Bearing Wear Example #1 – Inner Race Fault

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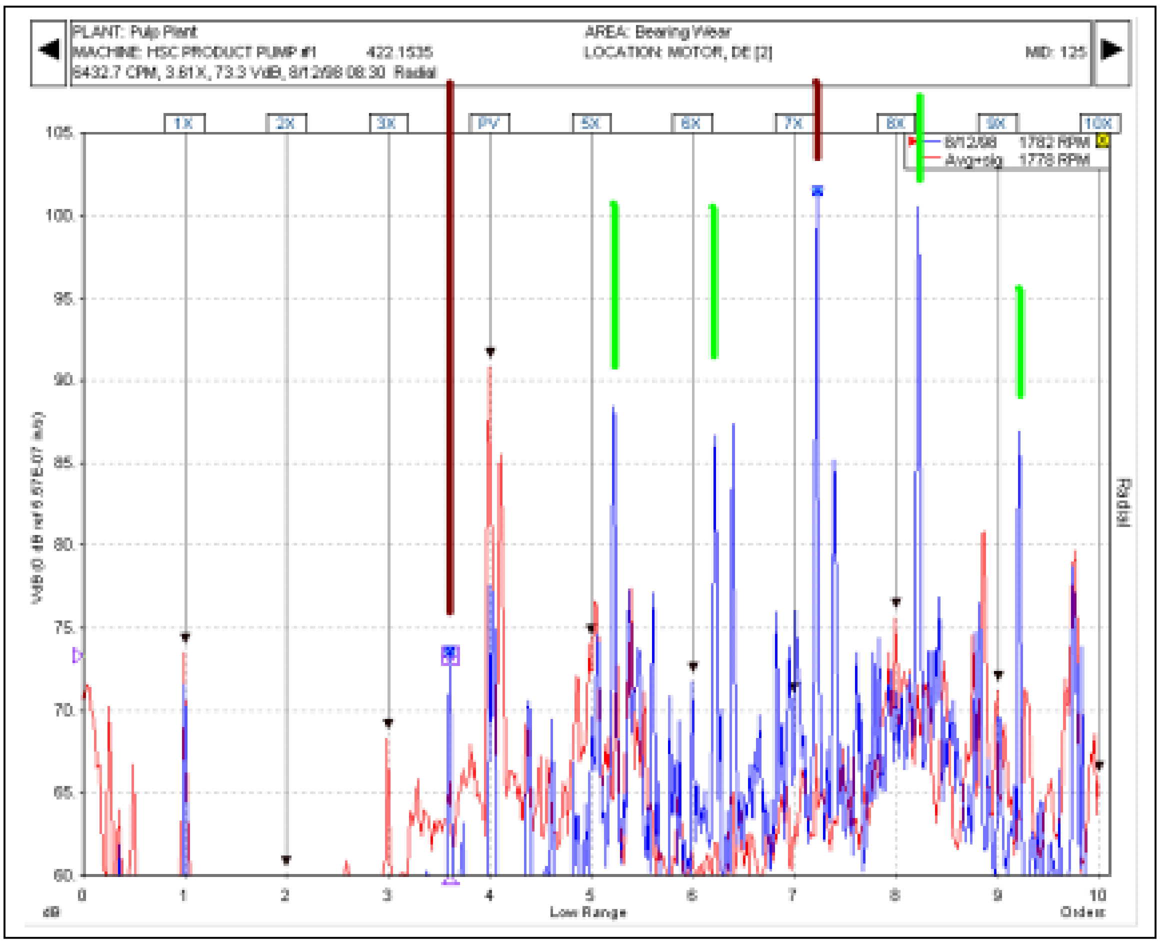
The following spectrum comes from the motor end of a horizontally oriented centrifugal pump. The data was taken in the vertical axis. The purpose of this example is simply to point out the evidence of a serious bearing wear problem and to explain why the existence of particular patterns in these data lead us to this conclusion.



