

LDPE Reactor mixer bearing faults – Part 1

This case story from the Porvoo low density polyethylene plant demonstrates the importance of online condition monitoring of the LDPE reactor mixer. This article is the first of a two-part series, providing insights in how the LDPE mixer was configured for monitoring. Part 2, will appear in the next issue of Uptime showing plots from three case stories.

End-user

Borealis, a leading provider of polyolefins, base chemicals and fertilizers, owns and operates the Porvoo petrochemical complex in Finland. The Porvoo complex consists of five plants that produce olefins (ethylene, propylene and butadiene), aromatics (phenol, acetone, benzene and cumene) and polyolefins (polyethylene, polypropylene). Low density polyethylene (LDPE) is currently produced in the plant with two lines delivering a total of 150k tonnes/year.

Machine monitored

One of the primary machines in the LDPE production plant is the autoclave reactor; the focus of this case story. It is a 6.5m long, 530mm diameter pressure vessel with a self-contained motor, which drives a long shaft with many mixer blades mounted on it (see Figure 3). The mixer portion of the reactor stirs the ethylene and peroxide mixture at high pressure to initiate and control the polymerization process (see a description of the LDPE



Figure 1. The Borealis Porvoo petrochemical complex, located 40 km east of Helsinki, Finland.

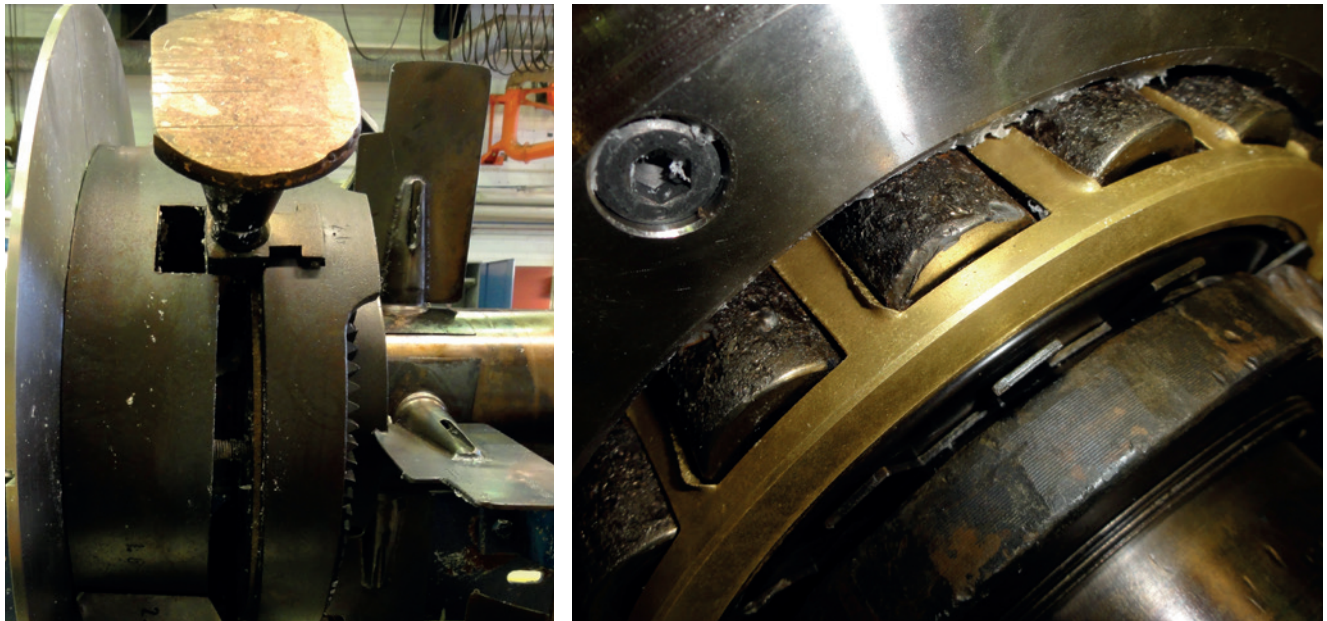


Figure 2. View of the damaged middle bearing of the reactor mixer, showing the fractured bearing housing (left) and the bearing rolling elements (right). The detection and diagnosis of this bearing fault is described in Part 2 of this article series.

