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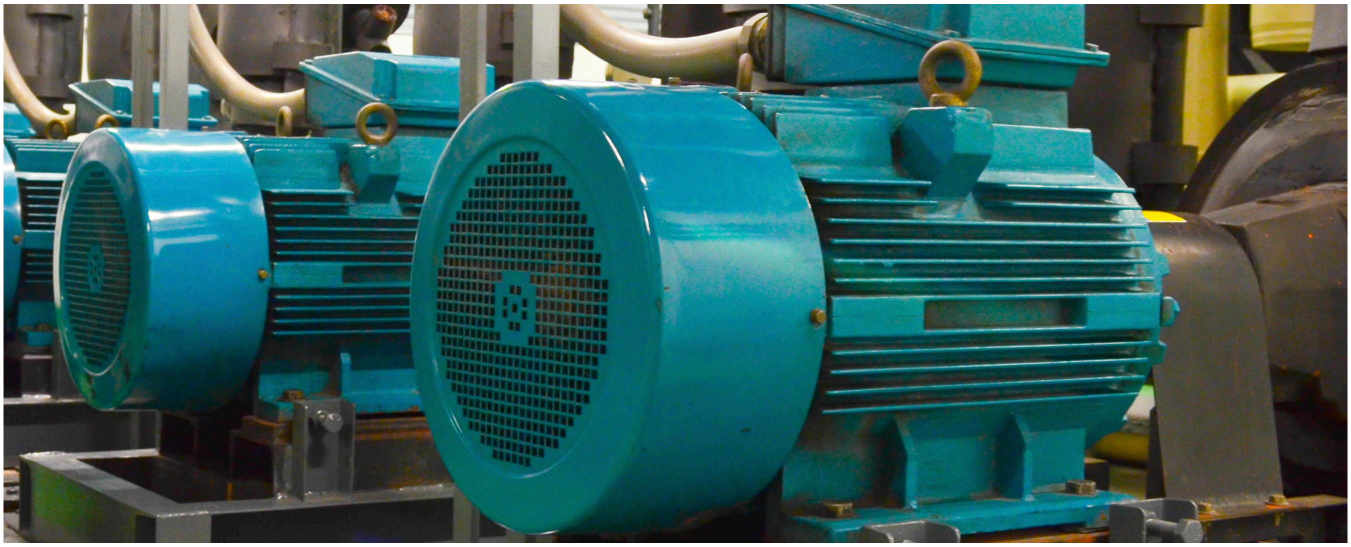

Creating an Effective Vibration Monitoring Program for Reliability Departments With Limited Resources

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Two Parameter Predictive Maintenance Program

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Introduction

It is the purpose of this paper to introduce a program for maintaining the overall efficiency of the predictive maintenance program while at the same time reducing the equipment typically used and the required skill level of the predictive maintenance technical staff.

A broadband vibration reading, in inches per second, was used at one time as an indicator of a vibration problem within the machine. This parameter is simple to calculate and was found to be useful for providing early warning of a fault for a very limited class of problems such as unbalance and misalignment. It was not a reliable indicator of many bearing faults that make up a significant fraction of total faults. Therefore, it was never widely used as a predictive maintenance tool.

It has been found that capturing time waveform data from a vibration sensor, followed by spectral analysis, is effective at identifying a large portion of faults typically found in industrial machinery. Using this data, corrective action can be scheduled and performed before catastrophic failures occur. This class of maintenance is generally referred to as predictive maintenance. A key factor in the success of this type of program is the collection of vibration data over time from which trends of selected data are established. It is generally recommended that the timing for the data collection be no less than one tenth of the mean time between failures. The mean time between failures is often difficult to specify, hence a popular time interval between data collections is monthly.

The implementation of a predictive maintenance program requires the use of specialized vibration monitoring equipment as well as a staff of specialized trained personnel. The knowledge base for vibration analysis continues to evolve which sets up required upgraded training for the vibration maintenance staff. Additionally, the hardware used for vibration data collection and analysis continues to evolve which enhances the data collection and analysis task. Obviously there is a need to upgrade the hardware and software on a seemingly short time schedule. Of course turnover within the vibration maintenance staff introduces the problem of efficiently training the new staff. There is a need to simplify the predictive maintenance vibration-monitoring task for the purpose of reducing the overall cost of both data collection and analysis. At the same time, the efficiency of the overall predictive maintenance program in identifying problems must not be sacrificed.

In the next section, several case studies will show how two key parameters can be used to establish the existence of a machine fault, and subsequently indicate that it should be examined further. These two parameters can also be used to indicate if there is a vibration problem, and consequently if there is a need for further data collection and analysis.

In the third section, conclusions regarding the establishment of the two parameters are presented. This is followed by a proposed program employing the two parameters.

Background

A few typical case studies that were identified to have serious vibration problems using vibration predictive maintenance methodologies are presented in this section. The objective is to assist in identifying two key parameters which are sensitive to problems manifesting themselves in:

a) Low frequency band - 0.3*running speed to 1000 Hz range
b) High frequency band - 500 to 20,000 Hz range

The respective parameters are:

a) RMS Velocity in the low frequency band
b) Absolute Peak Acceleration[1] in the high frequency band

[1]Observed over multiple machine rotations (20 suggested when feasible)

For the high frequency band parameter (absolute peak g-level), a chart for recommended alert levels are presented in Figure 1. These levels are recommended as an initial starting point. Individual experience may warrant refinement. The cases selected consist of a lubrication issue, defective inner race, cracked inner race, balancing problem, and a case where only two overall measurements were used (low frequency RMS velocity and high frequency peak acceleration.)

