Using Modal Analysis to Lengthen Bearing Service Life

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General

It is generally known that 80% of machine problems are attributed to imbalance, misalignment and structural resonance. Both imbalance and misalignment generate forces that result in damaging vibration responses. Structural natural modes are often excited by these forces, causing amplified vibration amplitude levels. Reducing resonance levels requires modal methods that determine what portion of the response is due to the forcing function and how much is due to resonant amplification. The following case study is a practical application of modal analysis procedures to measure the effects of structural natural modes related to the reduction of bearing service life.

A conveyer bearing service life problem

The primary conveyer system in a copper mine carries all the ore to the concentrator mill, where the raw material is reduced to manageable sludge. The separation process then screens the pure ore from the remnant sludge. Since the beginning of this operation, using the steel belted conveyer system, the mine has been experiencing significantly less than normal bearing service life.

There are three in-line stages of pulley drive power: the primary, secondary and tension take up. All require the support of large expensive rolling element bearings at each drive level. **Fig. 2** shows a diagram of the primary drive train. The secondary stage drive train is identical to the primary tension take-up stage, uses the same pulley bearings, but does not require the in-line motor and gearbox drive train.

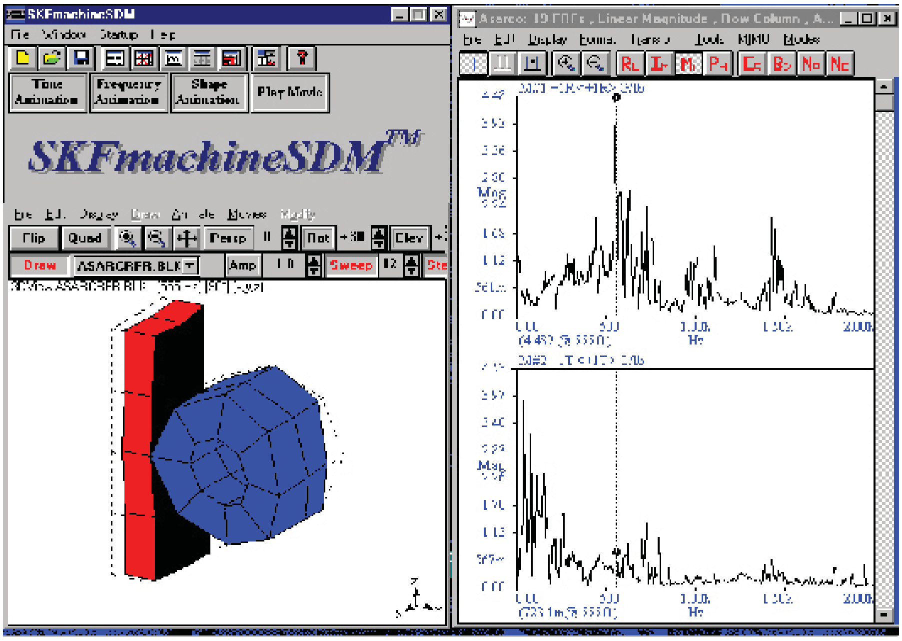

Fig. 1. Composite structure deformation and FRF plots of the pulley bearing.

The primary pulley bearings are known to fail in six to nine months, whereas the other pulley bearings last nine to eleven months. When these bearings fail, they are replaced in pairs. Historically, there are three sets of pulley bearings replaced each year at an estimated cost of $50 000 per set plus lost revenue of $17 000 per hour. Replacement time ranges from three to four days. In the past, some corrective measures have been tried, such as special lubrication procedures, modified bearing clearances, other bearing designs – all with limited success. It was recently decided that a structural modal investigation might shed some light on the cause of early pulley bearings failures. The SKF bearing mining specialist suggested SKFmachine software application to provide some clue as to the cause of the problem as well as a possible solution (refer to **fig. 1**). SKF Condition Monitoring Services was asked to measure the response signals to determine the mode shapes of the primary bearing pillow block. It was hoped that these mode shapes would give more insight as to the factors that affect bearing fatigue stresses. A video of a failed primary bearing revealed fretting wear on the outside bearing casing on either side of the load zone. This suggested a structural mode was squeezing the outer bearing case. To test this hypothesis, it was decided to measure the bearing block points in transmissibility and also measure the bearing condition with a portable data collector, the SKF Microlog.

