KNIGHTHAWK TECH NOTES

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"Cavity Acoustics "

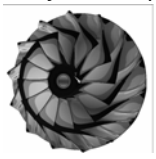
Once again you are in the conference room discussing the integrally geared compressor failure. This is the second failure of the system and as a plant maintenance engineer, the pressure is on to find out what happened and fix it. The production superintendent just informed everyone that the plant was sold out and now product will have to be shipped from the Middle East to supply the customers. The OEM has been in town and gave a presentation with all kinds of pretty color plots and charts, much like the first failure that occurred. The compressor has been running for years with no problems. All the plant did was debottleneck and increase production well within the limits of the compressor, but now you are experiencing open face impeller failures.

Both impeller failures experienced high cycle fatigue. The metallurgist calls it corrosion fatigue. The OEM pointed out how the compressor was within its limits and the SAFE diagram and the Campbell Diagram showed no problems. It seemed there was a general consensus that the failure was due to a slug of liquid in combination with corrosion.

You are "bugged" about the situation because of three major points. The first is that the compressor failed at the same rpm range, a higher rpm than the compressor ran before the plant was debottlenecked. The second point is there is no evidence of a slug, even though there are some liquids that the knock out bottles collect. The final point is that, for your entire career, you have observed pitting in these impellers.

After looking at the vibration data, everything was running smooth until the failure. One would have expected a slug to be picked up, but nothing was there. As far as the corrosion is concerned, the pits found still left a lot of "beef" in the impeller. The other point that really "bugs" you is the fact that the blade failures suggest it was the second mode and not the first, as one would expect with a slug of liquid.

This is a typical story regarding the so called "phenomena failures" for open face impellers.

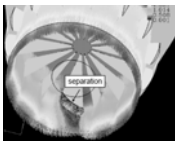


One of the biggest myths regarding the analysis of impellers is that, if a SAFE diagram analysis is conducted and it passes, there will be no forcing function to excite anything. It is an excellent tool for looking at IGV interference, but the fact is, the SAFE diagram does not include all the physics involved with impeller analysis. In particular, it does not include the "cavity acoustics". Yes, this is the same issue that occurs in reciprocating compressors where pulsation bottles and all kinds of studies are done to prevent the problem. It is frequently and most often not considered in centrifugal compressor design and never considered in compressor up-rate design. Most likely because the acoustical natural frequencies rarely cause interference, but when it does, your impeller is history.

So when "cavity acoustics" is mentioned, what is it? Every contained volume has acoustical natural frequencies. For a centrifugal compressor the diaphragm and volute comprise a contained volume at the impeller inlet. When there is a forcing function present that can excite the acoustical natural frequency, then the fluid will pulsate. This will cause two things to happen within the compressor. A turbulent flow disturbance will be present that will affect performance, or in the worst case, the pulsation frequency can couple to a natural frequency of the impeller. The bandwidth of this is very low, meaning that it would couple in an out at only a small rpm variance.

The physics in an existing problem can be captured with high speed data acquisition equipment using dynamic pressure transducers. If it is a new design, a good finite element (FE) model of the cavity will capture the response. Note that most computational fluid dynamics (CFD) analysis work does not resolve the acoustic waves. It has to be addressed separately. The following methodology is recommended to troubleshoot and fix a problem.

1. Metallurgical Analysis – The failure should be characterized. If it is fatigue then it should be classified as low cycle or high cycle and striations should be counted. Crack propagation time should also be determined.
2. Process Analysis – Process performance evaluation and simulation.
3. Controls and Instrumentation Review
4. Field Data Acquisition – A field study should be conducted to capture the vibration and pressure pulsations.
5. CFD – A full computational fluid dynamics model should be conducted of the gas path.
6. FE – A finite element acoustical model should be developed of the cavity. A modal analysis should be conducted on the impellor.
7. Root Cause Analysis



A good approach and methodology can eliminate the failure so there can be a "walk away" solution. As always, all analysis work and design efforts should be reviewed by a professional engineer that is competent in turbomachinery work.

KnightHawk Project Update

- Titanium Tower FFS - 1 / API 579 Analysis — Petrochemical
- Flange Leak - Offshore
- Main Lube Oil Pump Failure - Petrochemical
- Structural Dynamics - Off Shore
- Compressor Skid Structural Analysis - Off Shore
- Fitness for Service Waste Heat Boiler – Petrochemical
- Thermosyphon Analysis - Petrochemical
- Pump Metallurgical Assessment – Off shore - Africa
- Waste Water Treatment System Design Audit – Offshore
- Waste Heat Boiler Fit-For-Service – Petrochemical – Middle East
- 15 MW Compressor Audit – Petrochemical - Asia
- Refinery Settling Vessel - Petrochemical
- Desuperheater CFD - Power
- Material Handling Audit – Offshore
- Compressor Vibration – Petrochemical
- Vessel Fluid Dynamics – Petrochemical
- Gasifier Failure Analysis – Petrochemical
- Steam Turbine Failure - Power
- CFD of Exchanger - Petrochemical
- CFD of Pumps - Petrochemical
- 3-D CFD model of Polymer Pump – Petrochemical
- Pump Skid Design – Off Shore
- Rotordynamics – Off Shore
- Level 3 Waste Heat Boiler Fit For Service – Petrochemical

Cliff's Notes:

KnightHawk's staff has over 200 years of experience in turbomachinery problems. KHE has become an industry leader in open face impellers and we are your one stop solutions shop. We can execute all the items described above with our in house staff. We provide a complete solution to your turbomachinery problems. KHE's "Integrated Systems Approach" methodology for troubleshooting has been extremely successful in getting to root causes over the last 16 years.

I hope each and everyone has a wonderful Thanksgiving and that you are as blessed as I have been. Finally, all I have to say is "Go Tigers".

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