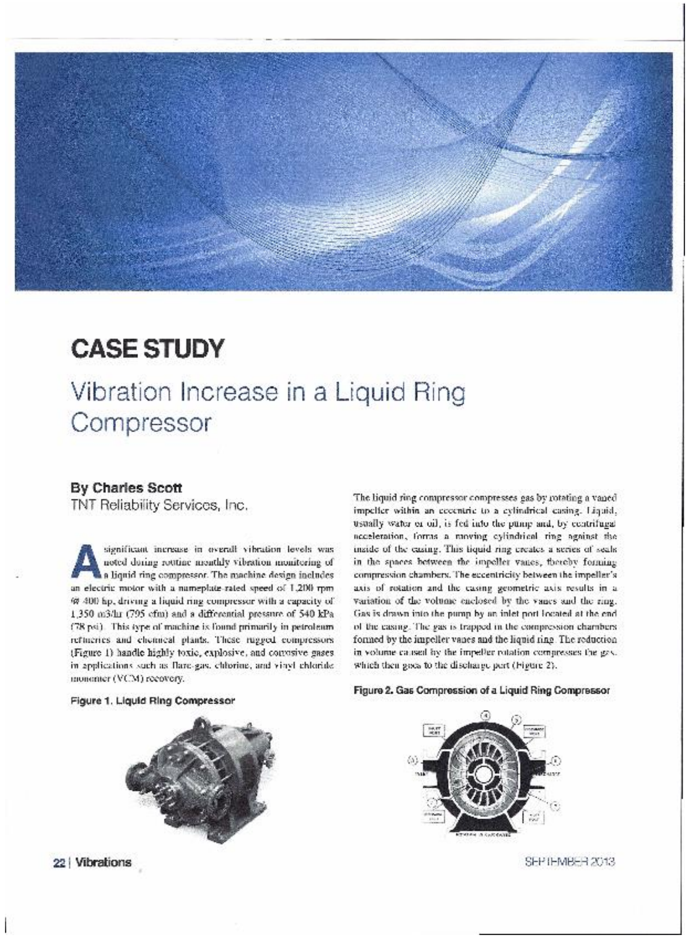
Vibration case study



CASE STUDY

Vibration Increase in a Liquid Ring Compressor

By Charles Scott
TNT Reliability Services, Inc.

A significant increase in overall vibration levels was noted during routine monthly vibration monitoring of a liquid ring compressor. The machine design includes an electric motor with a nameplate-rated speed of 1,200 rpm @ 400 hp, driving a liquid ring compressor with a capacity of 1,350 m3/hr (795 cfm) and a differential pressure of 540 kPa (78 psi). This type of machine is found primarily in petroleum refineries and chemical plants. These rugged compressors (Figure 1) handle highly toxic, explosive, and corrosive gases in applications such as flare-gas, chlorine, and vinyl chloride monomer (VCM) recovery.

Figure 1. Liquid Ring Compressor

The liquid ring compressor compresses gas by rotating a vaned impeller within an eccentric to a cylindrical casing. Liquid, usually water or oil, is fed into the pump and, by centrifugal acceleration, forms a moving cylindrical ring against the inside of the casing. This liquid ring creates a series of seals in the spaces between the impeller vanes, thereby forming compression chambers. The eccentricity between the impeller's axis of rotation and the casing geometric axis results in a variation of the volume enclosed by the vanes and the ring. Gas is drawn into the pump by an inlet port located at the end of the casing. The gas is trapped in the compression chambers formed by the impeller vanes and the liquid ring. The reduction in volume caused by the impeller rotation compresses the gas, which then goes to the discharge port (Figure 2).

