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Critical pipe stress

Once again, at your production facility, the operators have approached you about a 1,600 F line where the pipe shoe has come off of the structural steel, jammed against a beam and caused a failure of the structural steel. Working in operations, you have heard from the "old timers" this happens every two or three years. As the production engineer in charge of the area, your main concern is the failure of the pipe or breech of process containment as loss of hydrocarbon would be of great concern. When one of the operators was on coffee break, you asked him to determine to his best recollection when this happened. After that, you looked at historical run data and determined this occurred most often when there were more shutdowns. The next step was to talk to the plant engineering folks about the design. They said a pipe stress analysis had been run by the engineering contractor; it was audited, and there are no pipe stress problems.

This is common in plant operations where piping experiences remarkable thermal growth and the piping system was analyzed by an elastic approach. The piping was experiencing what is called "thermal walking." When the plant was shutting down, the pipe would not return to the original position. When a subsequent thermal cycle was experienced, the pipe would simply displace further. An elastic pipe stress analysis cannot take or determine a condition of thermal walking because "elastic" means it will return to its original position. "Thermal walking" in piping systems has led to failure of piping systems and has caused remarkable events at production facilities. The piping in question was operating in the elastic-plastic region. This means the pipe was operating within the stress-rupture curves and, with each thermal cycle, it would experience permanent deformation. Such a system is deemed "critical pipe stress" because of the operating pressures and temperatures.

Such a problem is best analyzed using the finite element method (FEM) that considers the plastic deformation of the pipe. In years past this was unthinkable and considered too costly, but that is no longer the case with the advanced software and computer horsepower available today. Today, pipe stress models can be created using FEM and accurate responses can be developed for critical pipe stress situations in a relatively short period of time. The other large advantage is the FEM captures localized, secondary stress in piping components typical elastic based software does not consider. When using the FEM, both a heat transfer and structural stress analysis is performed to obtain accurate results. The following steps are a methodology for tackling critical pipe stress:

1. Develop a process specification on what the operation and design conditions will be. This would include start-up and shutdown operations. Any transient conditions should also be included in this specification.
2. Consult with a materials engineer to determine the best material for the application that considers both reliability and economics. Sometimes the initial cost is not what is best long term.
3. Develop an elastic pipe stress model just to determine the overall layout required. Always start with a simple model. An elastic model will allow you to "get all the bug" out of the simulation.
4. Execute an elastic-plastic model to consider the plasticity effects in the system. It is important to have a subroutine that best fits the performance of the material. Sometimes destructive testing is required to obtain the correct properties for exotic materials.
5. Put in supports and limit stops to control any anticipated "thermal walking." This might involve putting in an entire floating system.
6. Refine the model to look at secondary stress points such as piping hardware attachments. Also consider welded joints where there is a change of material. This can be considered in the FEM as well.
7. Perform a detailed check and inspect the line after start-up to insure the line is behaving as anticipated.

As with any critical application, make sure the design is supervised and approved by a professional engineer competent in this area of expertise.

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