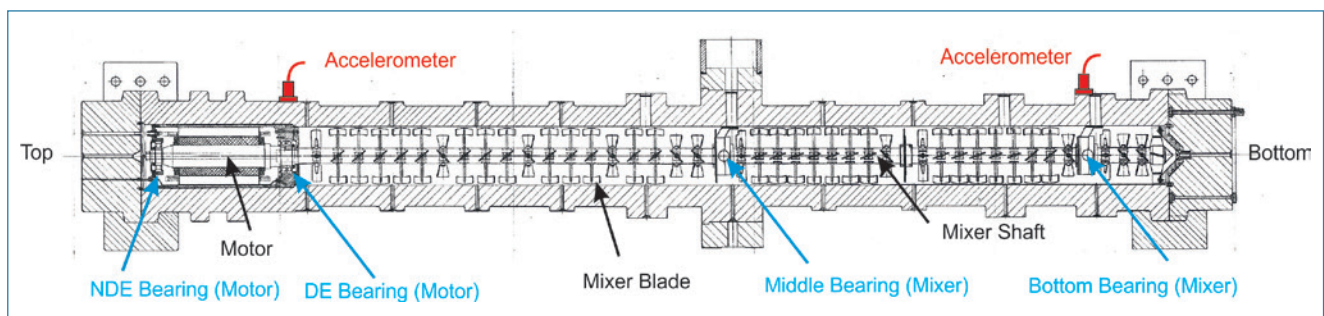


Figure 3. Autoclave reactor core showing location of the ATEX certified accelerometers and the bearings which are monitored by these accelerometers. The mixer shaft bearings are identical. (The reactor is shown on its side in this picture, normally it stands upright.)

process in the fact box). Given its criticality in the LDPE production process, any bearing failures in the mixer, will result in a plant shut down and lost production.

Temperature, pressure and the flow of peroxides are regulated in the reactor to control the LDPE properties. Because of the sensitivity of the polymerization process, this has to be carefully monitored and controlled. Any disturbances in the reactor, such as plugged output line or even a hot spot in a bearing, could trigger an uncontrolled reaction with

the potential to increase the pressure extremely fast. There are two rupture disks installed on the reactor to prevent over-pressuring.

Decomposition (decomp) of ethylene can occur under certain pressure and temperature conditions and results in the formation of hydrogen and methane, which are highly explosive. If a decomp leads to a catastrophic failure, it takes one day to change the mixer. A day's production loss is approximately 205 tonnes, which is over €318,000 (at Jan 2013 LDPE spot prices). If there

is secondary damage, it will take longer and incur increased maintenance cost to return the reactor back to service. Some plants change the mixer bearings frequently in order to avoid a failing bearing failure that can result in a decomp, but this causes unnecessary downtime.

Porvoo has adopted a condition monitoring strategy to carefully monitor the condition of the bearings and thereby extend the time between bearing replacement while preventing bearing failure and unplanned downtime.

LDPE Manufacturing Process

Low-density polyethylene (LDPE) is a thermoplastic polymer based on ethylene. The worldwide market for this plastic is approximately 18 million tons/year, €15.9 billion (2009). Around 65% of all LDPE production is extruded film, with plastic bags the most common product.

There are two different processes for making LDPE; autoclave and tubular method. Borealis uses the autoclave method at the Porvoo plant. The autoclave process uses two compressors to bring the ethylene up to reaction pressure; a primary compressor, normally a piston operated reciprocating compressor (typically four stages plus a booster stage, 250 bar), and the secondary compressor, normally a plunger operated hyper compressor (typically two stages, 1300-2000 bar). These compressors also take in unreacted recycle ethylene from the separators.

The autoclave reactor takes in the pressurized ethylene, to which organic peroxides are added to create free radicals, in order to initiate the polymerization process. This reaction propagates the formation of CH_2 polymer chains. The reactor mixer (shown with blades inside the reactor in Figure 4)

ensures even distribution of the polymerization process in the reactor. LDPE properties such as density and melt index are regulated by a combination of controlling reaction temperature (160-310 °C), pressure (1300-2000 bar), and by adding comonomers and modifiers. This determines, among other things, the extent of branching of the polymer chains. The temperatures and pressures have to be carefully monitored, however, to avoid the risk of reaction decomposition. This occurs when the ethylene or polyethylene decomposes into H_2 and CH_4 , which are highly explosive.

