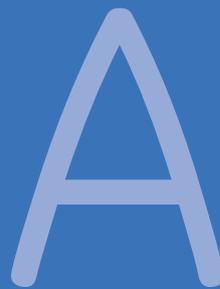


System 1* at Agrium: Nutrient for Growth

Fertilizer sustains world food and energy demands. At Agrium, a leading global producer and marketer of agricultural nutrients and industrial products, System 1* is making a positive impact on operation and maintenance, helping feed the production demand.

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Agrium Inc. is a major retailer of agricultural products and services in North and South America, a leading global wholesale producer and marketer of all three major agricultural nutrients, i.e. nitrogen, phosphate and potash, and the premier supplier of specialty fertilizers in North America. Agrium's headquarters is located in Calgary, Alberta, Canada, with four major production facilities in Alberta. At all of these facilities, critical process equipment is equipped with Bently Nevada condition monitoring systems. Since 2005, GE's System 1 online condition monitoring and diagnostics software has been implemented. Reliability engineers at these facilities actively use System 1 tools and data to monitor and troubleshoot machinery malfunctions. System 1 enables operations and reliability personnel to make decisions to continue production or increase process rates without potential damage to the machines, as well as determine outage scope when necessary. Based on System 1 information, a predictive maintenance program is implemented to maintain equipment in good condition and prevent costly replacements. As explained by Gerry Kydd, senior specialist of rotating equipment at Agrium Technical Services, "System 1 saves us money. It allows us to know when a machine is in real stress and to monitor closely while keeping it running until we can shut it down in a controlled way. System 1 also allows us avoid secondary damage to the process that can occur in an emergency trip." The following case histories demonstrate how Agrium achieved these savings.

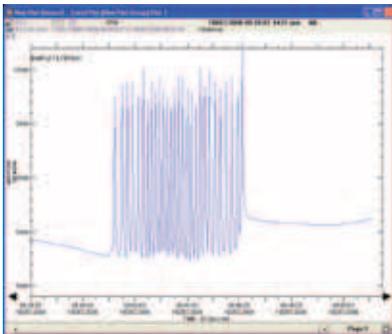
CASE HISTORY 1: Steam Turbine Overspeed

Agrium Fort Saskatchewan Nitrogen Operation produces 465,000 gross tons of Ammonia and 430,000 tons of Urea per year.

In March 2005, the overspeed protection system on a steam turbine driven process air compressor was inspected; the trip bolt cleaned and overspeed condition tested. In December 2006, during a process upset, a maintenance engineer noticed in System 1 that the speed momentarily spiked to 10335 rpm, well above the rated trip speed of

9523 rpm. Due to slow data capture intervals, there was no indication of the overspeed condition in the DCS. The overspeed protection trip bolt didn't act. The maintenance engineer alerted operations of this anomaly. At the next available outage in June 2007, the trip bolt parts were examined, and were found to be contaminated with thick, sticky sludge that prevented the mechanism from functioning properly. Thorough cleaning and testing ensued and the steam turbine was overspeed

trip checked successfully. In June 2008, the turbine was converted to an electronic overspeed trip. If the overspeed trip device malfunction had not been detected, the business impact for potential catastrophic machinery damage and process interruption was estimated at \$30 million in this single incident. System 1 paid for itself by providing crucial data in an otherwise unnoticed overspeed condition. Even if the probability for such incident were 1 in 100, the cost of the risk would be \$300,000.



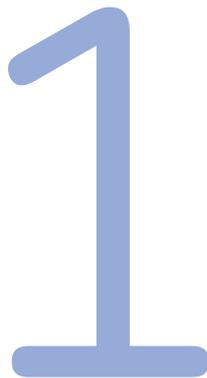
The turbine speed spiked to 10335 rpm in December 2006, above the rated trip speed.



Sludge in trip bolt mechanism.

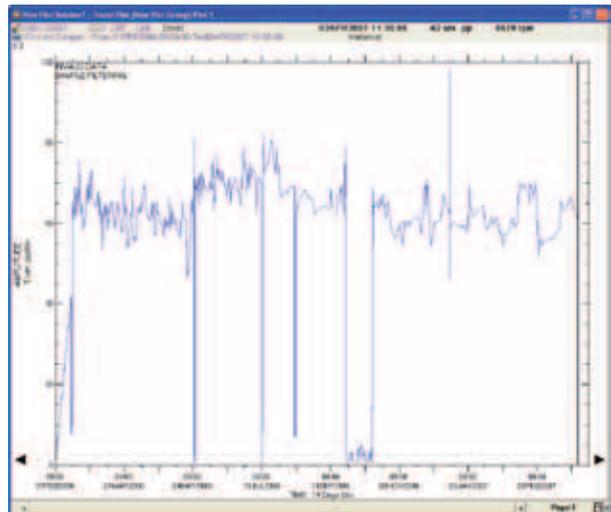


Process air compressor, compressor train.



