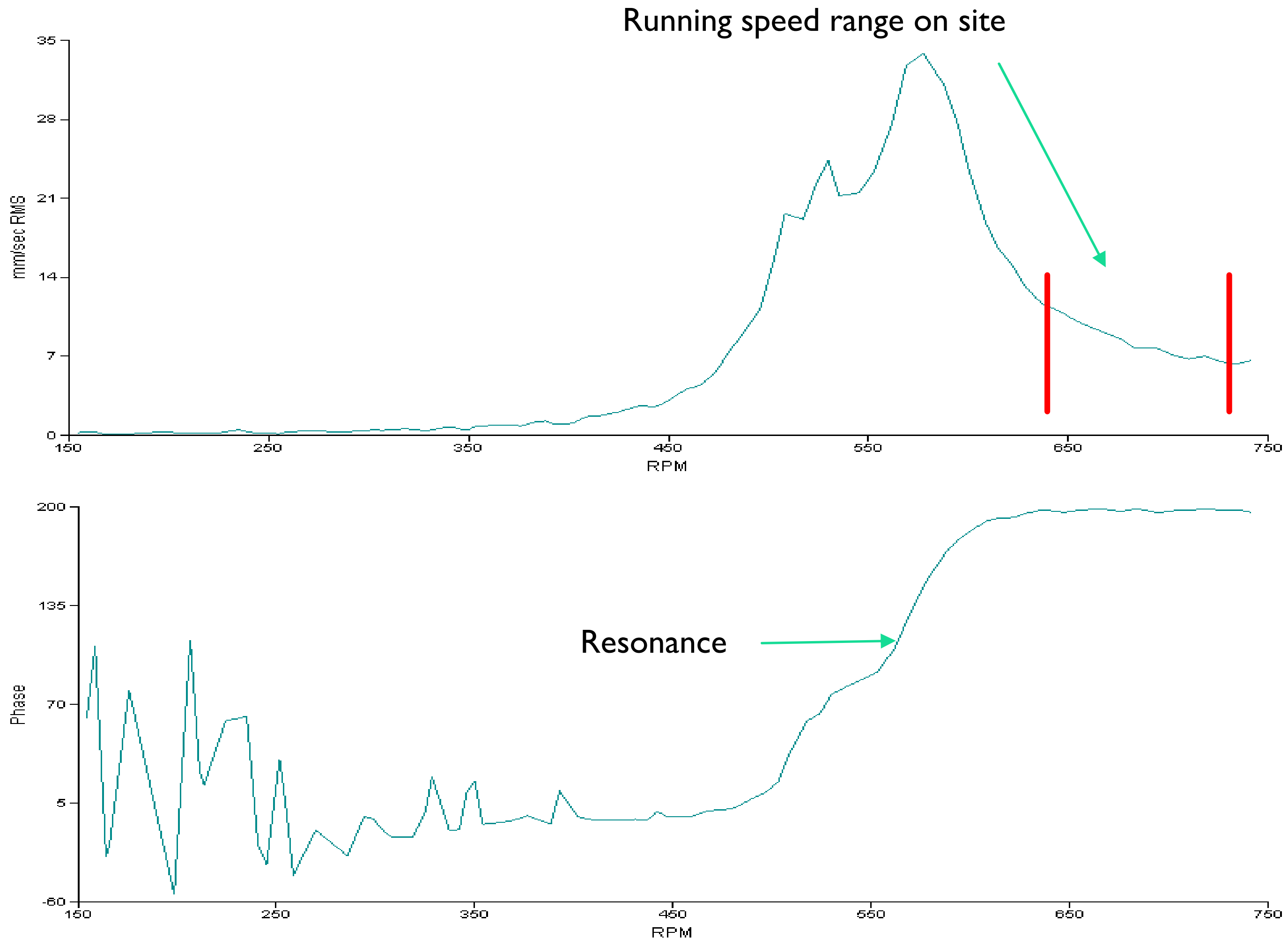
WORKSHOP: AMPLITUDE AND PHASE

- One order tracked
- Set up on a test bed no load
- Accelerometer location on the top of the motor (NDE)



ON-SITE: AMPLITUDE AND PHASE

- One Order tracked
- Set up on foundation under normal operational load
- Note how the structure changes the motion



WHY?