(Figure 1, Vibration Data – Motor End)

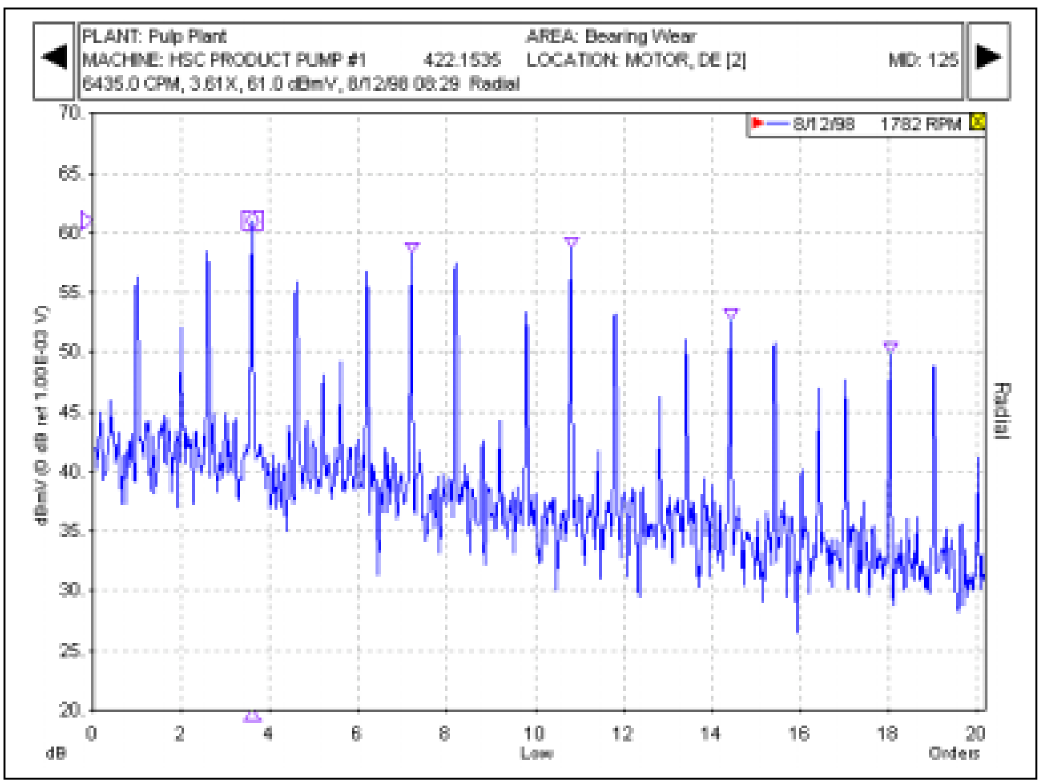
The red colored spectrum is a prior measurement from the same machine, which is used as a reference; the blue colored spectrum is the latest data. Without knowing anything about vibration analysis it is obvious that there are peaks in the blue spectrum that were not in the red spectrum. This is our first clue that something has changed.

The horizontal axis of this graph is in “orders” where “1” indicates the running speed of the machine. The first rule about bearing tones is that they rarely appear at frequencies that are exact multiples of the shaft rate. As we can see, many of the large peaks in the blue spectrum do not line up with shaft multiples.

The peak on the left marked with the maroon line falls at a frequency of 3.61x the shaft rate. This is a fundamental bearing tone, and we can see a harmonic of this tone, also marked in maroon, at 7.22x.

If we measure the distance on the graph between 0 and 1 on the horizontal axis with a scrap of paper, we will have a measurement of the shaft frequency of the machine. Moving the marked scrap of paper over to the peak at 7.22x, we can see that the peaks marked with green lines are separated from the peak at 7.22x by the run speed of the machine (they are at frequencies of 5.22x, 6.22x, 8.22x, 9.22x). These peaks are called "1x sidebands" and are caused by a fault in the bearings' inner race traveling in and out of the load zone with every shaft revolution. If one considers that the weight of the horizontal shaft is at the bottom of the machine, it will be clear that as a fault on the inner race travels down, it hits the balls harder. When the fault on the inner race is at the top of the machine, it hits the balls more softly. This repetitive change in the impact forces is called amplitude modulation, and this is what causes the 1x sidebands. If we take the same scrap of paper and place it by the peak at 3.61x, we will see that this peak also has 1x sidebands, although they are not marked on the graph.