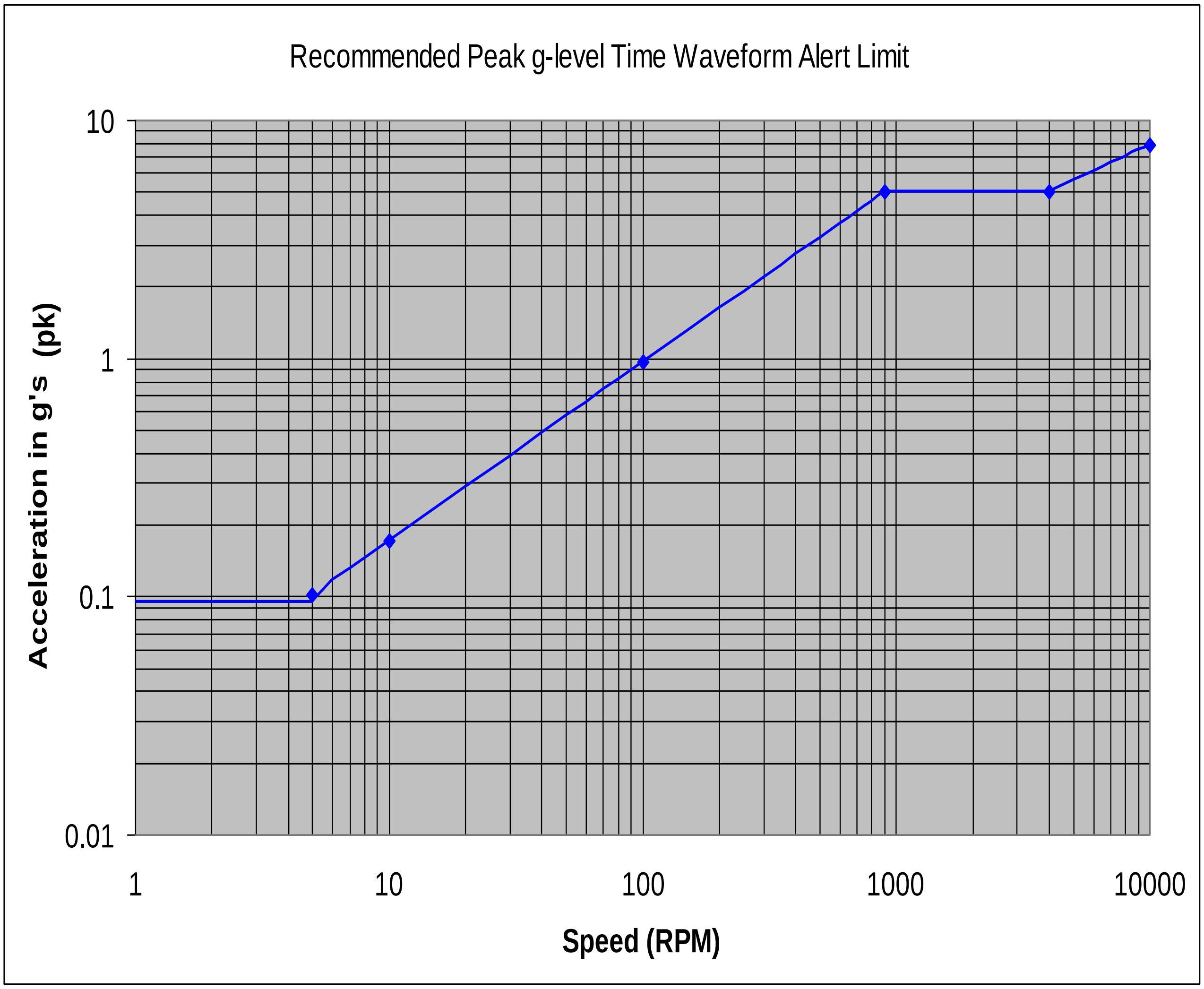


Figure 1
Recommended alert levels for the absolute peak g-level parameter

Case 1
Lubrication Issue

The first case is a high polymerize agitator that turns at 10 RPM. During an outage, one of the maintenance tasks was to clean out the grease packed bearings and repack them with fresh grease. The machine was placed in the outage and returned to service five months later. A trend plot of the absolute peak g-level (each peak reading was observed over 2.6 Revs) is presented in Figure 2. The absolute peak g-level was below the Alert level of 0.2 g's prior to the outage (see Figure 1
for recommended alert level). Following the startup, the peak g-level was near 0.5 g's, which indicated a fault was present. This initiated the diagnostic team to identify and correct the fault. By the time the probable cause of the fault was identified as the lack of lubrication (perhaps bearing was not repacked in grease), the peak acceleration had Increased to about 0.7 g's. At that point, grease was added to the bearing until the peak acceleration returned to the level that was present before the outage around 0.2 g's.

