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# Resolving High Vibration On a Vertical Pump

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# Presenter/Author bios

## **Sankar Ganesh – Technical Leader, MENAT**

Sankar is the Technical Leader for GE Bently Nevada Machinery Diagnostics Services in the MENAT region.

He received a Bachelor of Mechanical Engineering from Bharathidasan University, India, in 1993.

He has over 20 years experience in vibration field and 9 years with GE Bently Nevada, including rotating equipment balancing, vibration analysis, diagnostics and root cause analysis.

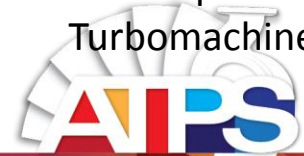
He has published case studies in METS and Turbomachinery symposium.

## **Mustafa Shalabi – Lead MD Engineer**

Mustafa works as Lead Machinery Diagnostics Engineer in Bently Nevada General Electric company, Saudi Arabia since December, 2012.

He is a certified vibration analyst CAT III by Mobius Institute. Mustafa graduated in 2006 with B.Sc. degree in Mechanical Power Engineering from faculty of engineering, Alexandria university, Egypt. He has been working in vibration diagnostics of rotating equipment for over 10 years. He started his career in 2007 as a condition monitoring engineer for rotating equipment.

In addition to his work as machinery diagnostics engineer, Mustafa is working as a Machinery Diagnostics training instructor in Bently Nevada.



# Abstract

There is a single stage vertical pump installed in Acetic Acid area in a petrochemical plant. The unit is vertical high pressure (HP) reactor feed pump (High speed single stage, 230 kW, 12338 rpm & 3.444 gear ratio) driven by induction motor through a flexible shim pack coupling.

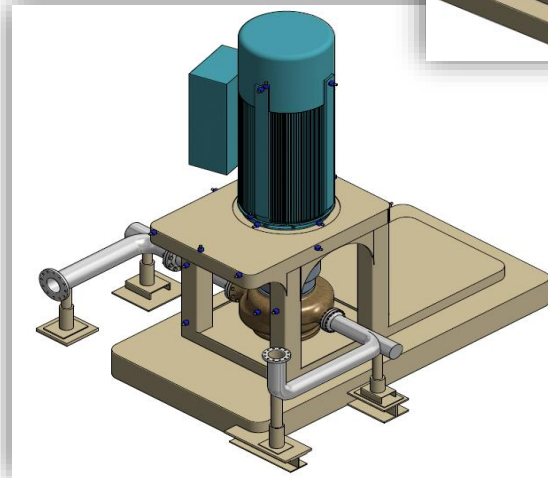
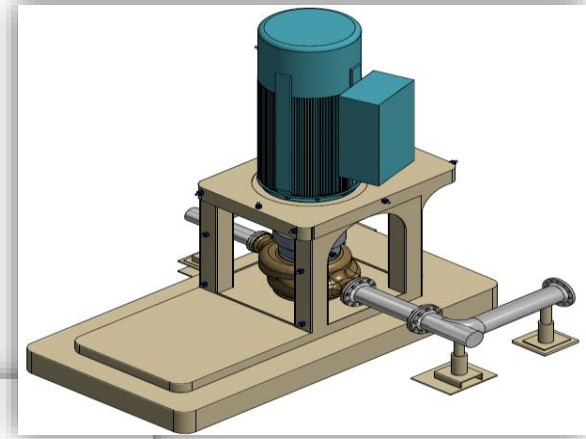
High vibration levels were observed on the motor, pump and structure for more than 2 years with 1X dominant vibration (1X motor dominant frequency). Assuming that the issue is completely structural as this motor was running well in the past, there were some structural modifications have been carried out at site with inadequate engineering calculations. The modifications were welding a total mass of 100 kg onto the structure and the installation of braces to the structure which did not yield any positive results. A systematic structural measurement along with the Operating Deflection Shape carried out at site with the help of experts did not reveal a significant issue with the structure itself except for the structural natural frequency being slightly closer to the running frequency of the motor. The timely right decision by the experts to carry out an onsite balancing on the motor, which was intended to remove the excitation force, yielded good results which exposed a mistake in the balancing activities carried out by a local vendor at work shop.

This case study is designed to outline how the high vibration issue was successfully diagnosed using various tests on site including the operating deflection shape, the root cause for the high vibration and finally how it was mitigated.



# Machine Details

- The unit is vertical HP reactor feed pump
- Single stage, 230 kW, 12338 rpm & 3.444 gear ratio
- Driven by induction motor (260 kW, 3585 rpm, ball bearings)
- Flexible shim pack coupling



# Problem Statement

- High vibration levels on the motor, pump and structure for more than 2 years (11 mm/sec Peak at steady state)

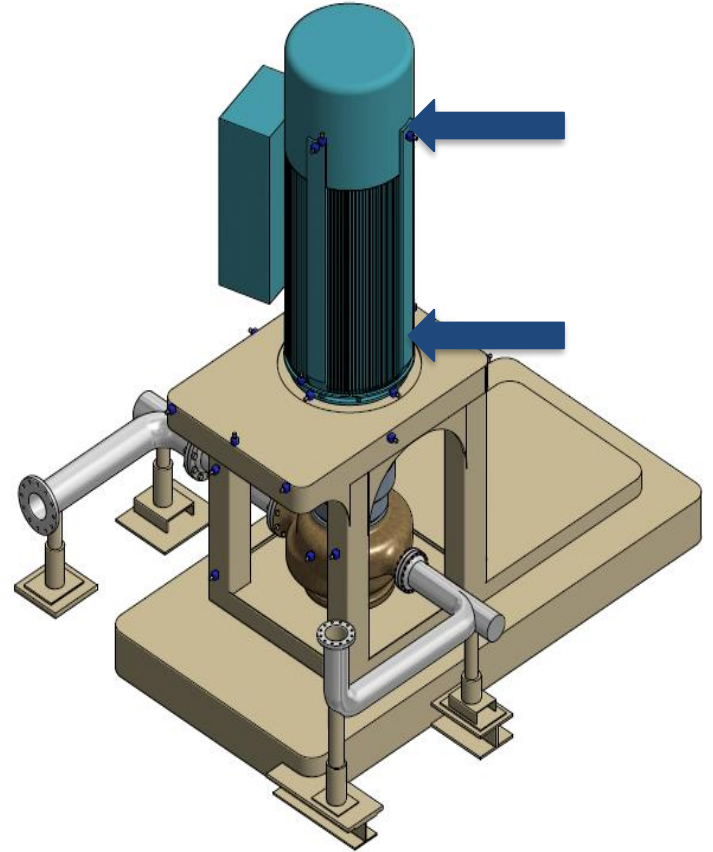
1X motor dominant vibration component.

- Bump test showed natural frequency at 43Hz
- Many trials were done by the End User to reduce the high vibration:
  - Total mass of 100Kg were added to the structure
  - Additional supporting braces
- Vibration levels remained as high as the original measurements