- Motor bearing failures, concentrated at the motor drive end

THE 'FIVE WHYS'

The motor Babbitt (white metal) tilting pad bearings fail

There is metal to metal contact

Overload fatigue - Increased dynamic load on the bearing

High directional vibration causing the coupling and prop shaft to overload the bearing

On site structural resonance amplifying the motion of the motor. This creates highly stressed/torsional load at the drive end of the motor

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CONCLUSION

- There are no issues with the motor rebuild, the balance and dynamics of the motor when operated unloaded in the test bay, >4mm/s RMS
- A structural resonance on site is causing an amplification of vibration levels
- This resonance increases the dynamic loads on the drive end bearing
- This then causes Babbitt fatigue, cracking, and Babbitt wiping due to rotor to stator contact

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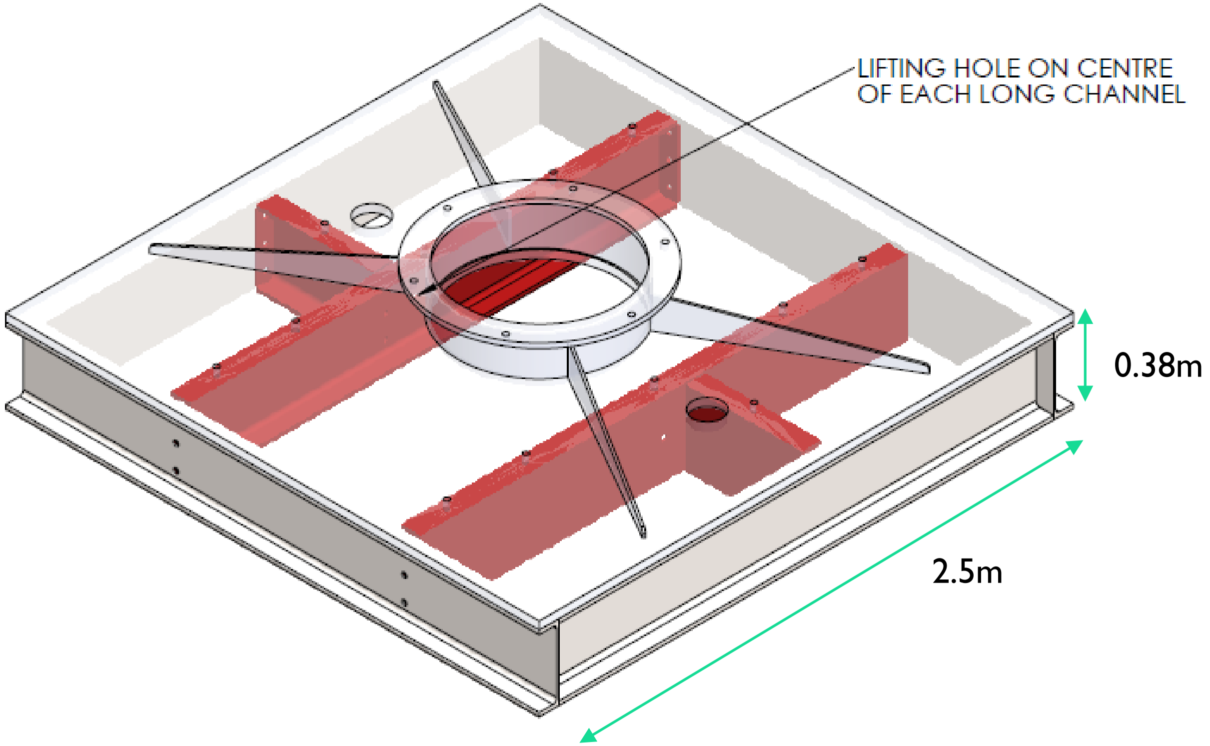
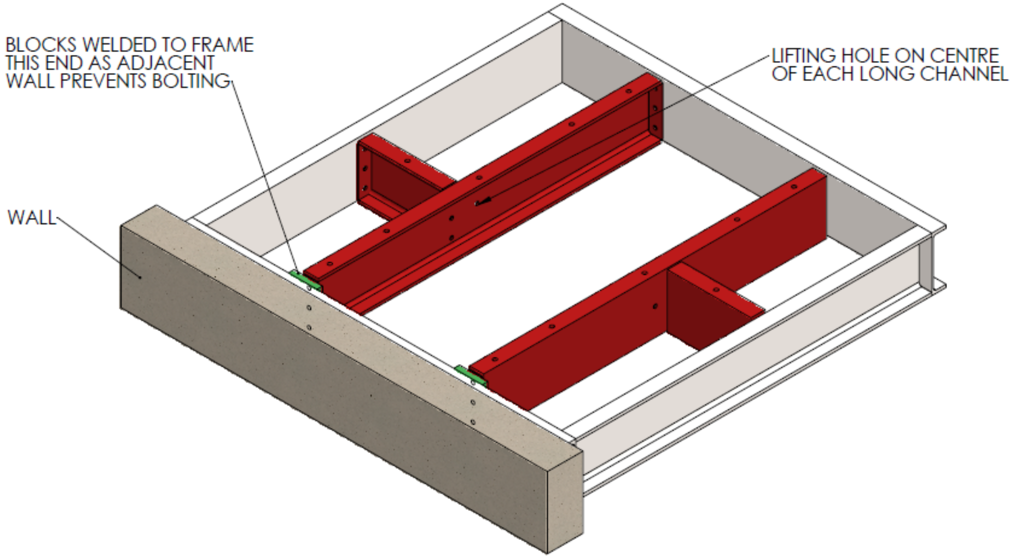
SUPPORT STEEL WORK: MODIFICATION

- A decision to stiffen the structure was made
- All good in theory but where does the energy go?





