Brüel & Kjær Vibro

Application Note

Monitoring strategy – Early fault detection of air-cooled heat exchangers

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ABSTRACT

Costly air cooler failures and consequential downtime can be avoided by monitoring these machines with a simple yet effective predictive monitoring solution. Constant percentage bandwidth (CPB) and selective envelope detection (SED) spectrum measurements provide fast, accurate and early detection of developing faults and give lead-time for planning maintenance ahead of time.

Why on-line predictive monitoring?

The air-cooled heat exchanger is used extensively in the petrochemical industry, often in groups of several hundred units for a single process. One of the most critical components to fail for induced-draft machines are the fan shaft bearings, which can result in the entire fan/shaft assembly collapsing on the tube bundle and causing extensive lost production and repairs. The bearing lifetime can be subsequently reduced by a number of factors such as prolonged unbalance. Safety monitoring can be used to protect the machines, but the trips can be untimely and numerous for such a large installation, which is no benefit for reducing downtime.

It is therefore important to effectively monitor the condition of the critical components such as the bearings to find out well in advance before a failure occurs. This way a shutdown can be planned for two or more machines that are still running but in need of maintenance.

Many end-users prefer a pure off-line monitoring solution using portable data collectors, but it is dangerous, tedious work for operators to climb up on the structure and take measurements for so many machines. The ideal situation is therefore an on-line predictive monitoring system (possibly combined with a safety system)

How to monitor?

Rolling-element bearing (REB) faults can be very difficult to detect because of their relatively low vibration energy contribution to the overall signal. The slow speeds of the fans make detection even more difficult. Furthermore there are many factors that influence the air cooler vibration signature, such as wind speed and direction, control loading, etc., which make it difficult to get a repeatable measurement.

Figure 1. Induced draft air coolers

Monitoring solutions

With a permanently mounted accelerometer placed on each bearing of each fan, it is possible to provide complete predictive monitoring capability for the most important air cooler faults, using specialized measurements like constant percentage bandwidth (CPB) and envelope detection (shown in Table 1). It is important to remember, however, that accurate instrumentation and sensors must used for any low speed application. Moreover, field bus connections are not recommended since these cannot reliably move very much data, especially for slow speed applications.

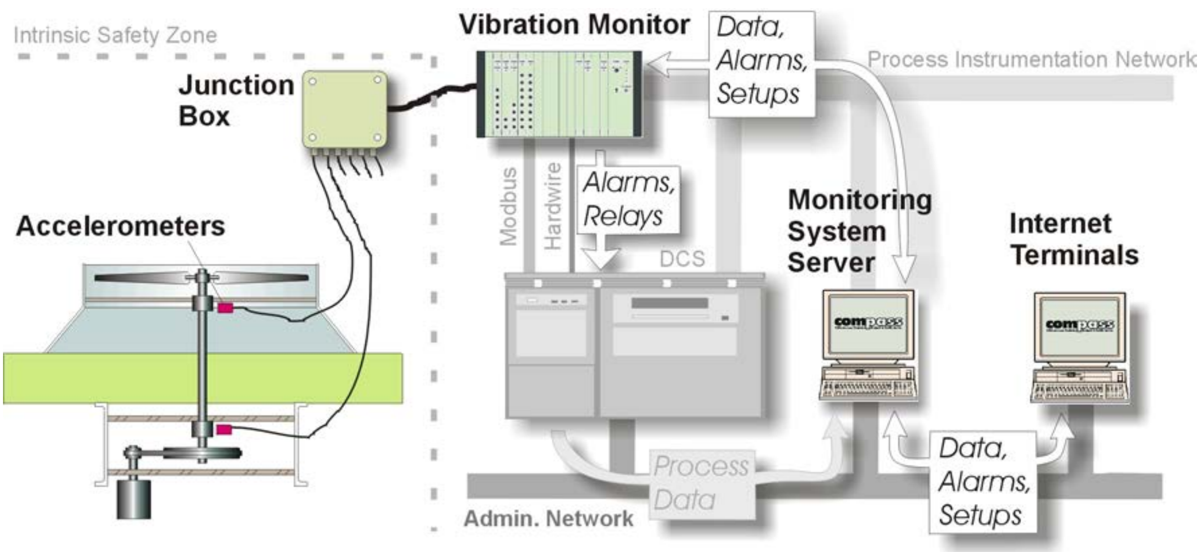

Figure 2. Typical combined safety and predictive monitoring application shown for an air cooler. For some applications a single accelerometer is sufficient for monitoring both bearings. A single accelerometer is sufficient in many cases for monitoring both bearings, if a dedicated monitoring technique is used such as a CPB measurement.

