Analysis Using AFT Fathom™ Reveals Root Cause for Fire Pump System Over-Pressurization

CASE STUDY

Fire Protection System

Power Generation Industry

Applied Flow Technology

CB&I Inc.
Pitman, New Jersey, USA
Platinum Pipe Award Winner - Correlation to Test/Field Data

In an undisclosed facility, a fire pump system had an over pressurization problem during pump starts, realizing discharge pressures of 200 psig (1379 kPa-g) in a system designed for a pressure of 175 psig (1207 kPa-g).

Charles Williamson, P.E., senior engineering analyst at CB&I, was asked to determine the root cause of the pressure surge and make recommendations for corrective action. The design details of the system and a sparse dataset were all that the owner could provide for the analysis.

> "As a modeling solution, [AFT Fathom and the XTS Module] provide the ability to emulate conditions that would otherwise be unattainable."

The pressure transient was the result of either pump over speed at startup or an unresponsive relief valve. Williamson presumed both issues were occurring to a degree. However, data for these two parameters were not collected originally. He used an innovative application of AFT Fathom and the XTS Module to reconstruct the unavailable test data for analysis.

Piping arrangement drawings, valve loss data and pump performance test data were used to prepare an accurate physical model of the system. Multiple pump field tests were used to prove the calibration of the system over a wide range of operating points. With design and test detail provided, Williamson confirmed the model's integrity and validity (see Figure 1).

Williamson independently analyzed the effect of the pump speed and valve modulation on discharge pressure and combined these contributions to the original test data.

Williamson suggested that the pump speed contributed to the early portion of the event and the valve response was delayed until late in the event. As he tracked the pump speed prediction, he observed the lowest speed that occurred after the first peak was at 7 seconds. After the 7 second lull, the second peak occured at 10 seconds. He assumed that the pump achieved its running speed in about 10 seconds. The pump speed was set to increase from the low at 7 seconds to 100% at 10 seconds and then remain constant.

Williamson applied this pump curve to the model and allowed the valve to track the transient from the 5 second event. He observed that the valve cycled open and closed twice. This was unlikely as once the valve began to respond it would not close while the pressure was above the set-point. Therefore, the second activation of the valve opening was most likely the true initiation of the valve. The valve response was initiated at ~7 seconds as the pump began its final ascent to 100% speed. As the pump achieved stable speed, the valve responded to the pressure surge, opening and continuing to modulate to the end of the simulation. It was apparent that the valve response time was too slow.

The composite result of this scenario is shown in the graph below (see Figure 2).

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By use of an innovative approach and a partial differential relaxation technique, Williamson recreated a robust simulation of the test. This, of course was an estimate of how the equipment would need to behave, in order to produce the observed pressure transient. This transient simulation made it possible to reconstruct the test data that was not otherwise available.

Once the analysis was presented to the owner, they disclosed that a number of modifications had been performed on the relief valve which slowed the valve response time down considerably. It was estimated that the valve which was originally designed to open in ~3 seconds took as long as 10 20 seconds to respond. The remainder of the project was directed toward restoring the faster response time for the valve.

