



Brüel & Kjær Vibro



Application Note

**Case study – Early fault detection
of unique pump bearing faults at a
major US refinery**



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The SETPOINT® monitoring system from B&K Vibro was selected by a major North American refinery to monitor several important pumps that could not be adequately monitored by other available online systems. The refinery had shown that a specific algorithm in their portable data collector for detecting rolling element bearing failures was highly effective and asked B&K Vibro to implement a nearly identical algorithm in SETPOINT®. This was urgent because the failure progression, which could occur in as little as 6 hours, had resulted in volatile hydrocarbon releases and subsequent catastrophic fires in the past, and thus required an online (continuous) rather than offline measurement approach. SETPOINT® delivered the functionality within one month, reflecting the ability to rapidly tailor the system to customer needs through firmware rather than hardware-dependent changes. Two case studies are presented showing how the system was tailored to detect specific failure modes and how it has proven itself in service.

Hi-tech refinery

The US-based refinery in this case study processes almost 250,000 barrels of crude oil per day to produce transportation fuel and lubricating base oils.

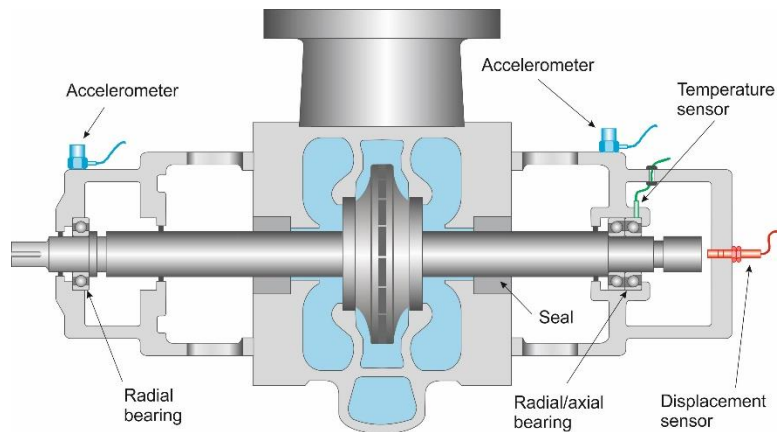


Figure 1. Location of the sensors on the solvent booster pump, as monitored by SETPOINT®.

As transportation fuel is a major product at the refinery and only 40% of the crude oil can be distilled into these products, a fluidized catalyst cracker and hydrocracker are used at the refinery to maximize fuel production.

Production is further enhanced by the solvent de-asphalting unit (SDA), where heavy residues from the vacuum distiller can be re-processed to produce a de-asphalted oil that is later hydrogenated and used as feedstock in the FCC.

Moreover, by utilizing clean fuel technology and a unique base oil catalytic dewaxing process, the petroleum products delivered by the plant are ranked to highest quality standards.

In addition to clean fuel technology, an extensive ongoing modernization project is under way that further improves the plant efficiency and reliability while also fulfilling strict environmental regulations for the future.

Failure prone pumps

The machine examined in this case study is the solvent booster pump, which pumps the extraction solvent under high pressure to the mixer/asphaltene separator in the SDA unit. There are three of these API 610 BB2 pumps, of which two must be operating at all times. If one of the pumps is down, then there is no spare. The pumps have had a history of bearing and seal failures over the years.



If the seals leak (e.g., a bearing failure causes the seals to open up), the volatile hydrocarbons escape and can ignite when they flash across the hot bearing or seal face surface, resulting in a fire. This has occurred several times in the past. Previous attempts to monitor the pumps failed, so eventually a SETPOINT® machine protection unit was selected to monitor them.

Unique monitoring strategy

Previously, all monitoring for the pumps was done only with a hand-held vibration instrument on a weekly basis. This was considered sufficient since there was normally a 6-month lead-time from bearing fault detection to failure. As some failures were occurring with less than six months lead-time at that time, it was decided to install a wireless system with 30 minute monitoring interval and continue using the portable for diagnostics.

The wireless system, which was only for condition monitoring, worked well for detecting typical bearing faults but was not effective for detecting fast developing bearing faults that were recently occurring at that time. The bearings in the pumps were failing without warning, which often led to a fire. The portable vibration device utilized a special measurement technique that could detect these particular faults but only with a 6-hour lead-time, which is completely impractical for a portable instrument.

In order to distinguish between a normal bearing fault (6 months lead-time) and that with an accelerated development (6 hours), it was decided to implement a temperature sensor, but there was still no machine protection with this monitoring configuration. Therefore a protective monitoring solution was needed that could reliably detect and distinguish between the fast and slow developing bearing faults, and shut down the pump in time, as described in Case study 1.

The SETPOINT® monitoring system for the solvent booster pumps currently employs the early bearing detection capability of the portable device, plus a voting logic shutdown strategy for both bearing vibration and temperature. The sensor configuration consists of two accelerometers that are radially mounted on the driven and non-driven end bearing housings, as shown in Figure 1. On the non-driven end (thrust bearing), a displacement sensor is mounted through the bearing housing to axially monitor the shaft displacement. This unusual configuration is based on the assumption that when the thrust bearing is at an advanced stage of failure or it is creeping along the shaft, there will be axial movement associated with this degradation, and this can be detected by the sensor. This is described in Case study 2. In such a case a quick shutdown is necessary, not only because of the advanced state of failure for the bearing or shaft, but also since this same axial movement can provoke a seal leak that can be ignited into a catastrophic fire.