Figure 2. Gas Compression of a Liquid Ring Compressor

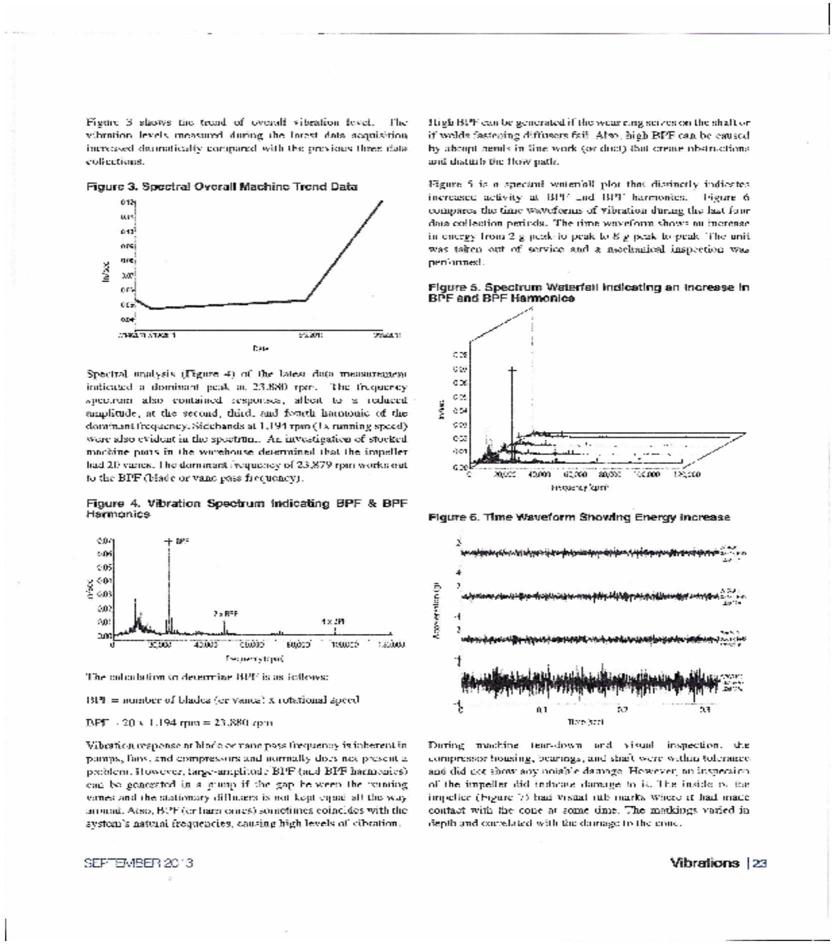


Figure 3 shows the trend of overall vibration level. The vibration levels measured during the latest data acquisition increased dramatically compared with the previous three data collections.

Figure 3. Spectral Overall Machine Trend Data

Spectral analysis (Figure 4) of the latest data measurement indicated a dominant peak at 23,880 rpm. The frequency spectrum also contained responses, albeit to a reduced amplitude, at the second, third, and fourth harmonic of the dominant frequency. Sidebands at 1,194 rpm (1x running speed) were also evident in the spectrum. An investigation of stocked machine parts in the warehouse determined that the impeller had 20 vanes. The dominant frequency of 23,879 rpm works out to the BPF (blade or vane pass frequency).

Figure 4. Vibration Spectrum Indicating BPF & BPF Harmonics

The calculation to determine BPF is as follows:

BPF = number of blades (or vanes) x rotational speed

BPF = 20 x 1,194 rpm = 23,880 rpm

Vibration response at blade or vane pass frequency is inherent in pumps, fans, and compressors and normally does not present a problem. However, large-amplitude BPF (and BPF harmonics) can be generated in a pump if the gap between the rotating vanes and the stationary diffusers is not kept equal all the way around. Also, BPF (or harmonics) sometimes coincides with the system's natural frequencies, causing high levels of vibration.

High BPF can be generated if the wear ring seizes on the shaft or if welds fastening diffusers fail. Also, high BPF can be caused by abrupt bends in line work (or duct) that create obstructions and disturb the flow path.

Figure 5 is a spectral waterfall plot that distinctly indicates increased activity at BPF and BPF harmonics. Figure 6 compares the time waveforms of vibration during the last four data collection periods. The time waveform shows an increase in energy from 2 g peak-to-peak to 8 g peak-to-peak. The unit was taken out of service and a mechanical inspection was performed.

Figure 5. Spectrum Waterfall Indicating an Increase in BPF and BPF Harmonics

Figure 6. Time Waveform Showing Energy Increase

During machine tear-down and visual inspection, the compressor housing, bearings, and shaft were within tolerance and did not show any notable damage. However, an inspection of the impeller did indicate damage to it. The inside of the impeller (Figure 7) had visual rub marks where it had made contact with the cone at some time. The markings varied in depth and correlated with the damage to the cone.

Figure 7. Visual Rub Marks Noted Inside Impeller

Further investigation revealed a crack in one of the impeller vanes (Figure 8). The rubbed and cracked impeller was determined to be the probable root cause of the dramatic increase in vibration.

