Peeking Under the Hood of TGrid Meshing Technology

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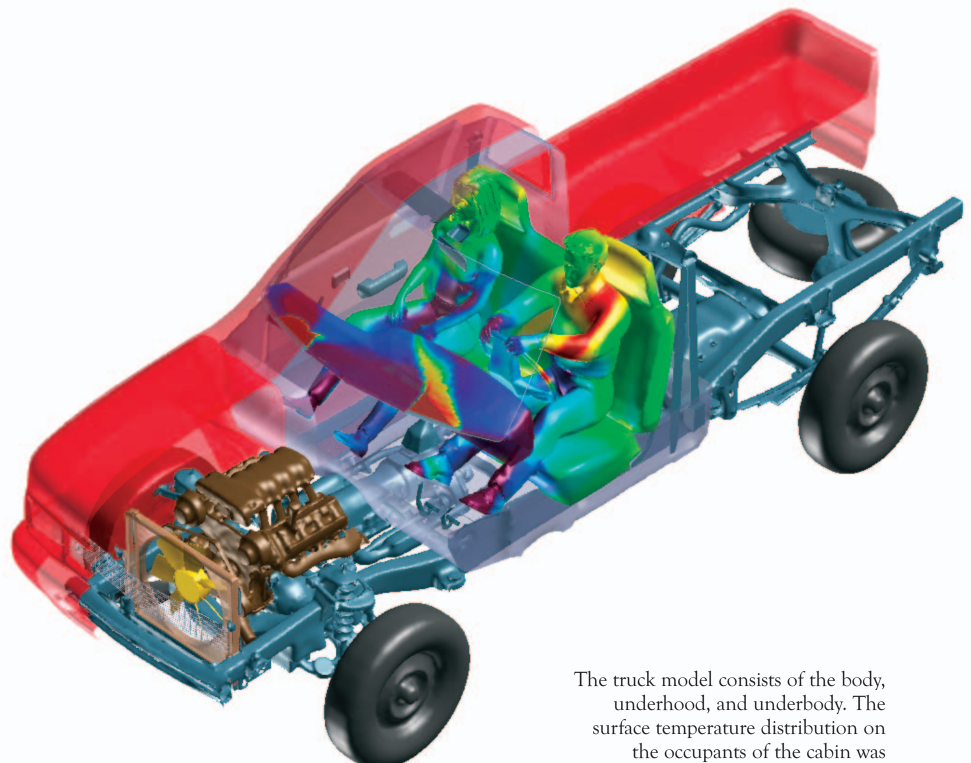
CFD SOFTWARE TOOLS are used today in virtually all stages of automotive development projects, from early design to final troubleshooting and adjustments. Thermal management is one critical aspect of such development as increased passenger comfort demands are resulting in more compact underhood packaging. Maintaining appropriate engine coolant temperature and efficiency, and installing thermal shields for components sensitive to hot engine and exhaust system parts are just some of the solutions that are required. In addition, reduced product development cycles have made the underhood meshing for thermal analysis one of the big bottlenecks in vehicle design.

In this example, a comprehensive model of a pickup truck is meshed and simulated using TGrid and FLUENT. The model encompasses heat transfer and turbulent flow on the exterior of the truck as well as in the underhood and underbody. A simulation of the cabin environment was performed separately.



The truck model consists of the body, underhood, and underbody. The surface temperature distribution on the occupants of the cabin was computed in a separate simulation

Surface Wrapping

The complexity of the geometry involved in an underhood CFD simulation poses several challenges. Traditional mesh generation approaches, which are based on connected and individually meshed boundaries, are both impractical and time-consuming. The surface wrapper approach in TGrid 4.0, however, is based on a coarse Cartesian grid overlaid onto the actual input geometry. This approach bypasses the need for a water-tight representation, and at the same time provides a significant amount of geometry simplification and cleanup. The application of this new method is demonstrated on the pickup truck underhood model with several hundred components.

Pre-Wrapping Steps

For this example, the work actually begins by using 3Matic-for-FLUENT. In this package, the vast majority of all CAD data can be processed in one single batch run. The process of stitching, closing holes, and skewness reduction results in an optimal starting geometry for the wrapping process in TGrid. In the pickup truck model, the geometry consists of 1,400 different parts and 400,000 triangular mesh elements. Usually though, there are a few holes and slits in the model that require manual healing. In this rough model, large holes are closed between the engine room and the passenger cabin, as well as around the wheels. These holes can now be closed quickly using several new tools that were added in TGrid 4.0, and diagnostics operations also exist to ensure that all leaks are sealed.

Using the Wrapper

The first wrapper operation starts with the size assignment, which typically ranges from fractions of a mm around the grille, fan, and cooling package, to around 30 mm at the back of the vehicle. A mix of fixed- and proximity-based size functions is used to ensure that important details are sufficiently captured. After initialization of the background grid, a crude wrapper surface consisting of nine million triangles is created. The wrapper surface is then imprinted on the feature edges of the original input geometry to better capture important details throughout the model.