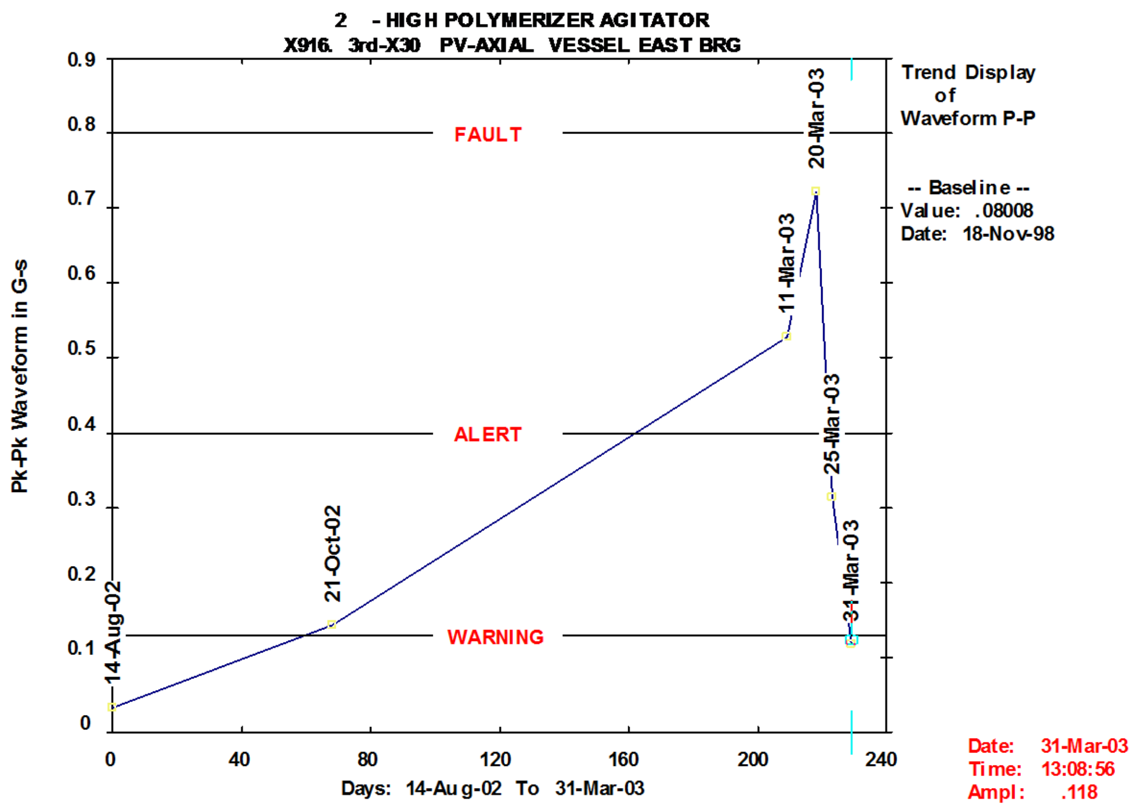


Figure 2
Trend plot of the absolute peak g-level for the polymerize agitator

Case 2
Defective Inner Race

The second case is an inner race bearing fault on the output shaft (turning at 156 RPM) of a hot mill pinion stand gearbox. Both the high frequency peak acceleration (g) and the low frequency RMS velocity parameter (ips) were trended over a two-year period. The trend for the high frequency peak acceleration is presented in Figure 3. For a shaft turning at this speed, the recommended Alert level (see Figure 1) would be set at 1.6 g's. In Figure 3, this level was reached around 600 days into the trend.

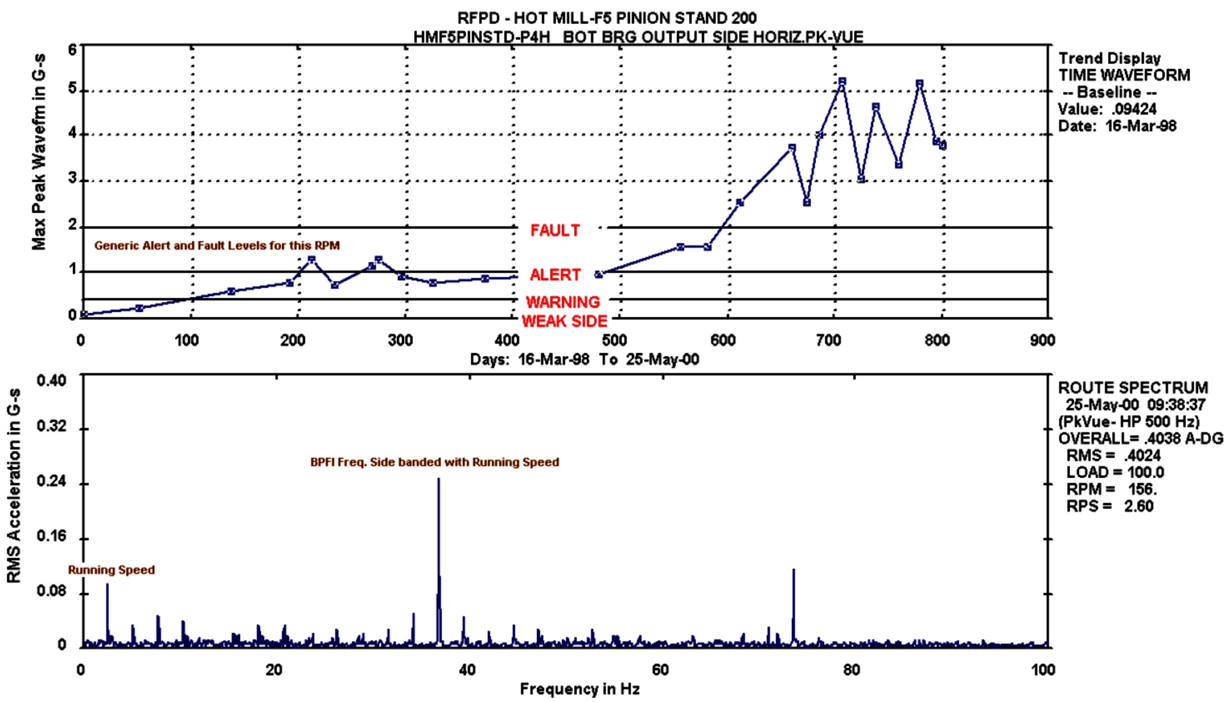


Figure 3
High frequency Absolute Peak g-level parameter trend
as well as the Peak g-level spectral data

The spectral data in Figure 3 identifies the fault as an inner race fault. The low frequency RMS velocity was also trended over the same time. It remained reasonable constant fluctuating around 0.03 ips for the entire 800 days of observation. The bearing's inner race (Fig. 4) as found to be severely cracked and replaced. The trend parameters returned to their original low levels following bearing replacement.