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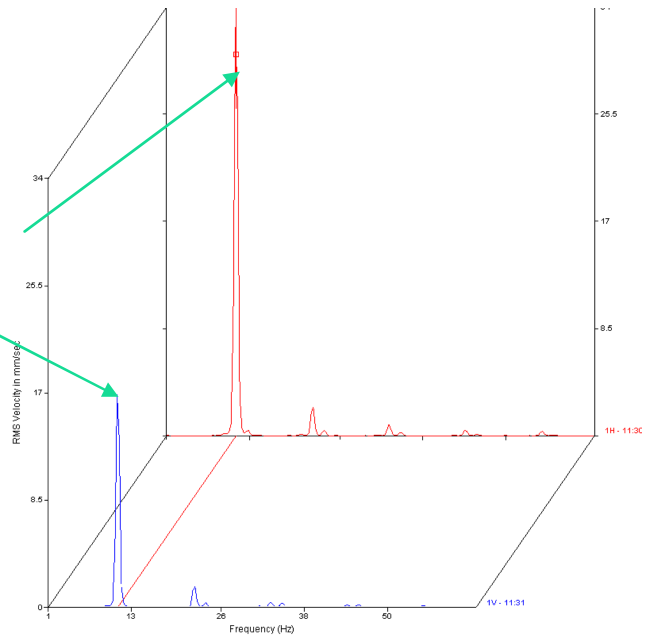
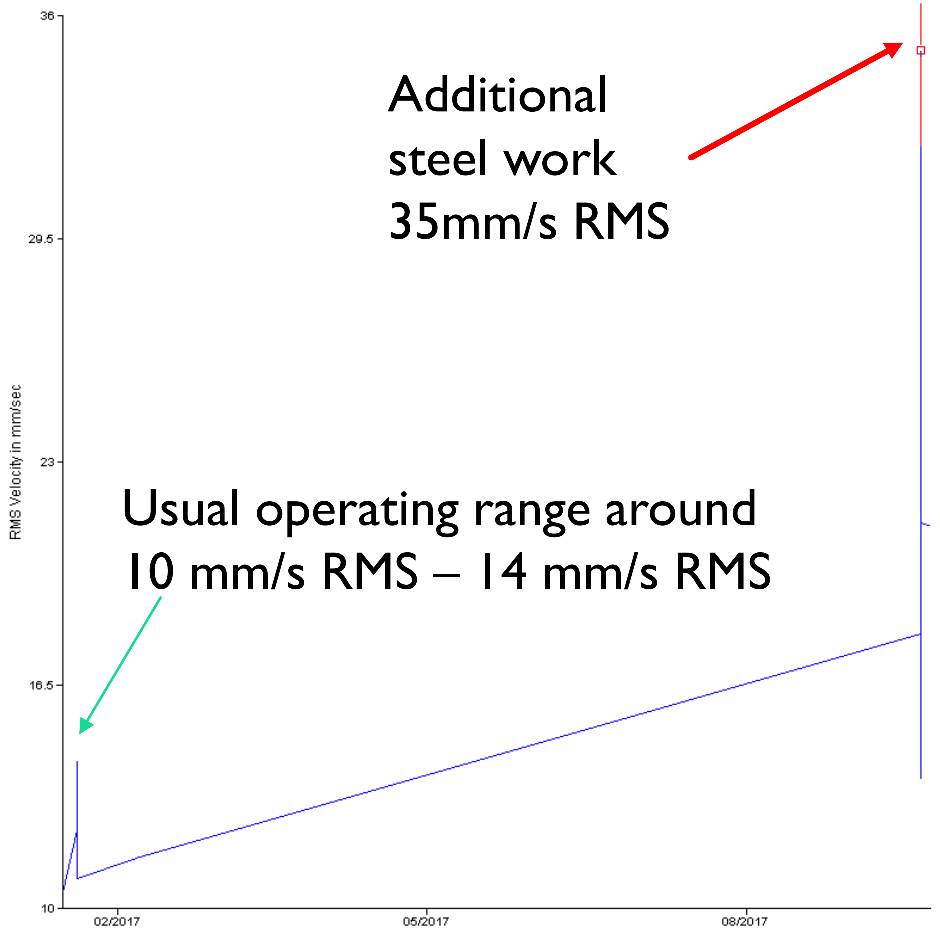
SUPPORT STEEL WORK:VIBRATION RESULTS

- Stiffening the structure increased the vibration levels to **35mm/s RMS**

Still high directional motion





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DYNAMIC VIBRATION ABSORBER

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WHAT IS A DVA?