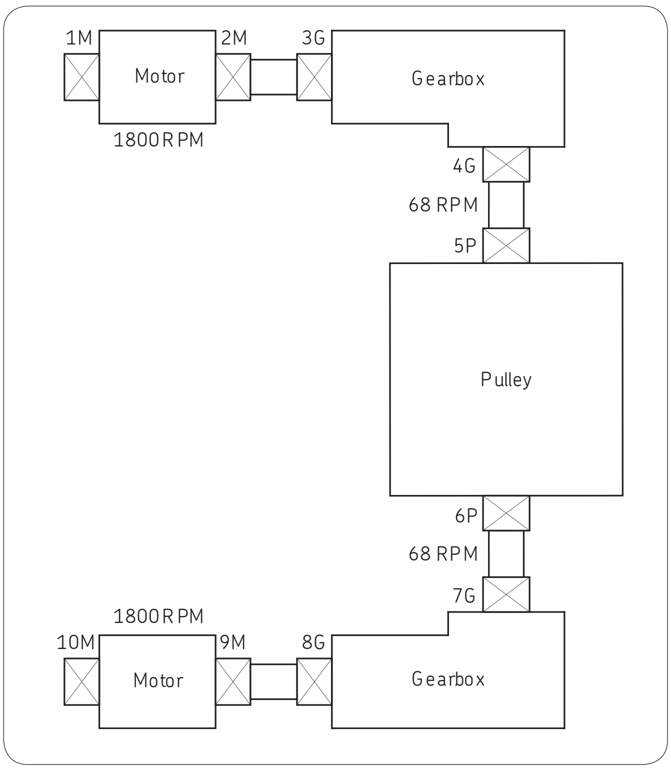

Fig. 2. Diagram of the primary drive train.

The measurement routine

The pillow block dimensions were not known until our arrival. After surveying the actual setup, it was decided to first apply reflective tape to all the drive shafts so that order analysis could be obtained in SKFmachine Shape format. Timing was opportune, since the conveyer was not able to be run consistently until the concentrator mill was back in operation. The bearing model was generated in SKFmachine. A measurement route of 18 radial points and six axial points were defined and downloaded to the CMVA 40 SKF Microlog for measurements between a reference and a roving accelerometer (transmissibility). At the same time, an order analysis route was programmed to collect shape data with the CMVA 55 SKF Microlog. Simultaneous raw data was stored on a two-channel DAT recorder. Another route was made using PRISM[4] software to measure vertical, horizontal and axial positions on the two supporting pillow block bearings. The measurement type format included acceleration to velocity, acceleration enveloping and order analysis. The conveyer was started in a sequence of motor drives before the conveyer velocity was stabilized at full load conditions. Measurements continued until the conveyer was forced to stop. Data collection was completed both for the modal analysis investigation and the bearing condition monitoring within this two hour time frame.

The measurement results

The acceleration enveloping plots (→ **figs. 3**, **4** and **5**) show significant evidence of outer race defects on both primary bearings with the predominant peaks in the axial direction.

This is clearly shown in waterfall displays of all acceleration enveloping measurements. More dramatic results are reflected in the mode shape animation (→ **fig. 6**), which demonstrates that the hypothetical mode, envisioned early on, is a possible problem source. The frequency is the ninth order of rotation, which approximates the defect frequency (8.77x) of the SKF 23776 pulley bearing.

