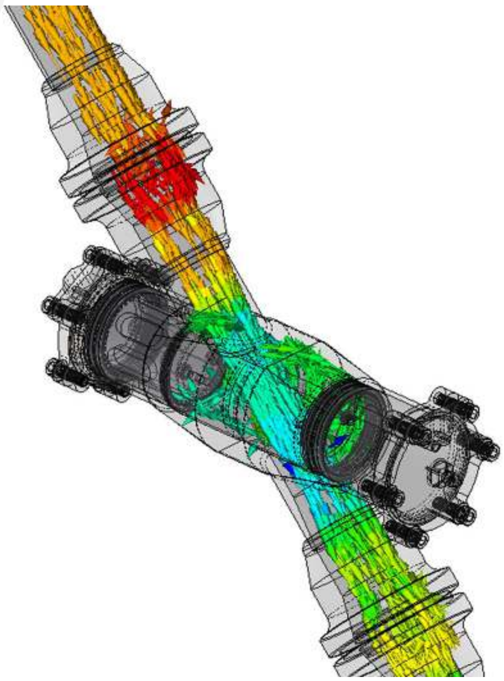
syncroness™
complex problems inspired solutions



LH2 and LO2 Valve Simulation

• November – December 2016

Objectives

• Support aerospace company's internal engineering team to meet end-of-year deadline
• Complete mechanical, thermal, and CFD analyses of multiple LH2 and LO2 valves

Approach

• Define system requirements, loads, and boundary conditions
• Use FEA to determine yield and ultimate factors of safety
• Use CFD to predict pressure drops
• Accelerate design schedule by working in parallel
• Suggest design improvements to meet requirements

Results

• Ran simulations on customer-proposed designs
• Recommended and integrated design improvements
• Increased factors of safety and reduced pressure drop across valves
• Completed simulations and delivered reports within six weeks

"Syncroness conducted CFD and FEA analysis on several valve prototypes, which I found to be extremely helpful. The analysis results were presented in a very clear manner, allowing my engineers to efficiently and effectively modify the designs as needed."

- Geoffrey Licciardello, Engineering Manager - Propoulsion R&D, XCOR Aerospace

A COMPLETE PRODUCT DEVELOPMENT PARTNER

- Brainstorming and Concept Generation
- Feasibility Studies and System Architecture
- Detailed Product Design
- Prototyping
- Design for Manufacturing (DFM)
- Verification Testing
- Manufacturing Assembly and Test Equipment
- Sustaining Engineering

Complex Problem

XCOR Aerospace asked Syncroness to analyze a family of valves, shown in Table 1, for an LH2/LO2 upper stage engine to demonstrate compliance with their customer's requirements. The valves are subjected to extreme operating pressures, temperatures, and flow rates. Syncroness simulated valve performance in parallel with XCOR's design of the valve assemblies.

Table 1: Summary of analyses completed

	FEA		CFD			
			LH2 Operating Condition		LO2 Operating Condition	
Valve	Material 1	Material 2	A	B	C	D
Size 1	X	X	X	X	X	X
Size 2	X	X				
Size 3	X	X	X	X	X	X

Finite Element Analysis (FEA)

After researching and documenting the material properties at the operating temperature extremes, we defined the fluid operating temperatures and pressures as well as the valve actuation pressure for each load case. The mesh was created such that there were a minimum of two elements across the thickness of any section. We further refined the mesh in areas of high stress and small geometric features. The mesh quality was verified by checking that the element aspect ratio and Jacobian fell within a desired range.

Initial simulations identified areas of high stress. Progressive mesh refinements were applied to these areas to show mesh convergence. When the change in maximum stress was less than 1% between subsequent mesh refinements, the mesh was sufficiently refined to capture the stress gradient in the region of interest. See Figure 1.

As a check of the simulation results, we compared the valve body stresses to the analytical solution of the hoop stress equation. In addition, we compared the overall valve body displacements to the results of a temperature-only simulation. Close agreement of our results to the calculated values gave us a high degree of confidence in the simulation results.