- It is a tuned spring mass system which reduces or eliminates the vibration of a harmonically excited system
- All rotating machines can induce vibration due to structural resonances. A dynamic absorber can be tuned to excite in such a way exactly counteracts the force from the structural resonance
- Properly implemented, a dynamic absorber will neutralise the undesirable vibration, which would otherwise reduce service life or cause mechanical damage
- Dynamic absorbers differ from tuned mass dampers in that dynamic absorbers do not require any damping to function satisfactorily

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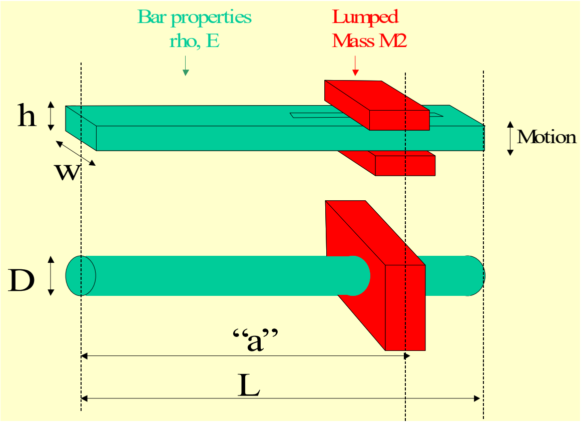
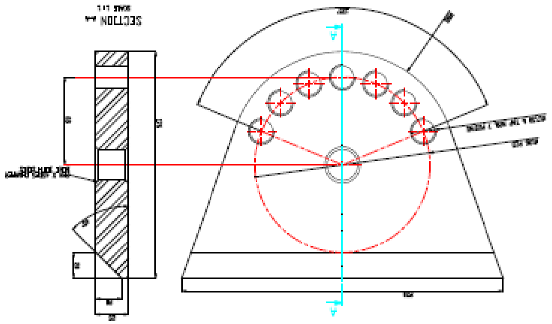
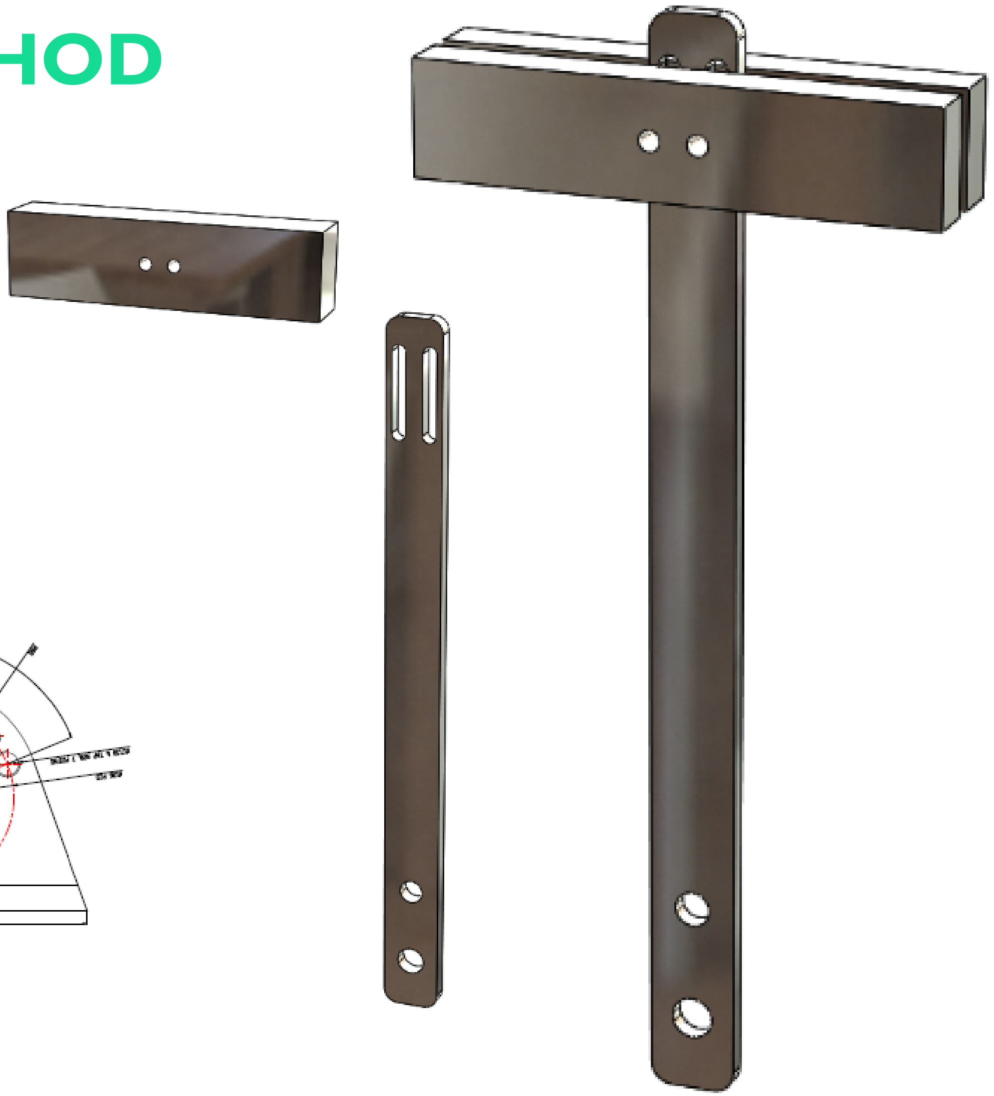
DVA DESIGN: DUNKERLY METHOD



