Shape Optimization of a Defroster Duct

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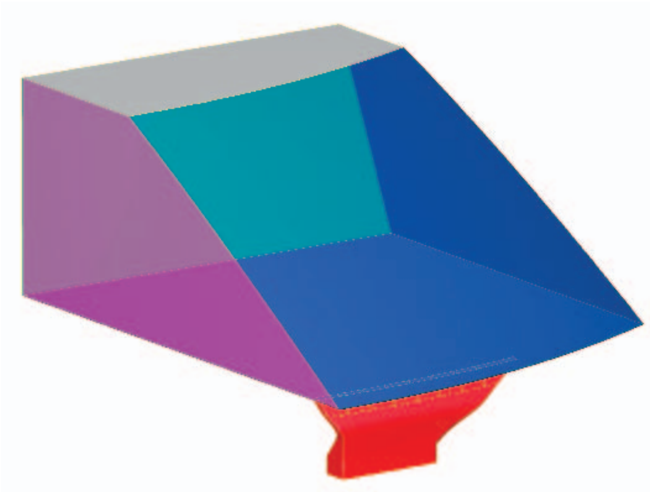
Courtesy of Hyundai-MOBIS

AN AUTOMOTIVE DEFROSTER is designed to remove frost from the windshield while adhering to government regulations regarding the time to clear a minimum specified area. Hot air is blown from the HVAC unit of the vehicle and through a duct to the inner surface of the windshield, where the defroster's performance is measured by the air temperature and velocity distribution. Optimization of the defrosting pattern is commonly achieved by altering the angle of the guiding grille at the windshield end of the duct to maximize the velocity impinging on the glass. Such intuitive tuning of the grilles, however, usually fails to produce flow patterns without some dead zones (areas of no air flow). Furthermore, the current numerical methodology – which involves making design changes in the CAD system and remeshing prior to simulating the flow field again and again – is painstaking and time-consuming.



Geometry of the automotive cabin with the defroster duct (red), windshield (blue), and symmetry plane (purple).

New techniques for design optimization have emerged that are based on parameterization of the CFD model. They automate the analysis process and greatly increase engineering through-put while reducing an engineer's time and effort. These techniques employ the integration of stand-alone software tools and the automation of the simulation processes. In this approach, software such as Meshworks/MORPHER from Detroit Engineered Products (DEP) is used for parameterization of the CFD geometry and for "morphing," or making rapid changes to the shape of an object within an allowable range of geometric parameters. FLUENT computes the air flow pattern for each new geometry. iSIGHT from Engineous Software enables the coupling (data exchange) between FLUENT and Meshworks/MORPHER, and provides optimization tools. The process is set up to run in a batch mode by executing a sequence of commands listed in script files. The overall purpose is to optimize a so-called "objective function." For the case of a defroster duct from Hyundai-Mobis, the objective function is to optimize the windshield air flow pattern so that uniform flow is achieved over the largest possible windshield area. This highly automated procedure requires less time and effort than that required to manually build new geometries and meshes for each geometry change considered, and yields optimized and refined design in the shortest development time.

The baseline (original) geometry of the defroster duct (top) and the optimum design (bottom)

Four shape design variables (DV) were defined for the defroster duct. These geometric parameters governed the shape of the duct and the angle of three of the grille vanes. A baseline FLUENT model was created, and subsequently parameterized for the four shape design variables using MeshWorks/MORPHER.

A design of experiments (DOE) process was constructed and, to fully explore the design space, a total of sixteen grille angle changes were studied. A parameter was introduced to assess and compare the results. Called the Percentage Area, it was defined as the percentage of total windshield area having velocity less than 1 m/s. Thus the objective of the exercise was to minimize this parameter for optimum performance. After the simulations were completed, an optimization algorithm was used to determine which case resulted in the minimum Percentage Area. In addition, a second optimization technique was performed in iSIGHT.

The study showed that the optimal duct design yielded a Percentage Area value of 17%, which is significantly better than the 42% value recorded for the baseline duct shape. ■

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