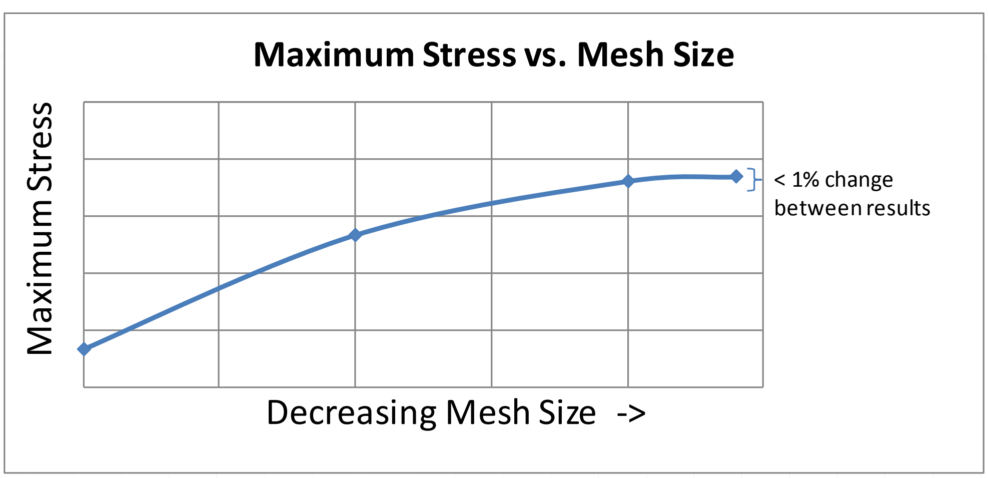


Figure 1: Mesh refinement illustrating convergence

syncroness
complex problems inspired solutions

The maximum von Mises stresses were then used to calculate factors of safety. Given the proposed design, these factors of safety did not meet the customer's requirements. Syncroness suggested specific changes, such as alloy selection and wall thickness increases. We simulated the design modifications to quantify the new maximum von Mises stresses and change in mass. XCOR was able to take these results into consideration during the design stage and support an aggressive development schedule.

CFD of Pressure Drop across Valve

Using computational fluid dynamics (CFD), Syncroness engineers simulated flow through two different valve assemblies for both LH2 and LO2 at four operating conditions. We used solution-adaptive meshing to refine the finite volume elements in high-gradient regions. We reported the pressure drop for each run for comparison to the requirement. See Figure 4.