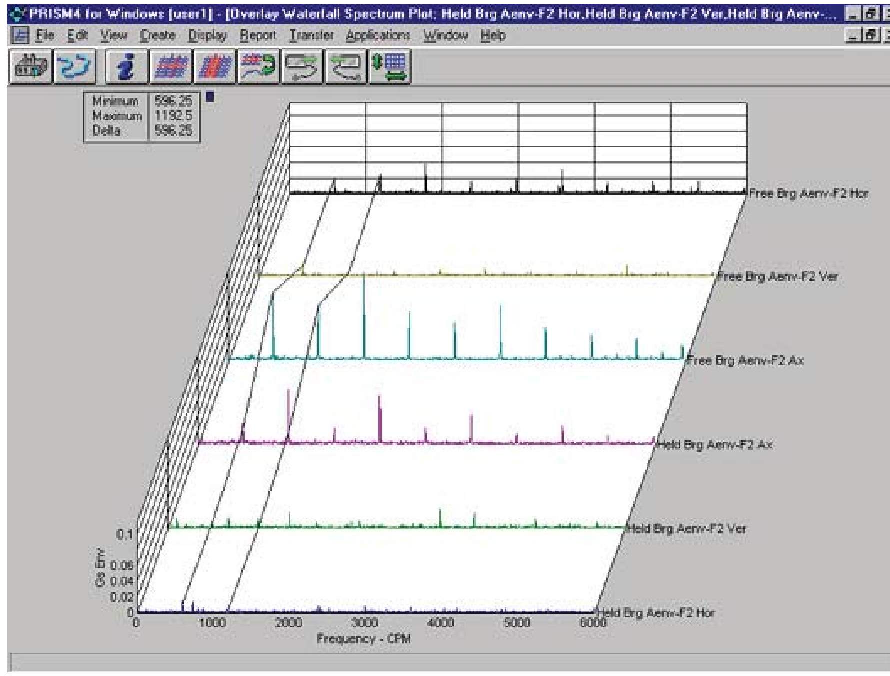

Fig. 3. Waterfall plot of pulley bearing envelope measurements.

Conclusion

The animated results seem to support the theory that a structural mode is the more probable factor in shortening the pulley bearing service life. A follow-on project will require calibrated FRF measurements to determine the modal constants for structural dynamics modification analysis. Optimum solutions are obtained by applying "what if" software simulated trials of hardware modifications. These proposed solutions will be applied to the system and tested again for proof of successful modification.

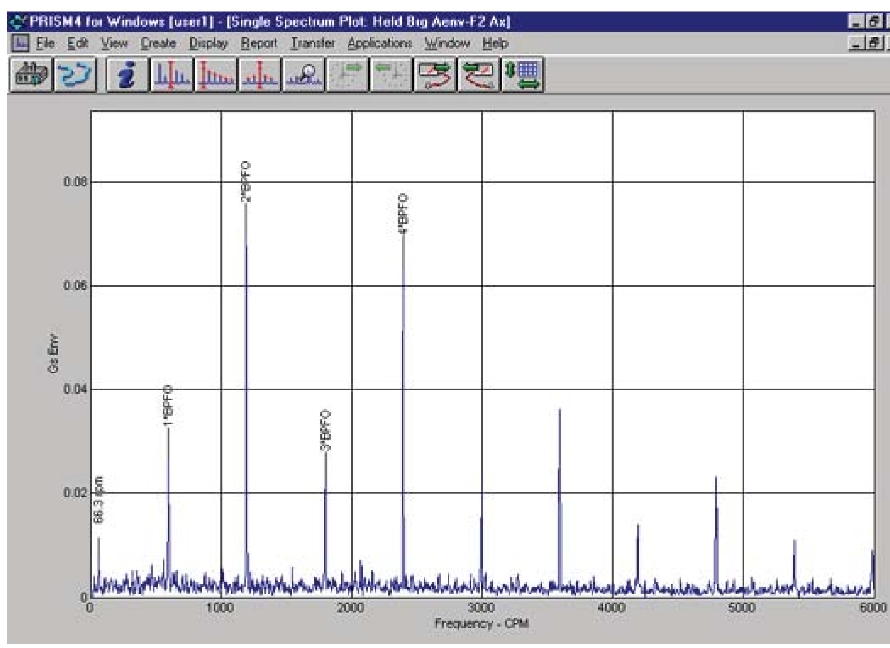

Fig. 4. Axial spectrum plot of pulley bearing held bearing.

Glossary

FRF (Frequency Response Function). The transfer function of a linear system expressed in the frequency domain. Commonly defined as the ratio of the Fourier transform of the system's response to the Fourier transform of the system's excitation function as magnitude and phase or real and imaginary parts. Whereas the transfer function of a linear system is, in a strict sense, defined as the ratio of the LaPlace transform of the system response to the input, the frequency response function is more generally used.

Resonance. The condition of vibration amplitude and phase change response caused by a corresponding system sensitivity to a particular forcing frequency. A resonance is typically identified by a substantial amplitude increase and related phase shift.