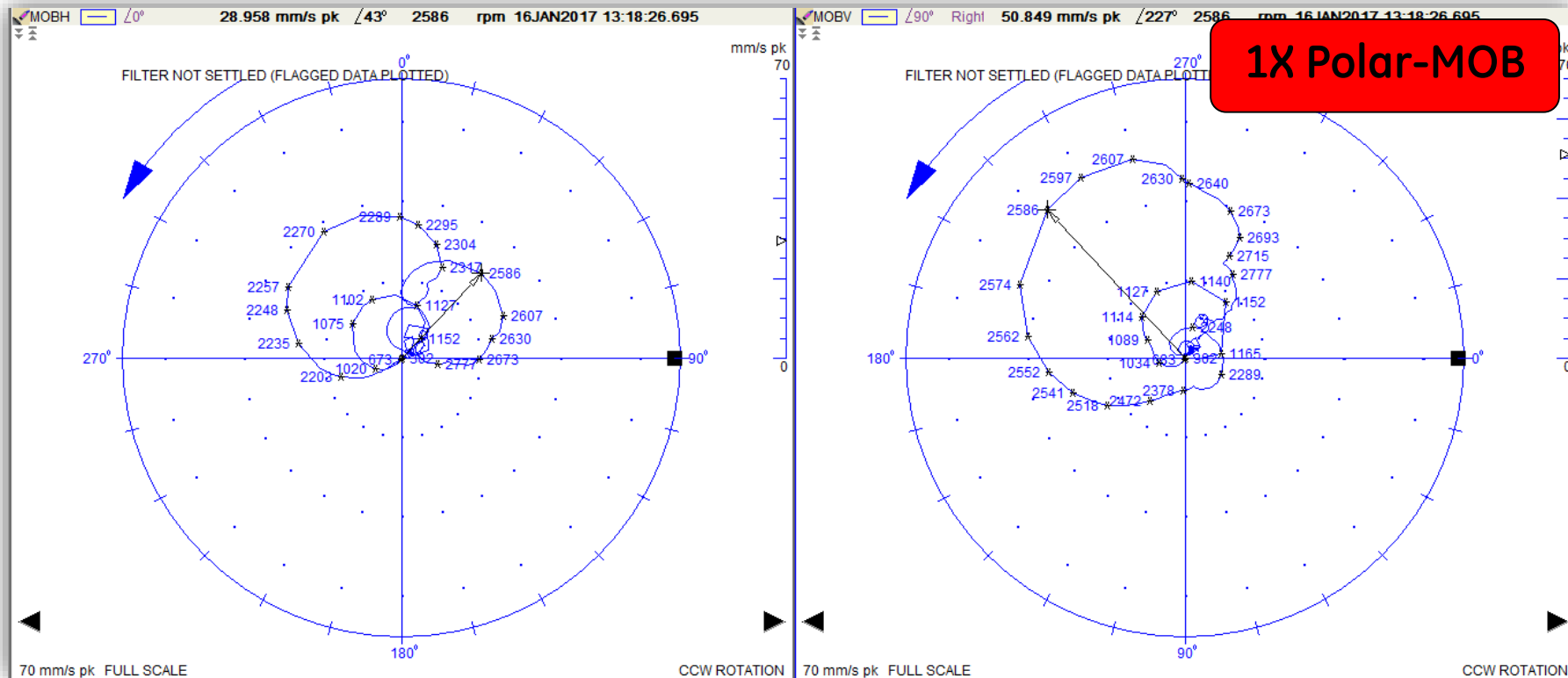


# Data Analysis– Coupled Run

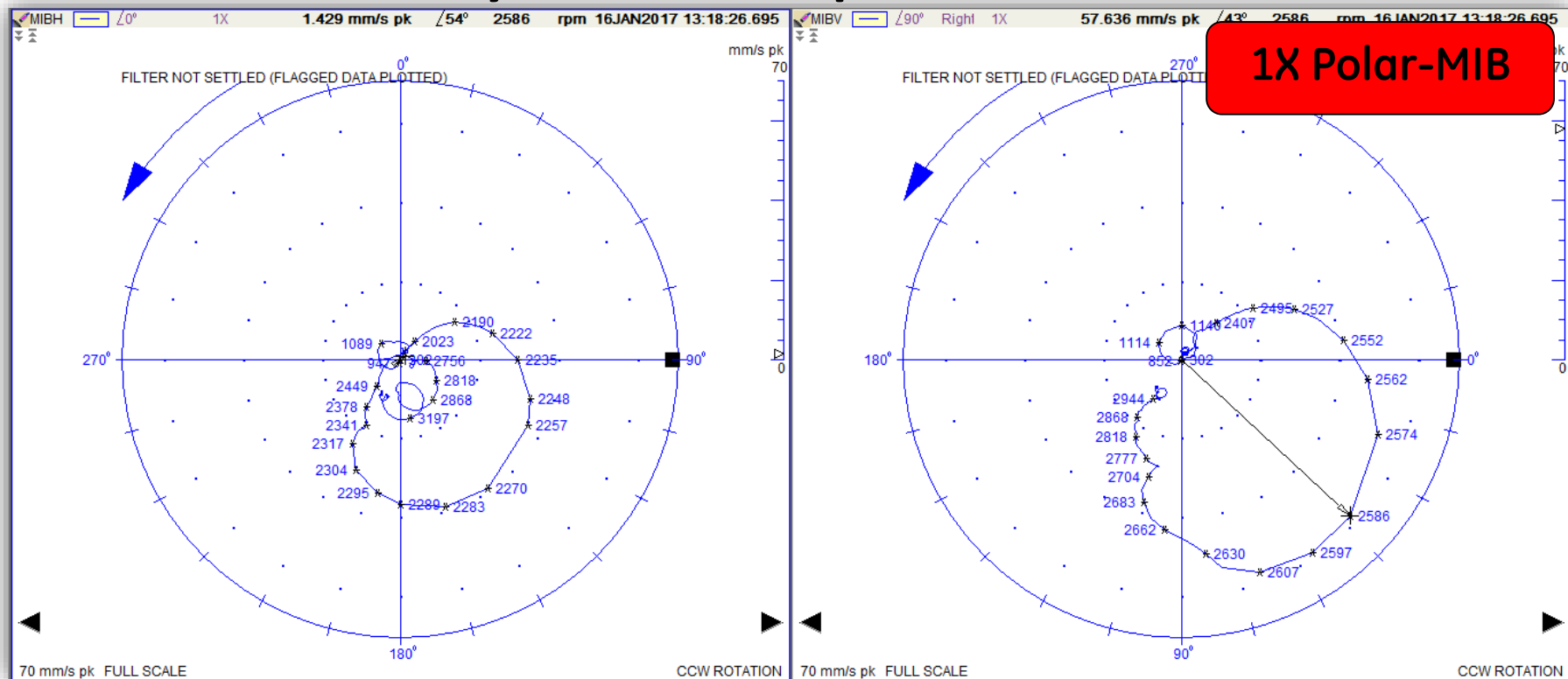
- High overall vibration levels with 1X motor dominant frequency
- Transient Start-Up / Shut-Down data showed that the unit is running well above the 2nd critical speed
- **The highest amplitude while passing the 2<sup>nd</sup> critical frequency (70 mm/sec Peak)**



# Data Analysis– Coupled Run “cont’d”



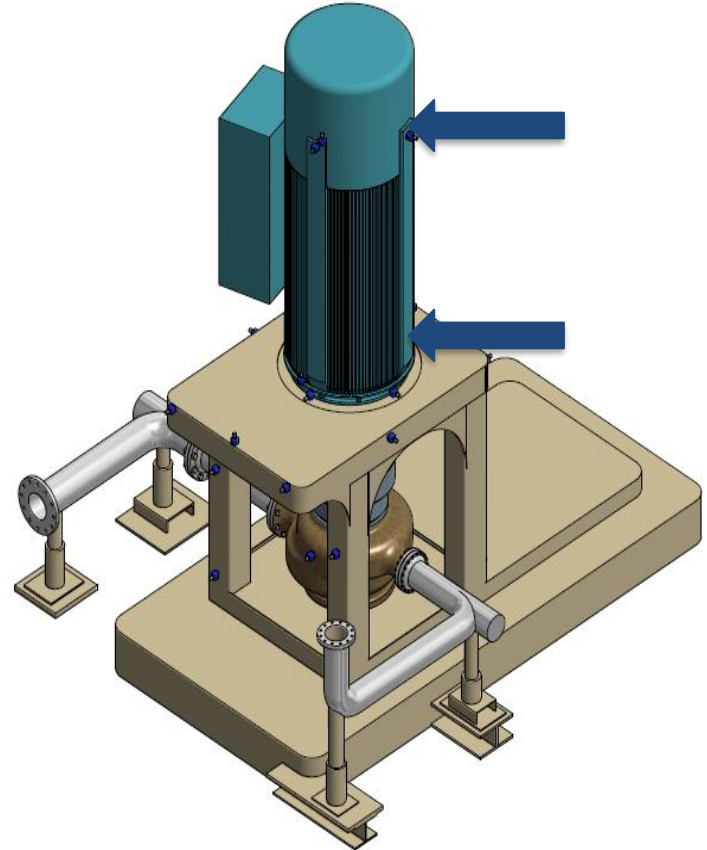
# Data Analysis– Coupled Run “cont’d”





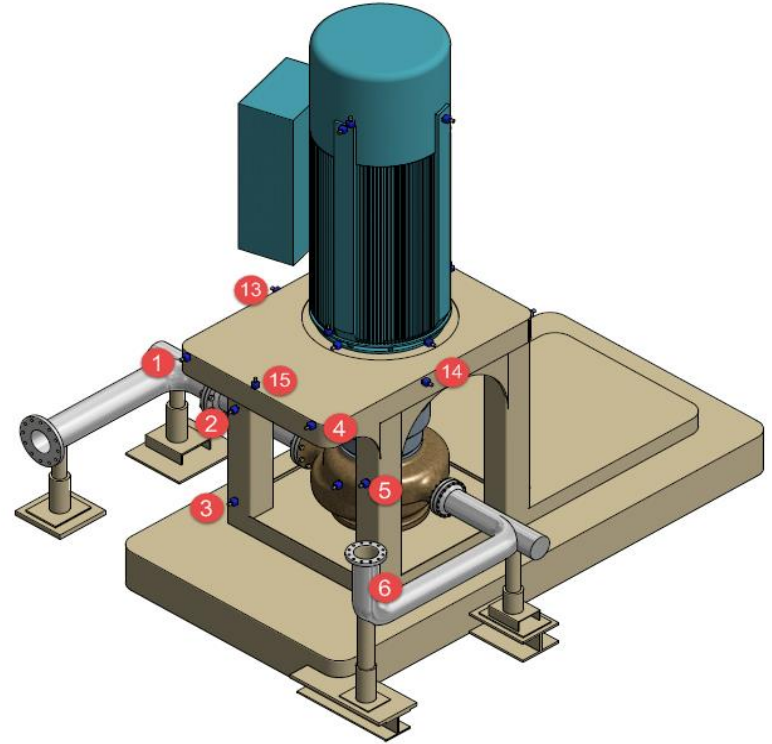
# Data Analysis— Solo Run

- High vibration at same locations as in coupled run
- **High residual unbalance response on the motor while passing 2<sup>nd</sup> critical frequency**
- **Bode & polar plots confirmed the residual unbalance response**



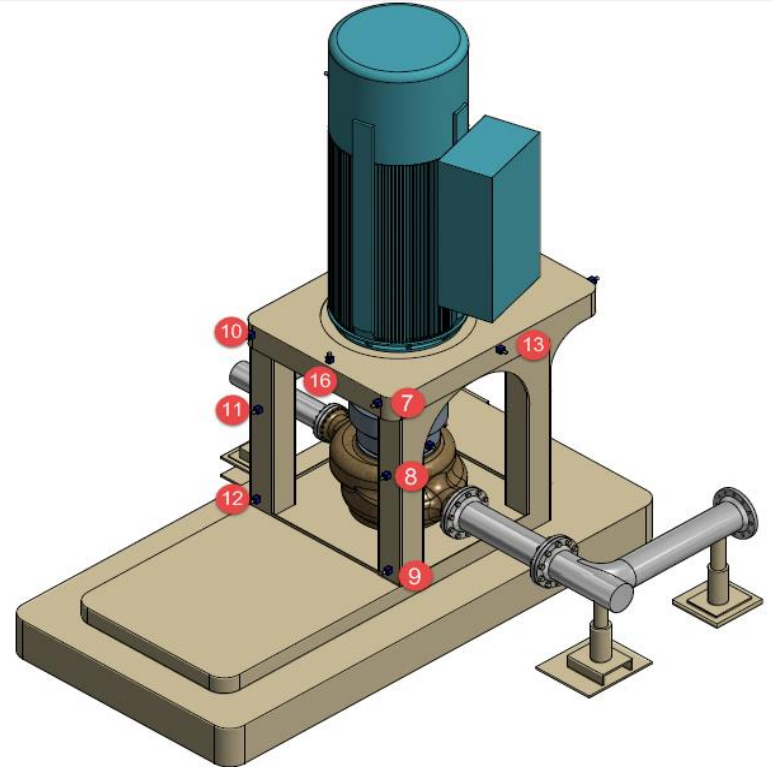
# Data Analysis-Structural measurement

mm/sec Peak	Coupled Run		Solo Run	
	Overall	1X <sub>motor</sub>	Overall	1X <sub>motor</sub>
Str#1	12.9	11.2	11.5	11.2
Str#2	8.5	6.2	6.7	6.2
Str#3	1.3	0.2	0.4	0.2
Str#4	12.5	11.2	11.6	11.2
Str#5	9.1	6.7	7.3	6.7
Str#6	1.7	0.5	0.7	0.5
Str#14	11.2	10.5	10	9.9
Str#15	3.1	0.9	1.5	0.9

