KNIGHTHAWK TECH NOTES

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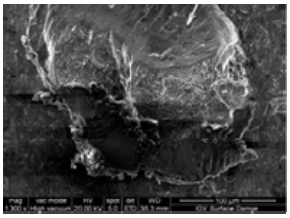
"Metallurgical and Materials Forensics "

There has been a major failure at your facility, and it involves one of the most critical pieces of rotating equipment: a main air compressor that provides air to the oxygen plant that services a large plant. As a young engineer just starting out your career, you watch as all the "big boys" with the white hair start the investigation. It amazes you to see the amount of internal and third party consultants involved. The vendor of the equipment is also involved. Broken parts are "sliced and diced," and the materials engineers go after it. You, along with your senior colleague, visit the local labs to observe what they are doing. Finally, a group gets together in a conference room. There are three metallurgists present, one representing each party: the internal group at the plant, the vendor, and a third party consulting firm. The participants have "micrographs," pictures and of course their credentials, which are a mile long. To your amazement there are three different opinions regarding the root cause of the failure. One is corrosion fatigue, another is foreign particle damage leading to fatigue, and finally there is just plain fatigue.

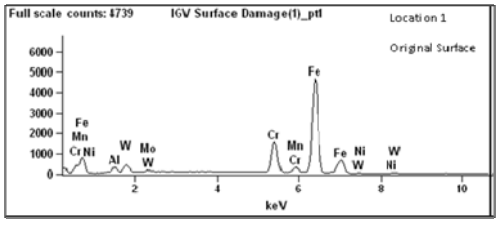


Then comes the good part; a scanning electron microscope (SEM) fractography. The purpose of this work is to shed light on the location of crack initiation and to determine the fracture mode. Then some Energy Dispersive X-ray Spectroscopy (EDS) is used to evaluate the chemical element constituents found in the failed parts. The EDS is used in conjunction with the SEM. EDS essentially analyzes the emitted x-rays so that surface elemental composition can be determined. The metallurgist discusses at the meeting whether the crack, initiated by corrosion, propagated in a transgranular or intergranular manner along the grain boundary. Also, from the SEM analysis, striations could be found to indicate fatigue and the number of cycles. Finally, it could be seen where the ductile overload occurred.

But, the question remains, what is the complete picture? All parties agreed that the part failed from fatigue, but what was the root cause. The original equipment manufacturer (OEM) says that things would have been fine if the corrosion had not occurred. However, the compressor which was an open face impeller failed quickly. Another point made was why did the corrosion not affect the other stages in the machine? So the forensics of the metallurgical analysis was important, but what was the real root cause?

In order to have fatigue, there must be reverse bending. To perform a complete evaluation, a multi discipline approach was taken as follows:

- Characterization of Physical Evidence – This is an important step. If the evidence (sample) is contaminated, it is possible that the EDS will provide false results and report other element constituents not really present.
- Process History Review – Usually one second data is taken from the process historian to evaluate what process conditions were present.
- Metallurgical Analysis – This is required, as discussed above, to characterize the failure.
- Field Services - In this particular case, field services were used to determine the natural frequencies of the impeller.
- Finite Element Analysis – It is not good enough to have the natural frequencies from a static test. The press fit on the hub could not be taken into account, or stress stiffening at running speed from the field services.
- Computational Fluid Dynamics (CFD) – This was used to determine the forcing functions driving the failure. There are also secondary wake effects leading to self excitation. These can only be determined though transient studies that CFD analysis can provide.
- Root Cause Failure Analysis – The information obtained from all the above is put together into a cause and effect analysis. As it turned out there was a critical resonant frequency at the particular running speed of this compressor. Although corrosion was present, the dynamic stresses were high enough to fail the impeller even if there had been no corrosion.



As can be seen, metallurgical and materials investigations often play an important role in forensics analysis of a rotating or static equipment failure. It is important that these investigations be directed by a professional engineer familiar with multidiscipline approaches.

Cliff's Notes: KnightHawk has performed some of the most complex mechanical and multidiscipline analyses in the industry. KnightHawk uses a unique "Integrated Systems Approach" that we believe is second to none. Let us explain how we can help you on your most challenging problems that you face in industry every day. We have a complete staff of Chemical, Mechanical, Electrical/Controls, and Metallurgical/Materials Engineers. Our testing and metallurgical lab is one of the best specialty groups around. KnightHawk had in its literature, the term *multidiscipline* 20 years ago, before it was commonly used in the industry.

By the time you receive this Newsletter, the Super Bowl will be over. I hope the Steelers will win but who knows. Stay warm and may you and your family be blessed.

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KnightHawk Project Update

- Compressor Skid Pipe Stress – Petrochemical
- Deaerator Efficiency – Petrochemical
- Gas Pipeline Coupling Failure – Oil & Gas
- Water Pump Failure Analysis – Nuclear
- Hydrolyzer Analysis – Petrochemical
- Centrifugal Compressor Failure Analysis – Petrochemical
- Jacketed Reactor Vessel Design – Petrochemical
- Compressor Redesign Startup Monitoring – Petrochemical
- Vessel Destructive Testing – Oil & Gas
- Cryogenic Tank FFS – Petrochemical
- Corrosion Analysis – Gas Pipeline
- Flare System Analysis – Petrochemical
- Reactor Failure Analysis – Petrochemical
- Filtration System Design – Petrochemical
- Oxidizer Redesign & Reconstruction – Petrochemical
- Creep Tensile Testing – Communications
- Gasifier Equipment Design – Power
- Pump Vibration Analysis – Petrochemical
- High Temperature Molten Salt Tank Design – Green Energy
- CFD Ethylene Furnace – Petrochemical
- Inlet Cone Design for TLE's – Petrochemical
- Bearing Design – Heavy Manufacturing
- Vaporizer Design – Petrochemical
- Transient Fluid Dynamics – Petrochemical
- Waste Heat Boiler Failure – Petrochemical
- Liquids & Solids Separation Technology Development – Coal