Figure 4
Picture of defective bearing from the hot mill pinion stand gearbox

Case 3
Cracked Inner Race

The third case is a cracked inner race on a press suction roll in a paper machine running at 220 RPM. For this speed machine, the alert level recommended in Figure 1 is 2 g's. The peak acceleration spectra and time waveform acquired on June 5, 2003 are presented in Figure 5. The peak acceleration of 14 g's is significantly greater than the recommended alert level of 2 g's. A picture of the cracked inner race is presented in figure 6 showing significant damage had occurred.

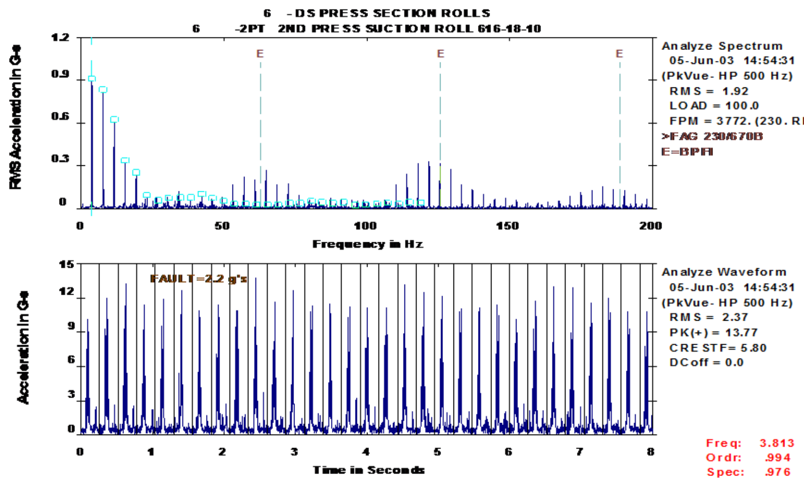


Figure 5
Peak g-level spectra and time waveform in peak g's from the press suction roll acquired on June 5, 2003. The peak g-level is 14 g's.

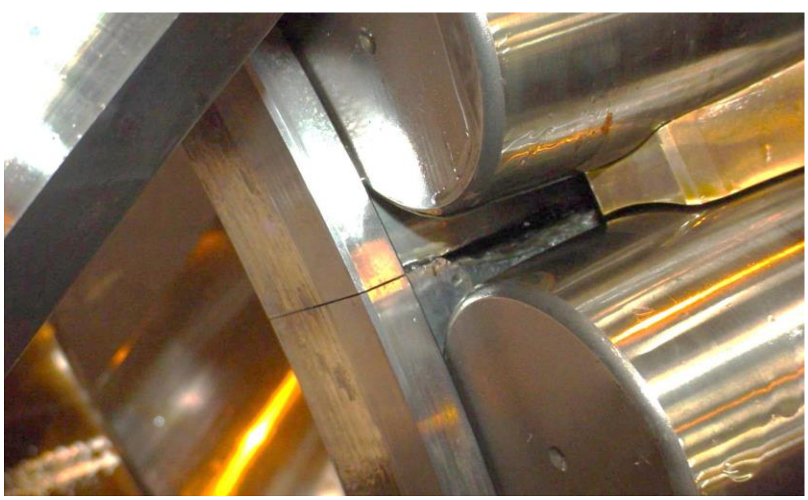


Figure 6
Picture of the bearing with cracked inner race from the press suction roll

Case 4
Balancing

The fourth case is for a high-speed fan (3300 RPM) with a balancing issue. The velocity vibration data (trend and spectra data) are presented in Figure 7. The trend data covers a time of one year. The trend of the peak velocity (units of ips) shows a peak of around 0.35 ips occurring on March 18, 2004. The spectral data presented in Figure 7 is at the time when the peak in the trend occurred. The only activity in spectral data is at one and two times the fan running speed (typical for a machine running out of balance). The trend of peak g-level and spectra from the high frequency data are presented in Figure 8. The suggested alert level from Figure 1 for this machine is 5 g's. The conclusion from the data presented in Figures 7 and 8 is the low frequency band velocity data are sensitive to balancing issues but the high frequency data are not.