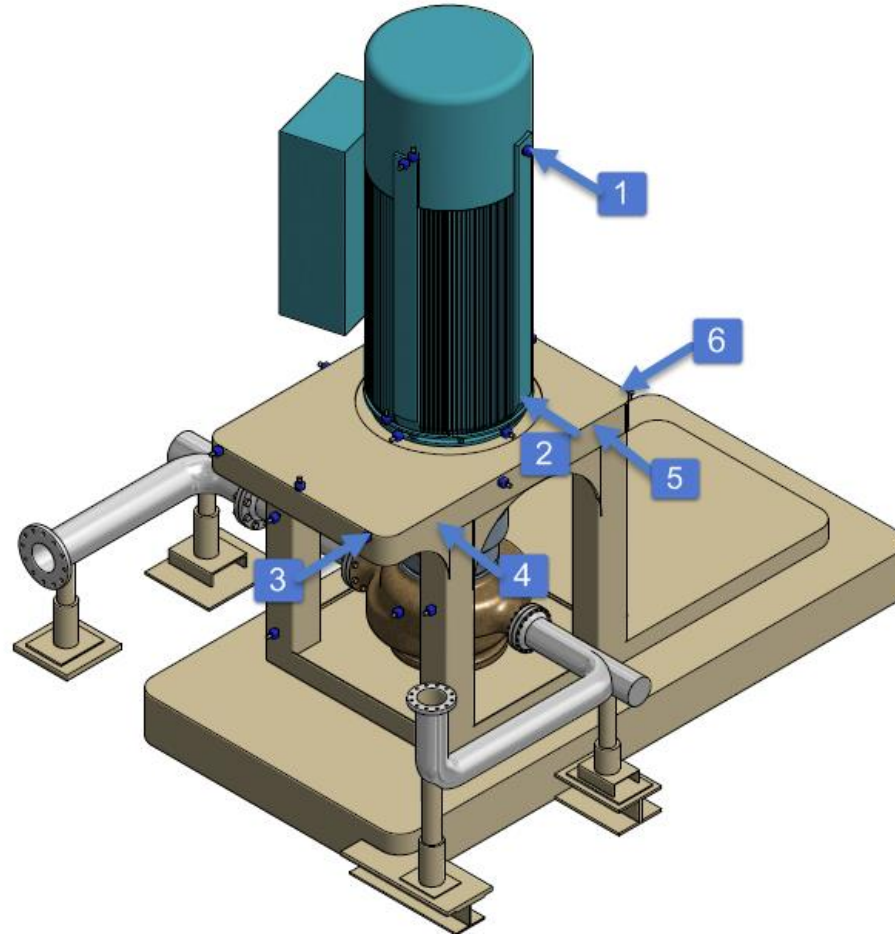


# Data Analysis-Structural measurement

mm/sec Peak	Coupled Run		Solo Run	
	Overall	1X <sub>motor</sub>	Overall	1X <sub>motor</sub>
Str#7	13.7	12.4	12.6	12.4
Str#8	9.8	7.3	7.8	7.3
Str#9	1.4	0.7	1	0.7
Str#10	12.7	11.5	11.9	11.5
Str#11	10.2	6.8	7.3	6.8
Str#12	1.6	0.7	0.9	0.7
Str#13	10.1	10.1	10.4	10.3
Str#16	4.1	0.9	2.4	1.2

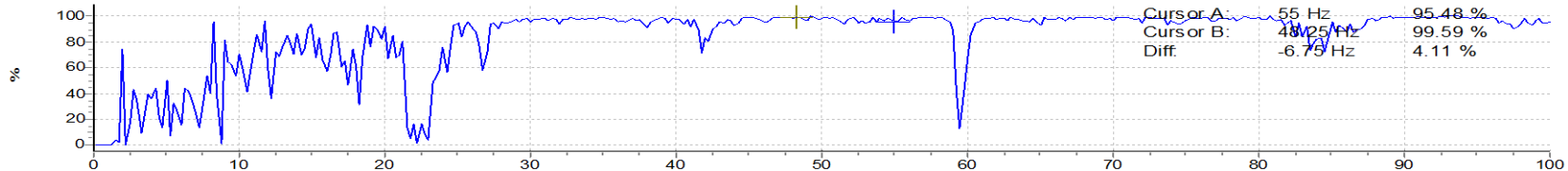


# Data Analysis-Impact Test

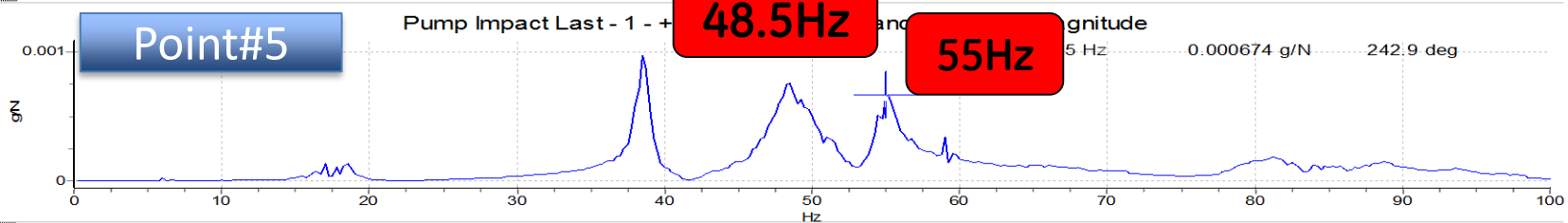


# Data Analysis-Impact Test "Cont'd"

Pump Impact Last - 1 - +X - Modal Accelerance 100 Hz - Coherence

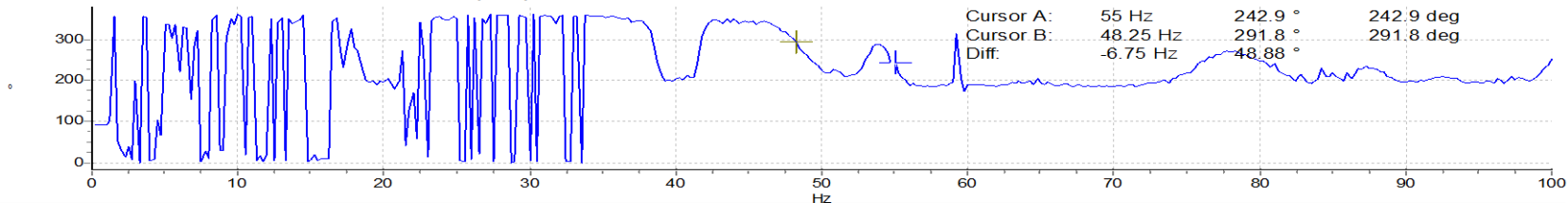


1/19/2017 8:48:26 AM



1/19/2017 8:48:26 AM

Pump Impact Last - 1 - +X - Modal Accelerance 100 Hz - Phase



1/19/2017 8:48:26 AM

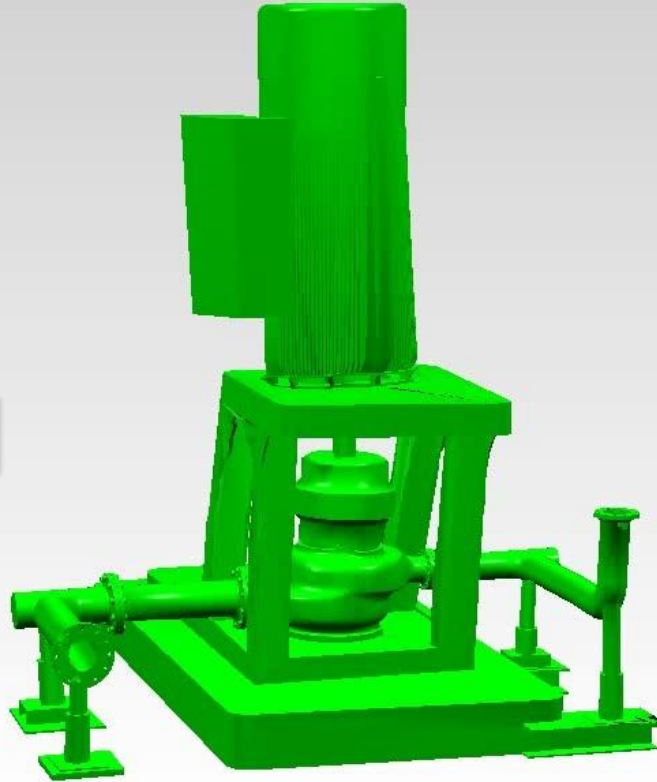
Point#5 Showed Natural Frequency Close to The Running Speed  
Other Points Showed Natural Frequency BUT Away from The Forcing Frequencies



# Data Analysis-Coupled Run ODS (Operating Speed 59Hz)

BLK Coupled Run\_Before  
Freq: 59.4 Hz, Damp: 0%  
Complex Shape

Circular Motion



Solo Run also showed the similar circular motion

# Action Taken

- Balancing shot was done by adding total mass of 178 g on the motor coupling hub (2 bolts were attached to the hub)
- Significant decrease in vibration levels on the motor and structure.
- The required final balance shot was 210 g as per vector calculations (at this balance plane; hub).
- There is no access to add final balance weights on the hub.
- It was decided to check the motor cooling fan as a balance plane in order to examine motor response to weights at NDE side.

