

Windshield De-icing Model

Courtesy of Visteon Automotive Systems

The de-icing of an automotive windshield is simulated using FLUENT (from Fluent Inc., Lebanon, NH) in this example. A finite layer of ice on the windshield is gradually melted in the transient analysis that includes the phase change of ice from solid to liquid. The FLUENT computational fluid dynamics (CFD) predictions are in excellent agreement with the melting patterns observed in a test vehicle.

The task of designing a windshield defroster is a difficult one. The defroster must adhere to government regulations regarding the time to clear a minimum specified area of the windshield. Previously, the process involved design, then construction of a trial defroster, followed by a testing program. Based on test results, adjustments to the initial design were made and the process repeated. At Visteon Automotive Systems, engineers have recently used CFD to augment this process. With a novel approach that uses a phase change model in FLUENT, they have been able to successfully predict the melt pattern that is observed experimentally. This success has paved the way to a more rapid turnaround time in the design phase of these systems.

The de-icing simulation performed at Visteon uses a steady-state flow field that emanates from grill work at the base of the inside of the windshield. The temperature of the air steadily increases with time and reaches steady-state based on a heater warm-up curve that is representative of the defroster output during

startup and normal operation. The windshield glass is modeled as a conducting wall, and a finite layer of solid ice is present on the outside of the windshield at the start of the calculation. The phase change model implemented in FLUENT through user defined functions makes use of an enthalpy-porosity method to track the fraction of solid (and liquid) in each control volume on the outside of the windshield. When the solid fraction reaches zero, the ice has melted and the windshield is assumed clear in that region.

To validate the model, the FLUENT predictions for a solid fraction of zero on the outside of the windshield

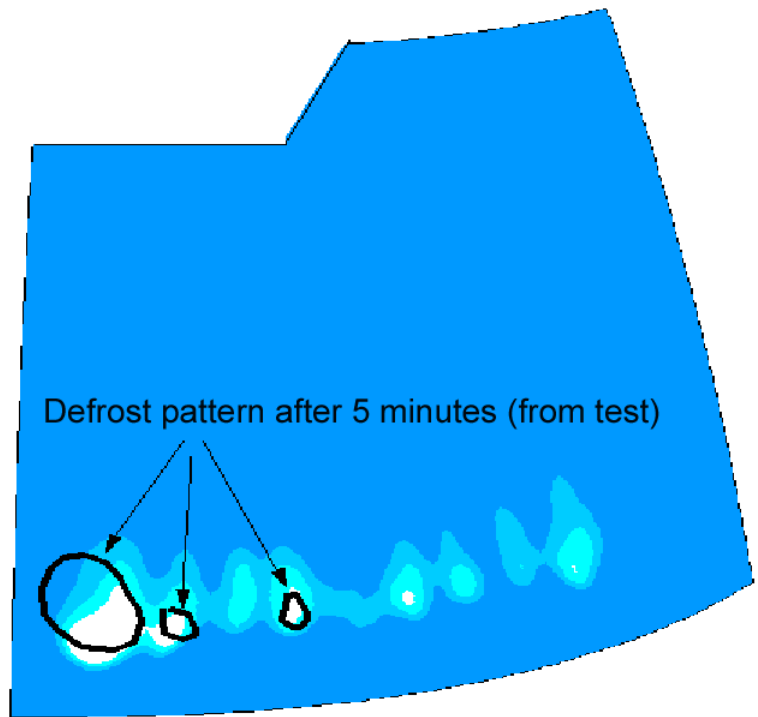


Figure 1: Comparison of FM VSS 103 defrost patterns from test and CFD analysis for Jaguar X200 at 5 minutes

