FLOWNEX®
SIMULATION ENVIRONMENT

MODELLING OF SPACECRAFT PROPULSION SYSTEM PRIMING IN FLOWNEX

CHALLENGE

When a rocket engine is started up at a high altitude or in space, the fuel lines must be primed first. Priming is the process of filling evacuated fuel feed lines with propellant. The propellant filling the fuel lines can slam against closed valves, causing large pressure surges that can damage fuel system components.

SOLUTION

Flownex was used as a tool to model the priming procedure. The dynamic pressures were recorded during a transient simulation of the priming procedure, and influencing factors such as the fuel line friction coefficient were investigated. A comparison between Flownex and experimental results was made, which helped to validate the Flownex model. Thus, this model can be used for future simulations of a fuel feed system.

BENEFITS

Accurate modelling of these pressure surges is an important step in the design of the fuel system since it provides the maximum pressures that the components in the system will experience. This will allow design engineers to select components that can withstand these pressures and help them understand what factors drive the pressure surges. Understanding the driving factors will make it easier to develop mitigation methods to minimise these pressures and provide a key simulation tool in the design path to reducing the total mass of the propulsion system.

INTRODUCTION

To start up a rocket engine at high altitude or in space, the fuel feed lines must be primed first. Priming is the process of filling evacuated fuel feed lines with propellant. However, this can lead to large pressure oscillations when the propellant slams against closed valves in the fuel feed system. The aim of this study is to model these pressure oscillations, which is an important step in the design process of the fuel feed system. It allows for the quantification of the maximum pressures required for structural design. It also aids in understanding the driving factors behind pressure oscillation magnitudes, which can be helpful for design optimisation. Besides for structural design, knowing the maximum pressures is also important when working with propellants such as hydrazine, which can spontaneously detonate at high pressures.

METHODOLOGY

In this study, a Flownex model of the test facility at DLR Lampoldshausen in Germany was set up, and transient simulations were run. The results obtained from the Flownex model were compared to the experimental results to validate the model. The test facility layout is shown in Figure 1 below.

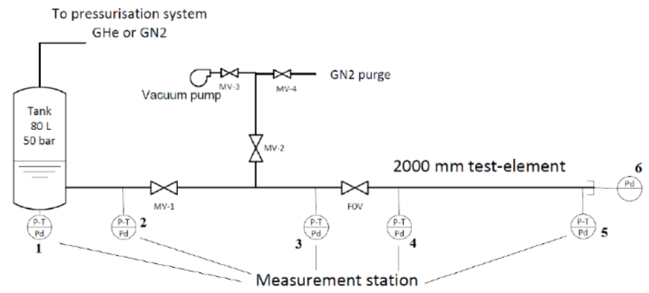

Figure 1: Fluid Transient Test Facility Layout.

The test bench has a tank that can be pressurized up to 50 bar, a pressurization system and a test section consisting of piping. The test bench is equipped with a fast-acting valve to allow rapid change of flow rates into the test section. The fluid within the test section can be either evacuated or pressurized. The flow network constructed in Flownex to model the test bench can be seen in Figure 2 below.

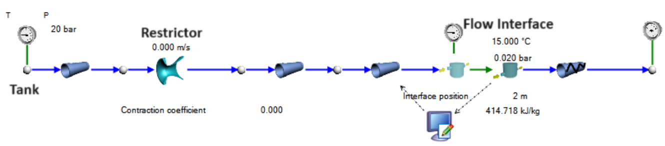

Figure 2: Flownex Model of Fluid Transient Test Facility.

The flow interface component is used to model the interface between the propellant and the gas, the restrictor models the valve, and the upstream node represents the gas volume in the tank. Once all the components in the network had been configured, transient simulations were performed.

RESULTS

Two simulations were performed: one in which the fluid in the test section was pre-pressurised to 20 bar and the other in which the test section was evacuated to 20 mbar. The results are shown in Figure 3 and Figure 4 below. In each case, the test bench results are on the left and the Flownex simulation results are on the right.

Pre-pressurised case:

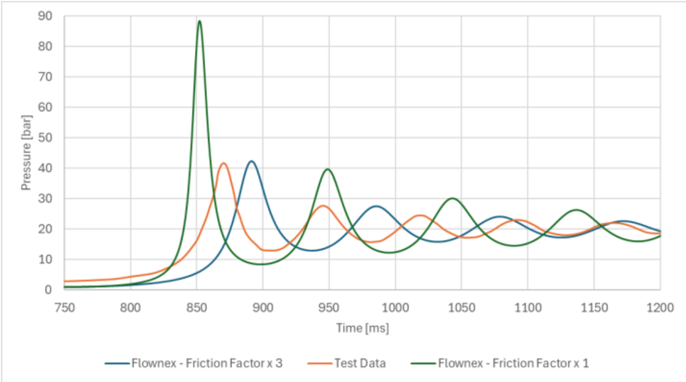

Figure 3: Pre-Pressurised Case: Results Comparison.

Evacuated case:

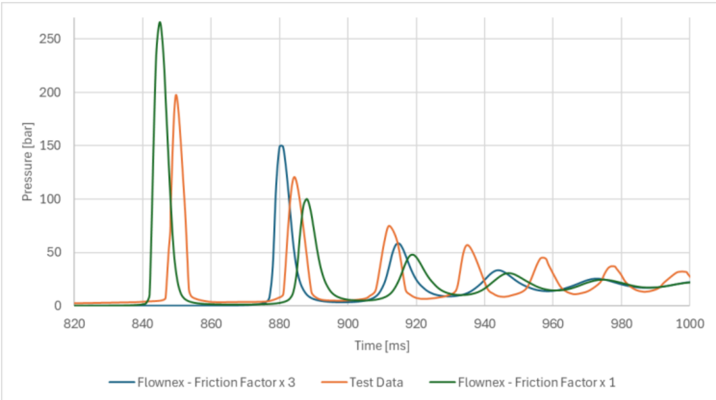

Figure 4: Evacuated Case: Results Comparison.

For the Flownex results, the green line indicates the pressure when an ideal pipe friction factor is used. This resulted in an overprediction of the pressure magnitudes. When a more realistic friction factor was used (blue line), the results of the Flownex simulation displayed the correct behaviour and magnitudes. Overall, the Flownex simulation results corresponded well with the experimental data in both cases.

CONCLUSION

In this study [1], Flownex was used to model the pressure oscillations that occur when priming a spacecraft propulsion system. Two cases were simulated, one with a pre-pressurized pipeline and one with an evacuated pipeline. The Flownex predictions matched the test bench experimental data well and, therefore, validated the Flownex model. The simulation results can be used to aid in the design of the fuel feed system components and to improve the mitigation of high-pressure fluctuations in the rocket engine fuel feed system.

[1] V Britz, B du Toit, H T Jeon (2013) Flow Network Modelling of the Priming of Spacecraft Propulsion System