By: CLIFF KNIGHT, Owner/President
KnightHawk Engineering

The complete picture

Your weekend was just wiped out and it is Monday morning. The team has worked around the clock to get your compressor back up and running. The planned outage was another six months away, but the hope was to run for an optimistic five years. It did not happen. Your focus was to get the plant back up and running, so the broken impeller parts are just left in the corner of your office.

It took a process analysis and an in-depth understanding of its effect to determine what happened on the compressor.

With the compressor running and the plant production on spec, the plant manager is happy and so is the rest of the crew. The next weekend has passed and everyone has caught up on sleep and now the big meetings start. The plant manager lays out how much the failure has cost and force majeure had to be declared. He wants some answers and everybody is looking at you as you are the maintenance manager.

You assemble a team of folks to help with the pending investigation. They include operations, maintenance, process, safety and engineering. The parts are sent out to a metallurgical lab to perform a failure analysis. Everyone works to exhaustion, looking at time history plots. With the machine having a good history, everyone is really not concerned about the ball game. It has run long and it nearly made the planned outage. Finally, the outside metallurgical lab comes in to present the results of their failure analysis. The answer is corrosion fatigue. It's explained and a report is written up and sent to all of the bosses. Everyone can relax. Then the next machine fails. Another iteration of all this occurs and the metallurgical lab comes back with the same answer: corrosion fatigue.

You think, now that is interesting. We have an impeller that ran for several years and the failure was corrosion fatigue and then another ran for several weeks and it is corrosion fatigue. No one told the lab how long each of the impellers ran; they just asked for a failure analysis. This time the big boss is serious and all are called out on the carpet. You think about everything and your gut tells you that you don't have the complete picture.

In fact, you don't. The metallurgical analysis was not a failure analysis. It was a metallurgical analysis. The spare impeller that was put in had several years of exposure from a previous run, so the gun was jumped to corrosion fatigue. It might have had some corrosion, but everyone would agree the second failure was too quick for corrosion to kick in. So what does a failure analysis of this major piece of critical equipment involve? It is a multiphysics approach consisting of process, controls, operations, design, maintenance, mechanical and metallurgical analysis. The cause of this failure was cavity acoustics.

You might ask yourself, what is cavity acoustics? In layman's terms, it is a condition where internal noise is amplified in the compressor case and it causes the impeller to vibrate and fail. From a technical standpoint, internal pulsation is being developed from an acoustic natural frequency that is excited by a forcing function. A dynamic pressure pulsation is developed and a forcing function couples with the mechanical natural frequency of the impeller causing it to vibrate at a resonant frequency. When this happens the impeller fails quickly. A change in feedstock leading to a molecular weight change caused this rare coupling in the system. It took a process analysis and an in-depth understanding of its effect to determine what happened on the compressor.

An approach one may consider is the following:

- Historical assessment
- Process analysis
- Mechanical analysis
- Controls review
- Maintenance assessment
- Metallurgical and materials analysis
- Root cause analysis

The solution to this problem was a minor process change. The cost was likely millions in lost revenue for the facility. These types of problems should be reviewed by a professional engineer competent in failure analysis of these systems.

For more information, visit www.knighthawk.com or call (281) 282-9200. ●