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Fracture analysis

The morning meeting at the plant was a tough one for you. As an area engineer, you're not satisfied with the information you're receiving from your team's investigation into a major compressor wreck. 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 OEM and have a long delivery time. One thing that bugs you is all of the sister plants around the world with the same process have the same impeller material and 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. Things just don't add up.

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 reverse loading occurs in the impeller, which means a dynamic stress was present. The fact the impeller failed suggests the endurance limit was exceeded. After putting all of the facts together, it's time to dig deeper to see what is really going on. 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 one was never 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 a quarter 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 2-to-5. Does this mean we have found the root cause of the failure? 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. To do this requires evaluating the transient and steady state operation of the compressor. This might require additional instrumentation being 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 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 they would exceed the endurance limit of the metal with no corrosion.

A recommended approach is:

1. Put together a team consisting of process, controls, mechanical and metallurgical experts. The area engineer should facilitate the team.
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.
4. Field services should be performed to capture the dynamic pressures and vibrations.
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.
6. A root cause failure analysis should be conducted based on information collected.
7. Design changes can be made to fix the problem.

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

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