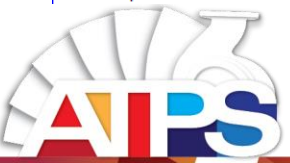
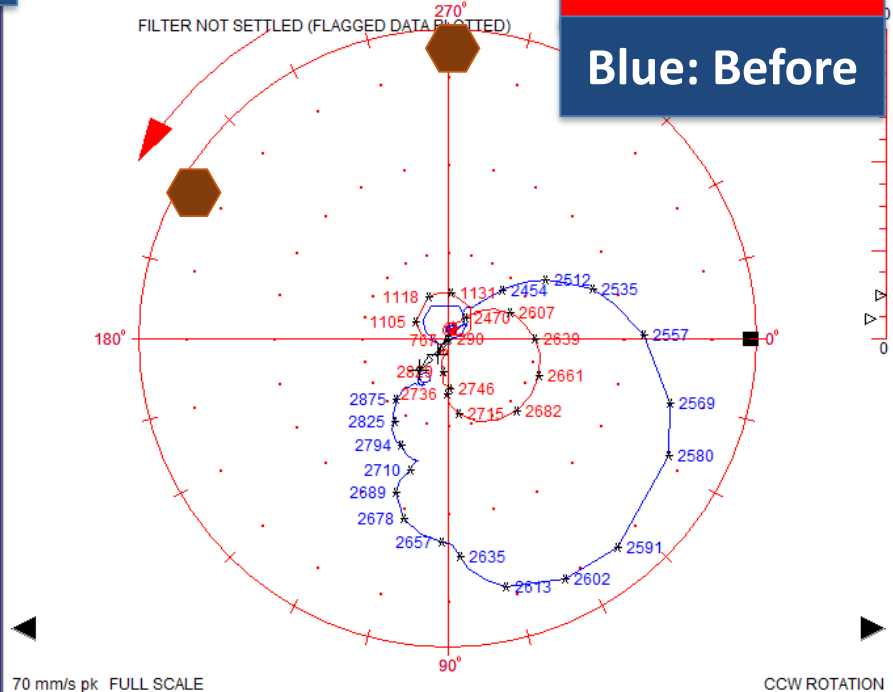
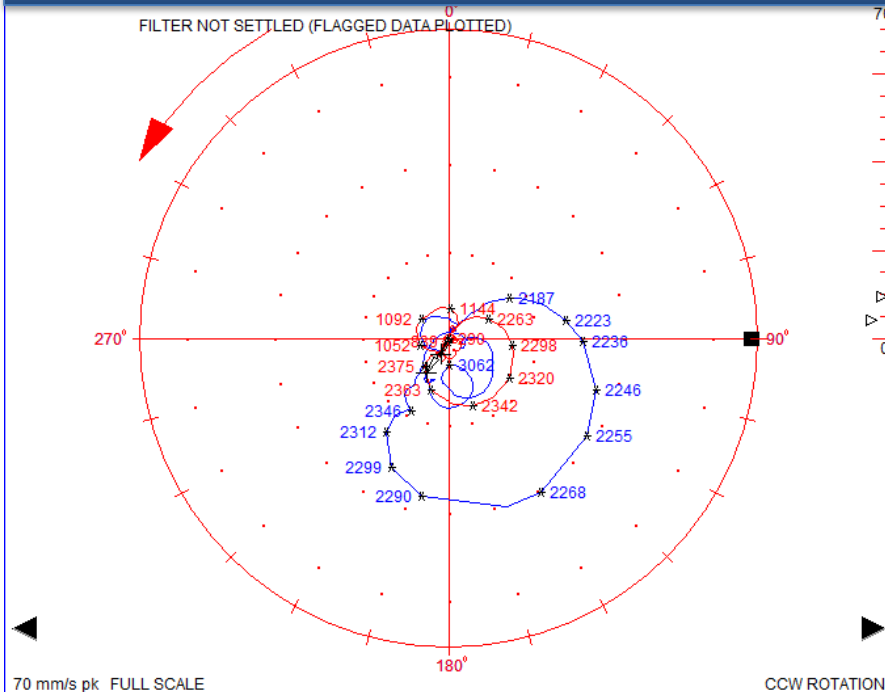


# Action Taken-Cont'd

## Weights Added on the Coupling Hub

MIBV	—	∠90°	Right	1X	9.523 mm/s pk	∠133°	3
MIBV	—	∠90°	Right	1X	4.149 mm/s pk	∠124°	3

**Red: After**  
**Blue: Before**





# Action Taken-Cont'd

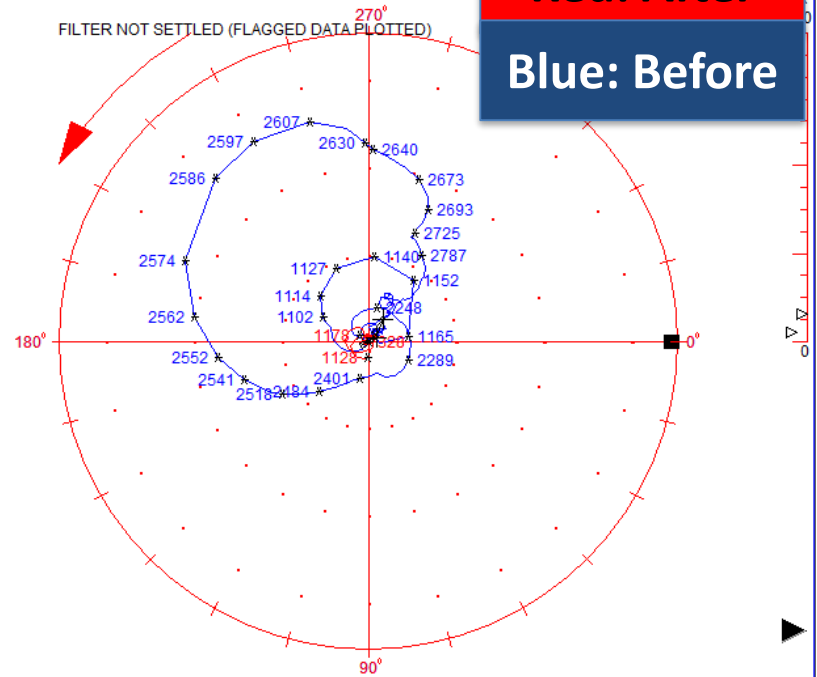
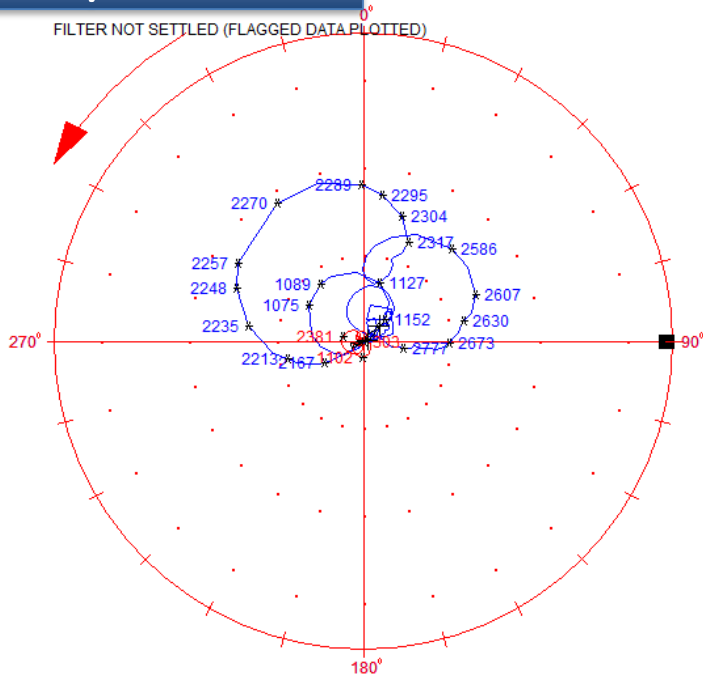


# Action Taken-Cont'd

Coupled Run

3582 rpm 16JAN2017 13:19:20.213  
 3584 rpm 19JAN2017 10:30:57.365

MOBV —  $\angle 90^\circ$  Right 6.213 mm/s pk  $\angle 303^\circ$  3582 rpm  
 MOBV —  $\angle 90^\circ$  Right 1.939 mm/s pk  $\angle 335^\circ$  3584 rpm