The reaction is terminated at the bottom of the reactor and the LDPE melt exits for the high pressure (HP) and low pressure (LP) separators, where it is cooled, and unreacted ethylene is re-compressed and recycled back to the autoclave reactor. Low molecular weight polymers (wax, oils) are removed in other separators. The purified LDPE exits the LP separator and is then sent to the extruders where the melt is homogenized, more property enhancing additives are added, and the final product is pelletized and de-gassed before packaging and delivery.

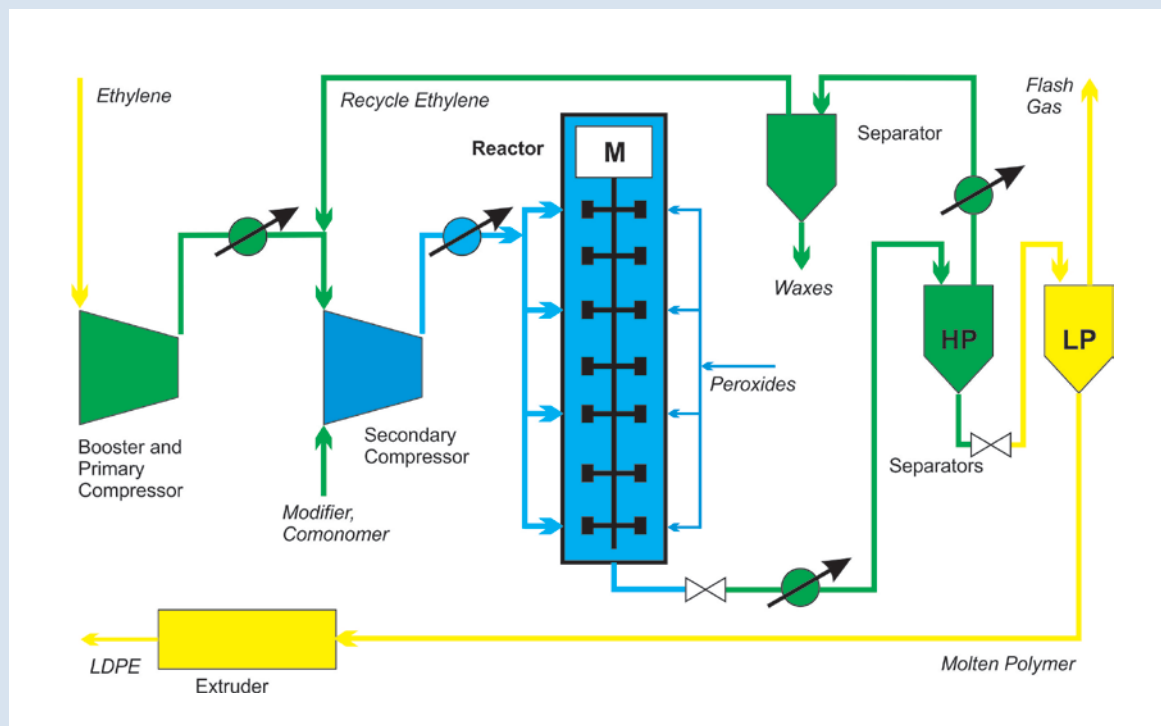


Figure 4. Simplified diagram of LDPE process, where blue denotes very high pressure (1400-2000 bar), green moderate pressure (40-250 bar) and yellow low pressure.

Monitoring Strategy

The Compass system, commissioned at Porvoo in 2001, is used for safety and condition monitoring of the reactor in the two LDPE lines at the plant. The same system is used to monitor the primary and secondary compressors and the extruders in the same plant, as well as other Borealis petrochemical complexes in Europe.

As shown in Figures 3 and 5, the four rolling element bearings in the reactor are monitored by two accelerometers. The primary fault detection measurement used is a bandpass acceleration measurement. The setting for signal response is nearly the same as that for a RMS and peak-peak measurement settings. The frequency range of 1-5 kHz captures the rolling element bearing resonance frequencies, providing accurate, early indication of a developing bearing fault.