CASE HISTORY 2: Step Changes in Exhaust Bearing Vibration

The maintenance engineer uncovered another malfunction of the steam turbine in case history #1 in February 2006. After an outage, the radial vibration on the exhaust bearing step-changed from about 40 micron to 60 micron, and then went as high as 80 micron occasionally. During the outage of June 2007, the turbine was run solo as part of the overspeed test. The shaft centerline plot from the solo test rundown was compared to that of the coupled rundown before the outage, and distinctive differences between the shaft centerline movements and vibration levels were observed. It was concluded a significant component of the vibration was caused by internal and external misalignment. Turbine alignment keys and supports were lubricated with Molykote® 321 in June 2007, and vibration decreased from 60 microns to 50 microns. In the outage of July 2008, the plant replaced the coupling and re-aligned the turbine and compressor. After the outage, vibration dropped and settled out at 40 microns. As explained by the maintenance engineer, “System 1 allowed us to see dynamic response of the turbine in real time. Although the 40-micron level is higher than desired, it is acceptable, but the 80-micron level is just a step away from a shutdown and overhaul. The potential consequence of such a failure would be an unplanned outage at \$5 million lost production. Even if the probability of this failure were 1 in 10, from this single incident we saved \$500,000.”



Vibrations were around 40 microns prior to February 2006 outage; the vibration jumped to 60 microns on the start up and went as high as 80 microns.

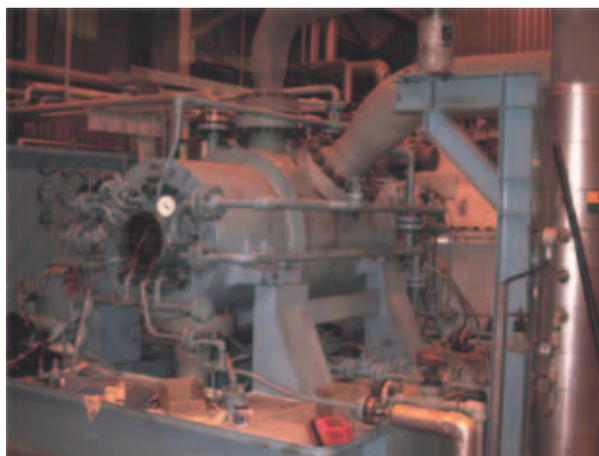
CASE HISTORY 3: Thrust Bearing Damage by Electrostatic Discharge

It has been well documented that electrostatic discharge can gradually destroy bearings when arcing erodes the babbitt metal surface. This case provides new insights into the failure mode of thrust bearing damage caused by electrostatic discharge. Explained by Gerry Kydd, "The tilt pad thrust bearing that was experiencing electrostatic damage showed hardly any axial displacement even though the amount of babbitt erosion from the pads was severe. Temperature measured by embedded probes was actually giving an earlier indication. It turns out that the bearing pad can tilt progressively more and thus maintain axial positioning until the damage to the pad trailing edge is very severe. You may only get a couple of mils movement and think you are more or less OK, but it is misleading. At the point the axial position starts to move, the bearing pads may actually be badly damaged and starting to wear into the thrust disc. If the disc is integral with the shaft then expensive rotor replacement will be needed. For this failure mode, both temperature and thrust position are required for the diagnosis and this is something that I had not previously seen in the literature."

3 Joffre Nitrogen Operation produces 480,000 tons of ammonia per year. The heart of the process is synthesis gas compressor. The thrust bearings in the compressor high-pressure case are furnished with proximity probes and embedded temperature probes. At the beginning of November 2008, an apparent upward trend of bearing temperature was noticed at the inboard thrust bearing, but the outboard bearing temperature remained stable. In the previous three months, the inboard bearing temperature increased from 90C to 120C. During the same time period, the axial position measured at the inboard bearing only moved 3 mils. The orbit-timebase plot for inboard radial bearing vibration was examined and no distinct changes noticed.

The plant maintenance technician was concerned about possible thrust bearing damage, so an outage was planned. On November 17, 2008, the compressor was shut down. The inboard thrust-bearing pads had over 0.020 inch Babbitt removed from the trailing edge and were down to the steel backing. The root cause was electrostatic discharge. Consequently, grounding brushes were repaired and a back up brush installed. Since then, it has kept the problem from re-occurring. In this case, the plant maintenance team shut down the compressor on the strength of both System 1 data and DCS data. The damage was limited to only the thrust bearing and no other rotating or stationary parts were affected. The maintenance cost of the planned outage was minimized compared to emergency shut down at an inopportune time. System 1 saved the plant a potential loss of \$250,000.