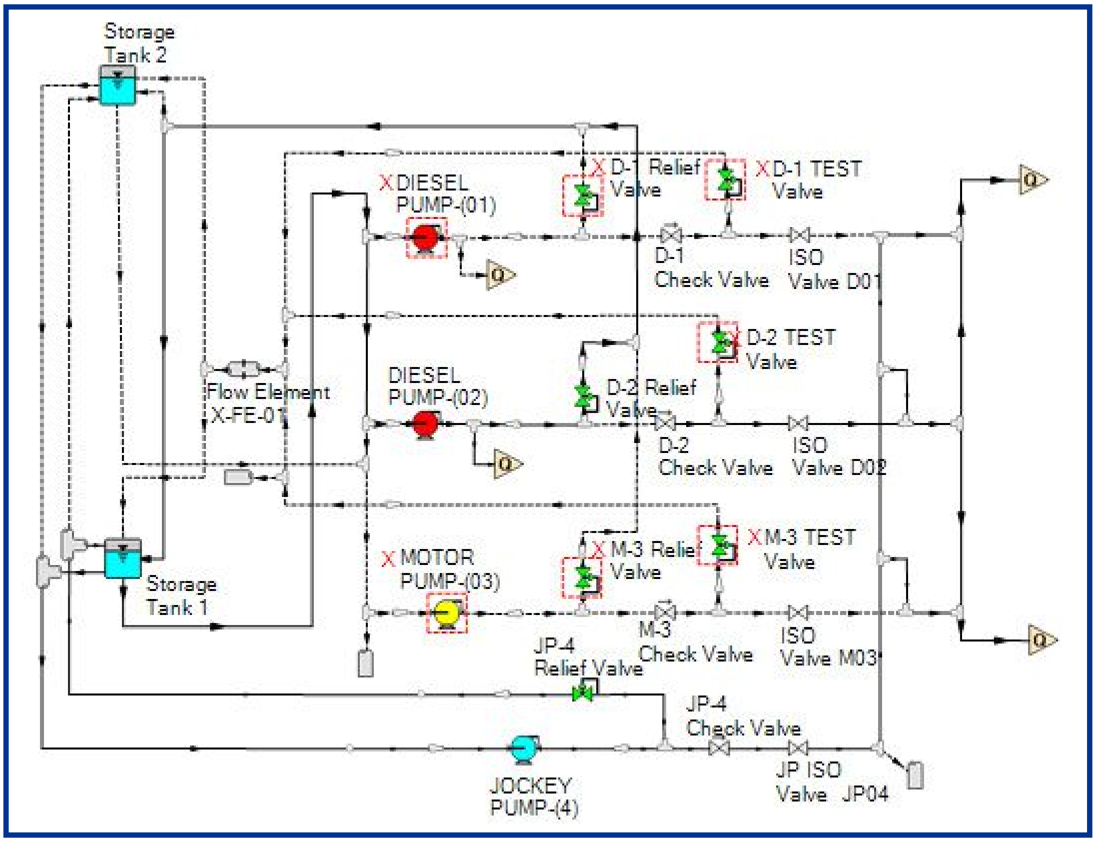

Figure 1 - Fire pump system

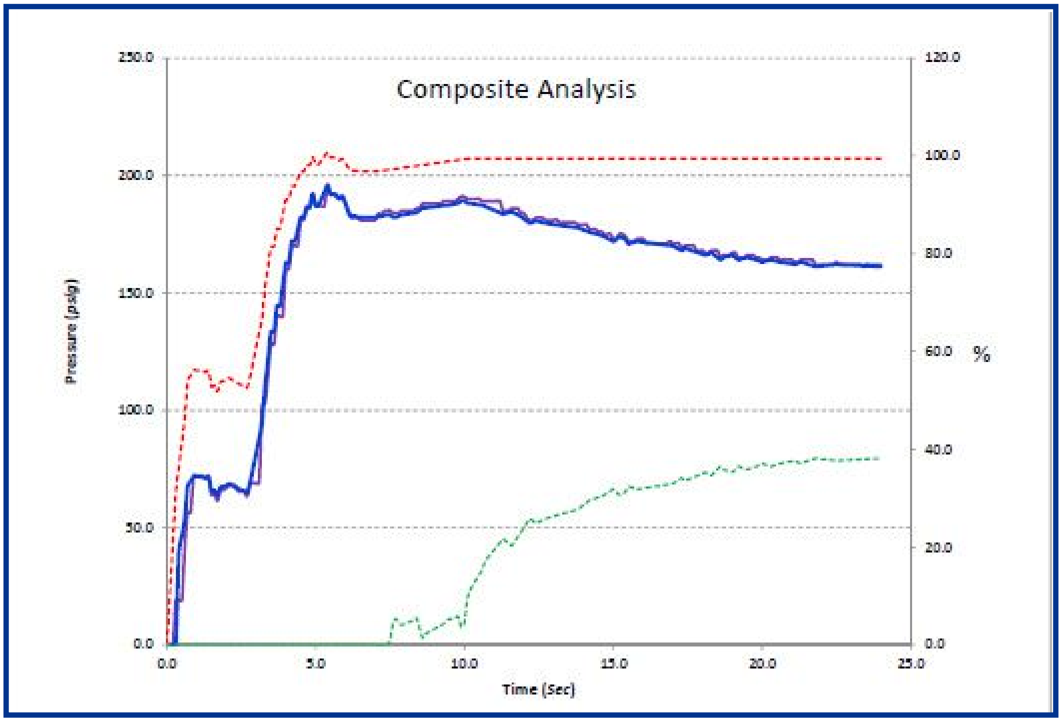

Figure 2 - Composite analysis of scenario

The pump speed (red) and valve positons (green) are depicted (dashed lines) in terms of the percent scale on the right of the graph. The resulting actual discharge pressure (blue) tracks similarly with the predicted pressure (purple) on the left hand pressure scale.