Alarm limits for this measurement are normally established through experience. Generally, the first alarm indication (Alert) is set to occur approximately one month prior to the Danger alarm, which identifies a need to change the entire mixer (reconditioned unit).

After a bearing fault has been detected, Envelope analysis is used to identify the location of the bearing fault and determine its severity. A FFT velocity spectrum can also be used to identify the bearing fault frequencies if the noise floor is not too high. If a bearing fault further develops, it creates a secondary vibration signature which is visible in the velocity trend and spectrum. Sometimes the velocity spectrum identifies

vibration at rotating frequency and its harmonics. These are generally process related and usually disappear in a short time.

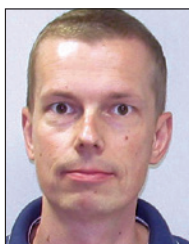
If the polymer sticks to the blade, this results in unbalance. If the polymerization process is unstable, this creates a broad low frequency vibration. (See Figure 6.)

Conclusion

In this issue of Uptime, Part 1 of this article series presents general information concerning the monitoring strategy of an autoclave reactor in an LDPE plant. In the next issue of Uptime, Part 2 of this article series will present three actual case stories.

Acknowledgement

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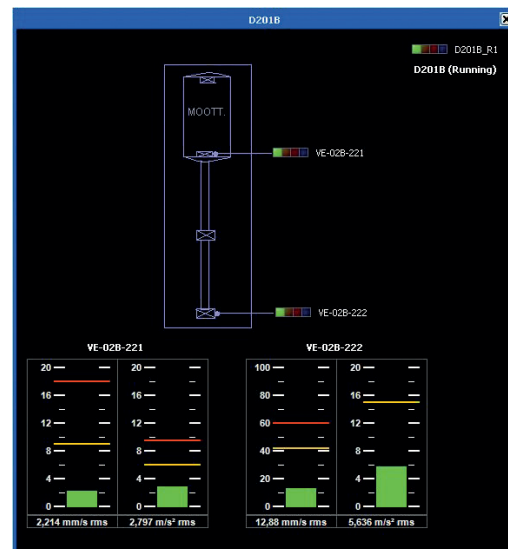


Figure 5. Machine view screen showing the traffic light status of the two measurement points and a real time acceleration bandpass vibration measurement display.

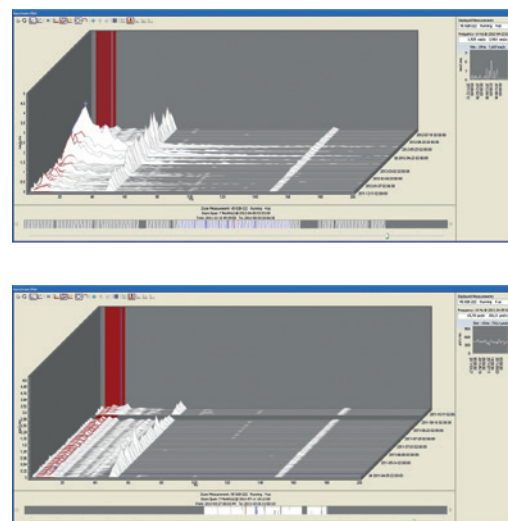


Figure 6. Process related low frequency vibration shown on the left. Normal plot shown on the right.

LDPE REACTOR MIXER BEARING FAULTS

– PART 2

CASE STUDY



This case story from the Porvoo low density polyethylene plant demonstrates the importance of online condition monitoring of the LDPE reactor mixer. This article is the second part of a two-part series that graphically demonstrates three case stories. Part 1 which gave, background information on the monitoring system configuration, appeared in the previous issue of Uptime (www.bkvibro.com).



CASE STUDY OF BEARING FAULTS ON THE REACTOR MIXER

Some examples of bearing faults that have been detected in the reactor are shown in three different case stories.

Case 1: DE motor bearing fault

The driving end (DE) motor bearing, the most robust of all the bearings in the reactor (comprises of two sets of rolling element bearings) is the bearing

that fails the most often. As seen in Figure 1, some of the bearings have a relatively short life cycle; there were 11 shutdowns to replace damaged/worn bearings during a five year period.