- Bar Cross Section
- Length
- Free Distance to weight
- Bar diameter
- Bar width
- Bar height
- Density
- Young's Modulus
- Target resonant frequency





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DVA SITE INSTALLATION

Safety
tethers

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DVA SITE INSTALLATION:VIDEO

- Normal Speed

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DVA SITE INSTALLATION:VIDEO

- Slow Speed showing the point of flex

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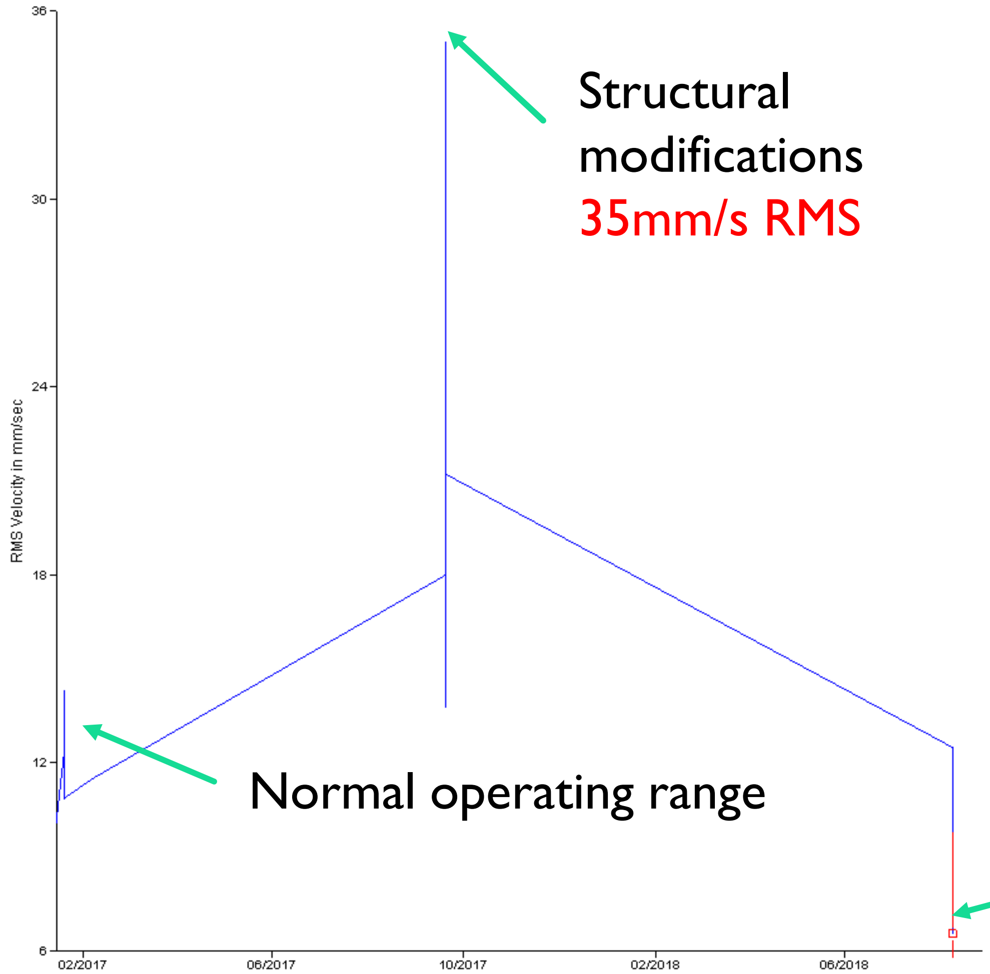
VIBRATION RESULTS: OVERALL LEVELS



