Nursing an Unreliable Boiler Feed Pump Back to Health

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An electric power generating plant located in the Northeastern U.S. had suffered through chronic boiler feed pump failures for eight years. The plant's difficulties had begun once the particular generating unit that was involved was switched from base-load to modulated-load operation. In fact, the longest period of operation that the pump had been able to log between major rotor element overhauls was only five months.

The pump OEM had been contracted to resolve the problem under the condition that any solution would be paid for only after it was demonstrated to be successful. Based on detailed vibration signature testing and subsequent hydraulic analysis, the OEM decided that the internals of the pump were not well enough matched to part-load operation. Consequently, the pump OEM had proposed replacing the rotor element with a new custom-engineered design.

Although the pump problem displayed some of the characteristics of a critical speed issue, both the OEM and the plant management were confident that this could not be the source of the trouble. The reason was because previous carefully performed rotor dynamics analyses had indicated that the factor of safety between running speed and the predicted rotor critical speeds exceeded a factor of two. However, the financial risk that was associated with relying solely on the hydraulic and the rotor dynamic analyses was considerable. The combined financial exposure to the plant's owners was approximately $350,000. Because of this significant expense, MSI engineers were invited to provide the generating plant's management with a "third-party" opinion about the source of the boiler feed pump's repeated failures and how to resolve them efficiently.

To assess the cause of the chronic machinery malfunctions, MSI performed experimental modal evaluations of the boiler feed pump (Figure 1) using its proprietary time-averaged pulse (TAP™) technique. TAP incorporated time-averaging statistics to improve the signal-to-noise ratio rapidly under operating conditions. Time averaging reduced the amplitude ratio of the random naturally excited vibration versus the impact-coherent vibration during signal processing. This greatly emphasized the effect of the "bump" while the machine continued normal operation.

The critical speeds of all rotating machinery can be determined under operating conditions with this technique so that impact or "bump" testing for natural frequencies can be conducted without shutting down the machines. With TAP, an impact or bump test properly accounts for the boundary conditions that are set up by the operating condition. This feature is especially advantageous for multistage, high-energy, variable-speed pumps, where the rotor-dynamic characteristics are speed and load dependent. Moreover, an existing or potential problem can be identified without any downtime of the tested pump or nearby equipment; this can provide a very important advantage in a broad range of applications and industries.

TAP is superior to "waterfall" or "cascade" plotting, the most common method of determining critical speeds. This consists of a succession of spectra as the rotating machine runs up to full speed or coasts down between the operating and static conditions. The TAP technique eliminates the problems that often lead to incorrect conclusions being drawn from a cascade plot. These may include:

- The dynamic coefficients of bearings and annular seals (Lomakin effect) can be substantially different between the transients of start-up and shut-down versus steady-state operating condition.
- The excitation source and magnitude is unknown. Therefore, the frequency response cannot be quantified in terms of the damping at each natural frequency to determine if it is critical or not.

The experimental modal testing performed while the machine operated quickly established that one of the rotor-critical speeds of the pump actually existed far from where it had been predicted to be. That particular critical speed had dropped into the pump's running speed range of 4,900-5,750 RPM. The unintended shift in critical speed appeared to be the sole cause of the boiler feed pump's reliability problems (see Figure 2).

Analyses were then conducted to help identify the source of the shift in the rotor-critical speed. A number of "what-if" iterations were performed using the OEM's rotor-dynamic computer model (Figure 3). These were verified with a similar model that was constructed by MSI engineers using the ROMAC (rotating machinery and controls) software code from the University of Virginia's ROMAC Industrial Research Program. The analytical results from both models consistently showed that the particular rotor natural frequency value and the rotor mode deflection shape could best be explained by improper operation of the pump's coupling end bearing.

Therefore, the coupling end bearing of the boiler feed pump was removed and was thoroughly inspected. Inspection revealed that the end bearing had a critical clearance that deviated far from the designed value. Ultimately, the discrepancy in the clearance was found to have been caused by a drafting error on the end bearing's manufacturing drawing, meaning that the mistake was carried over each time that the end bearing was repaired or was replaced. Installing a correctly constructed end bearing shifted critical speed of the rotor upward to very near its expected nominal value (Figure 4) and well out of the pump's operating speed range. The boiler feed pump prone to failure has since run for more than three years without need for an overhaul. Identification of the root cause of the pump failures eliminated considerable expense.

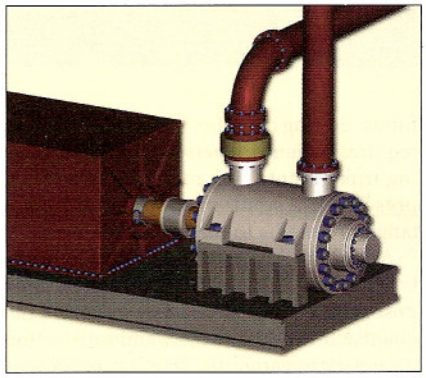

Figure 1. Steam-turbine-driven, barrel-type, main boiler feed pump.

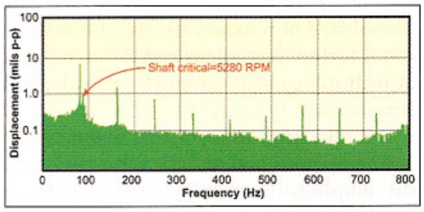

Figure 2. The 0-800 Hz (0-48000 RPM) vibration spectrum of boiler feed pump operating at 4900 RPM before any equipment modifications.

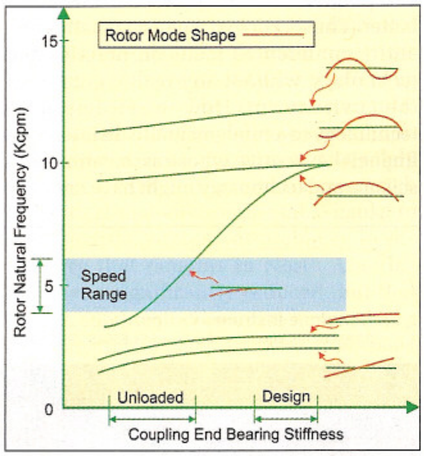

Figure 3. Results of "what-if" rotor dynamic analysis of boiler feed pump.

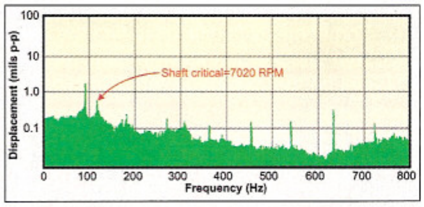

Figure 4. The 0-800 Hz (0-48000 RPM) vibration spectrum of the boiler feed pump operating at 5750 RPM after pump's end bearing was modified.

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