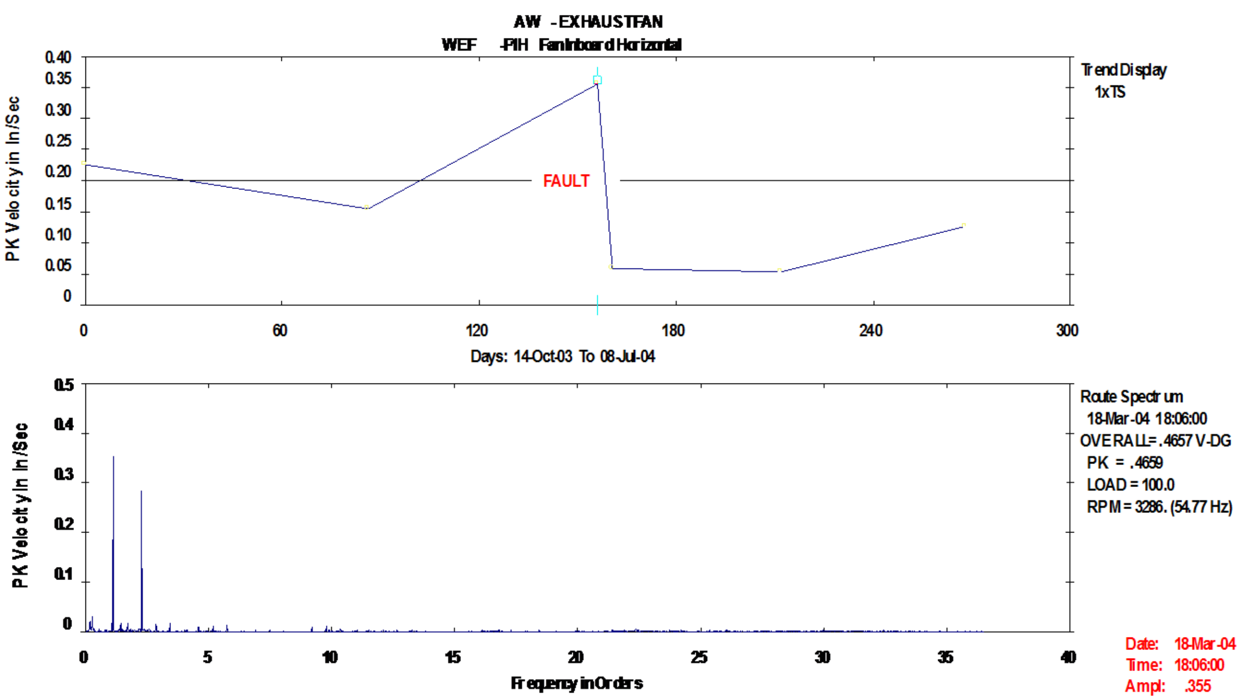


Figure 7
Spectra and trend low frequency velocity data from high speed fan

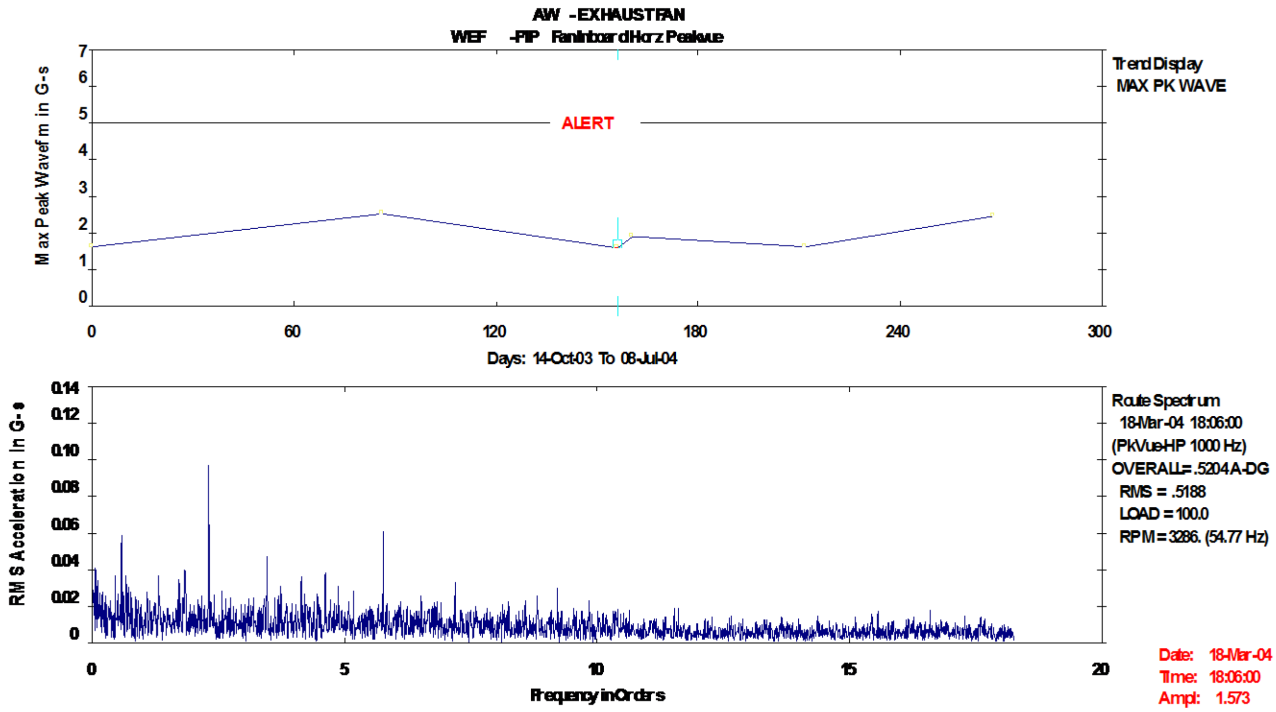


Figure 8
spectra and trend high frequency peak g-level from high speed fan
(same machine and time as that in Figure 7)

Case 5
Two Parameter Measurement

The fifth case is from a standard accelerometer (IMI Model 603C01) mounted on a centrifugal pump. The sensor was connected to an EchoPlus® Wireless Junction Box (IMI Model 672A01). RMS Velocity and the True Peak Acceleration are two parameters computed within the junction box, periodically at time intervals preset by the user. The parameters are then transmitted wirelessly from the junction box to a central receiver and data collection software. The overall velocity parameter data are presented in Figure 9. The trend window is about 6 months. The dropout was when the machine was shut down for bearing replacement.

