Bearing Monitoring Helps Plant Run More Smoothly

A new technique for detecting bearing defects in service, a high frequency acoustic emission (HF-AE) method, could prove a practical way of warning of impending bearing failure on plant. Maintenance costs during the lifetime of machine installations on plants are very high, often 50 to 200% of the invested value. Not surprisingly, increasing attention is being given to ways of reducing these costs and the associated loss of production while a machine is standing idle.

One way of reducing costs is to install effective condition monitoring equipment able to predict failures and so allow planned maintenance, avoiding expensive emergency shutdowns. In this respect, a new monitoring technique developed at SKF's Engineering and Research Centre (ERC) could prove a valuable tool for the maintenance engineer.

Fig. 1. SKF Microlog data collector/analyzer equipped with SEE technology to detect early bearing damage. It will operate as a stand-alone frequency spectrum analyzer or a data collector for PRISM4 – SKF's specialized software for in-depth historical analysis of preventative maintenance data.

Spectral measuring

SKF's process is called ***SEE*** (Spectral Emitted Energy), which gives some indication of how the process works. The signal from a transducer, a wide band piezo accelerometer, is filtered in the range of 250 to 350 kHz and enveloped. A low pass filter then ensures that only the low frequency envelope components remain – a signal that can be analyzed using normal analysis equipment. Extensive testing is still being carried out, but a system has already been installed at BS Llanwern to measure 120 points on a blast furnace feed system monitoring gearboxes, conveyors, stove fans and pressure flow controllers. A patent has also been granted in the United States.

Choice of techniques

The detection of the different types of potential failure sources can be achieved in a variety of ways, for example, by measuring vibration level, stress/strain conditions, acoustic emission, temperature and power. If the level of one or more of these parameters increases with time, it indicates a potential problem in the machine.

To reveal bearing defects by vibration signals from velocity or acceleration requires extensive signal processing, as the vibration signal is often more dependent on the structure than on the defect resulting in the defect signal being hidden in the noise.

Techniques such as tuned low frequency filtering and envelope detection can help reveal the defect signal, but these have to be adapted to the application and depend on machine dimensions and bearing sizes. However, ERC's high frequency acoustic emission (HF-AE) technique should be applicable over a wide variety of applications.

Low and medium frequencies

Vibration monitoring for bearing defect detection can be divided roughly into low (0 to 20 kHz), medium (20 to 100 kHz) and high frequency (> 100 kHz) techniques. "Noise" mostly in the range below 20 kHz produces signals not directly related to bearing defects and is caused primarily from imbalance, misalignment, structural resonance, etc. The level and energy content of such noise is very high compared to the energy content of signals coming from bearing defects, and the signal to noise ratio is therefore often poor.

In the medium frequency range, higher structural resonances can also occur, but properties of the materials in the machine usually characterize the measured vibration. Wavelengths of vibrations at these frequencies are often comparable with the dimensions of parts in the bearing of bearing housing and so standing waves may occur, giving rise to nodes and antinodes.

Positioning of the transducer becomes critical and, depending on the machine or bearing dimensions, signals may be amplified or attenuated, resulting in a variable signal to noise ratio. In certain applications, good results can be obtained in this frequency range; in other applications the method may not work at all.

High frequency range

In the high frequency range above 100 kHz, material properties are "sounded out" as vibration wave lengths are small in comparison to the dimension of the transducer. In general, damping in steel does not increase rapidly until frequencies higher than 20 MHz are reached. For frequencies around 0.3 MHz, attenuation is hardly noticeable. The other disadvantage of monitoring with very high frequency signals is the cost of analysis equipment (although this can be reduced by using a multiplier or enveloping technique), and it was to solve these problems that the HF-AE technique was developed.

High frequency acoustic emission (HF-AE) measuring principle

The HF-AE transducer is a very wide band piezo accelerometer that responds at frequencies up to several MHz. Every time a defect in a bearing is over-rolled, it produces a short impact type of pulse that is repeated at a fixed frequency determined by the geometry of the bearing and its speed of rotation. The signal produced by the defect is therefore a train of pulses, which has as its Fourier transform another train of pulses. The frequency content of each pulse is very wide, but filtering in the 250 to 350 kHz band reduces the amplitude of the pulses and also removes much of the "noise". Although the pulses are reduced in energy, they still occur at the same intervals; the repetition frequency of the defect signal is not changed by filtering.