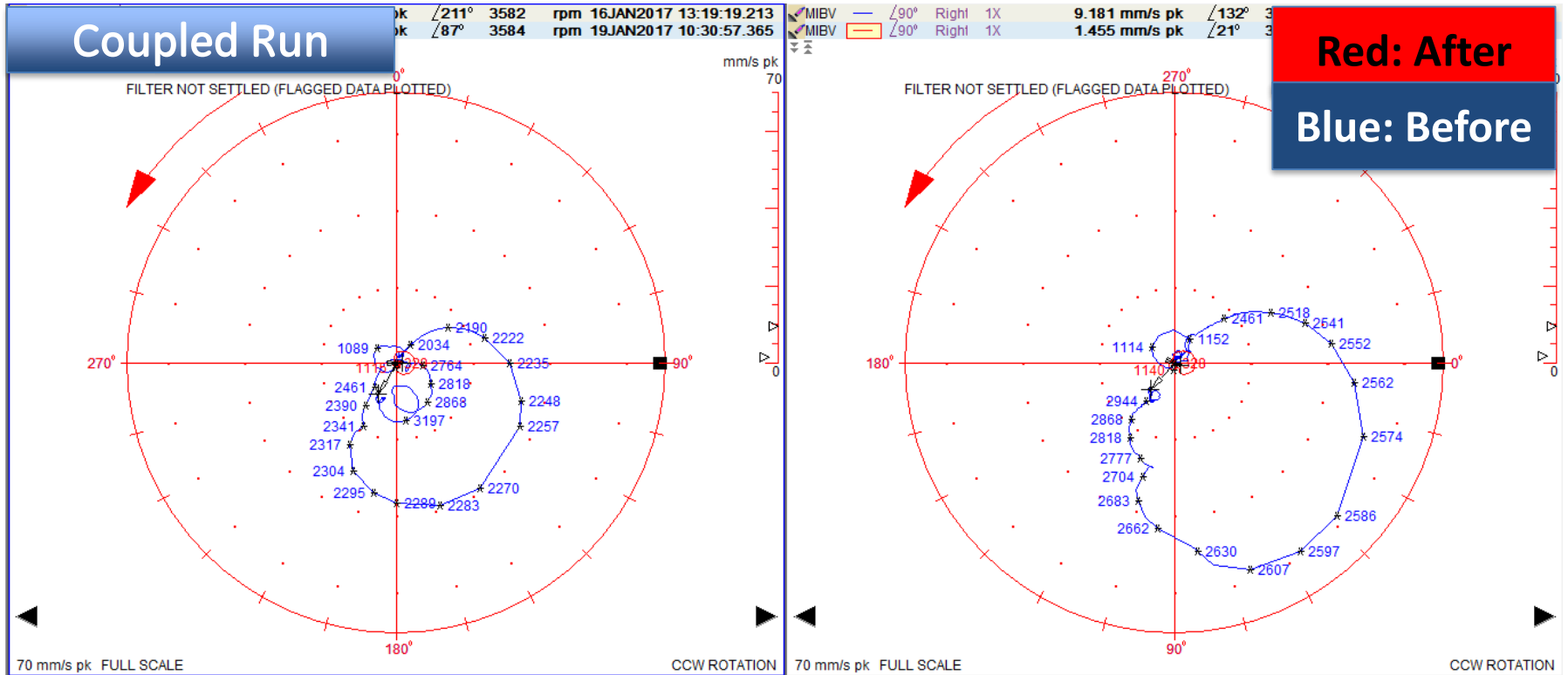


Red: After

Blue: Before



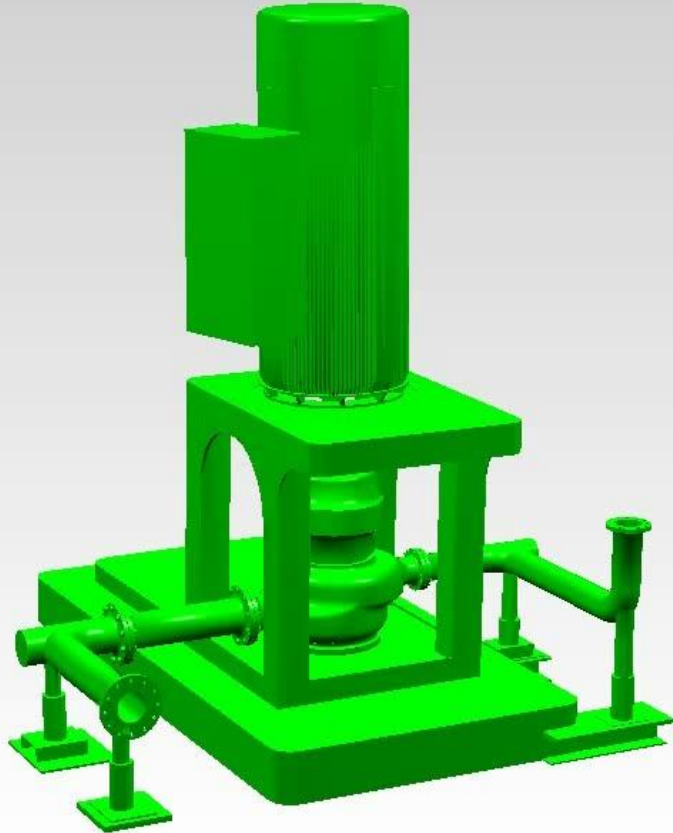
# Action Taken-Cont'd



# Post Analysis- ODS after balancing at 59Hz)

BLK: Coupled\_Run\_After  
Freq: 59.4 Hz, Damp: 0%  
Normal Shape

Twisting Motion



# Conclusion & Recommendations

- The extremely high vibration levels on the motor, pump and structure -mainly due to motor rotor residual unbalance.
- ODS showed circular motion due to unbalance response.
- In-situ balancing reduced vibration levels to acceptable values.
- After balancing, the twisting motion remained due to the natural frequency of 55 Hz.
- Structure design to be reviewed with the OEM to shift the natural frequency above 20% operating speed.



# Lessons Learned

- **Extensive measurement and detailed analysis in the field helped to identify the root cause quickly** - substantially reduces the duration of unplanned downtime.
- Workshop balancing to be done competently to avoid **unnecessary balancing exercise**
- A verification of vibration levels at workshop would have avoided downtime and time for troubleshooting exercise in the field.



# Thank You



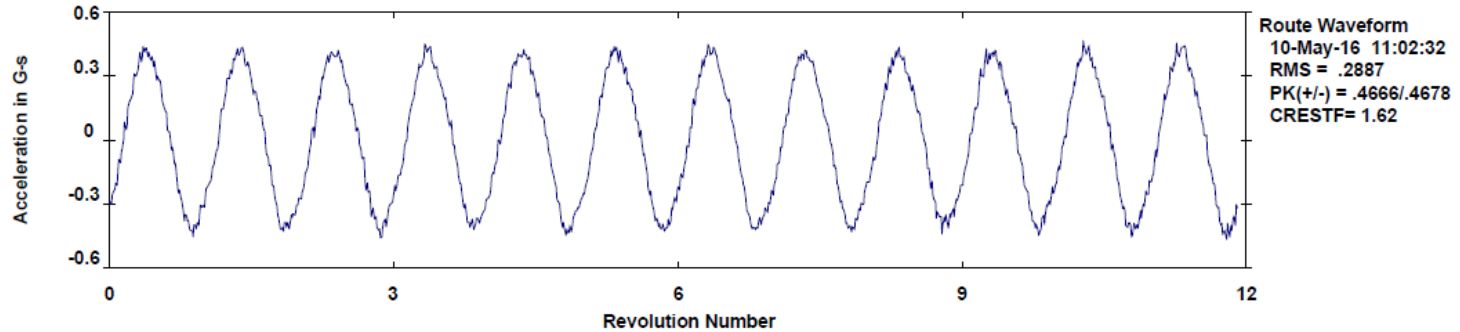
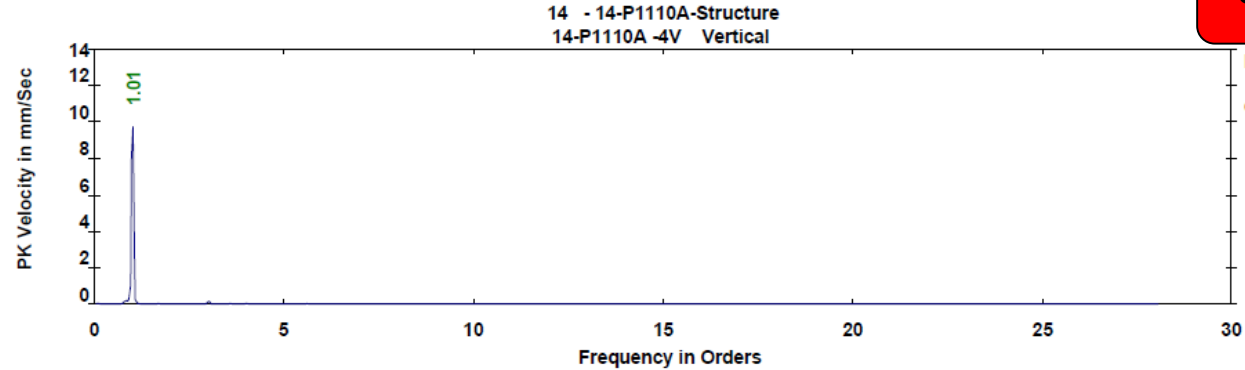
# Appendix