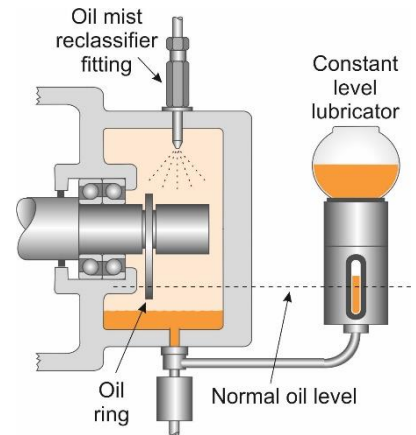


Figure 2. Case study 1: Lack of lubrication caused by over-pressure delivery of purge oil mist. Resulting oil level is below the oil ring so there is no lubrication. Sight glass incorrectly indicates sufficient oil level because of oil mist over-pressure.

Case study 1: Loss of lubrication to the pump

After several bearing failures of the solvent booster pumps, including some that resulted in a fire, it was determined that this condition was caused by loss of lubrication. As a typical bearing has a lead-time of 6 months from fault detection to failure, lubrication starvation accelerated this degradation to only 6 hours. The root cause, however, was unknown. Subsequent investigation revealed that the cause of the loss of lubrication was due to the purge mist lubrication system. As shown in Figure 2, the bearings are lubricated by an oil ring. Oil mist is injected into the bearing housing at a pressure slightly greater than ambient to act as a purge, in order to avoid contaminants from entering the housing.



The oil mist in this scenario is insufficient to lubricate the bearings on its own.

As a result of an installation error, an improper reclassifier fitting was mounted to the bearing housing during a previous service that allowed abnormally high over-pressured oil mist to push the oil level in the housing below the oil ring, and at the same time gave a false reading on the constant level lubrication system eye glass.

As there was no contact between the oil ring and the oil, this resulted in loss of lubrication to the bearing. After determining the root cause of the problem, the correct reclassifier was installed and the loss of lubrication problem ceased.

As a follow up, a SETPOINT® protective system was selected to replace the legacy condition monitoring system. To achieve this, it was modified to employ the early bearing fault detection technique used by the handheld so the fault could be monitored continuously. This monitoring technique, which was not available previously with an online system, was coupled with bearing temperature through relay voting logic. This enables the SETPOINT® system to quickly trip the pump before damage is incurred or a fire is started.

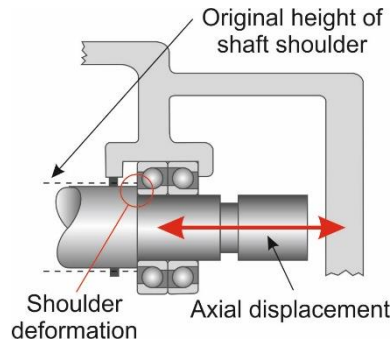


Figure 3. Case study 2: When the outer diameter of the shaft was reduced, the reduced height of the bearing shoulder deformed due to thrust loading, which allowed the shaft to axially displace.

Case study 2: Axial displacement of pump bearing

During a previous major refurbishment of one of the solvent booster pumps, the damaged shaft was replaced by one that was newly machined instead of being repaired. Unfortunately, the replacement shaft was not completely up to spec; the outer diameter of the shaft bearing shoulder was undersized. After several months of operation, the newly installed SETPOINT® protective system issued an axial vibration alarm on the pump.

At first it was believed that it was a false alarm but after the pump was disassembled and inspected, it was quickly observed that the shaft shoulder where the radial/axial thrust bearing sits up against was damaged, as shown in Figure 3.

This was later determined to be caused by the thrust loads in the pump pressing the bearing against the smaller shoulder and deforming it, which in return allowed the bearing to axially move along the shaft. In this case the alarm was not the result of loss of lubrication or a defective bearing, but a deformed bearing shoulder on the shaft.

If the pump shaft is allowed to move in the axial direction, even for a small displacement, this can unnecessarily stress the mechanical seals and lead to a leak. A leak on this pump can potentially ignite and result in a catastrophic fire.

During service, a shaft with the correct dimensions was installed and the problem of axial movement or “creep” of the bearing disappeared.

Benefits of early detection

The solvent booster pumps presented two special monitoring challenges that could not be addressed by the legacy condition monitoring systems. Early bearing fault detection is very important for these and many other refinery pumps, since the radial or axial displacement of a failing bearing can provoke a premature seal leak, which cannot be tolerated because of the risk of fire.

In the first case study, the SETPOINT® system was selected as a protective solution, partly because of its ability to be modified quickly to the special application requirements by making only firmware changes.



In the second case study the SETPOINT® system proved successful in avoiding a seal leak caused by unexpected axial movement of the shaft. This was done using a displacement sensor that was not present on the previous system.

The SETPOINT® system is designed to detect all kinds of faults, including installation and service faults, not just typical bearing wear.

The SETPOINT® system paid itself off within the first year of installation. Satisfied with the results, the refinery is currently assessing monitoring other pumps with the SETPOINT® monitoring strategy in an effort to increase asset reliability, reduce maintenance and pump lifecycle costs, improve machine uptime and mitigate the risk of costly fires.

Brüel & Kjær Vibro GmbH
Leydheckerstrasse 10
64293 Darmstadt - Germany
Phone: +49 (0) 6151 428 0
Fax: +49 (0) 6151 428 1000
info@bkvibro.com
www.bkvibro.com

BAN 0081-EN-11
Author: Mike Hastings
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