Figure 8. Crack Noted in Impeller Vane

A review of the maintenance history of the liquid ring compressors at this site revealed that previously, in one of these units, an impeller vane had broken completely off, wedging it inside the fluid end of the machine and causing a catastrophic failure. The damage caused by the component failure resulted in a total loss of the machine. The replacement cost for this machine was $360,000, with a six month lead time.

The combined cost for rebuilding the compressor described in this case study was only $60,000. Also, all parts that were needed for the rebuild were on-site in warehouse stock. The savings realized following the corrective action determined by vibration analysis was in the range of $300,000.

This case study shows the importance of and justification for an effective vibration program at a manufacturing facility. Condition monitoring programs demonstrably contribute to the bottom line of the company.

BIOGRAPHY

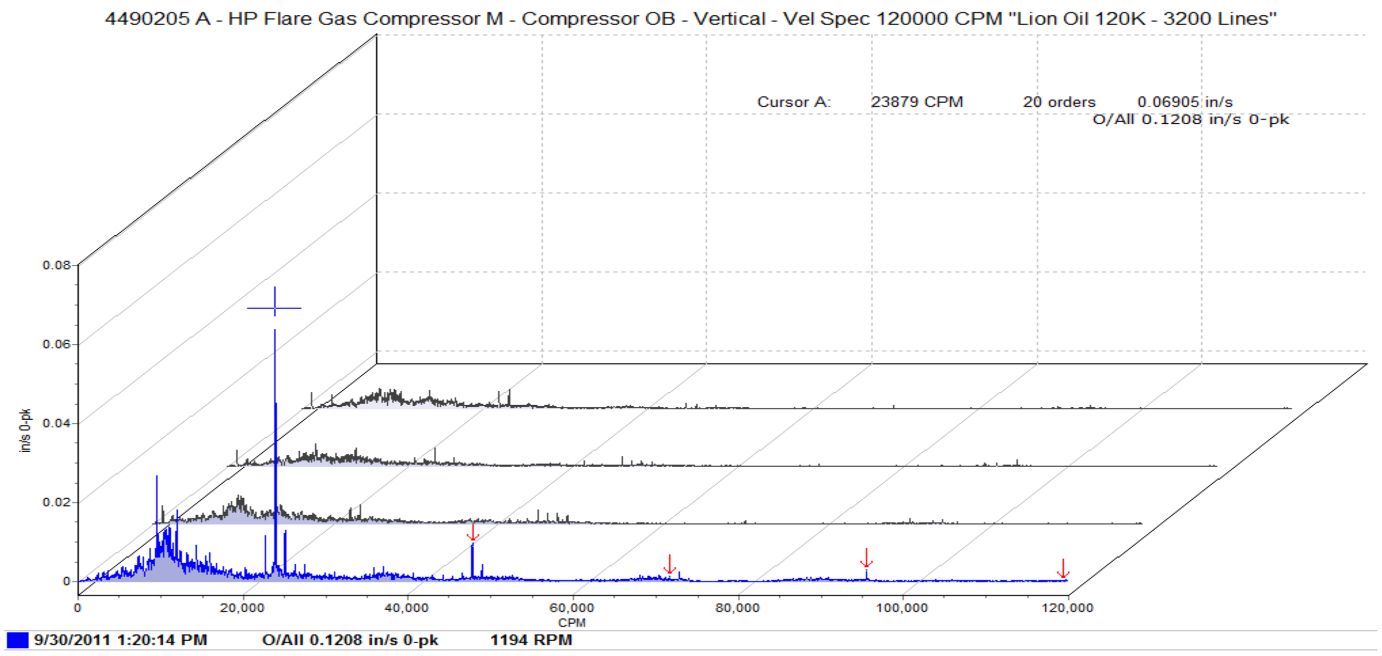
Charles Scott owns TNT Reliability Services, Inc., a technical service company providing state of the art technologies to manufacturing and industrial facilities. He has over 12 years of technical equipment experience, for the past 8 specializing in vibration analysis. He holds an AAS in Industrial Technology from South Arkansas Community College and holds Vibration Institute certification as a Vibration Analyst Category II, as well as Category III Vibration Analyst certification from Mobius. Scott is also certified by SDT as a Level I Airborne Ultrasound Inspector and by Reliability Testing Services as a Level I Thermographer. He can be reached at cscott@tntreliability.com.