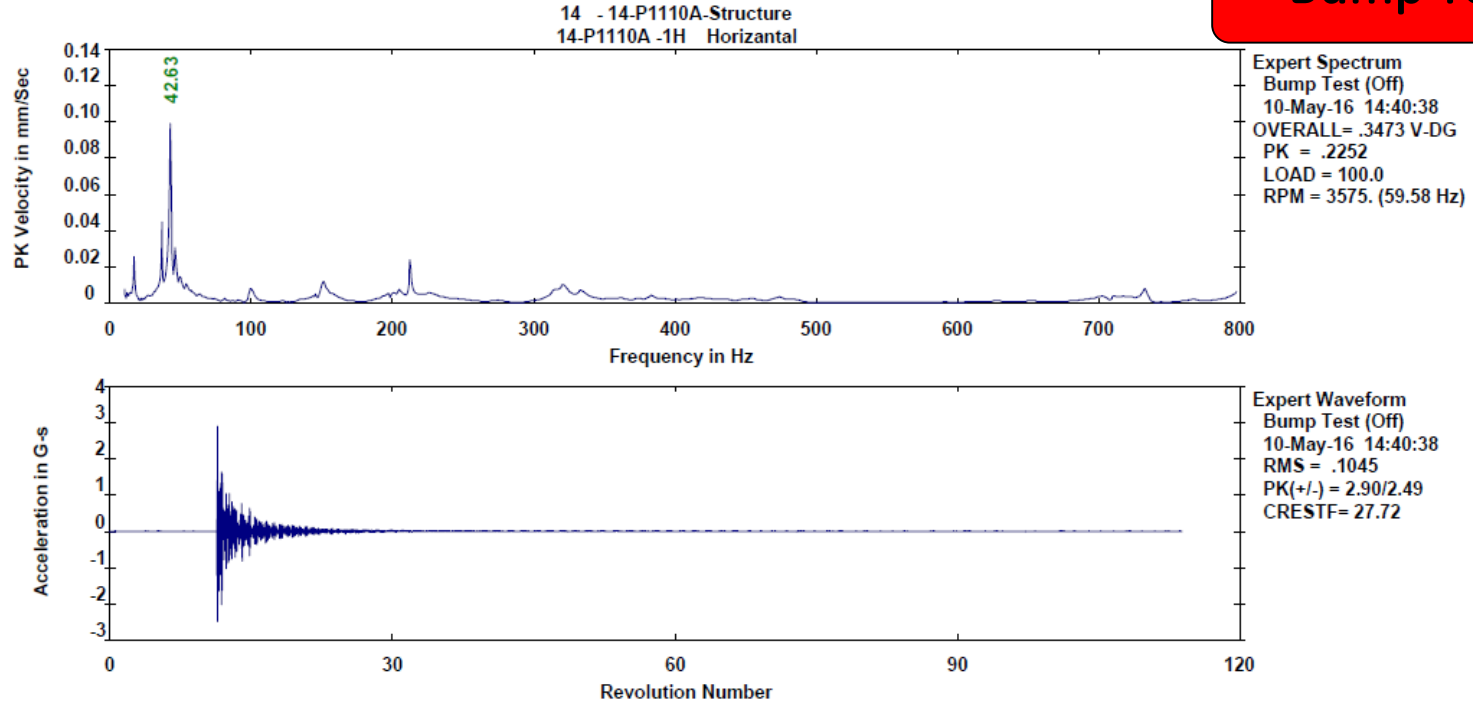
# Problem Statement

Spectrum- 1X

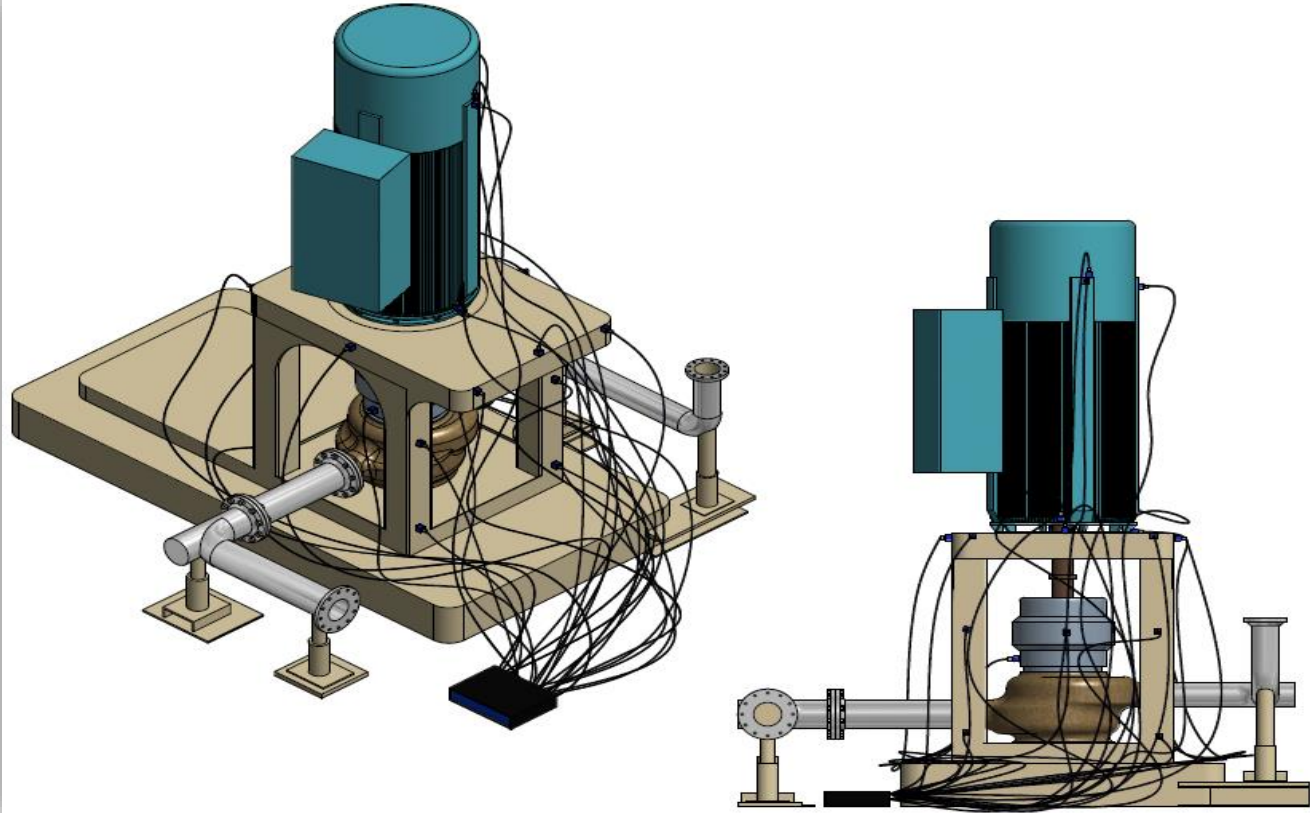


# Problem Statement

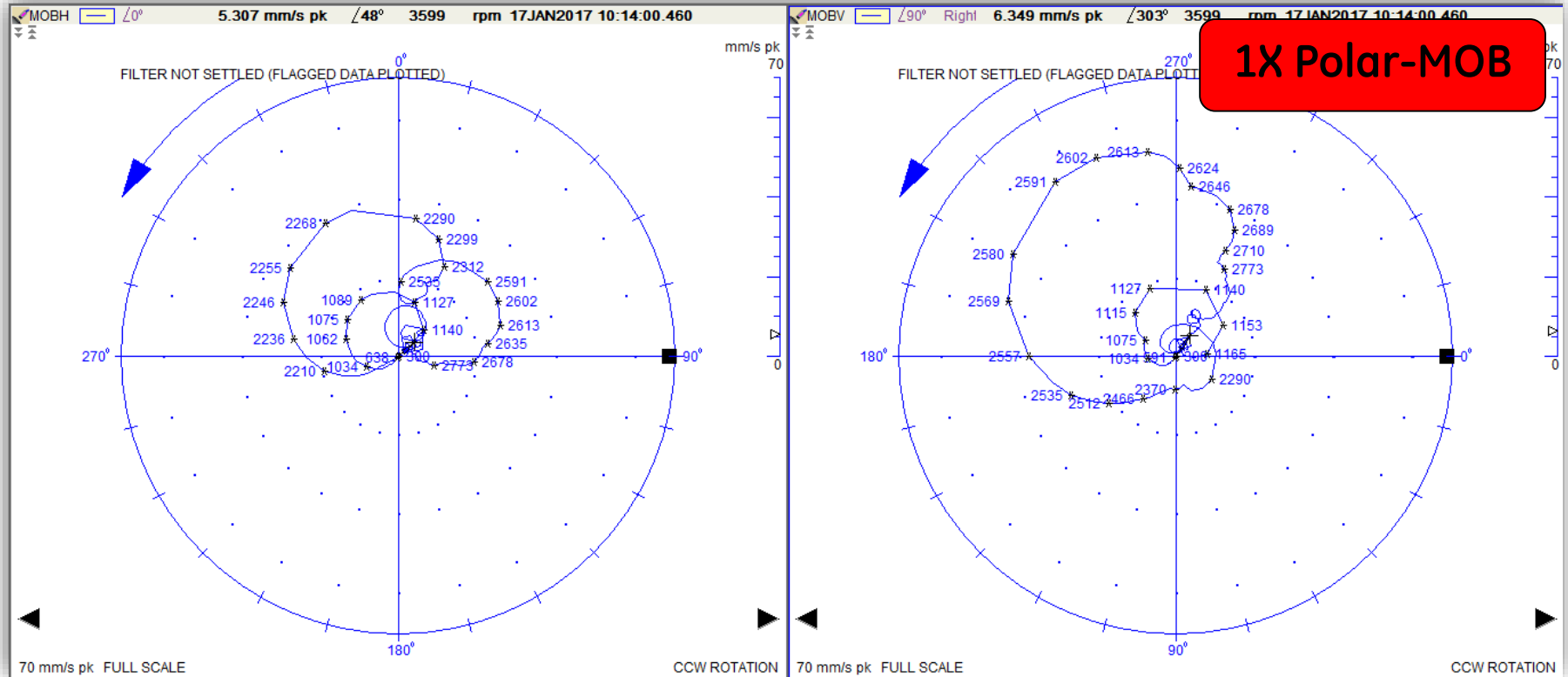
## Bump Test



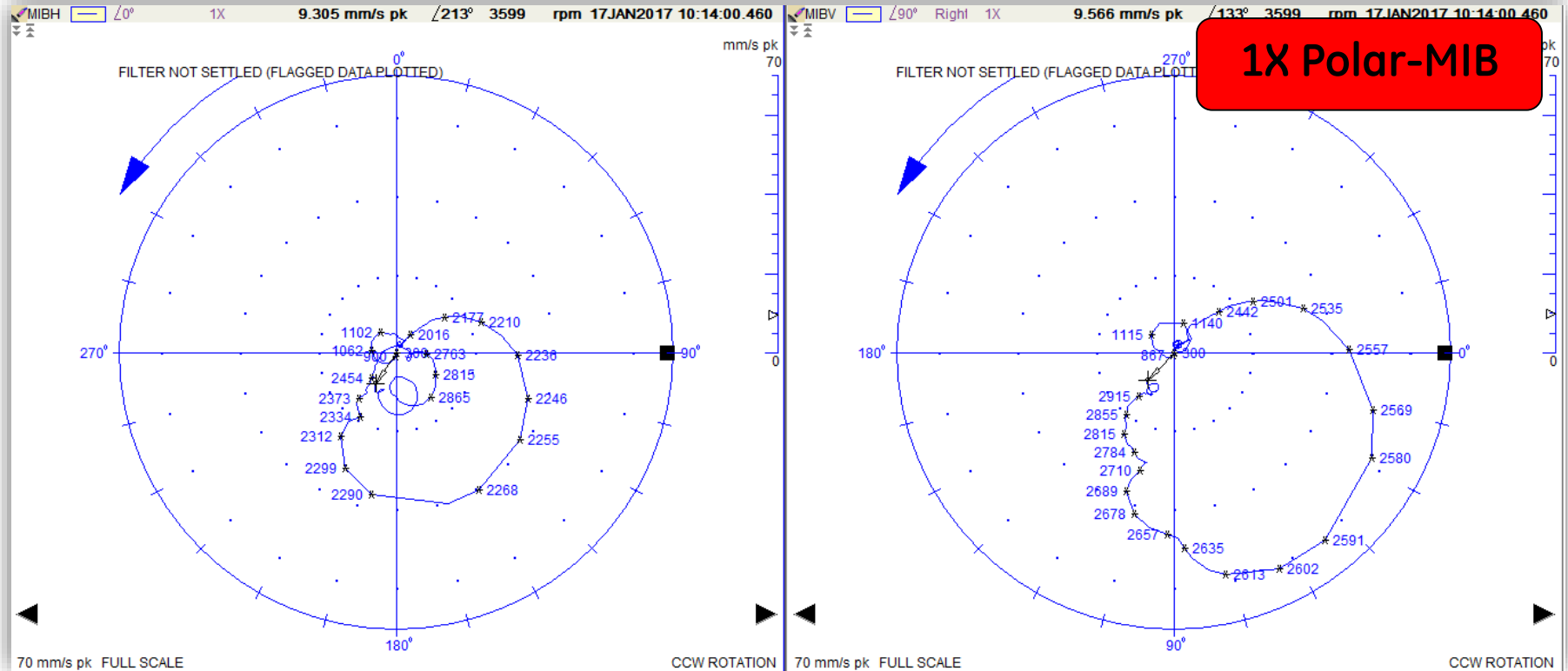
# Action Plan



# Data Analysis— Solo Run “cont’d”



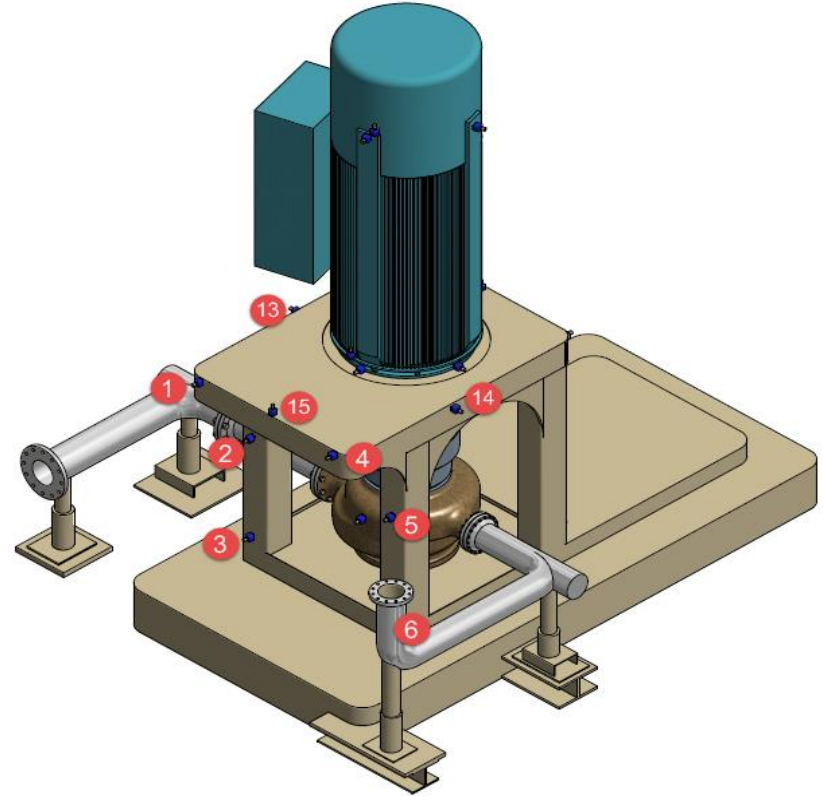
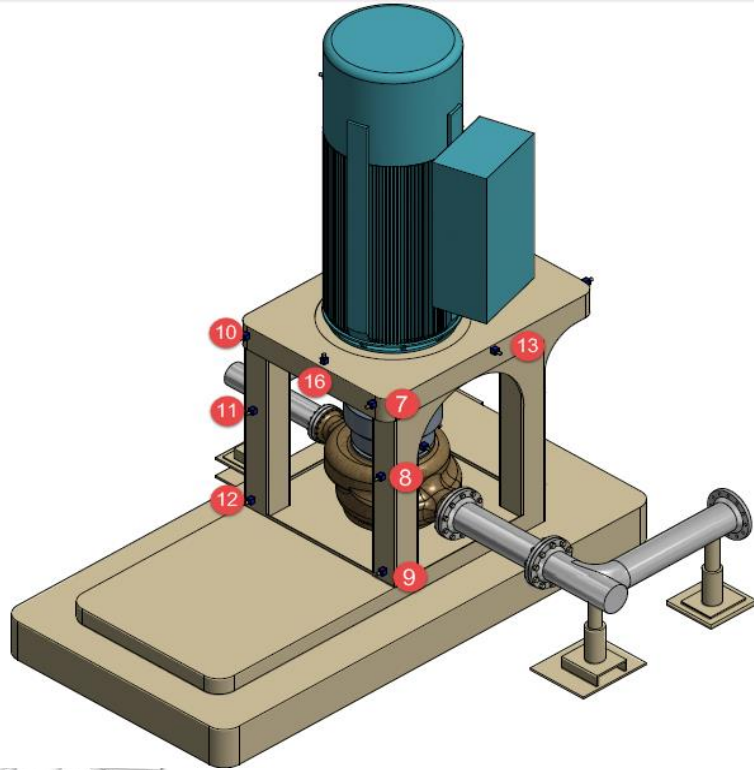
# Data Analysis– Solo Run “cont’d”



