

Science, Art, and Field Smarts

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Making the proper decision regarding the actions to take on a failing machine requires the use of science to detect the signals, art to interpret the data and field experience to temper the results so that the correct decision can be made. All too often, instruments are sold that leave the impression to the buyer that it will provide the user with the answers. Vibration spectra do not provide users with the wisdom required to make the proper decision as to whether or not to take a machine out of operation nor provide any advice as to what corrective actions to take. The following case histories are real-world examples of these techniques put to good use.

Example 1. The supervisory instrumentation on a steam turbine alerts the operators to the fact that the vibration on the turbine is above normal. Should the machine be shut down, costing the owner a half million dollars a day to see what is wrong? The next logical thing to do is to use some science to more closely examine the problem.

A spectrum analyzer is brought in to sample the vibration signal and a fast-Fourier transform is performed on the data to determine the frequency content and the amplitude of each spectral component. The DSP (digital signal processor) chip calculates 10,000 multiplications and 400 square roots, and the spectra are produced.

The art part of the process now takes hold. The analyst notes that the reason that the vibration on the turbine is above normal is because of the presence of a component at half the operating speed.

Having been to a number of vibration schools, the most obvious thought is that the bearing is loose or the seals are rubbing, either of which could produce exact half-speed vibration. However, since this analyst has been around the block a few times, he or she decides to look further. Science tells the analyst that when the frequency resolution is factored in along with the window factor, it is possible that the resolution is not good enough to positively tell if the vibration is exactly at half speed. The analyst then decides to increase the resolution. Alas, the vibration is not at exactly half the operating speed. That eliminates the rub and looseness theories.

At this point, it is obvious that it is good that we have both science and art. As it turns out, the vibration is 0.5% below running speed. Oil whirl is a possibility, but it is usually in the 43 to 48%

region. It is now time for the field-smart technician to get involved and start asking some questions. A talk with the plant manager and maintenance manager is in order.

The first question to be asked is, "When did this problem start?" Answer: "When we replaced the bearings." Second question: "What are the bearing metal temperatures?" Answer: "They are normal and constant from bearing to bearing." The field-smart person thinks: That helps rule out misalignment, which can load up one bearing and unload the one next to it, triggering oil whirl on the unloaded bearing. The third question: "If the oil temperature is increased, does that change the vibration?" Answer: "Yes. If we raise the oil temperature the vibration will drop." Fourth question: "Does this turbine have a critical speed at just under half the operating speed?" Answer: "As a matter of fact it does." Fifth question: "Were the replacement bearings identical in design to the original?" Answer (after a long pause): "Not exactly."

This problem turned out to be oil whirl that had locked onto the rotor's first natural frequency, resulting in a condition known as oil whip. The root cause was that the replacement bearings were not of the proper design. The solution was to put the unit on a permanent on-line monitor and make adjustments to the oil temperature as necessary until the bearings could be replaced.

Example 2. A 4000-HP feed pump motor destroyed its bearings after the first hour of operation following an overhaul. The motor was sent back to the repair shop, the rotor was rebalanced and the bearings replaced. Again, the bearings were destroyed after less than an hour of operation. The next action was to return the motor to the manufacturer where it was put into a high-speed balance pit and balanced at full operating speed. When it was returned, after one hour of operation, the bearings were again destroyed. All clearances, lubrication, and alignment checked out. The analytical part of the scientist reasoned that there must be something different about how the motor operates in the field under load versus when the rotor runs at full speed. The analyst, knowing the nature of large high-speed sleeve bearing motors, installs proximity probes on the motor so he can get a clearer picture of the actual shaft motion, rather than just the response of the casing.

The data from the proximity probes are

clear. As suspected through the valid reasoning of the scientific method, the vibration was indeed quite different on the motor at full load versus when operating unloaded. The synchronous vibration increased by a factor of 4:1 at full load. Cascade spectra, bodé plots and run-out calculations all showed that the rotor took on a bow at full load. The obvious conclusion was that the rotor had shorted laminations that resulted in uneven heating of the rotor and the cause of the load-dependent bow. Further investigation revealed that the motor shop had dropped the rotor which probably damaged the laminations.

All of this was quite interesting but did not solve the customer's main dilemma of what to do to allow the motor to run. The plant was operating with a 250-megawatt de-rate that was costing significant amounts of money each day.

Now it was time for the field-smart guy to get involved. Having worked on large generators for years, he knows that the solution is a compromise balance shot. What he does is install a balance shot that results in the motor running rough in the no-load condition. However, as the motor load increases, the thermal vector from the rotor bow cancels out the no-load unbalance that had been introduced by the balance shot, and the motor operates smoothly at the loaded condition. In this case, the motor was operated for eight years with the compromise balance shot installed with no further actions required.

Example 3. A nuclear power plant had a large turbine-driven, steam generator feed pump that had high vibration and a history of failed couplings. The teeth in the coupling were sometimes destroyed, and in one case, the coupling cracked.

The field-experienced technician was the first to arrive. He told them that the alignment was not proper and advised the plant to alter the cold alignment settings by setting the turbine 0.02 in. higher than the pump. The plant maintenance people said they could not do that because that would not agree with the manufacturer's recommendations. The field-smart guy said he had seen this problem before and that the manufacturer's recommendations were wrong and to call him again when they decided to do what he recommended.

The science guy arrived on site to examine the situation. Based on the fact that the pump was center mounted, he said that it should not grow, and that since

the turbine was hot, it would grow. Therefore, the turbine should be set low relative to the pump. This was in agreement with what the manufacturer said. Unfortunately, the coupling did not agree with the scientist or the manufacturer.

The analyst now arrives on the scene. He is a close friend of the field-smart guy and had conferred with him before his arrival. He suggested to the plant operators that they monitor the alignment to see how much movement there actually was. This required mounting some brackets, and because it was a nuclear plant, it took 6 months to get permission to do so. Say good-bye to another \$15,000 coupling during that 6-month period. The analyst finally got the dyn-align bars installed, and as predicted by the field-smart guy, the turbine needed to be set 0.02 in. higher than the pump instead of lower than the pump as recommended by the manufacturer and verified by the science guy.

This happened because the turbine dropped significantly when vacuum was drawn on its condenser, and the pump, even though center mounted, did move up because the pedestals holding the center mounting keys heated up. The field-smart guy was not a genius or anything; he had just been there before. Once his recommendations were followed, the coupling failures ceased to be an issue.

Conclusions. The point here is really not to talk about particular case histories, but to illustrate the need for science, art and the use of field knowledge in unison when identifying a problem and coming up with a solution.

The use of spectrum analysis, time wave analysis and orbit analysis all require that science be applied properly. Digital sample rates, windowing and signal-to-noise considerations along with proper transducer selection are absolutely vital. If the data are not taken properly, then even the best artist and savvy-

est street-smart analyst will not have the correct information to work with.

On the other hand, if even the best data are handed to someone with no field experience, they will stare blankly at the screen of their spectrum analyzer and not have a clue as to what the problem is, let alone know what to do about it.

Finally, after good data have been obtained and a proper analysis performed, the analyst must be willing to talk to management, operations, and maintenance personnel to try to get to the root of the problem and come up with an acceptable solution. Like parts of the body functioning together, it takes accurate science, well developed art and field experience all working together to come up with the root cause of the problem and then to lay out a proper course of action that minimizes economic costs. 

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