Heating Up Off-Road Vehicle Cabins

By **Morteza Marivani**
Group Research and Development Scientist
Product Development and Group Technology Manager
Advanced Simulation Center
Mobile Climate Control
Vaughan, Canada

Comfortable Rail Travel
ansys.com/comfortable-rail

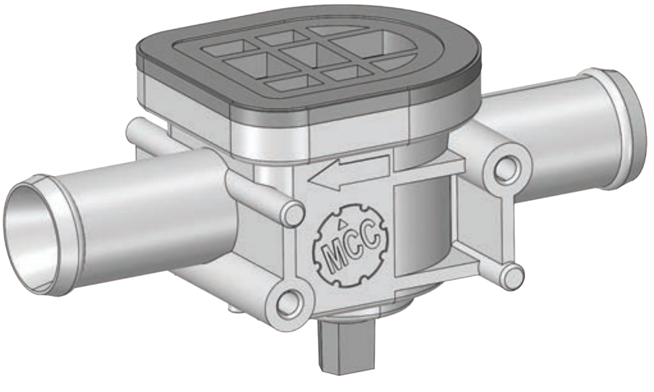
Off-road vehicle machinery operators — like those on a construction crew — spend long hours in their equipment under a wide range of weather conditions and want to precisely adjust the temperature of the cabin. By utilizing simulation, Mobile Climate Control engineers are creating heater valves that enable occupants to have full control of cabin temperatures for maximum comfort.

“Fluent accelerated the redesigned valve’s speed to market by enabling engineers to spend minimal time on the meshing and maximum time on solving the flow problem.”

Construction crews operate year-round, often performing in extreme cold. Operators running machinery like excavators rely on custom-engineered climate control systems to keep them comfortable and protect them from the elements.

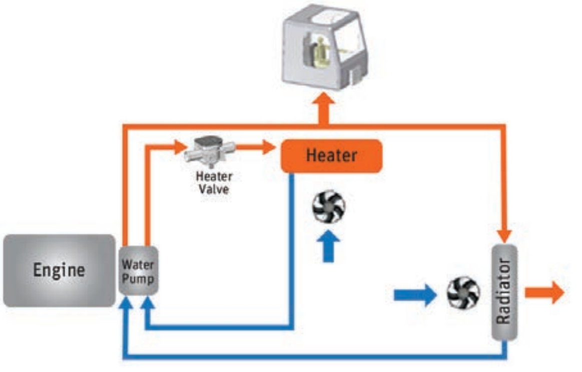
Off-road vehicles heat their passenger cabins in the same manner as commercial cars and trucks. Ethylene glycol coolant, better known as antifreeze, cools internal combustion engines and prevents damage to engine blocks. The coolant is pumped through the engine and radiator, enabling the engine to release heat.

On cold days when operators want to heat their cabin, a portion of this coolant absorbs the heat from the engine, warming it to near-boiling temperatures. The hot coolant then flows through heater core tubing, which serves as a heat exchanger between the coolant and cabin air. As a blower fan pushes air over the heater core tubing’s metal fins, the coolant’s heat is absorbed or transferred to the airstream that heats the operator’s cabin. A heater valve connected to a control knob controls the air temperature by regulating the amount of coolant that flows through the heater core. More coolant means hotter air is delivered into the cabin.



Valve model

Mobile Climate Control (MCC) applied ANSYS Fluent to simulate the pressure-driven flow through the heater valve. Mosaic poly-hexcore meshing created a high-quality volume mesh of the flow field quickly



Cabin heating cycle

and efficiently. MCC engineers developed an optimized design for the valve geometry that maximized its ability to precisely control the volume of coolant that flows through the valve at each position of the valve’s knob to improve cabin heat control.

COOLANT FLOW THROUGH THE VALVE

The control valve’s inner core rotates 60 degrees in total between its fully closed (0) and fully opened position (60). Historically, the valve performed well at positions between 15 degrees and 45 degrees because it experienced maximum liquid flow. However, between 45 degrees and 60 degrees, the flow did not change, so fine control of heating was not possible. To address this, engineers focused on redesigning the geometry of the valve’s inner core to achieve maximum volumetric flow rates with the valve fully opened at 60 degrees.