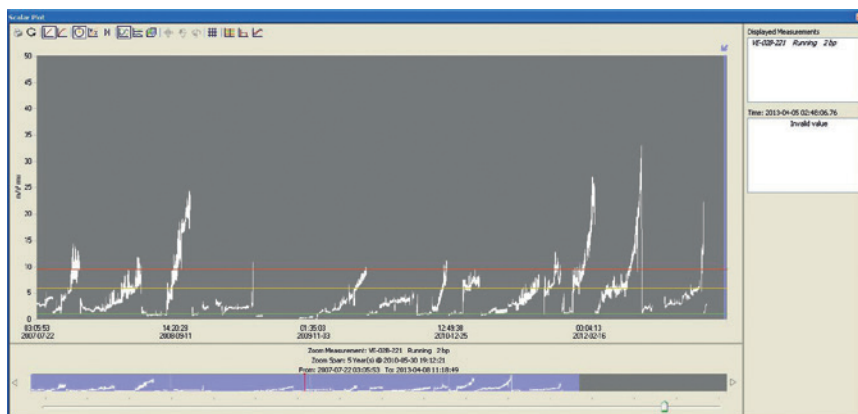


Figure 1. Bearing vibration trend over a 5 years period showing primarily the DE motor bearing. (Acceleration band-pass measurement).

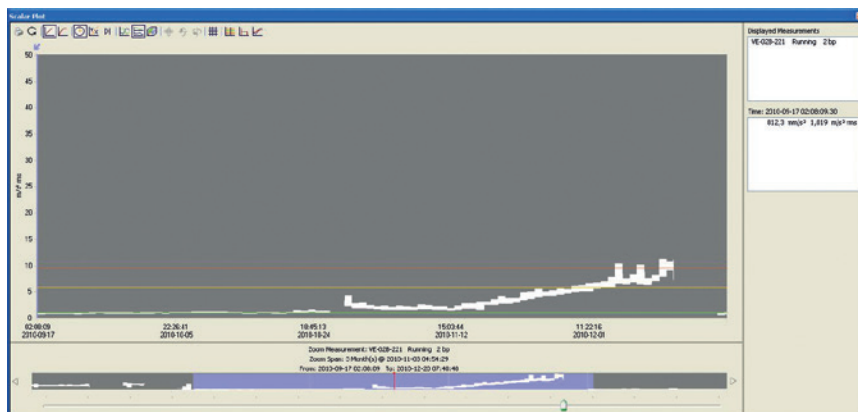


Figure 2. An example of a DE motor bearing fault trend. (Acceleration band-pass measurement).

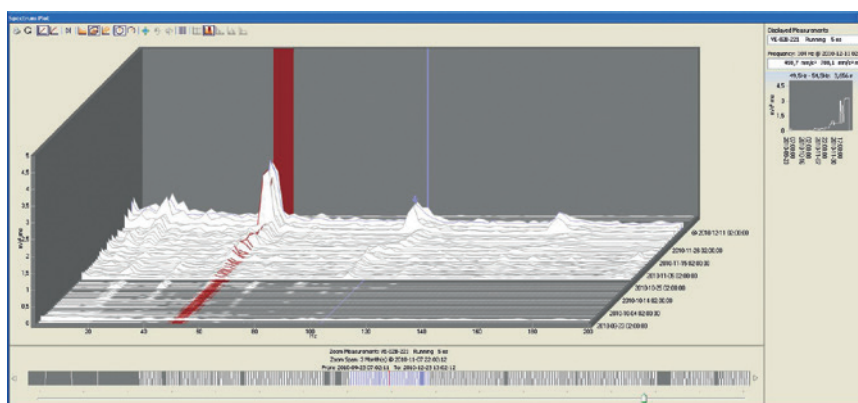


Figure 3. Ball bearing fault frequency trend (49.5-54.5 Hz) over a period of five weeks. Mixer was changed afterwards. (Envelope spectrum for acceleration).



Figure 4. Condition of damaged DE motor bearings when reactor was disassembled after shutdown. Although the damage looks quite severe, only one set of the bearings was affected.