Measurements	Freq. (Hz)	Faults
CPB spectrum	0-10k	Unbalance, misalignment, belt drive and fan faults
SED spectrum	0-10k	REB faults

Table 1. Measurements for predictive monitoring of air coolers.

Other measurements, such as overall values, are well suited to safety monitoring applications, but have limitations for low-speed rolling element bearing fault detection. The low energy bearing fault signals can only be detected shortly before failure, if they can be detected at all. This is not enough for predictive monitoring.

Brüel & Kjær Vibro's **Constant Percentage Bandwidth (CPB)** spectrum measurement is specially designed for predictive monitoring applications and has optimally filtered frequency discrimination for early detection of all kind of faults. It is preferred over the FFT, which is an excellent diagnostic tool for many applications, but has limitations for automatic monitoring to alarm limits of low-speed machines such as air coolers.

The FFT has simply "too much" resolution for reliable, repeatable automatic fault detection. This is especially true at the higher frequencies, where narrow-band, low energy resonances excited by bearing faults appear. It is difficult to set alarm limits for the FFTs on these narrow peaks, which can vary considerably in amplitude and actually shift. For the CPB, the higher frequency resonances indicative of a bearing fault are actually spread out over a wider frequency range, making it much more reliable to detect. The CPB is also more effective than the FFT for detecting non-sinusoidal vibrations, such as that caused by broken component impacts or high frequency noise modulated by bearing faults.

Finally, the CPB is a more simple measurement, easy to interpret, and not as sensitive as the FFT to slight process changes, which could cause false alarms.

The **Selective Envelope Detector (SED)** is a measurement dedicated to diagnosing REB faults, especially if the running speed is less than 3 Hz. This is because the low frequency bearing faults can often modulate higher frequency “carrier” signals such as bearing fault harmonics, structural resonances or even noise. The original bearing fault frequencies can then be recovered by “demodulating” its carrier (i.e. rectifying it and then low pass filtering it). The SED is much better suited to air cooler applications than other REB measurement techniques because it can be used for machines at speeds below 3 Hz (the spike energy measurement, for example, requires a minimum operating speed of at least 15 Hz).

Earlier fault detection with adaptive monitoring strategy

Air coolers can have a number of different operating states due to climatic conditions and process control. Wind direction, variable frequency motor drives, auto-variable fan pitch and other climatic and control schemes can vary the load and speed of the fans considerably, thus resulting in entirely different vibration signatures. Brüel & Kjær Vibro systems allow for individual alarm limits to be set up for different speed and process operating regimes, thus giving early fault detection without the risk of false alarms.

