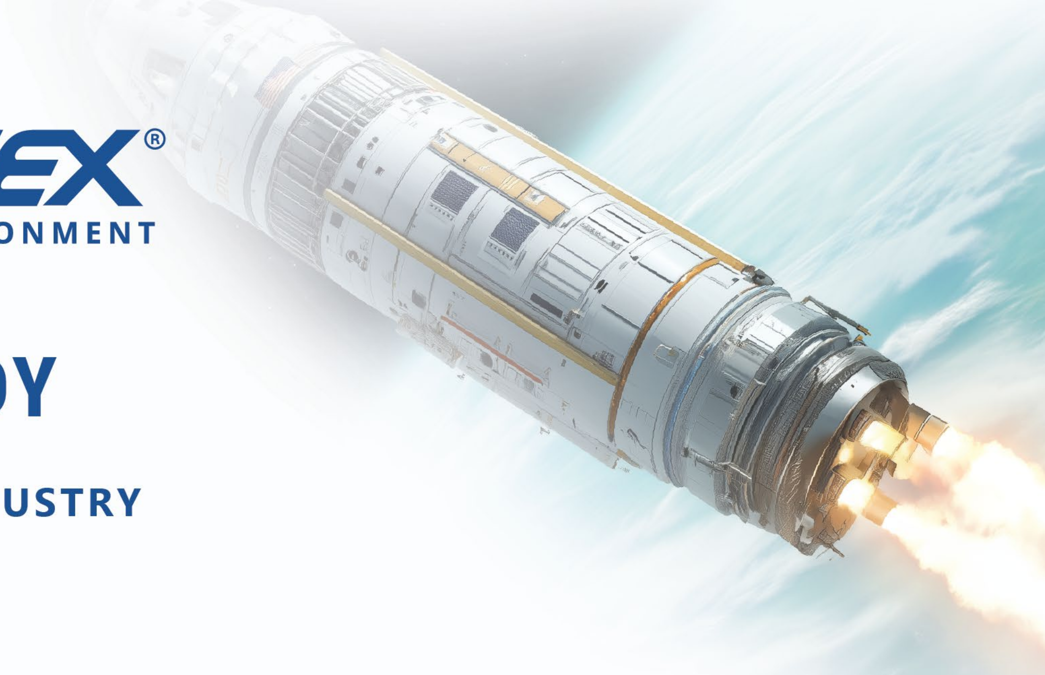
FLOWNEX®
SIMULATION ENVIRONMENT



CASE STUDY

SPACEFLIGHT INDUSTRY

VALIDATING A SCALING PROCEDURE FOR CRYOGENIC PRESSURE FLUCTUATIONS

A scaling procedure based on dimensional analysis was developed to enable the performance of transient pressure fluctuation simulations on a scaled model of a cryogenic fluid flow system. This procedure was applied in Flownex, a 1D simulation tool, and the results from the scaled model were compared to test data from a full-scale system to evaluate the accuracy of the scaling procedure approach.

SPACEFLIGHT

CHALLENGE:

Simulation of transient pressure fluctuations in cryogenic fluid systems is important since such fluctuations induce stress on a system and must be considered in the overall design. These fluid systems can, however, be very large and complex, making setting up and running such simulations difficult and time-consuming. There was therefore a need to develop a method to accurately model such complex systems using less time and energy.

BENEFITS:

Developing a scaling procedure and having a simulation tool that is compatible with such a scaling procedure is therefore advantageous in saving the time and energy required to perform these simulations, allowing the user to obtain results in less time and to fast track the design process. Flownex was used for the scaled simulation model derived from the scaling procedure being investigated. Flownex was ideal for this application, since it can simulate transient flow of cryogenic fluids in fluid flow systems. Its solver is also well-adapted to accurately model transient pressure fluctuations in such a flow system.