It is intriguing to note that the thrust movement, less than 5 mils, was far less than amount of the thrust bearing pads erosion, over 20 mils. Electrostatic damage showed up predominantly as a bearing temperature excursion. The change of bearing temperature was more indicative of damage than that of bearing axial position.



Synthesis Gas Compressor, High Pressure Case.

CASE HISTORY 4: Radial Bearing and Thrust Bearing Damage by Electrostatic Discharge

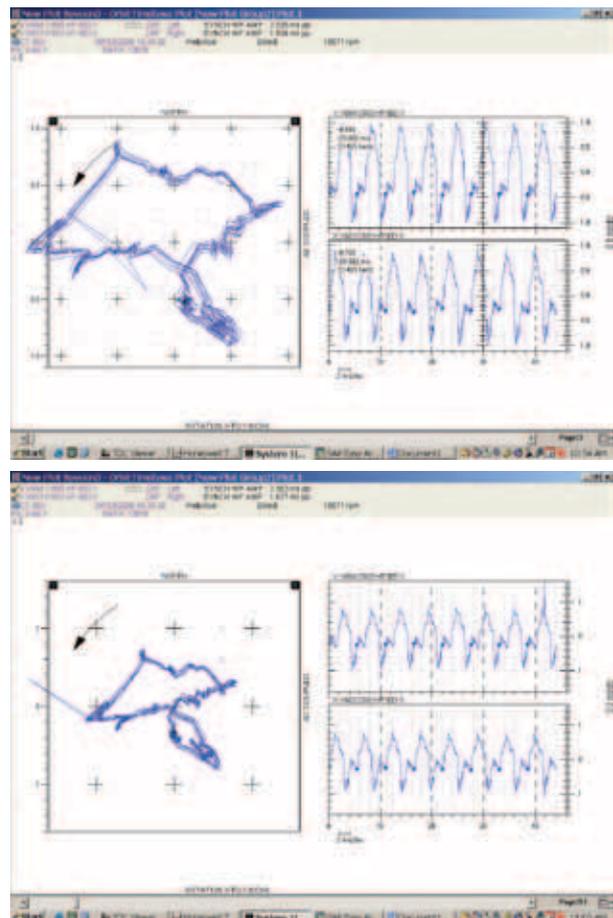
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Redwater Nitrogen Operation is Agrium's largest nitrogen producer. It produces 960,000 gross tons of Ammonia per year, as well as Ammonium Nitrate, Ammonium Sulphate, Urea, and Nitrogen Solutions.

The synthesis gas and ammonia refrigeration compressors at the Redwater operation have experienced grounding problems from time to time, as static charges build up from impinging droplets of water in the wet stages of the steam turbines. In February 2008, the rotating equipment specialist at the plant observed erratic orbit patterns on both compressors and a slight increase in temperature of the syngas turbine thrust bearing. The random abnormal shaft vibration could not possibly represent any actual shaft movement. The enlarged orbit on the refrigeration compressor also indicated inboard bearing clearance had opened up. Electrostatic discharge was considered to cause the spikes. After reviewing System 1 data, the plant had a planned outage for other reasons in April and used the opportunity to inspect the syngas turbine thrust bearing and refrigeration compressor radial bearing. The grounding brushes were found badly worn on both machines. Severe surface erosion was found on the pads of the syngas turbine thrust bearing and some wear on the refrigeration compressor radial bearing leading to replacement of both. When the compressors returned to service, no more abnormal orbits were observed. The abnormality in the orbits was attributed to the radio frequency interference from the static discharges occurring in close proximity to the radial vibration probes. Accordingly, the plant revised the preventive maintenance program to inspect and replace the grounding brushes on a monthly interval or as necessary based on System 1 data. The static grounding brush maintenance has kept the bearing conditions stabilized. The plant engineer concluded, "System 1 allowed us to stay on top of the situation until we could shut down and replace the thrust bearing. In some of our past experience, we have found that static discharge can destroy a bearing in only a few months. Even though System 1 was not designed to monitor static discharge within a piece of equipment,

it is very beneficial to pay attention to any anomaly in the data. If we had not noticed this increase level of static discharge in our two machines, we would not have been able to run them to our 2009 turn around." A premature shut down could cost the plant many millions of dollars in production losses.