Post-Wrapping Steps

Typically, the post-wrapping operation starts by resolving topological problems like overlapping, self-intersecting and folded faces. The next step, through a series of operations that preserve the features, is to reduce the cell count and improve the quality. Coarsening, in combination with smoothing, swapping, and using automatic local skewness improvement tools, produces the final optimal surface mesh. Zone separations of the wrapper surface ensure that part and boundary names are preserved. At this point, the original geometry can also be removed.

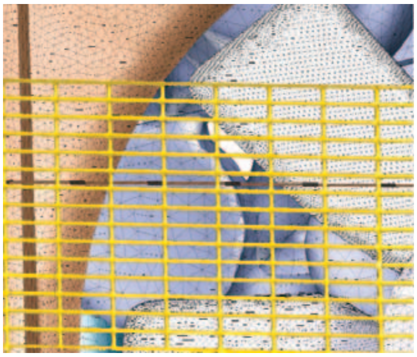
The final surface mesh of the pickup truck consists of 2 million triangles with a worst surface skewness value of 0.85. The bounding-box primitive is used to create the domain around the truck and wheels, which are intersected and re-meshed.

Volume Meshing and Solution

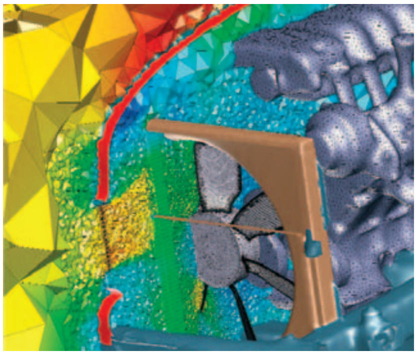
Before generating the final volume mesh, special attention is given to the fan, which needs very high-quality surface mesh resolution. The fan is also encapsulated in a cylindrical domain to enable the moving reference frame (MRF) feature in FLUENT. The crude heat exchangers and pre-heaters are replaced by carefully created prismatic block regions. These regions are connected to the surrounding wrapper surface using edge loop imprinting and intersection commands. Several loops of local refinement are applied on the initial tetrahedral volume mesh to improve the mesh density around the fan and gradually around the whole engine compartment. Of the final 15 million-cell volume mesh, a vast majority of the highly skewed tetrahedral cells are automatically fixed using the cell-modify and auto-correction functions, resulting in a final worst skewness value of 0.98.

The flow and thermal problem is solved in FLUENT 6.3 using the realizable k-ε model. The standard NTU heat-exchanger model is used with an inlet coolant temperature of 363 K. As mentioned above, the fan, with a speed of 2500 rpm, is resolved using the MRF model. The inlet air temperature is 273 K, and the engine parts have a specified temperature of 383 K. The results illustrate the detailed flow and thermal features through the engine compartment, and under the truck. The success of this highly complex analysis illustrates the enormous potential that the TGrid surface wrapper brings to other problems with a similar level of difficulty. ■

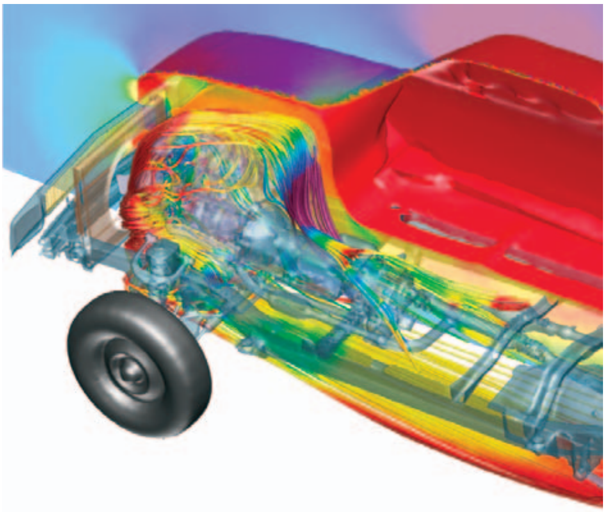
All figures postprocessed by FIELDVIEW from Intelligent Light



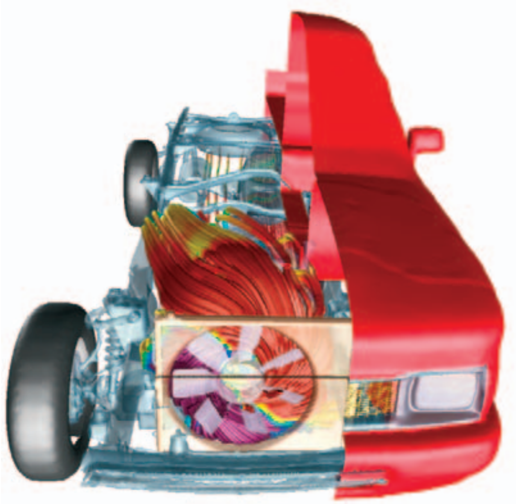
A view of the surface mesh through the front grille shows the increased detail on the edges of the fan blades



The tetrahedral volume mesh in the vicinity of the engine consists of regions with a wide range of cell size



Pathlines colored by temperature illustrate the flow in the underhood and underbody regions



The flow generated by the front fan is shown in this cutaway view