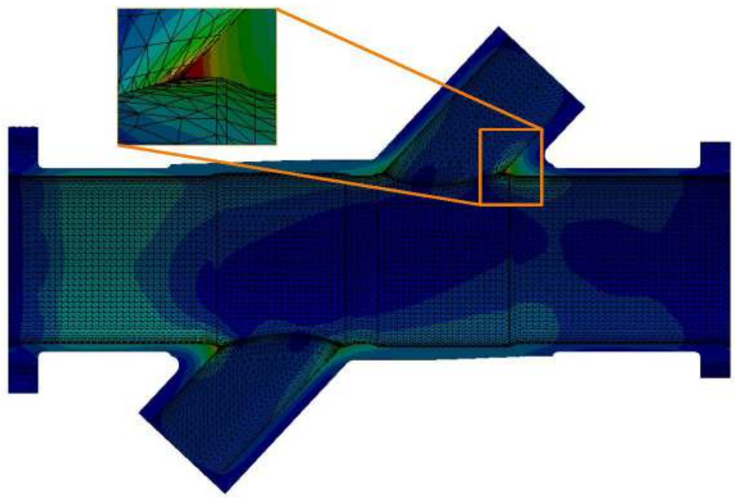


Figure 2: FEA results of initial design showing high stress elements

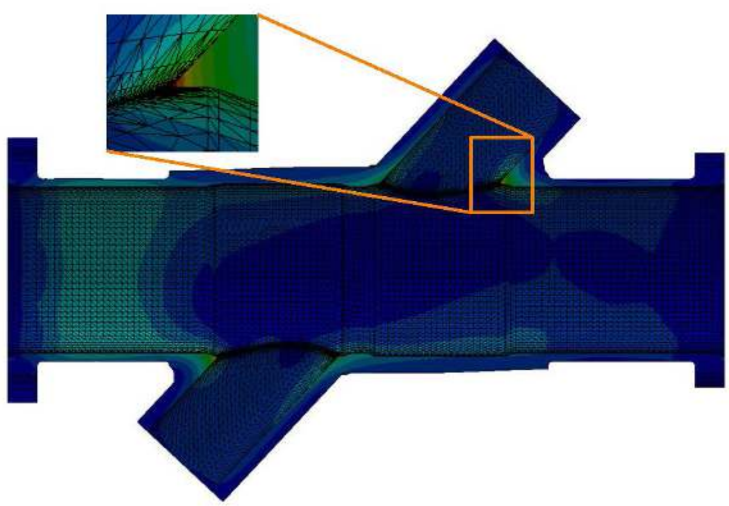


Figure 3: FEA results of proposed design that met the required factors of safety

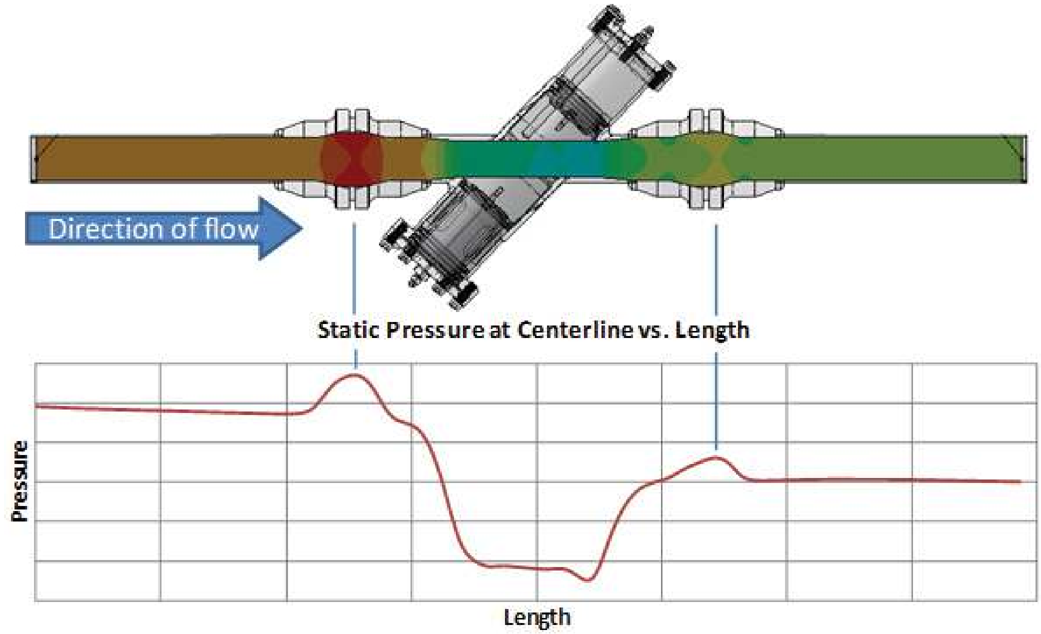


Figure 4: Static pressure along the centerline of the valve

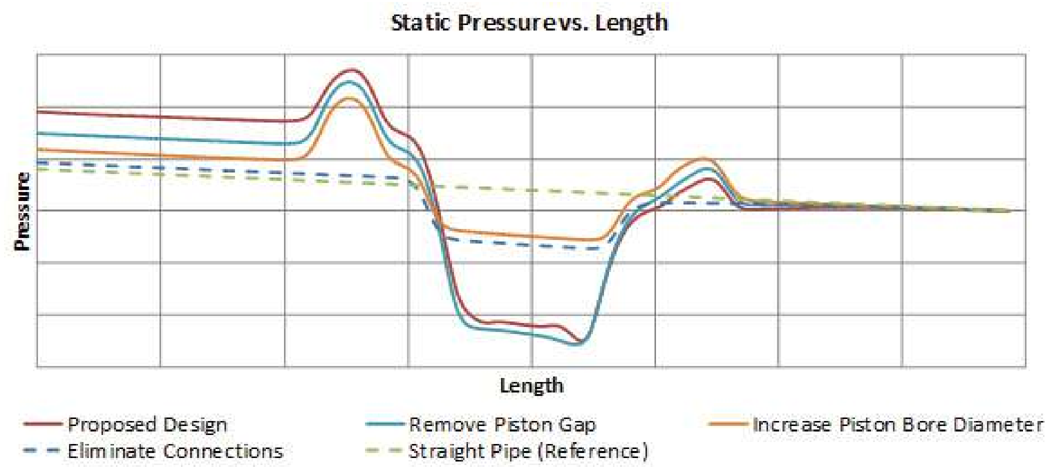


Figure 5: Contribution of design elements to pressure drop across valve

Syncroness' results helped XCOR to understand the details of the valve performance. We ran simulations with incremental modifications to quantify the relative contributions of design elements to the pressure drop of the system, as shown in Figure 5. For example, the results highlighted the relatively large contribution of the internal profile of the fittings to the overall pressure drop. Knowing which potential changes would have the most impact to the pressure drop of the system allowed XCOR design engineers to make informed decisions during the valve development cycle.

Syncroness' Solution

From initial discussions in November through delivery of analysis reports in mid-December, Syncroness simulated a family of LH2 and LO2 valves for a wide range of operating pressures, temperatures, flow rates, and materials as shown in Table 1. The system pressure drop, as well as areas of high stress, were identified. Recommendations were made to improve factors of safety, and a suite of design elements was analyzed to quantify their impacts on the overall pressure drop. XCOR received vital information to improve their valve designs and support a very aggressive development schedule.

syncroness™
complex problems inspired solutions