1X Polar-MIB

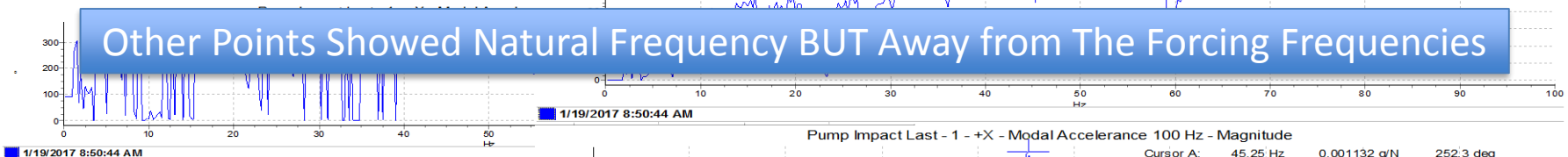
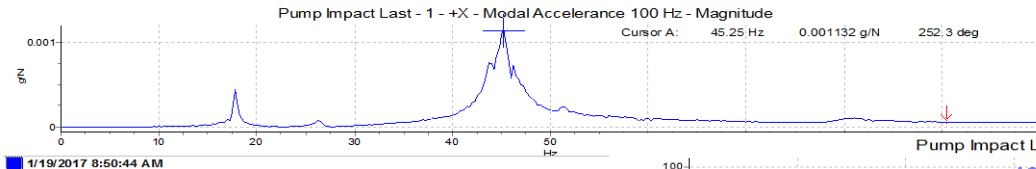
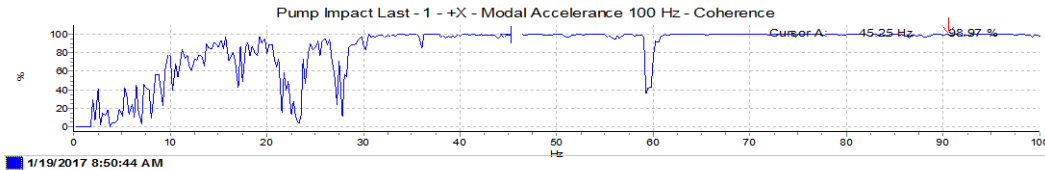


# Data Analysis-Structural measurement

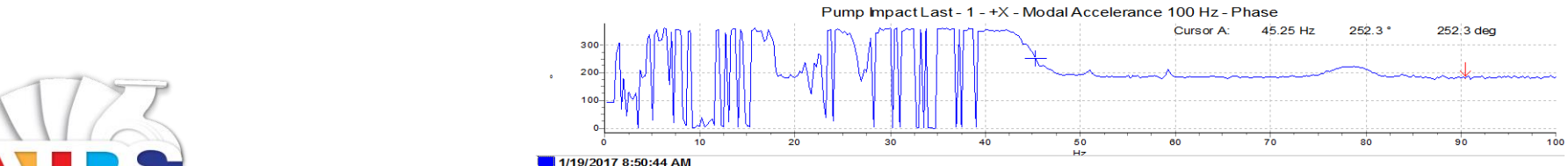
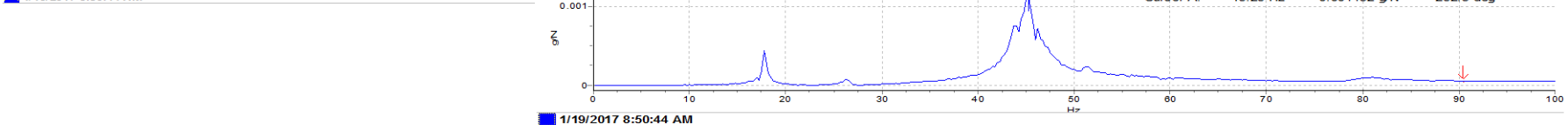


# Data Analysis-Impact Test "Cont'd"

Different Locations



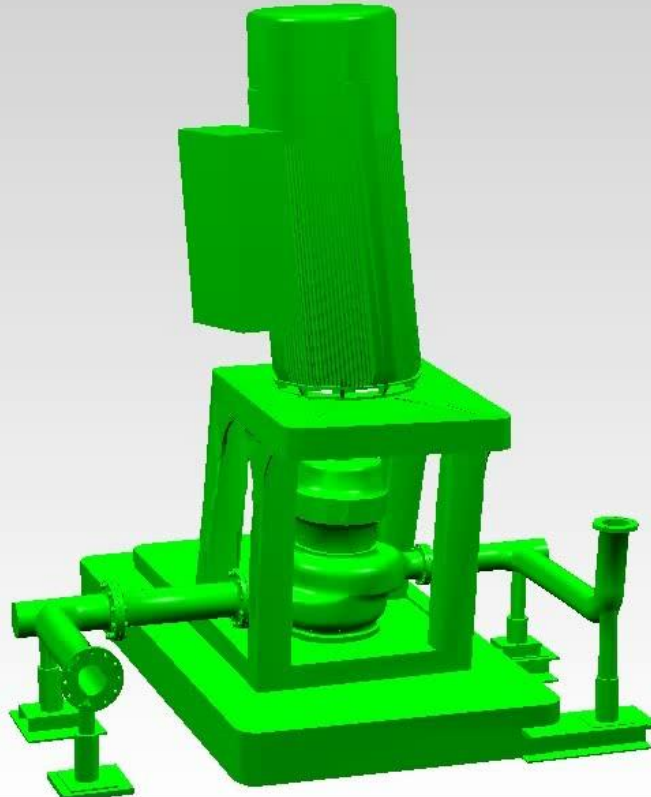
Other Points Showed Natural Frequency BUT Away from The Forcing Frequencies



# Data Analysis-Solo Run ODS (Operating Speed 59Hz)

BLK\_Solo\_Before  
Freq: 59.4 Hz, Damp: 0%  
Complex Shape

Circular Motion





# Conclusion

- ODS showed circular motion due to unbalance response.
- Extremely high vibration levels were observed on the motor, pump and structure with  $1X_{\text{motor}}$  dominant frequency are mainly due to motor rotor residual unbalance.

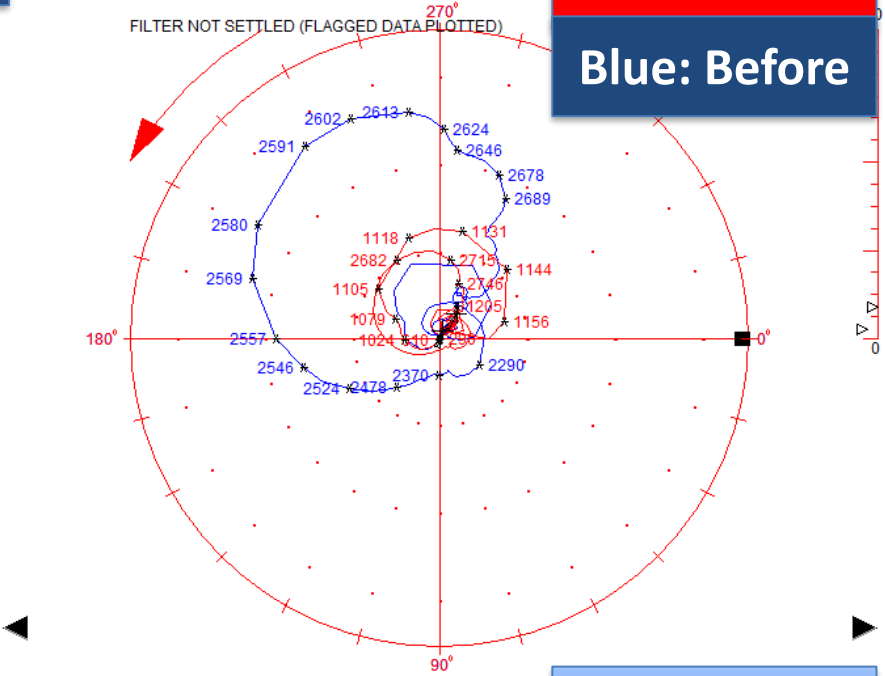
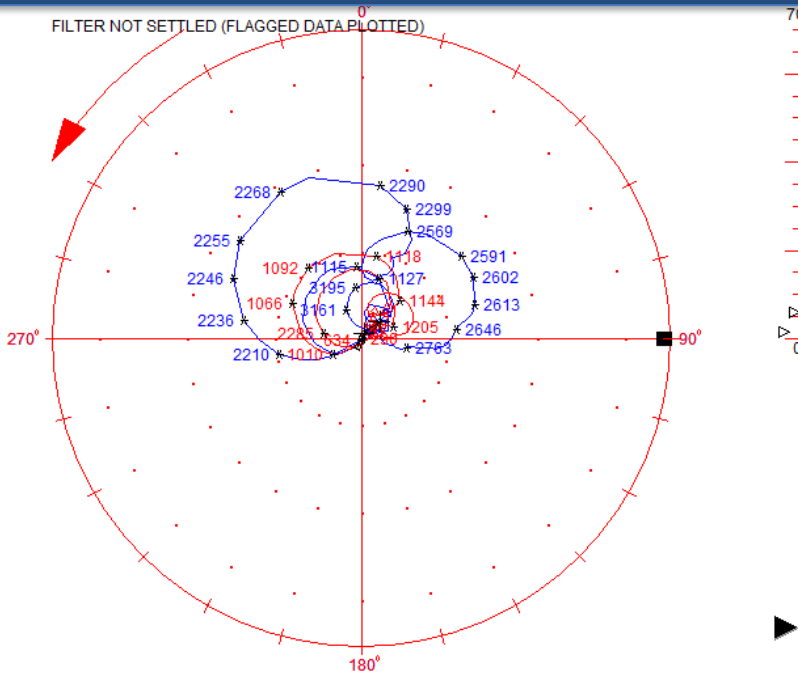


