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The unlikely structural transient

Your production facility is no different than any other. It has happened again, and this time you are determined to get to the bottom of the problem. Structural piping and supports failed, and operations may have to shut down due to risk. You are a maintenance engineer at a large petrochemical facility, and the maintenance manager is on your back because operations is on his. This is the fourth time this has come up this year. Every time you go out to the field all you find are broken parts, and everything is operating smoothly. You take measurements and review all you can. You have turned over every rock and all roads lead to a dead end.

An approach to the problem may be as follows:

1. Select a root cause analysis team. The team should contain folks from engineering, maintenance, metallurgical, process, controls and operations.

2. Discuss the failure with the operators. The operators believe, in general, all the failures were mostly the same. While the specifics of the failures were different, it involved broken supports and/or instrumentation.

3. Look at the evidence. Send samples to a lab that can determine what type of fractures have occurred. Be careful to consider secondary consequential damage versus primary failure modes. This is important because secondary consequential damage may put you on a wild goose chase. A good example may be ductile overload is found along with fatigue. It could be either way for the primary modes. Was the forcing function and impulse resonant in nature or a time-dependent function? The sequence of fractures must be characterized. This can be done by identifying all possible scenarios that could occur.

4. Complete a design review in parallel or after the metallurgical investigation is done. The failure involved piping and supports, so a pipe stress analysis is appropriate. During the design review, it is important to understand the behavior of the system. This will help in determining primary and secondary modes of failure. In this particular case, nothing was found in the design that would suggest a problem.

5. Execute long-term monitoring. This can be accomplished with telemetry and data sent directly to your computer. It is a good idea to consider looking at process parameters as well, so you can capture what the process is doing at the same time. In this case, a transient pulse is found and it appears to be random. Next, it is decided to do the test again, incorporating dynamic pressure transducers as well as static transducers. From that test, it is found to be a pressure pulsation. Finally, you have a direct correlation it is coming from the process.

6. Evaluate the process. The process guys swear the pressure is steady and there is no pulsation in the system. They bring plots showing how steady their processes are with no pulsations. The problem is the data is time averaged and the transient is just a few milliseconds. Based on this, the process dynamics have to be reviewed. What can cause a pulse in the system to create such a large load condition? The dynamic pressure was only 25 percent of static pressure. However, over that large of a pipe area the loading can be high when it is transmitted to the supports. Finally, it is determined a possible area of concern is a static mixer where multiple flow streams merge. A computational fluid dynamics model is developed to include the kinetics of the process at the mixing location.

7. Put everything together. It is determined the root cause was constituents flashing out in the static mixer in a low-pressure zone. It occurs randomly because certain pressure/temperatures within the operating range had to occur for the flashing to occur. In other words, all the stars had to align a certain way.

This problem would have never been solved without finding out what the forcing function was and where it was coming from. Also, it was a multiphysics problem with process interacting with mechanical. The problem was fixed by a simple modification to eliminate the low-pressure zone.

All problems like this should be reviewed and approved by a professional engineer competent in failure analysis.

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