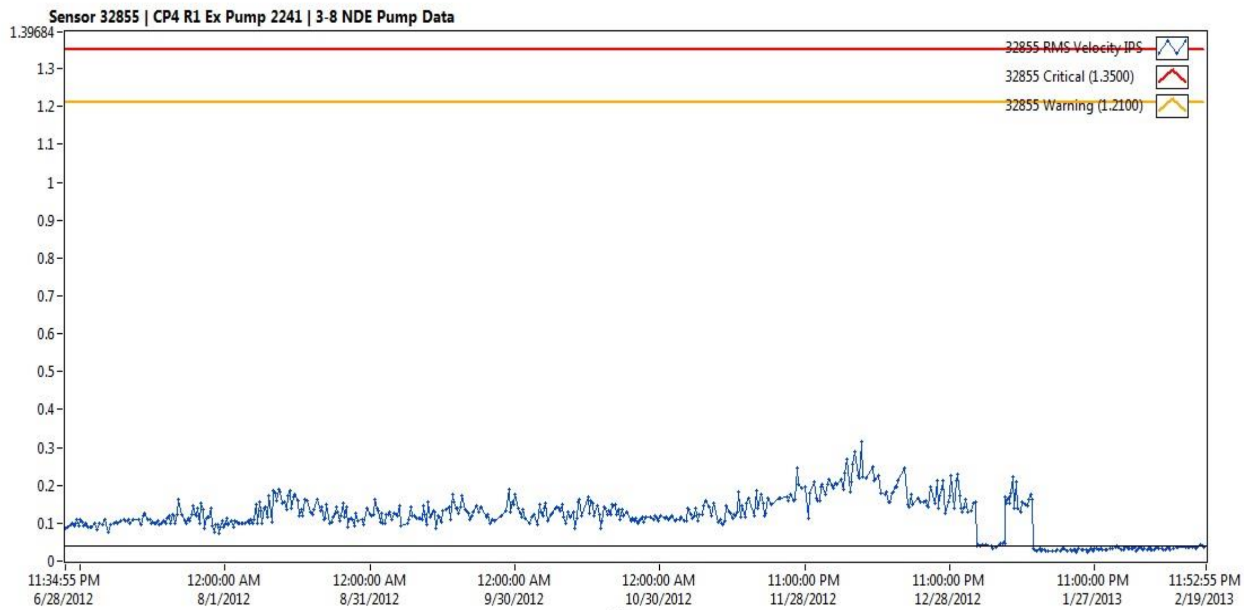


Figure 9
Trend data for the RMS velocity parameter on the centrifugal pump over 6 months

The RMS velocity trend parameter did not change very much from before until after the bearing change out on January 15, 2013(Fig. 9). In contrast, the True Peak Acceleration went from a peak of 27 g's prior to bearing change to a quiet 1 g following bearing change out. The fault chart in Figure 1 suggest that an alert level for this speed machinery should be set at 5 g's which is well above the 3 g level in Figure 10 following the bearing change out. A picture of the inner race from the defective bearing is presented in Figure 11.

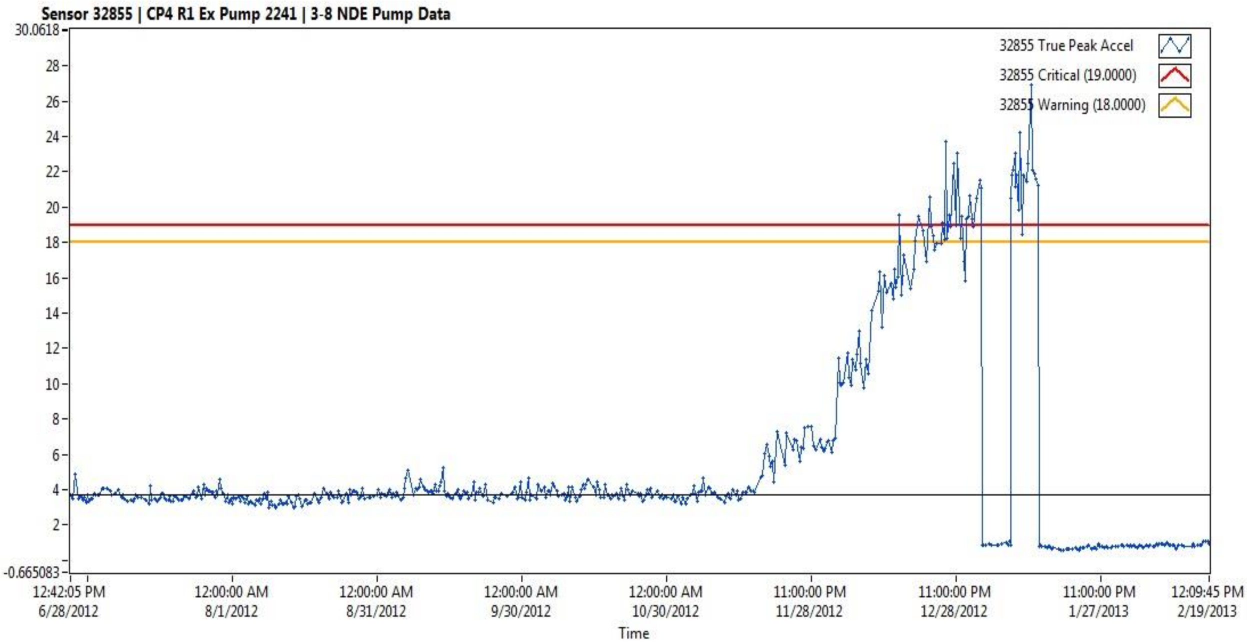


Figure 10
Trend data for the Peak g-level parameter from the centrifugal pump over 6 months