# Action Taken-Cont'd

## Weights Added on the Coupling Hub

MOBV	—	∠90°	Right	6.736 mm/s pk	∠304°	3602 rpm
MOBV	—	∠90°	Right	1.889 mm/s pk	∠284°	3599 rpm

**Red: After**  
**Blue: Before**



**OB-Solo Run**

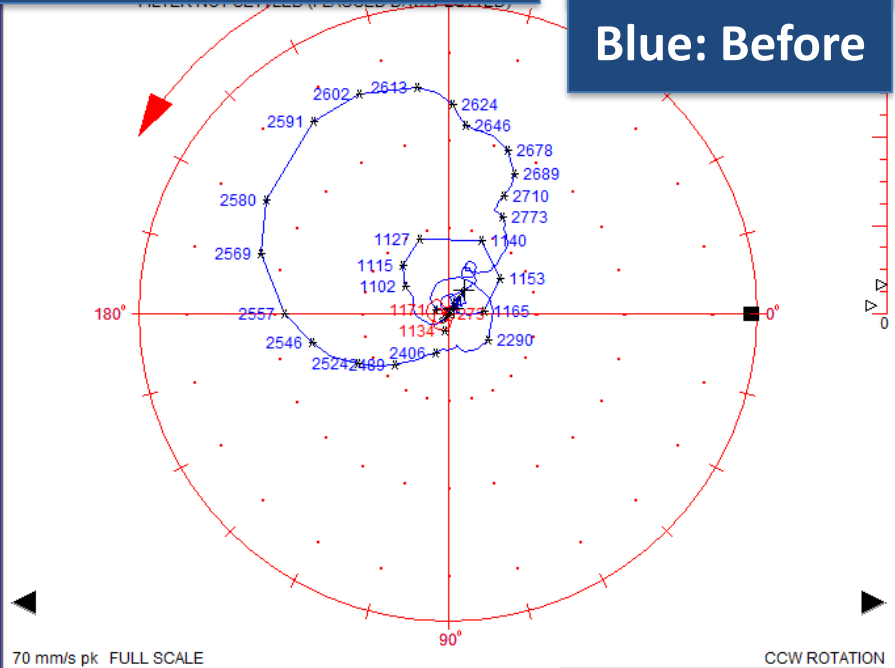
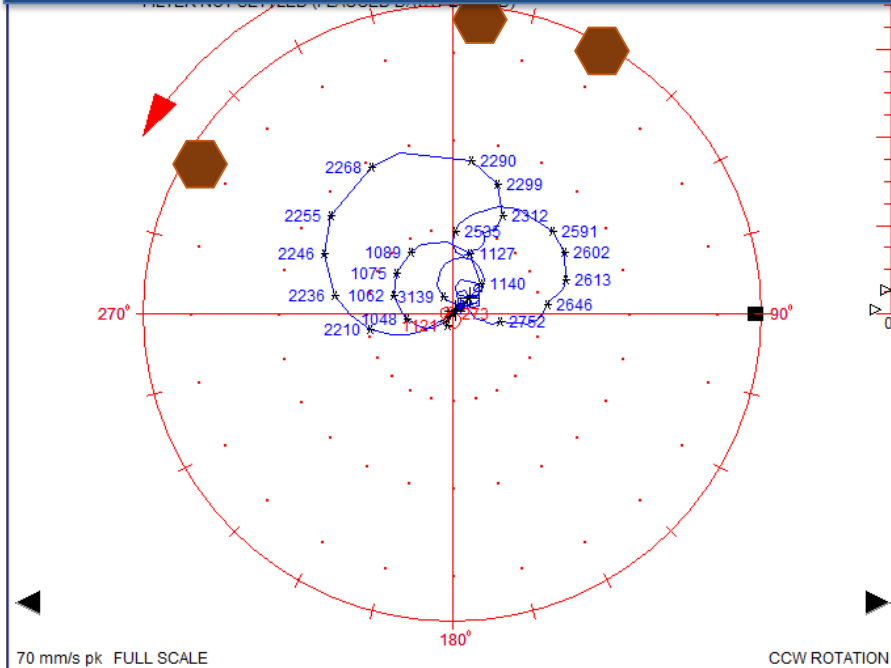


# Action Taken-Cont'd

Total of 186 g of Old Wrong Weights Removed from the Fan

Red: After

Blue: Before



OB-Solo Run

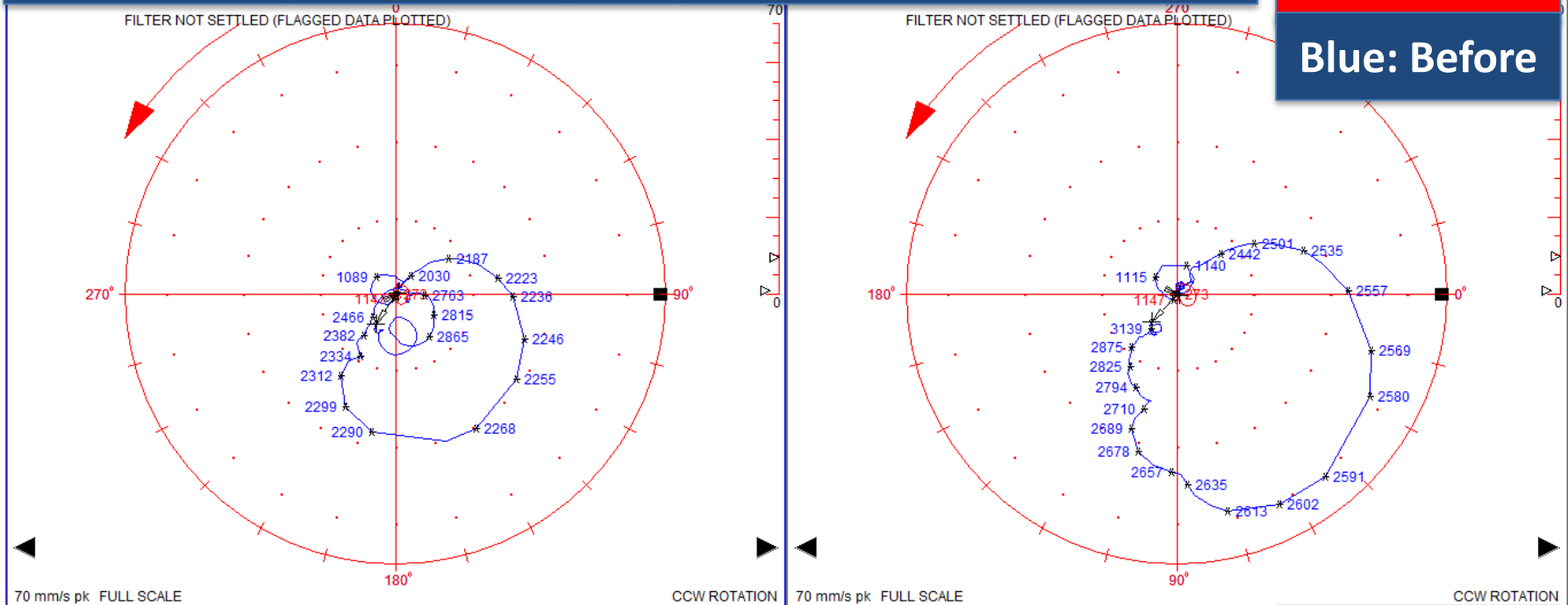


# Action Taken-Cont'd

Total of 186 g of Old Wrong Weights Removed from the Fan

Red: After

Blue: Before



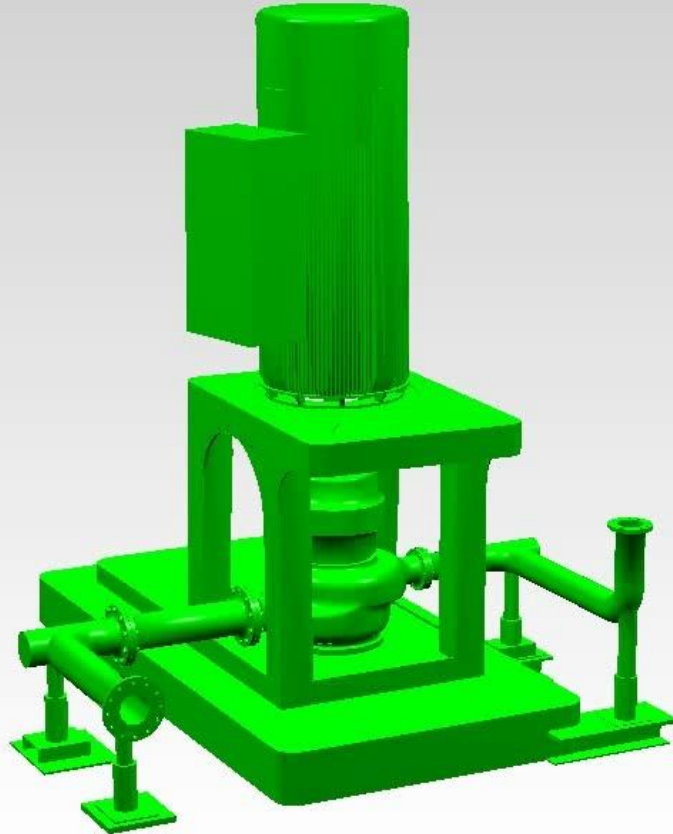
IB-Solo Run



# Post Analysis- ODS after balancing at 55Hz)

BLK: Coupled\_Run\_After  
Freq: 55 Hz, Damp: 0%  
Normal Shape

Twisting Motion



# Conclusion & Recommendations

- ODS showed circular motion due to unbalance response in addition to slight structural twisting motion.
- After balancing, the twisting motion remained due to the natural frequency of 55 Hz as indicated from the impact test data.
- Structure design to be reviewed with the OEM to shift the structure resonance frequency to at least 20% above or below the operating speed frequency.