Case 2: DE motor bearing fault – Delayed replacement

In certain situations, production requirements may delay when a bearing can be serviced. In such a case a

bearing fault is carefully monitored to ensure that the risk of bearing failure is still minimal until, for example, the next scheduled shutdown. Five examples of this can be seen in Figure 6, where

the bearing was allowed to operate after it exceeded the Danger alarm limits. A single example of this is shown in Figure 5.

Figure 5. An example of a DE motor bearing fault trend where repair was delayed due to production requirements. (Acceleration bandpass measurement.).

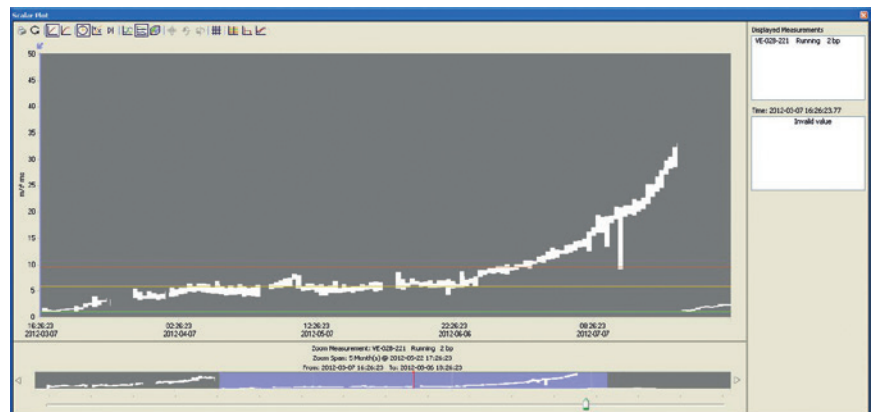


Figure 6. Multiple bearing faults seen over broadband frequency trend over a period of five months. Mixer was changed afterwards. (Envelope spectrum for acceleration).

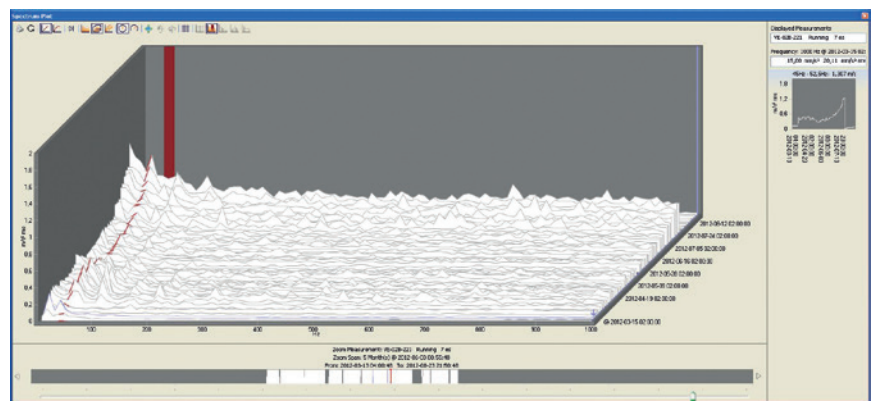
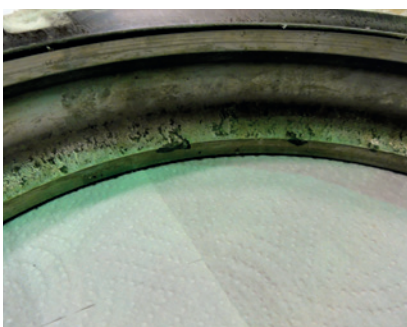


Figure 7. Condition of damaged DE motor bearings when reactor was disassembled after shutdown. Left: Outer race. Middle: Inner race. Right: Rolling elements. Both sets of the DE motor bearings were equally affected in this case (only one set shown), which is a much more severe situation than that shown in Case 1 (Figure 4).



Case 3: Middle shaft bearing fault

Sometimes there are short shutdowns for process or other reasons not directly related to the reactor. Shutting down the reactor carries risks in itself.