SOLUTION:

A derived scaling procedure was used to scale down a fluid flow system and model it in Flownex. The model was then used to simulate a transient pressure fluctuation. The results of the Flownex simulation were then scaled back up to be compared to the test results of the full-scale system. The results comparison was accurate enough for the scaling procedure to be validated. The scaling procedure can therefore be used for future scaled simulations. Using scaled models to simulate a system reduces simulation complexity, configuration and solving time.

INTRODUCTION

Simulation of transient pressure fluctuations in cryogenic fluid systems is important since such fluctuations induce stress on a system and must be considered in the overall design. These fluid systems can, however, be very large and complex, making setting up and running simulations of them difficult and time-consuming. Developing a scaling procedure and having a simulation tool that is compatible with such a scaling procedure is therefore advantageous in saving the time and energy required to perform these simulations. In this study, Flownex was used in conjunction with such a scaling procedure to validate the scaling procedure against the results of a test on a full-scale system.

SYSTEM DESCRIPTION & FLOWNEX NETWORK

The cryogenic flow system that was modelled using Flownex in conjunction with the developed scaling procedure was a test system developed by Majumdar and Flachbart (Ghosh & Bhuvana, 2020) for the modelling of fluid transients in rocket propulsion systems. The system consists of several flow paths, junctions, contractions & expansions, etc. along which cryogenic fluid flows. The full-scale system was used for transferring liquid oxygen and liquid hydrogen. A fluctuation in the flow is induced by, for example, the opening and closing of a valve. This fluctuation, in turn, induces a pressure fluctuation in the system, which creates stress on the system components. The scaling procedure was formulated in two parts: firstly, by fixing the fundamental dimensions, secondly, by deriving the dimensionless parameters and performing dimensional analysis. The scaling procedure was then applied to the full-scale model to calculate the inputs required for the scaled model, which was constructed in Flownex.

OBJECTIVE OF SIMULATION

The objective of the Flownex simulation was to test the accuracy of the scaling procedure that was developed.

DESCRIPTION OF SIMULATION

The Flownex network described above was used to perform a transient simulation of a fluid transfer operation using liquid nitrogen. In the transient simulation, a pressure fluctuation was induced by a rapid valve closure.

RESULTS

The resulting pressure oscillation was recorded over time, scaled up, and compared to the pressure oscillation from the full-scale model. The results are shown in Figure 1 below.

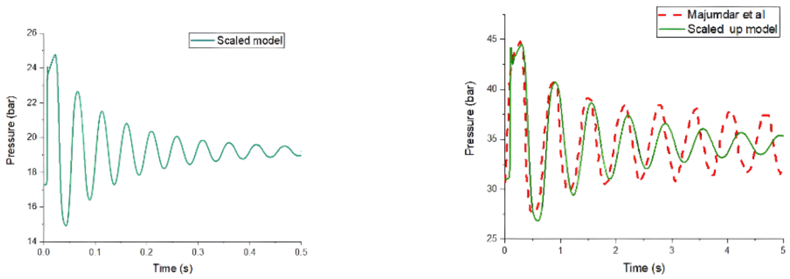


Figure 1: Results comparison: Scaled Model and Full-Scale Model.

From the results shown above, it is clear that the scaled-up results compare well with the results obtained from the full-scale model. The scaled model's pressure fluctuation dampens out more quickly than the full-scale model, most likely due to using different fluids (liquid nitrogen in the scaled model provides more damping than liquid hydrogen used in the full-scale model). Liquid nitrogen was used as a safety precaution since the authors planned to prototype the scaled model.

CONCLUSION

A successful derivation of a scaling procedure was done and applied to a scaled-down fluid flow system model in Flownex to simulate a transient pressure fluctuation. The results of the Flownex simulation were then scaled back up to be compared to the test results of the full-scale system. The simulation was successful, and the results comparison was accurate enough for the scaling procedure to be deemed validated.

Ghosh, P., & Bhuvana, R. (2020). *Scaling procedure for predicting pressure fluctuations caused by fluid transient.* Kharagpur: IIT Kharagpur.