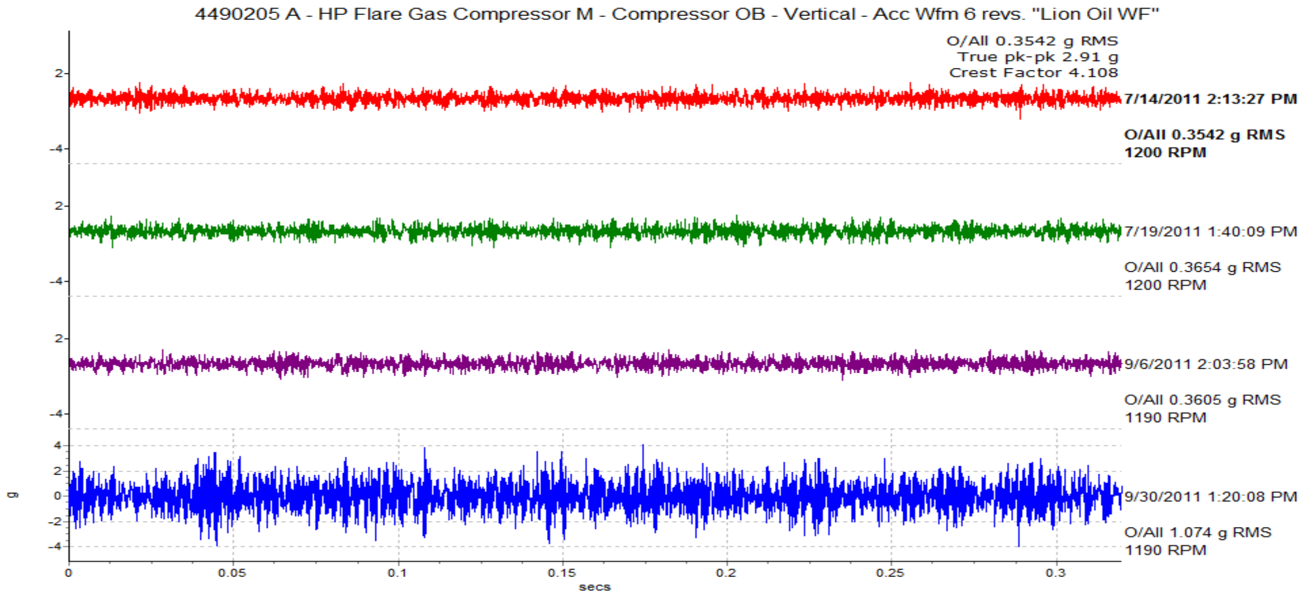
Case Study

Liquid Ring Compressor

Capacity of 795 cfm & Differential Pressure of 78 psi

1200 rpm





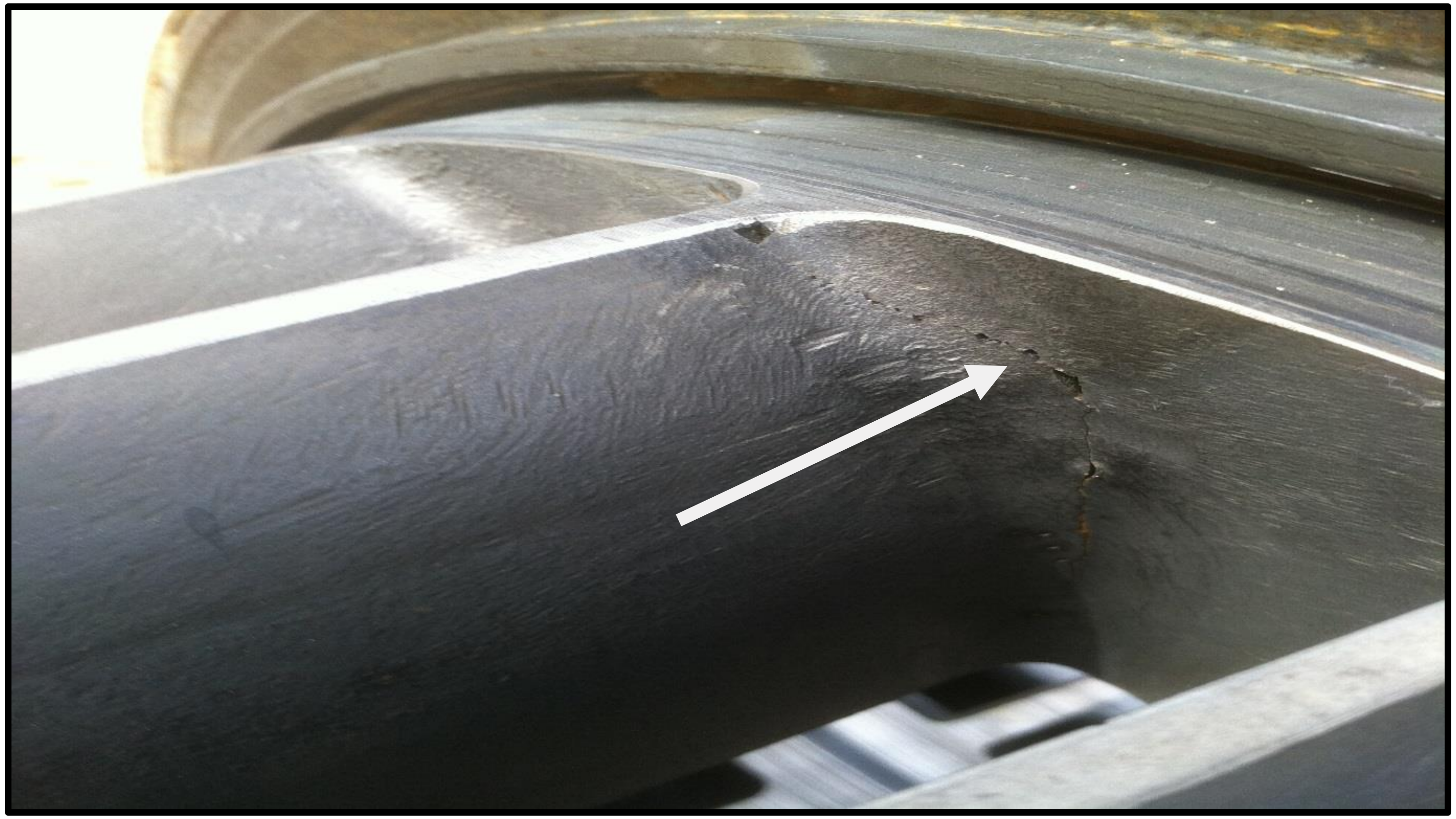
Case Study

Increase In Vane Pass Frequency & Harmonics

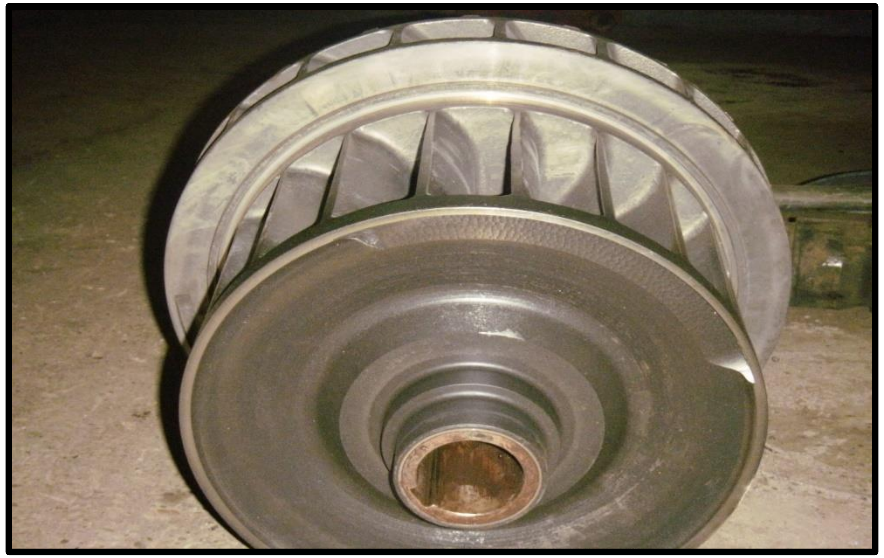
Energy in Time-Based Waveform Increasing

Overall Vibration Amplitude Still Considered Low at 0.12ips

Case Study



Inspection Found The Cause - Cracked Impeller Vane



Case Study Results

Maintenance history of the liquid ring compressors: previously, an impeller vane had broken completely off, wedging it inside the fluid end of the machine and causing a catastrophic failure. The damage caused by the component failure resulted in a total loss of the machine. The replacement cost for this machine was $360,000, with a six-month lead time.

By finding the problem predictively, rebuilding the compressor was only $60,000. Proactive planning due to predictive knowledge resulted in a **savings of approximately $300,000.**