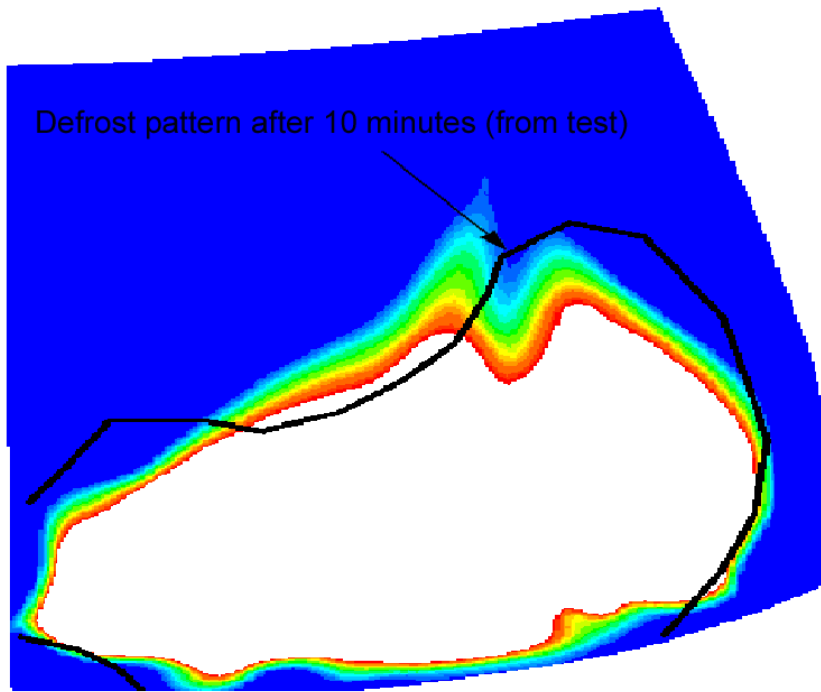


Figure 2: Comparison of FM VSS 103 defrost patterns from test and CFD analysis at 10 minutes

geometry is the passenger compartment and instrument panel. The model was originally developed using a CAD program, and the CAD geometry was then used to build a 3D tetrahedral mesh for use in FLUENT.

In this example, a CFD analysis of a de-icing unit has shown excellent agreement with experimental measurements. The transient analysis makes use of an increasing temperature in the defroster flow field, typical of startup conditions, and tracks the decreasing thickness of the ice on the external face of the windshield. After 5 minutes, the completely clear regions match the observed patterns, but the CFD results also show regions where the ice is thinning and about to clear. The observed and computed patterns at 10 minutes are almost identical. This analysis illustrates the power of CFD to save time

in the design cycle for these units, thereby cutting back on the overall cost of development. At Visteon, CFD is now being used extensively for this purpose.

can be compared to test results for the defrost patterns at different times. In Figure 1, the defrost pattern after 5 minutes of the CFD calculation (blue and white) is compared to test results after 5 minutes of defroster operation (black lines). Good agreement is seen. Note that the FLUENT results show not only the regions where complete melting has occurred, but regions where the ice layer is beginning to thin and where complete melting will subsequently occur. After 10 minutes of operation (Figure 2), the agreement between experiment (black line) and the FLUENT prediction is excellent. This agreement gives support for the phase change model to be used for this type of complex analysis.

The CFD results for the defrost pattern after 15 minutes are shown in Figure 3 along with a more detailed image of the windshield and interior geometry. The defroster unit is positioned below the windshield, and the output from the unit passes to the windshield through a set of grills, as shown. Also included in the

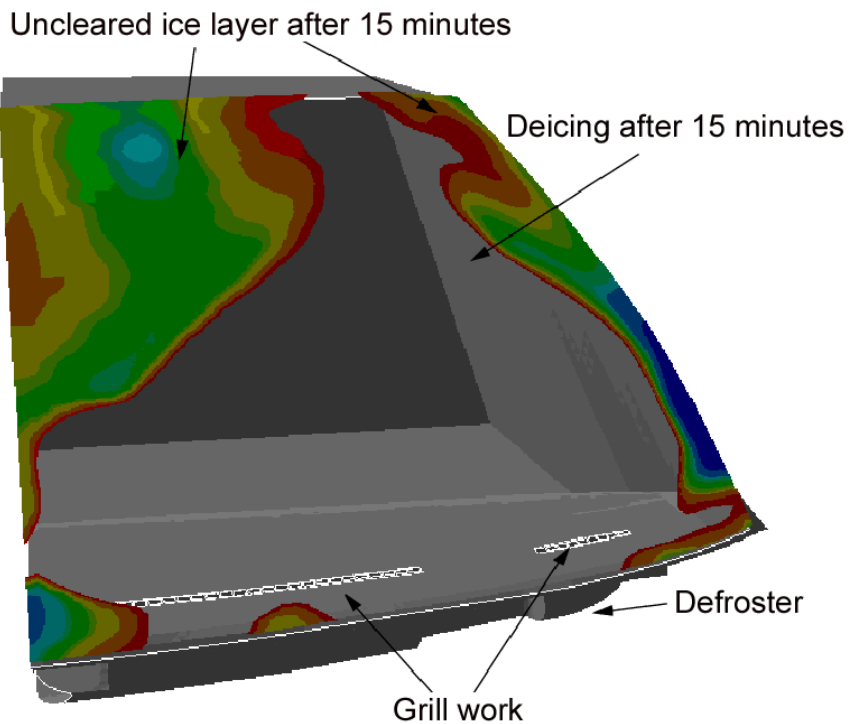


Figure 3 : Prediction of defrost pattern on windshield at 15 minutes into FM VSS 103 defrost test