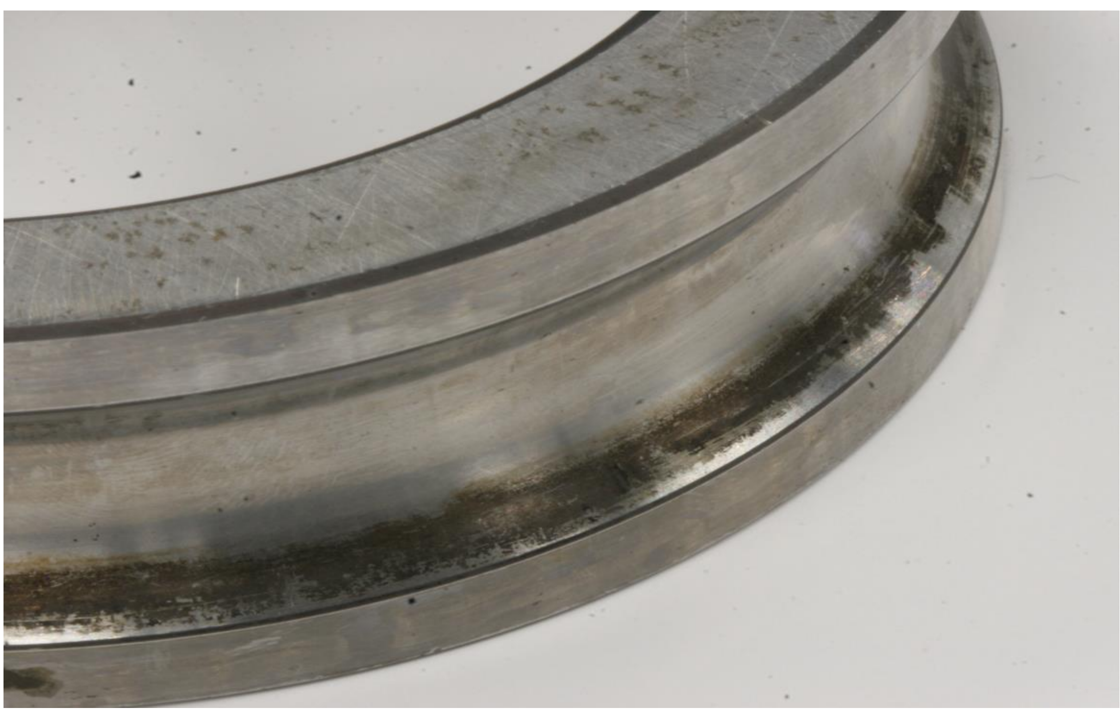


Figure 11
A picture of the inner race of the bearing removed from the centrifugal pump

In the case of the Echo® Wireless System, the band filtering is slightly different than discussed in the background section. The low frequency band measured by the RMS velocity parameter is about 3 Hz to 2300 Hz for velocity. It is also recommended that alarms should be set a little lower (50% of normal) when monitoring low speed machinery (<180 rpm) with this system. The high frequency band measured by the true peak acceleration parameter is 2.3 to 15 kHz.

Conclusions

The case studies in this paper demonstrate that many vibration problems common in industrial machinery can be detected and their severity can be approximated by trending two key parameters. These two parameters are the RMS velocity for the low frequency range and the peak acceleration[1] for the high frequency range. The overall velocity parameter, nominally 0.3 times running speed to 1000 Hz, is most sensitive to problems such as balancing, alignment and looseness. The peak acceleration parameter, nominally 500 to 20,000 Hz, is sensitive to problems that lead to impacting, friction and fatiguing. As the problems worsen, both of these parameters generally will trend upward.

The two parameters identified above offer an alternative to the normal walk around predictive maintenance approach where measurement points are identified and extensive vibration data acquisition and analysis are carried out. The purposes are to identify those machines having vibration related problems and asses the severity of the possible fault. This requires specialized hardware, software and skilled analyst. Usually the sensor is an accelerometer that is temporarily mounted to the measurement point until the data acquisition at that point is complete. This procedure is repeated until all data are acquired, and this could possibly require a few hundred measurement points per day. The two-parameter approach would require an accelerometer be permanently mounted on each measurement point. The time interval between subsequent measurements would be significantly reduced relative to the walk around approach, such as 8 hours compared to one month or one quarter. Vibration measurements only once per month may be insufficient to prevent failure from serious lubrication faults.

[1] Observed over multiple machine rotations (20 suggested when feasible)

Recommendations

It is recommended that the two-parameter program discussed in this white paper be considered in part (or fully) for predictive maintenance activities. The advantage of the two-parameter program lies in its' simplicity of execution. One or both of the parameters would have alert and fault levels preset. When these parameters are exceeded, the staff would follow a preset procedure to respond. It could be as simple as having an analyst to verify the fault and define the next set of actions. Or it could be changing out the component that has exceeded the fault level.