SIMULATING THE CONTROL VALVE

MCC first used Fluent to model the original valve’s performance. Engineers imported the valve’s 3D CAD models into Fluent and used the task-based watertight geometry workflow to create a high-quality, poly-hexcore volume mesh with Mosaic meshing technology. They ultimately reduced meshing time from three hours to less than an hour to obtain acceptable mesh quality for the fidelity required.

ANSYS Fluent simulated the flow field inside the valve and provided insights on how engineers could optimize the valve’s inner core geometry to reach their goal. Engineers were then able to manually change the

“Without simulation, engineers would not have been able to observe and understand the flow pattern.”

valve’s inner core geometry to improve its performance through better control of the volumetric flow rate. The team was able to re-run the simulation, see the result, determine the amount of improvement and finalize the geometry of the inner core. If engineers conduct this process through trial and error using a physical prototype, it would be very expensive and time-consuming.

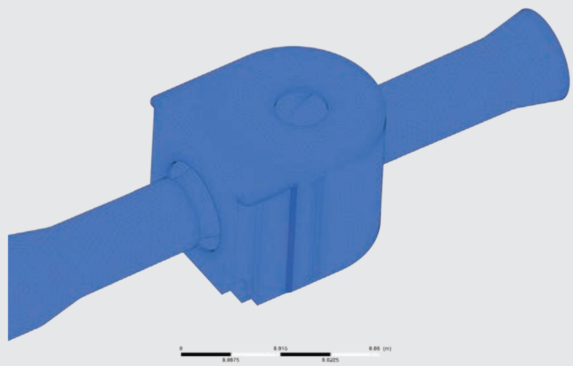
The simulation results revealed the heater valve’s flow rate curve (volume of liquid per unit time) in its different positions — from fully open to fully closed — in five-degree increments. This allowed engineers to

extract the volumetric flow rate amount at different valve angles for any specified inlet pressure for the valve and compare it with actual valve performance in the field.

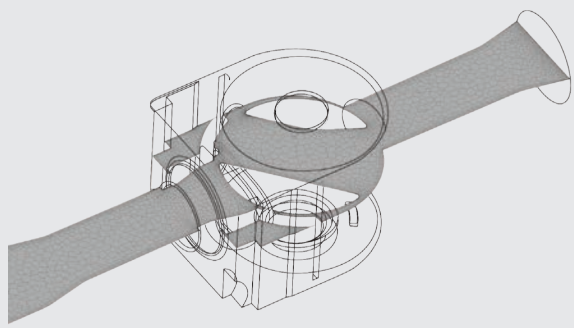
Without simulation, engineers would not have been able to observe and understand the flow pattern through the valve’s inner core and they would not have been able to improve the core’s geometry to reach their goal.

Fluent accelerated the redesigned valve’s path to market by enabling engineers to spend minimal time on the meshing and maximum time on solving the flow problem. The speed and ease for creating this excellent mesh generated quick results and allowed more designs to be evaluated.

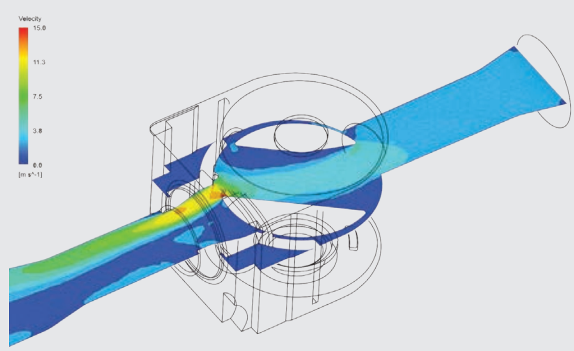
MCC optimized the valve’s design to improve the overall performance of the heating system. Operators now have precise control for adjusting the cabin’s interior temperature.



Overall volume mesh for CFD simulation



Cross section of created volume mesh



Velocity contour plot of valve at partially opened position