The presence of 1x sidebands is common to bearing wear (when the fault is on the inner race) and therefore the existence of these sidebands confirms that these tones are in fact bearing related. If this vibration were coming from another machine next to the one we are examining for instance, it would not create this pattern of 1x sidebands, thus we can rule out external vibration.

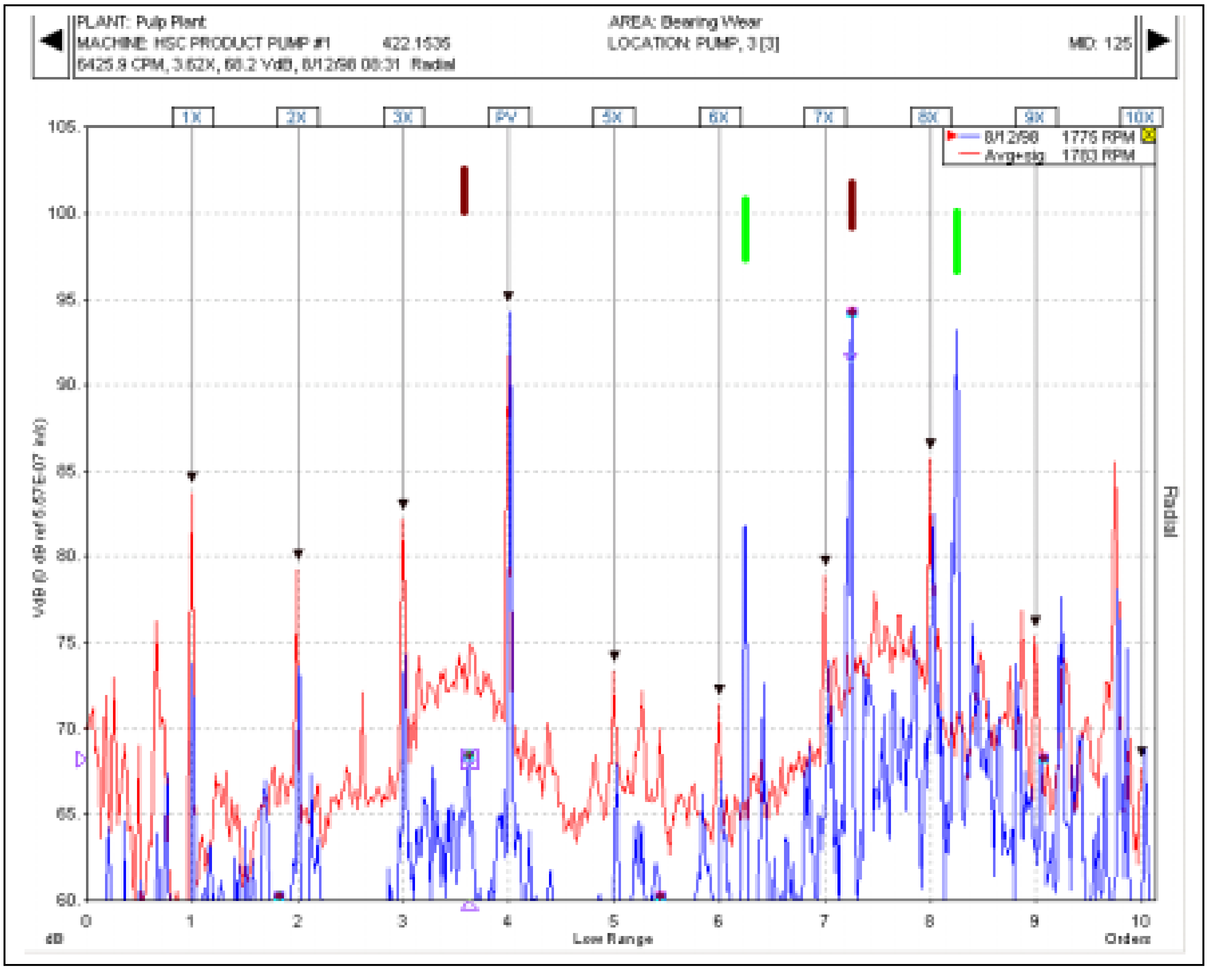


(Figure 2, Demodulated Data - Motor End)

Demodulation

Although we currently have more than enough evidence to confirm that this is in fact a bearing problem, a high frequency enveloping measurement (often called demodulated data) provides additional confirmation. As we shall soon see, this measurement also confirms that the bearing problem is on the motor end of the machine, not the pump end. The spectrum in figure 2 above is the demodulated spectrum from the motor end of the machine. Here we can see the same 3.61x peak (and harmonics) that we see in the spectrum in figure 1.

Because demodulated data results from a high frequency measurement, it is more sensitive to location. This is because high frequency vibration cannot travel as far and probably will not travel through a flexible coupling.