In this particular case, when the process was started up again, higher than normal vibrations were observed. In the course of just a few days the vibration amplitude doubled, as indicated

in Figure 8. The mixer was changed the next day. Upon disassembly, it was seen that hardened polymer had found its way into the bearing and caused the bearing to fail prematurely.

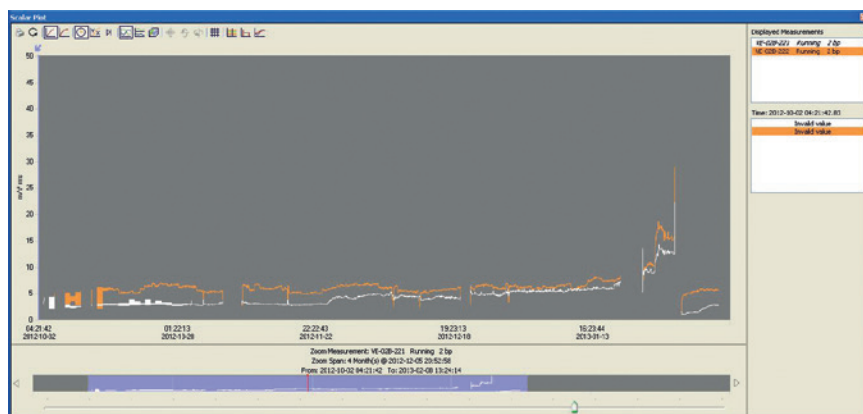


Figure 8. Orange: Lower accelerometer measurement trend for the mixer shaft bearings. White: Upper accelerometer measurement trend for the motor bearings. The trend is normal up to the process shutdown but immediately after the reactor was put back into service, the vibration increased. Although the damage was limited to the middle mixer shaft bearing, this influenced the vibration on the upper accelerometer. (Acceleration bandpass measurement.).

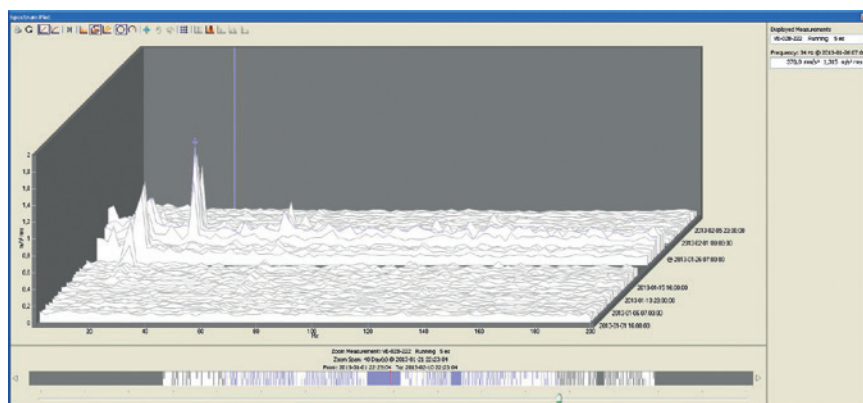


Figure 9. Amplitude trend for running speed harmonics and bearing fault frequencies from the lower accelerometer. (Envelope spectrum for acceleration).



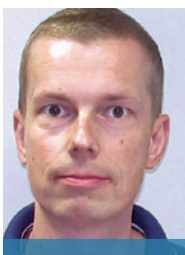
Figure 10. Condition of the middle bearing when the reactor mixer was disassembled after shutdown. Damaged bearing (right) caused by polymer that entered the damaged bearing housing and hardened. The fractured bearing housing is shown on the left.

CONCLUSION

As the reactor mixer is a critical machine in the LDPE process, the bearing fault detection cases in this article prove that online condition monitoring is an absolute imperative for this machine. Not only to avoid costly production losses due to downtime, but also to avoid consequential damages that occur as a result of decomp, possibly provoked by defective bearings. As can be seen in some cases, the bearing fault can develop quickly as shown in Case 1, or even in a non-linear progression as seen in Case 3. This in itself precludes the use of offline monitoring using portable instrumentation. Moreover, premature bearing failures can be instigated by factors other than wear. This could be due to process conditions such as deposits on the mixer blades or even polymer that enters the bearing housing (Case 3) and can develop very quickly.

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