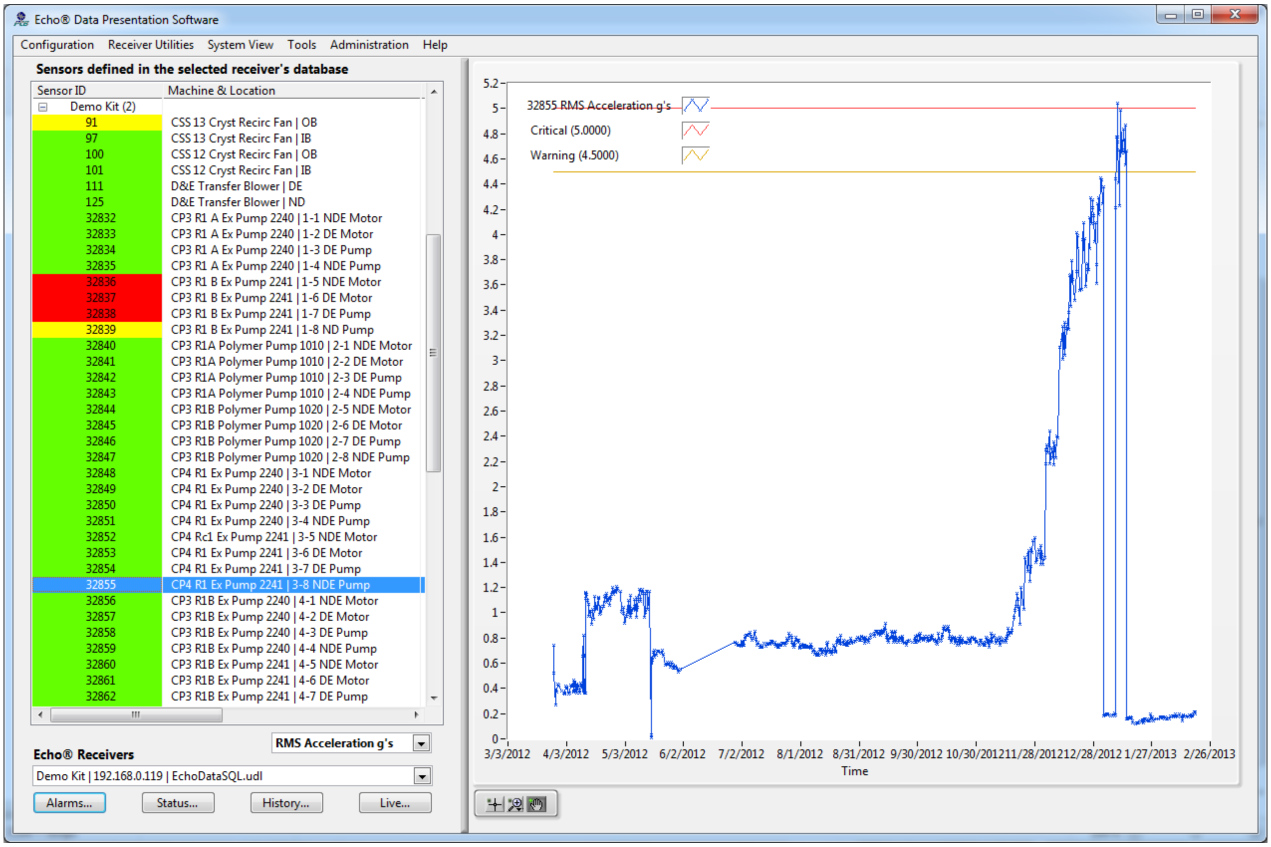
Executing the two-parameter approach does not require a highly skilled vibration analyst team or current advanced equipment employed in the walk-around predictive maintenance program. This method does require a permanently mounted accelerometer at each monitoring point. IMI carries an extensive inventory of low cost industrial accelerometers (603,607 and 608 series). Once the sensors are mounted, there must be a way to forward the status of each to appropriate staff. IMI Sensors offers a 4-20 mA Transmitter (682B05) specifically designed for Bearing Fault Detection. This unit can be connected to any standard ICP® accelerometer and provides both an overall RMS velocity and True Peak acceleration signal for communication with a PLC or DCS. Its RMS measurement covers the low frequency band at 10-1000 Hz, and its True Peak measurement covers the high frequency bandy at 1 or 5-100 kHz (depending on internal settings.) The 682C05 Bearing Fault Detector also has a third output for the raw acceleration signal, which is useful for detailed diagnostics with a data collector.

IMI Models 607A11, 682B05, and 649A03

IMI Sensors also offers the Bearing Fault Detector Plus (model 649A03), which combines filtered transmitter electronics and accelerometer into one small package. This unit can be mounted directly to the bearing housing and connected to a PLC or DCS. Although it can only output one measurement at a time, this unit has 5 measurement options: RMS acceleration, True Peak acceleration, Compensated Peak acceleration (using bearing diameter and speed to normalize output), Crest Factor, and Crest factor Plus (based on original combination of the peak, RMS, and crest factor) for improved detection on variable speed machinery. Similar to model 682B05, model 649A03 has an over RMS acceleration output (high pass filtered at 2500 Hz) and True Peak acceleration output (high pass filtered at 250 Hz.)

Echo® Wireless Vibration System

Finally, the parameters could be sent back via the IMI Echo® Wireless Vibration Monitoring System. The strength in Echo® lies in the transmission range you can have between the sensor and the receiver. It can transfer vibration measurements across a distance of 2500' to ½ mile in typical industrial environments. This narrow bandwidth system allows for vibration monitoring of hundreds of points across an entire plane; however, it has limited data transfer rate. Therefore it is not practical to send the raw vibration waveform data back using Echo®, but the periodic filtered measurements work perfectly with the two parameter method.



Echo® Wireless Vibration Monitoring Software
Trend Plot (Above) and System Overview with Alarms (Below)

As seen in Case 5, both low frequency and high frequency faults can measured accurately and detected early using the two parameter method with the values transmitted by the Echo® Sensor and EchoPlus® Junction Box. This allows a predictive maintenance program to efficiently operate and only focus on full spectrum data collection and analysis when necessary. Using the Echo® software pictured above, condition monitoring can be done at-a-glance with the various vibration trend plots and alarm panels.

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