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Planning for shake down

Design improvements at operating power plants continue to challenge plant staff and original equipment manufacturers (OEMs). While basic design calculations consider the capacity of components and stresses resulting from their use, few consider vibration issues in great detail in the design. Vibration can lead to instrumentation failure, cracking and fatigue damage, or early degradation of the installed equipment, leading to increased OEM costs and plant outages.

This is usually justified since real-world vibrations from flow-induced sources or interaction with plant-supporting structures are notoriously hard to predict. Typically, only rotating equipment receives consideration of operating vibration issues. For most systems, there are far too many potential vibration response modes and potential sources of vibration unique to the specific installation to design around all of the problems. Therefore, it is critical to provide for initial shake-down testing of the system and to plan for the diagnosis of potential problems.

Diagnosis of vibration issues is more than simply taking accelerometer data at specific locations. Real diagnosis should attempt to determine the cause of the vibration through evaluation of structures responding to the vibration source. This can include computer modeling of building steel, piping systems, or even acoustic or computational fluid dynamics models for flow-induced vibration (FIV) issues.

A recent project highlights this process. Initial shake-down operation of a large steam piping system, featuring five control valves in parallel, caused piping vibrations that disrupted flow meters and other equipment in the send-out piping. Operation of one of the valves resulted in the high vibration levels, and an investigation of the cause of the vibrations was warranted. The effort included testing of the piping utilizing dynamic pressure transducers and accelerometers, and modeling of the acoustics and piping structure. The testing was performed on two days and included multiple valve positions and flow rates to cover a range of operating conditions.

In this case, FIV issues related to the operation of the first valve was the primary cause of the piping vibration. Typically, FIV arising from a location in the piping causes resonation of pressure pulses throughout the piping network. Increased dynamic pressures and pipe acceleration were recorded when the first valve was opened, and the degree of response with flow was indicative of FIV.

An acoustic model of the system was developed to help predict the source of the FIV pressure oscillation amplification over a range of frequencies, and the model results compared reasonably well to the test data. The acoustic model showed that the valve itself was not the source of the pressure oscillation, but the likely source was a tee connection downstream of the valve, and the test data indicated that the header outlet tee was a more likely source.

A piping configuration change was planned to route the valve outlet past the problem area. This modification eliminated the source of the vibration, and post-modification tests showed the reconfiguration successfully mitigated the vibration. In fact, the pressure and vibration levels were now lower than during operation of the remaining four control valves.

A similar process was used in the modification of a heat recovery steam generator. In this case, a flow distribution grid experienced high FIV levels and needed to be replaced. Knowing the potential for FIV issues, the new grid was evaluated for vibration issues, and increases in support strength were proposed to add rigidity to the structure. Instrumentation was added to monitor strain and accelerations of the new grid, and during the project, a sight window was added to confirm the motion of the structure. Start-up testing of the replacement grid showed that the new design operated smoothly, and the instrumentation provided critical feedback confirming this condition.

Both of these examples show that proper diagnosis should include a complementary investigation involving instrumentation and engineering analysis. Proper planning to instrument and evaluate components during start-up can ensure that the correct solutions are developed before they become either short-term or deep-seated problems for plant operation.

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