KNIGHTHAWK TECH NOTES

September, 2011

PHONE: (281) 282-9200 • FAX: (281) 282-9333
WEBSITE: www.knighthawk.com

Issue 11.07

Fracture Analysis

The morning meeting at the plant was a tough one for you. As an area engineer you are not satisfied with the information you are receiving from your team's investigation into a major compressor wreck that has happened yet again. The conclusion from the team has always been corrosion fatigue, and suggestions have been made to change the material to a more exotic type. The cost of the impeller would be more than five times the original equipment manufacturer (OEM), and have a long delivery time. One of the aspects of the work conducted by all the "high powered" experts that really bugs you is that all the sister plants around the world with the same process have the same impeller material, and yet do not experience these failures. Also the plant has a long history of running in this service with this material in other pumps and compressors. So in your mind "things just don't add up". The words "corrosion fatigue" resonant in your mind. Also, there is no doubt in your mind that the team is one of the best in the business.

Any area engineer should take a broad base look at the facts and ask questions. Questions were asked about this not happening with other pieces of equipment in sister plants using the same materials. In fact, the team was correct with their conclusions. The cause of the problem was corrosion fatigue. However, the key term here is fatigue. Fatigue translates to the fact that in the impeller reverse loading occurs, which means in practical terms that a dynamic stress was present. The fact that the impeller failed suggests the endurance limit was exceeded. After putting all the facts together it's time to "dig deeper" to see what is really going on. For the impeller to have failed, the endurance limit must have been exceeded. You ask the team to show you the Goodman Diagram so you can see the interaction of the steady state and dynamic stresses. The team does not produce a diagram, because none was ever developed. The reason is the team focused on "corrosion" as being the major player in this "corrosion fatigue" problem.

A typical allowable dynamic stress in an impeller on the Goodman diagram is ¼ of the tensile stress of the material. This assumes the material is good, and meets the ASTM standard for the material. However, corrosion can cause pitting, and reduce the endurance limit by another factor of two to five. Does this mean we have found the root cause of the failure? The answer is a flat "No!" No Goodman, Campbell, or interference diagram was developed.

The next step is to look at the process, and determine the exact details of what may be different. There must be some reason for the change. To do this requires evaluating the transient and steady state operation of the compressor. This might require additional instrumentation be incorporated into the process to better capture the process transient events.

In this particular problem, the molecular weight of the process changed during a transient period of operation when the plant was running at a higher capacity. This caused an excitation of the cavity acoustics, which ultimately led to the excitation of the impeller blades. A forcing function was present that matched a natural frequency of the impeller. Higher level analysis determined the impeller would have failed anyway, even without "derated" endurance conditions present. In other words, the dynamic stresses were so high that they would exceed the endurance limit of the metal with no corrosion.

A recommended approach to this problem is as follows:

1. Put together a team consisting of Process, Controls, Mechanical, and Metallurgical experts. The Area engineer should facilitate the team or even an "outsider" who is independent. In that case, the Area engineer should be involved with the team as a team member.
2. Perform a Metallurgical analysis of the fracture surface to characterize the type of fracture.
3. Perform a process analysis looking at both the steady state and transient operations. Evaluate any changes that have occurred such as a slight increase in speed of the compressor for example.
4. Field services should be performed to capture the dynamic pressures and vibrations. This information would be useful to determine if any active cavity acoustics are present or secondary wake disturbances.
5. A complete mechanical review should be conducted, and detailed finite element models should be developed of the impeller. Interference diagrams should be created and evaluated. Be aware that some diagrams do not consider cavity acoustics, and secondary wake disturbances at the tip of the impeller. In this case finite element acoustic models should be developed of the cavity and computational fluid dynamics models should be conducted of the flow path.
6. A root cause failure analysis should be conducted based on all the information collected.
7. Design changes can be made to fix the problem.

Often the fixes can be easily made. In the example discussed above a lower rpm during the process transient where the plant was running at a lower molecular weight fixed the problem.

Many of these failures are complex and detailed in nature, and all work conducted should be reviewed and approved by a professional engineer competent in machinery failure analysis.

Cliff's Notes: KnightHawk is your one stop shop for analysis of rotating equipment and static (fixed) equipment. We can get to the details and the real root cause because we have the equipment, metallurgical and materials lab, field services, and specialty engineering group. Everyday our team is working on some of the most complex applications in the world so let us show you how we can meet your needs.

From the personal side……School is back in session and here we go again with football, home-work, and the teachers. By the way, I have found the ultimate discipline method for boys. My 14 year old has a 4G Android mobile phone. When the grades go down the SIM card is swapped out to the hottest "Pink" phone for all the girls. It is remarkable how fast the grades go up and things get right. My son tells me this is spreading rapidly throughout the district as many boys are getting "pink" phones for discipline.

Cliff Knight
cknight@knighthawk.com

KnightHawk Project Update

- Transfer Line Exchanger – Petrochemical
- Clamping Connector Analysis—Petrochemical
- Titanium Tower FFS – Petrochemical
- Separator Flow Analysis – Petrochemical
- Brittle Fracture Analysis – Petrochemical
- Screw Mixer Failure – Petrochemical
- Depentanizer Tower FFS – Petrochemical
- Well Bore Flow Analysis – Oil & Gas
- Motor Bearing Failure – Water Treatment
- Bearing Fluid Flow Analysis – Subsea
- Riser Stack Analysis – Offshore
- Gas Pipeline Coupling Failure – Oil & Gas
- BOP Analysis – Subsea
- Motor Thermal Analysis – Subsea
- Pump Vibration Analysis – Petrochemical
- Vessel Destructive Testing – Oil & Gas
- Critical Pipe Stress – Petrochemical
- Corrosion Analysis – Gas Pipeline
- Centrifugal Pump Rotor Reverse Engineering – Petrochemical
- Reactor Failure Analysis – Petrochemical
- Balanced Torque Measurements – Power
- Creep Tensile Testing – Communications
- Gasifier Equipment Design – Power
- High Temperature Molten Salt Tank Design – Green Energy
- Transient Fluid Dynamics – Petrochemical