Structural modifications 35mm/s RMS

Normal operating range

After fitment of DVA 6.5mm/s RMS

Location	Radial (Deg.)	Normal Operational	Structural Mods	DVA
NDE (TOP)	0	10.86	35	5.41
	90	8.21	18.17	5.82
DE (BOTTOM)	0	2.41	9.55	1.27
	90	2.11	5.92	1.57

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VIBRATION RESULTS: OVERALL WITH SPEED

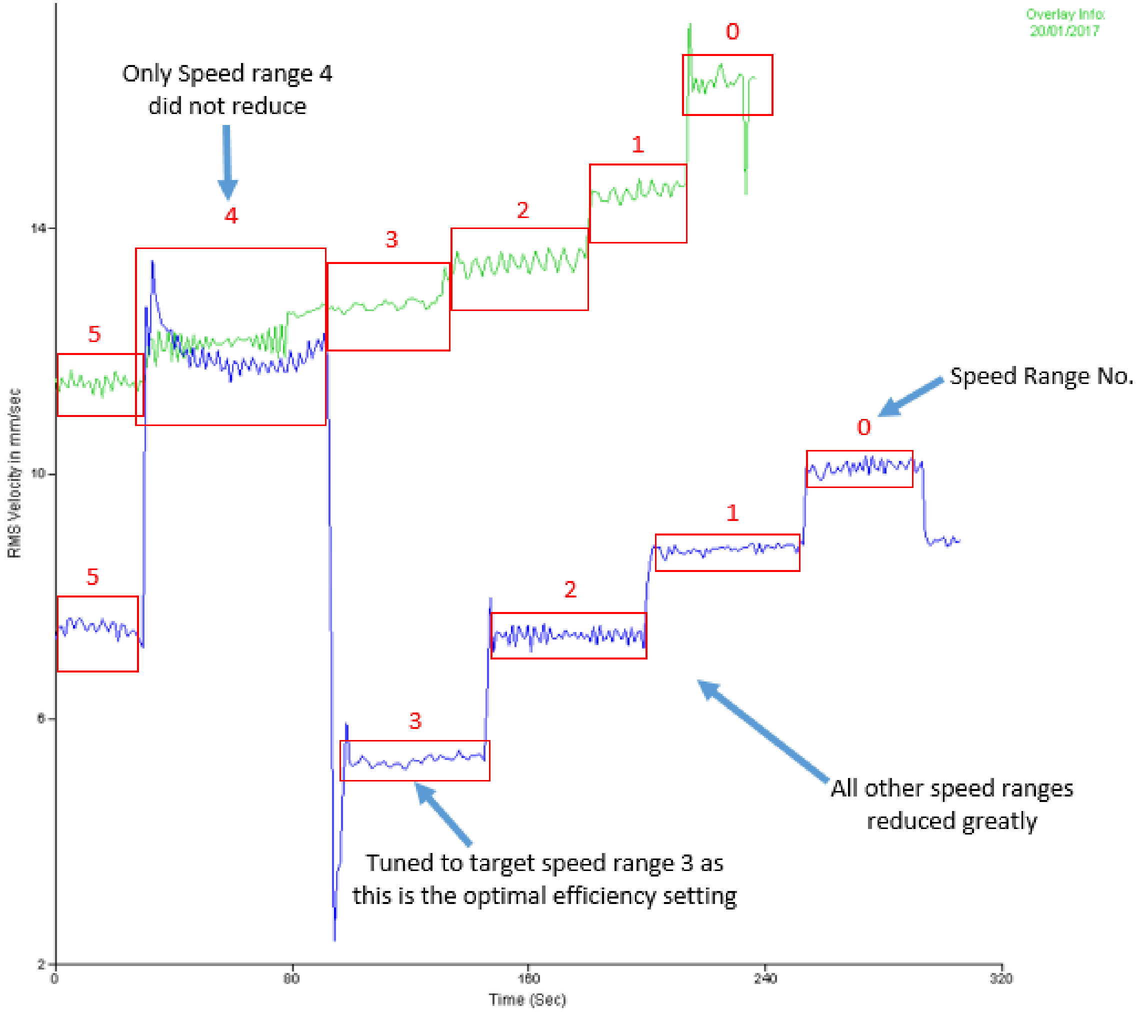


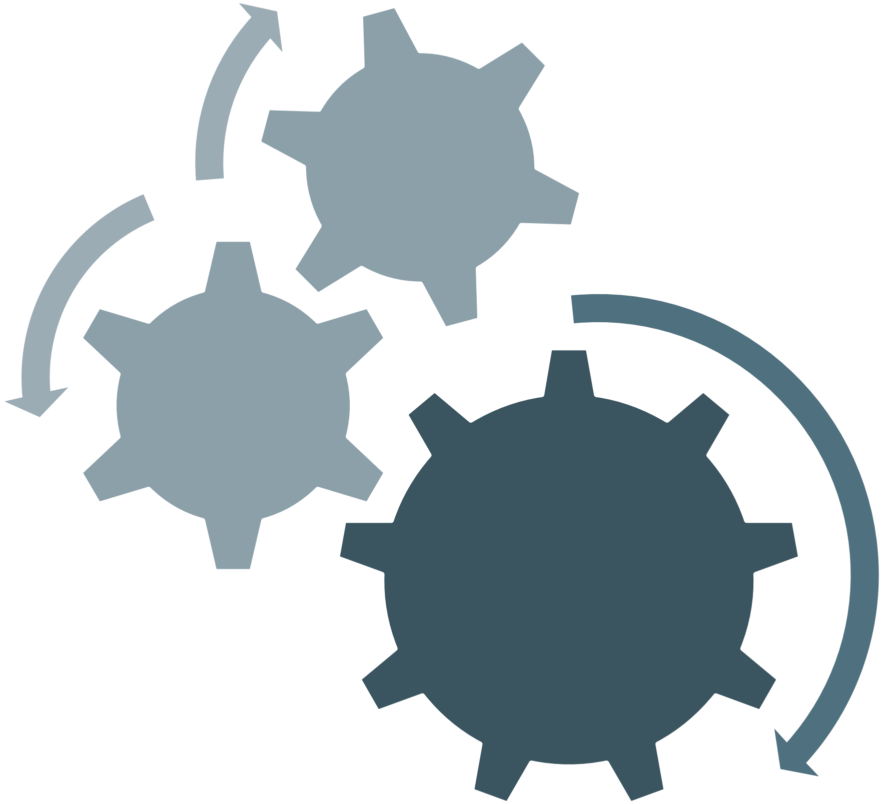
TABLE OF DIRECTIONAL RATIO VIBRATION DATA

- This table is the difference in the radial vibration velocity in mm/s RMS (Lower the number the less stress to the bearings)

Location	Normal Operational	Structural Modifications	Vibration Dynamic Absorber
NDE (TOP)	2.65	16.83	0.41
DE (BOTTOM)	0.30	3.63	0.30