The basis of the newly developed technique is very similar to enveloping – a monitoring technique well reported in the literature. The major differences with the new technique are the frequency range being treated (around 300 kHz), well away from the structural resonances, and the relatively large distance between the frequency range of the enveloped low frequency signal and the frequency band (carrier) from which the information is derived.

The processed signal coming from the HF-AE monitor is a low frequency (0 to 20 kHz) rectified signal and can be processed by standard analysis equipment in either an analog or digital way. RMS value, peak value and Kurtosis can all be calculated.

Results

Practical trials on compressors and pumps have shown that SEE can be used to identify incipient bearing damage in good time before failure can occur. Monitoring instruments have been developed to allow practical application using instruments that extend from handheld units to FFT (Fast Fourier Transform) analyzers and complete on-line systems.

Prototype systems have been tested in a number of installations. For example, in a papermill in Sweden, HF-AE monitors have been installed as computer front-ends in a permanent condition monitoring system. The units have been in service for over three years now and all have worked well. **Fig. 2**, from this application, compares a waterfall of spectra from the HF-AE unit and from a standard low frequency accelerometer at the same measuring point.

Even though the speed was varying considerably from measurement to measurement, the accelerometer spectra always exhibit peaks at the same frequencies. In fact, what is being measured is the structural response rather than anything that is a function of a defect. The structural response is the sum of the response in all the natural frequencies and this is independent of speed. No peaks at the bearing defect frequencies can be seen.

The HF-AE spectra shows distinct peaks at the frequency associated with an outer ring defect of the bearing and its higher harmonics. These peaks shift with the speed of the machine. Because of these results, this bearing was dismounted and an outer ring defect was found.

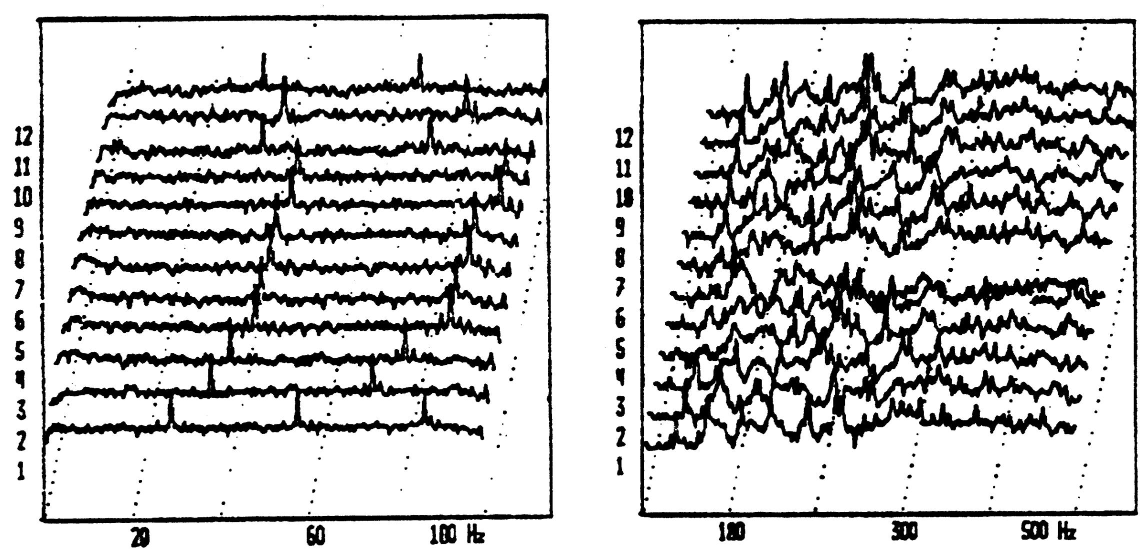

***Fig. 2.** Waterfall of spectra from the HF-AE unit (left) and from a standard low frequency accelerometer (right) at the same measuring point.*

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