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CASE STUDY
SPACEFLIGHT

FLOWNEX® SIMULATION ENVIRONMENT

Design of a lightweight Pressure Regulator for Pressurization of Propellant Tanks on Commercial Space Launch Vehicles

CHALLENGE

The Aerospace Systems Research Institute (ASRI) in South Africa is developing a suborbital rocket that will function as a test bench for key technologies being developed for a larger orbital rocket. The suborbital rocket is propelled by a pressure-fed liquid fuel rocket engine. A pressurising gas is fed into the fuel tank through a regulator to backfill the tank as fuel is consumed. The regulator must be designed to maintain the correct pressurising gas flow rate while being as efficient and simple as possible.

SOLUTION

Flownex was used to size a regulator based on flow requirements, and to track conditions in the pressurizing gas and fuel tanks during operation. This provided a platform for detailed analytical and mechanical design of both the regulator and the tanks. The Flownex simulation also provided a baseline for design optimization of the regulator.

BENEFITS

By designing and optimizing a custom regulator for this application, the overall design of the suborbital rocket is as efficient, simple, and functional as possible. An optimized regulator design minimizes weight, which maximizes rocket performance. An optimized design also ensures the lowest chance of failure of both the regulator and the rocket.

UNIVERSITY OF KWAZULU-NATAL ™
INYUVESI YAKWAZULU-NATALI

> *Flownex is playing an important role in our rocket engine and launch vehicle development work, and I expect that the extent of this role will increase with time.*

University of Kwazulu-Natal
***Jean Pitot –** Associate Professor*

INTRODUCTION

The Aerospace Systems Research Institute (ASRI) in South Africa is designing a suborbital launch vehicle that will function as a test bench for key technologies that are being developed for an indigenous Commercial Launch Vehicle (CLV). The suborbital launch vehicle, shown in Figure 1 below, is propelled by a pressure-fed liquid fuel rocket engine burning kerosene and liquid oxygen (LOX). The LOX tank must be maintained at a constant pressure to ensure a constant flow rate of LOX to the rocket engine combustion chamber. This is achieved by feeding the LOX tank with pressurized helium at a specific rate. The aim of this study was to design a regulator to maintain the correct flow rate of pressurized helium throughout tank blowdown. Flownex, a 1D flow simulation tool, was used to determine which regulator designs would fulfil this design requirement.

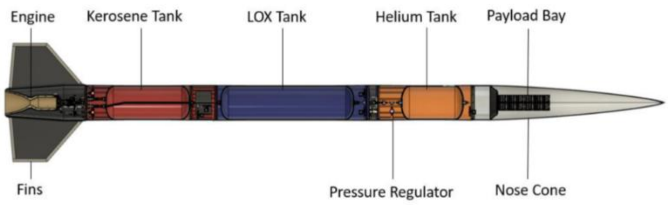

Figure 1: Suborbital Launch Vehicle

METHODOLOGY

After researching commercially available regulators, it was concluded that none were suitable for this application due to their excessive weight or prohibitive cost. Therefore, it was necessary to design a custom regulator. Figure 2 below shows the design of a general pressure regulator that was used as a reference.

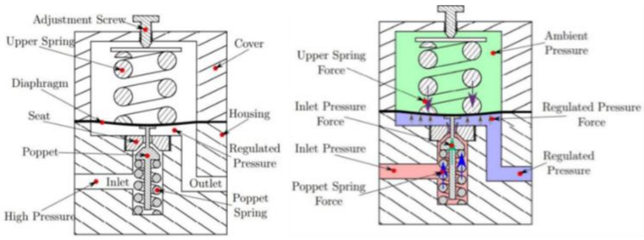

Figure 2: Pressure Regulator Design

The Flownex network constructed to simulate the flow through the regulator can be seen in Figure 3 below.

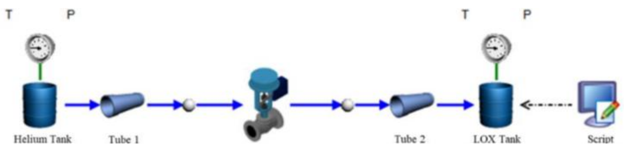

Figure 3: Flownex Network with Regulator

A script was used to change the ullage space in the LOX tank over time to model the flow of LOX to the combustion chamber. The regulator was sized by changing the inlet/outlet area until the required helium flow rate was achieved. Flownex was also used to track the variation in conditions in the helium tank during operation.

Once the initial sizing was complete, detailed analytical modelling was conducted on the regulator design. This included force balance and compressible orifice flow calculations, which aided in the sizing of all subcomponents.

RESULTS

Figure 4 below shows the results of the Flownex simulation of the system after initial regulator design. Change in pressure and temperature in the helium tank and the mass flow through the regulator over time are shown.

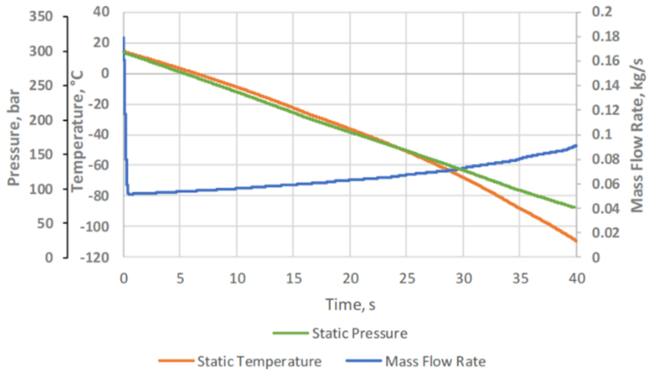

Figure 4: Helium Tank conditions and Regulator Mass Flow Rate

The resultant component design after conducting detailed analytical modelling can be seen in Figure 5 below.

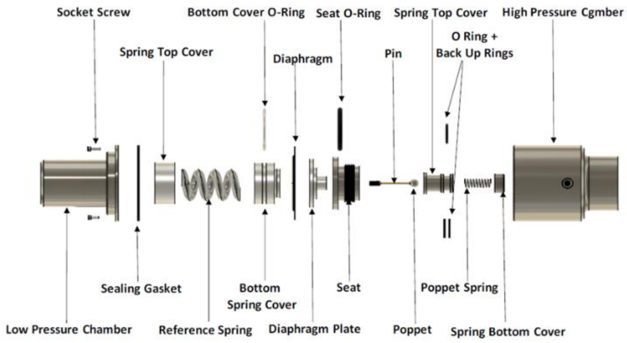

Figure 5: Pressure Regulator Mechanical Design

CONCLUSION

A study was done to design and optimize a pressure regulator for a fuel tank pressurization system of a suborbital launch vehicle [1]. Flownex was used to model the flow between the pressurizing gas tank and fuel tank through the pressure regulator. Additionally, Flownex was used to optimize the regulator design and track the conditions in the pressurizing tank during operation. The results from Flownex allowed the designers to size the regulator accordingly for detailed mechanical design.

[1] Brooks, M., Msomi, S., Harrylal, S. & Pitot, J., 2024. Preliminary Design of a Flight Weight Regulator for Pressurization of Propellant Tanks on Commercial Space Launch Vehicles. Durban: University of KwaZulu Natal.