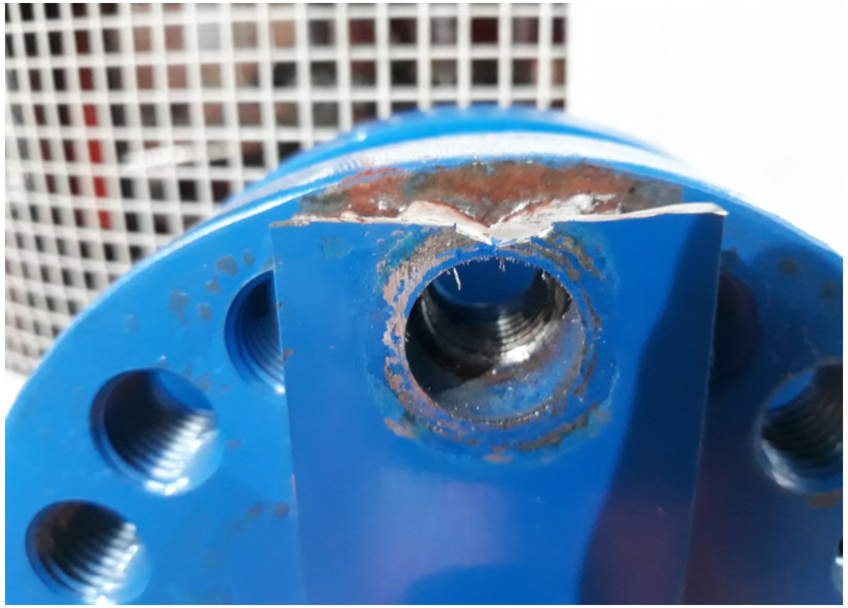
12 MONTH INSPECTION

- Follow Up



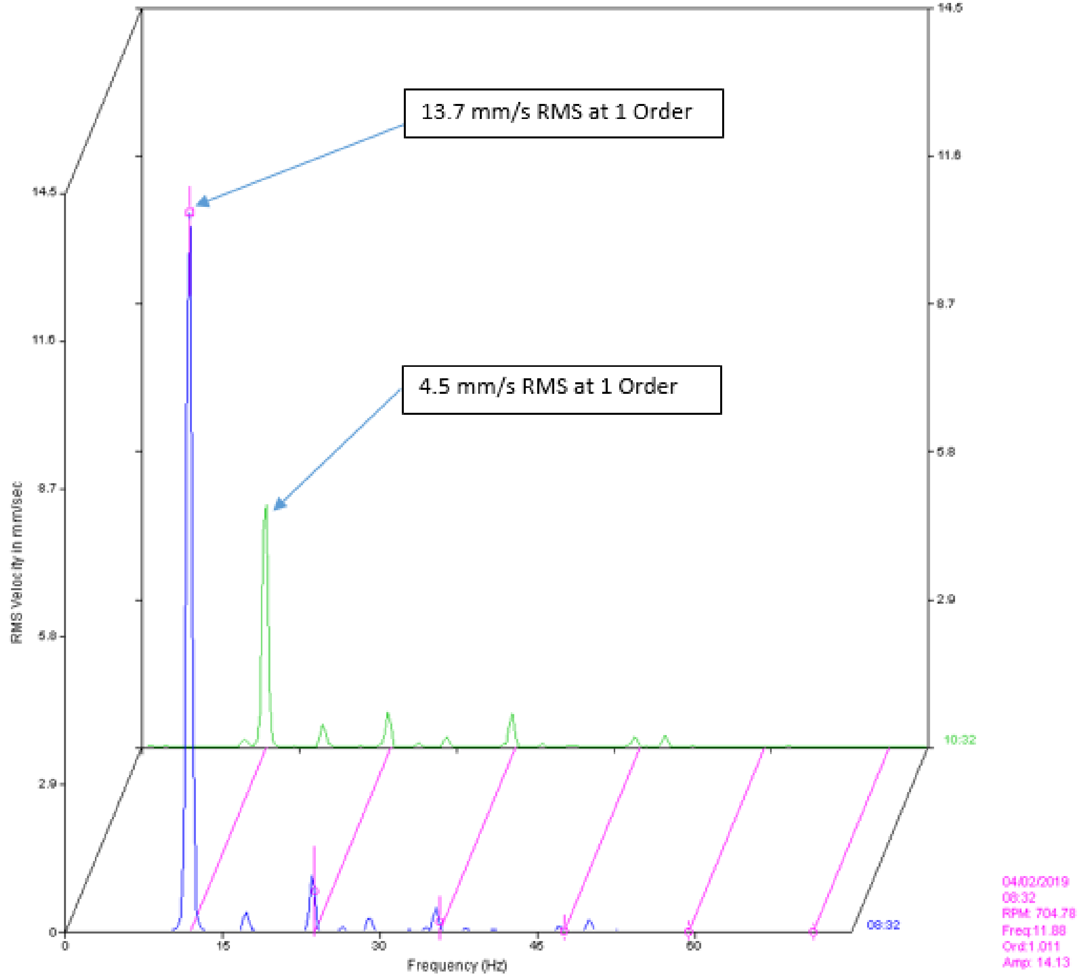
12 MONTH FOLLOW UP ON TRIAL

- The fatigue rate for the main arms of the Dynamic Vibration Absorbers are 11/12 months



INSTALLATION OF REPLACEMENT DVA ARMS

- One order vibration reduced from 13.7 to 4.5 mm/s RMS after the DVA Arms were replaced



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DVA: SUMMARY

- The Dynamic Vibration Absorbers have been successful in absorbing the vibration energy from this asset ensuring low vibration levels and correct dynamic motion
- This will enable the asset to run longer in operation before maintenance/repair increasing the functionability of the pump and reducing the overall operational life costs of the asset
- The average costs to change the motor bearings is £15,000, if the motor failed the average cost for a full overhaul and rotor rewind is £55,000. This excludes the costs of loss of production and associated financial and reputation costs.

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HOW WE CAN HELP

When a business requires support with or development of Health Based Maintenance we work in partnership in;

Upskill your team with Practical Mentoring in

- Ultrasound Airborne and Structural Borne
- Infrared Thermography-Low Voltage, Mechanical and Process
- Vibration Analysis
- General Maintenance Practices
- Practical Reliability Engineering

Contracted Reliability Services

- Contemporary Condition Monitoring consultancy to assist clients with the mangement of their Health Based Maintenance program

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TECHNOLOGIES AND SERVICES

Vibration Analysis	Lubrication	Thermography	Ultrasound
Unbalance	Gear faults/wear	Bearings	Inadequate lubrication
Looseness	Wrong oil/mixed	Overheating	Steam traps/valves
Resonance	Oil degradation	Steam traps/valves	Bearings
Pump issues	Contamination	Flammable gas leaks	Flammable gas / air leaks
Gear faults/wear	Fuel dilution	HV issues	HV issues
Inadequate lubrication	Leaking seals	Electrical wiring faults	Corona discharge arcing
Bearings	Bearings	Heat exchanger blockage	Heat exchanger tubes/plate
Steam traps/valves	Overheating	Refractory applications	

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