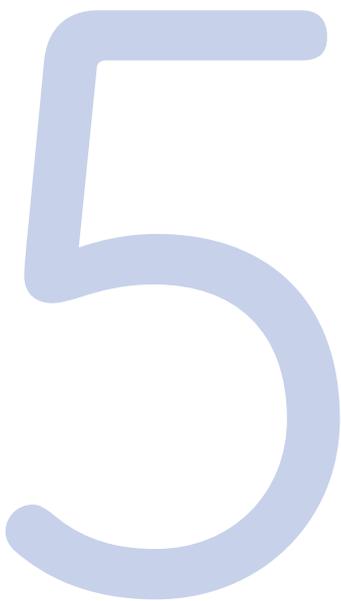
Similar to Case history #3, the syngas turbine thrust bearing experienced substantial damage, while the thrust transducers didn't show any significant axial movement. Again, the thrust bearing temperature also increased indicating the damage.



These random anomalies of the turbine vibration could not possibly represent any actual shaft movements. These were at the turbine HP casing radial bearing closest to the thrust bearing. Some anomalies still appeared at the bearings on the opposite end of the machine, quite a distance from the discharges themselves.

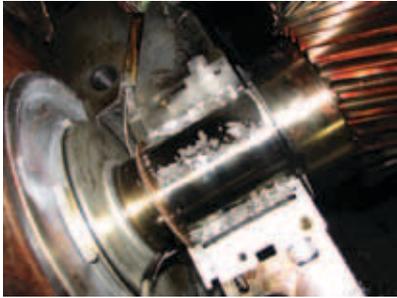
CASE HISTORY 5: Air Compressor Oil Pump Failure

Carseland Nitrogen Operation produces 535,000 gross tons of Ammonia and 680,000 of Urea annually. System 1 was commissioned on critical equipment in 2008.

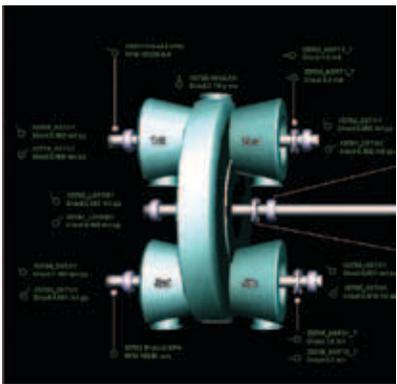


System 1 proved its value at 5AM Sunday, January 25, 2009. The main lube oil pump failed, and a few minutes later, the integral-gear air compressor tripped on high thrust vibration. The plant reliability engineer was alerted to the incident and quickly reviewed System 1 data. High axial movement was revealed at the thrust bearing on the high-speed shaft, starting about 20 seconds before tripping from losing pressurized lube oil. The high axial movement caused serious damage to the thrust bearing. First stage shaft radial bearings also experienced high vibration before and during the trip. The dominant radial vibration component was at running speed, 1x. Radial bearing damage was also found. To support the diagnostics, plant engineers reviewed DCS data, including data trends of thrust bearing temperature, lube oil pressure and running speed. Without this wealth of data, the likely scenario would have been restarting the compressor. But, based on data, a decision was made to remove the compressor cover for inspection and repair. Severe bearing damage and impeller damage was observed and a complete overhaul of the compressor was undertaken. The replacement parts cost more than \$200,000 in

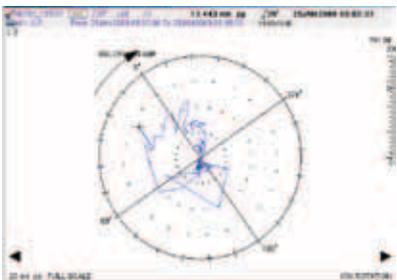
material and labor, and it took more than a month to put the compressor back in service due to unavailability of some required parts; while the plant ran at reduced ammonia production. After this incident, several corrective actions were taken. The lubrication oil pump operation procedure was revised and an accelerometer installed on the main oil pump to catch pump faults early. The plant reliability engineer was convinced of the System 1 value in the unexpected trip situation. The trip data collected by System 1 proved to be extremely helpful in diagnosing the trip. Also, machine related parameters were in System 1, enabling diagnostics to be carried out in a timely fashion. The reliability engineer commented “as the compressor overhaul was a pretty big and costly job, it was crucial to make the right decision whether go forward and overhaul the compressor, or run it up based on uncertain thrust movement threshold setting. If the compressor had been restarted, it is inevitable that even higher production losses and repair costs would have occurred. Having data available in System 1 helped save money in terms of maintenance time, as we knew what was wrong and what parts to order.”



Air Compressor High speed shaft thrust and radial bearing damage required a complete overhaul.



Motor driven 4 stage Air Compressor



Air Compressor 1X Vibration Polar plot just after failure from 5:00.

Summary

The cases presented here illustrate that System 1 provides critical data and diagnostic capabilities to Agrium facilities to detect and monitor equipment problems, make informed decisions for scheduling outages at the right time and carry on preventive maintenance programs based on equipment condition. ■

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