Transmissibility. The non-dimensional ratio of the response amplitude of a system in steady-state forced vibration to the excitation amplitude.

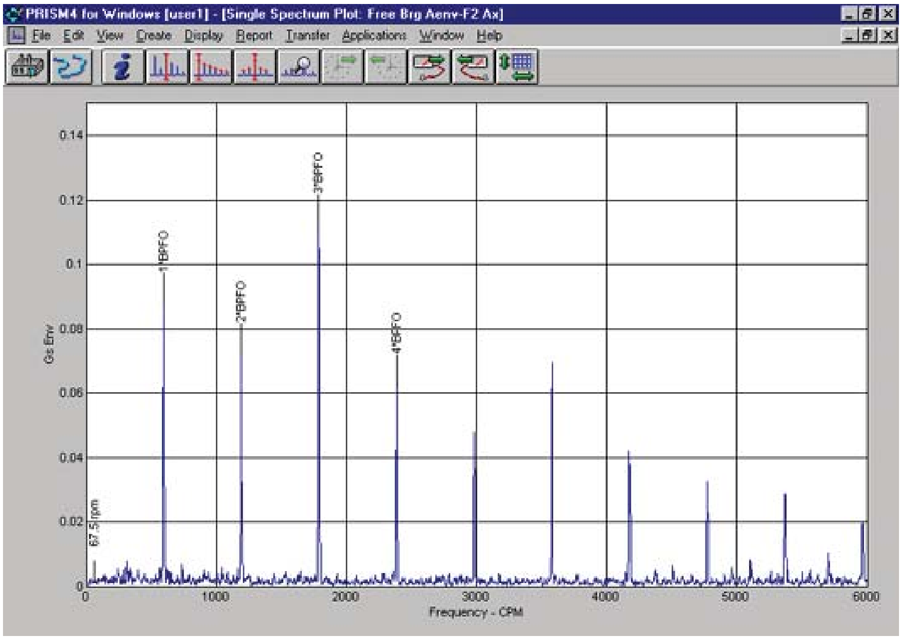

Fig. 5. Axial spectrum plot of pulley bearing free bearing.

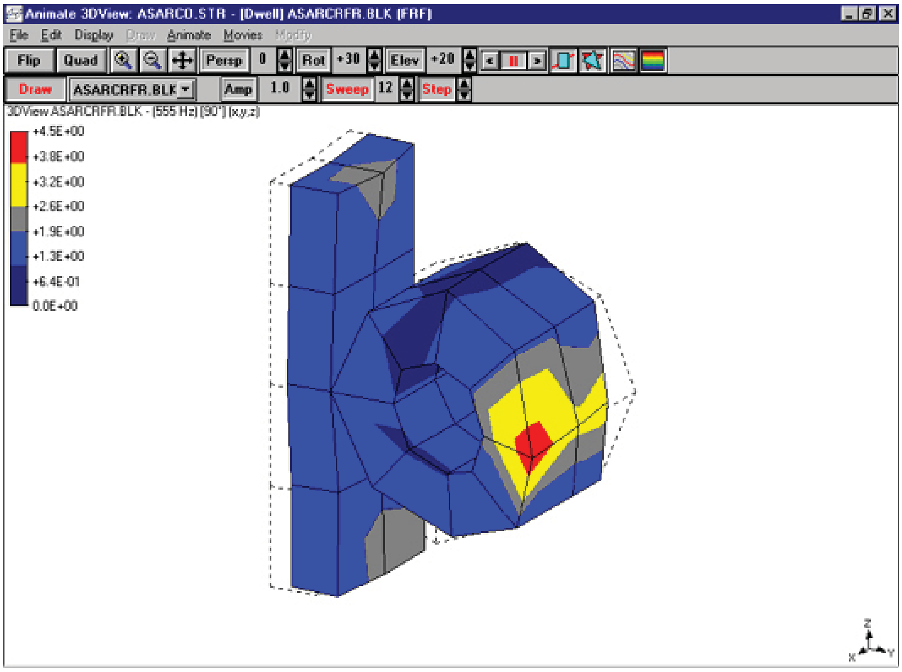

Fig. 6. Contour deformation pattern of the pulley bearing.

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