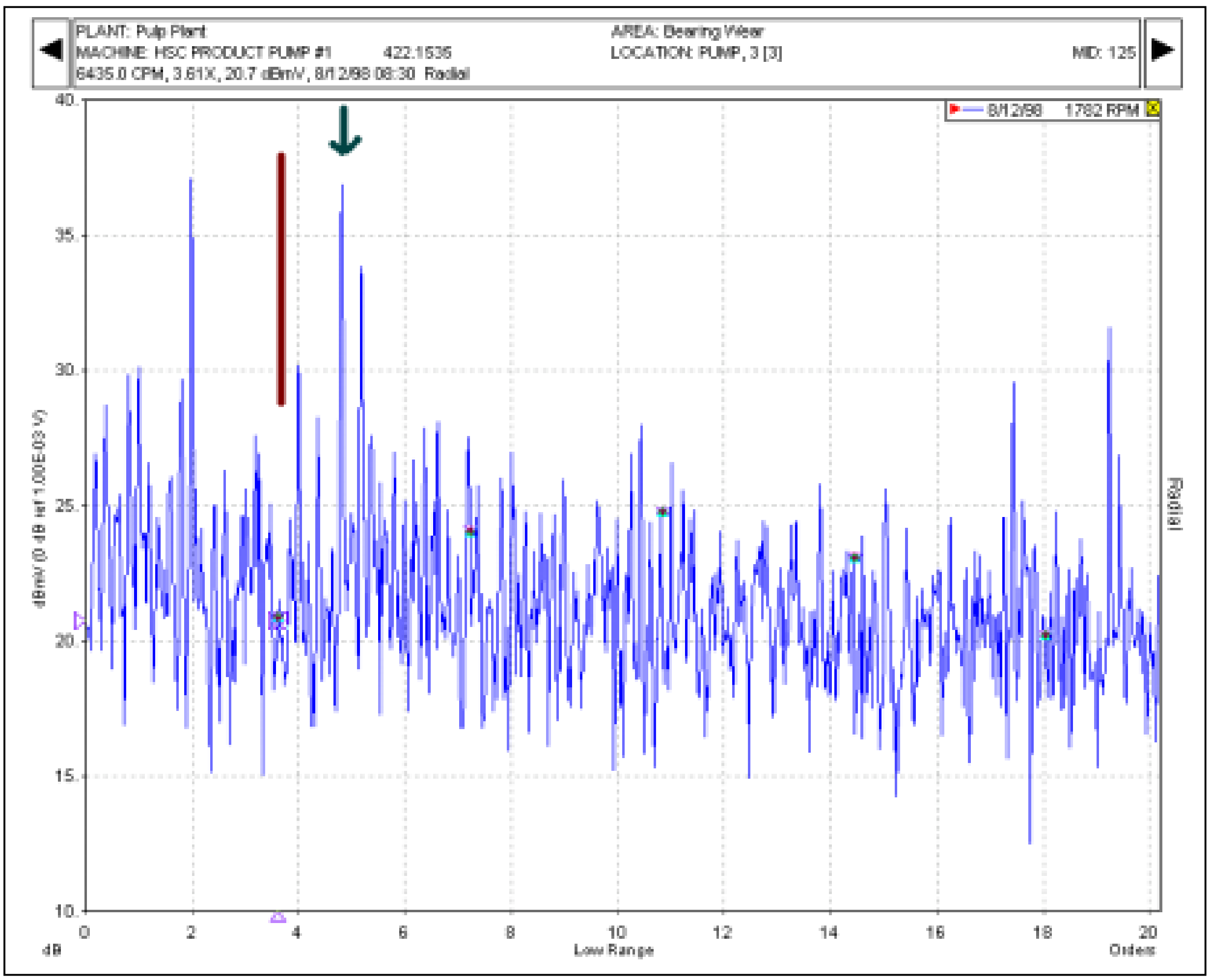


(Figure 3, Vibration Data - Pump End)

The Pump End

In figure 3 above, we can see that the same peaks marked in maroon at 3.61x and 7.22x that we saw on the motor end of the machine, as well as the 1x sidebands marked in green. If we had not already looked at the demodulated data, it would be difficult to determine at this point whether it is in fact a pump bearing or motor bearing that has a fault, since the vibration is apparently able to travel from one part of the machine to the other.

If demodulated data were not available, one could check calculated bearing frequencies to see if these tones coincide with expected failure frequencies (assuming the pump and motor have different bearings in them), or, one could make an assumption that the vibration levels should be higher the closer one is to the faulty bearing. Unfortunately, the latter assumption is not always correct.



(Figure 4, Demodulated Data – Pump End)

Demodulated Data – Pump End

In figure 4 (above), we have the demodulated data from the pump end of the machine. We can see here that there is no peak at 3.61x (marked in maroon) as there clearly was on the motor end demodulated data (figure 2). This is again due to the fact that the high frequency demodulated signal could not cross the coupling. Therefore, we now have confirmation that the fault is at the motor end.

There is a peak at 5.4x however, marked with a green arrow in figure 4. This is a distinct bearing tone on the pump end that is being detected in the demodulated spectrum. If we go back to the regular vibration data from the pump (figure 3), the peak at 5.4x cannot be found. This is because the demodulation technique is much more sensitive to bearing faults than the normal spectrum and therefore we can see these bearing tones in the demodulated spectrum before they have enough energy to appear in the regular spectrum. This does not mean the bearing must be replaced however, it simply means a small fault is in its initial stages of development.

Conclusion

The presence of new peaks in the spectrum at the motor end, that were not exact multiples of the shaft rate, was the first indication that a bearing problem likely existed. The presence of 1x sidebands around these bearing tones confirmed that this vibration was in fact bearing related, as external vibration would not cause this effect and because this pattern is common to inner race faults. Because the same peaks were present in both the motor and pump ends of the machine, demodulated data was utilized to confirm that the bearing problem was on the motor end. This is because the high frequency information used by the demodulation technique does not travel far and probably could not cross a flexible coupling. The presence of the same peak at 3.61x in the demodulated data from the motor end therefore confirmed that the problem was at the motor end.

The demodulated data from the pump end did not contain this peak at 3.61x, but it did contain a bearing tone at 5.4x that did not appear in the spectral data from the pump end. This served as an indication that the pump bearings also had an incipient fault, although not severe enough to take action against. This is due to the fact that demodulation is quite sensitive to small faults. All of this information was easily determined without knowing the make or model of the bearing in question.