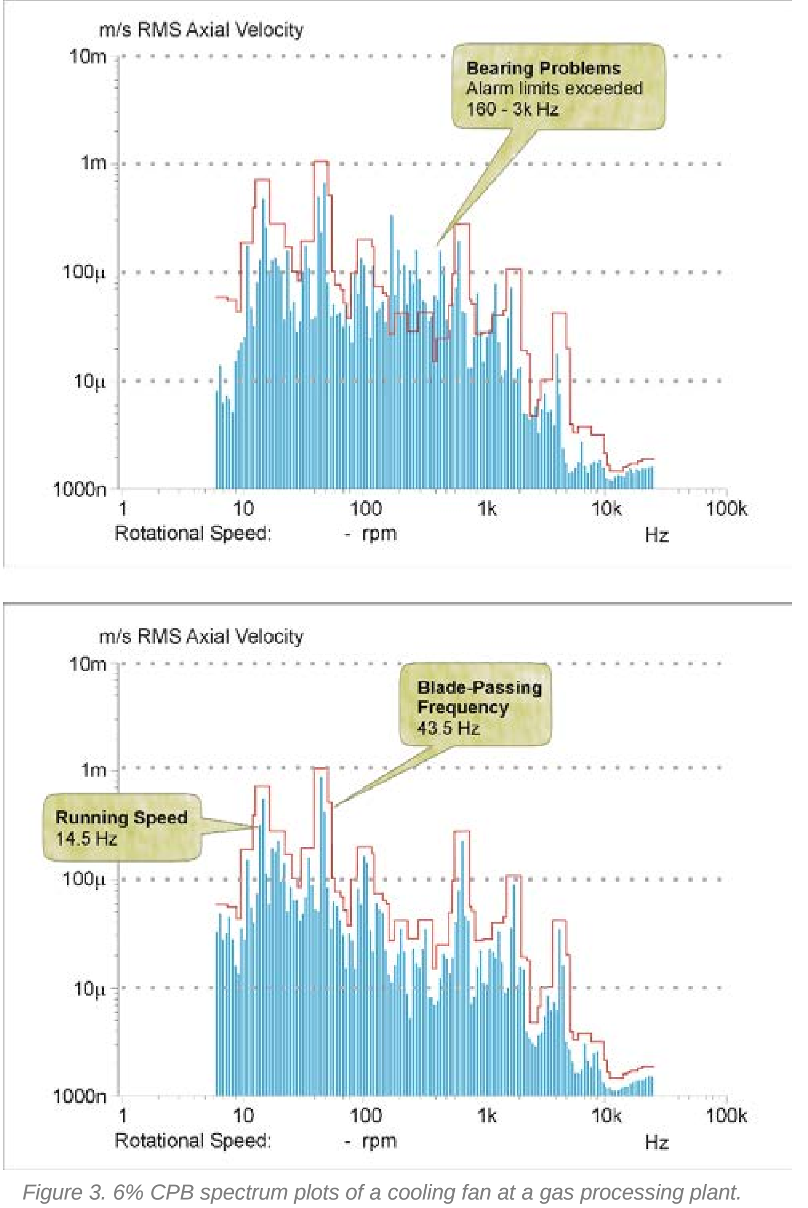

Figure 3. 6% CPB spectrum plots of a cooling fan at a gas processing plant. Lower plot shows a normal signature, upper plot shows resonances excited by a bearing fault.

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Monitoring system configuration

As described in our website, Brüel & Kjær Vibro offers a number of different predictive monitoring solutions for different air cooler applications - including intrinsic safety installations:

- Permanently installed (on-line) safety and condition monitoring systems
- On-line condition monitoring system used together with an existing safety system
- Combined safety system with portable instruments (off-line) for condition monitoring (e.g. where data is taken from outputs at ground level, not from the top!)

Our wide range of systems gives more flexibility in finding a solution that best fits the required application. A permanently-installed solution can be used in a plant-wide installation where other machines are monitored, whereas a combined safety and portable condition monitoring system is a cost-effective solution for smaller applications. In either case, Brüel & Kjær Vibro offers comprehensive training and support packages - including long-term service agreements - to ensure the end-user gets the most benefits out of their system.

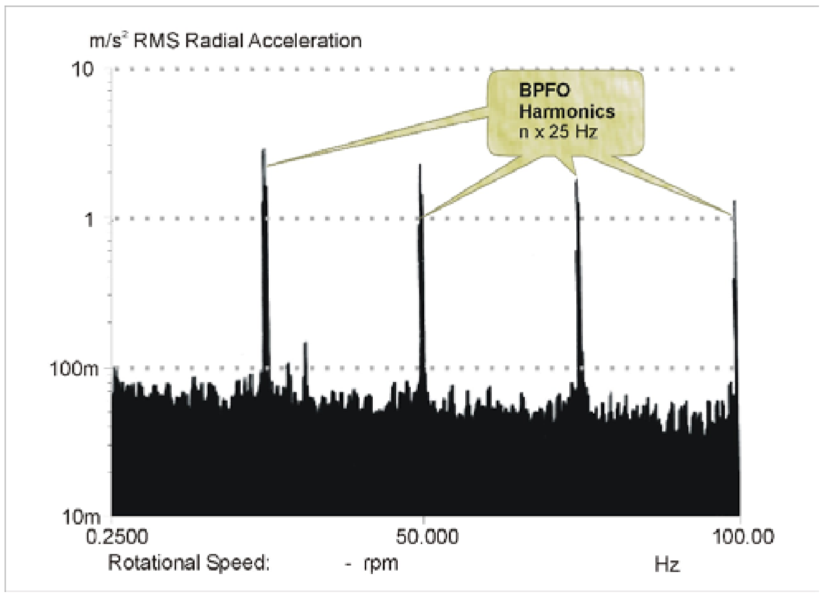

Figure 4. SED spectrum plot showing an outer-race bearing fault.

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Date: 13.10.2014