Adapting A High-Speed Train to Winter in Russia

Simulation helps prevent traction problems for rail travel during extreme weather conditions.

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The Velaro RUS train

Pathlines depicting airflow through the floor panel and traction components

When operating a high-speed train in the winter, one thing certain to be encountered is snow. At such high travel velocities, snow can swirl up and accumulate in the cooling air channels of the individual cars. This buildup of snow can be so large that the outside air taken in to cool the cars is reduced or the intake duct completely blocked. As a consequence, there can be a rise in temperature in the cars and under the floors that must be alleviated. If the temperature under the floors gets too high, the result can be failure of traction system components such as the main air compressor, traction converter, traction converter cooler, exhaust air unit and cooling fan of the traction bogie (the chassis carrying the wheels), which can lead to shutdown of the train.

At Siemens AG in Germany, designers faced an extreme snow buildup challenge while engineering the Velaro RUS, a 10-car, 600-passenger train built in Germany for operation at speeds of up to 155 mph (250 km/h). To solve the snow problem faced during Russian winters, Siemens installed an air intake on the roof to cool the traction components under the floor panels. In the summer, ventilation grates at the side slots of the under-floor components are opened so that some of the cooling air can be drawn in laterally. When the snow starts to fall, however, these grates are closed, which reduces the total cooling air flow by about one-third.

To completely seal the air flow in such a way that it can properly cool the traction components and also prevent snow from building up between the components, engineers designed a tray that encloses the traction component system. On most high-speed train cars, the traction components are fixed to the chassis and form the lower part of the car. On the Velaro RUS, the tray is fixed rigidly to the chassis, while the components are connected to the chassis elastically.

The ventilation system itself combines two main strategies. In the first strategy, the air is drawn in from above the roof and diverted to the lower floor panel. In the second, the air is distributed through the panel using a series of fans to direct the air at the components that need extra cooling.

In order to examine the cooling system of the Velaro RUS, researchers at the computational fluid dynamics (CFD) lab at the Friedrich-Alexander University, Erlangen-Nuremberg decided to use software from ANSYS, including ANSYS ICEM CFD tools to generate the grids and the ANSYS CFX product to perform the CFD computations. To ease the mesh generation process, university researchers divided the geometry into eight sections; the tetrahedral meshing capability of the ANSYS ICEM CFD tool was able to generate meshes even for the most complex geometry details. The research team then assembled the eight meshes employing general grid interfaces and a set of dynamic boundary conditions using the CFX Expression Language.

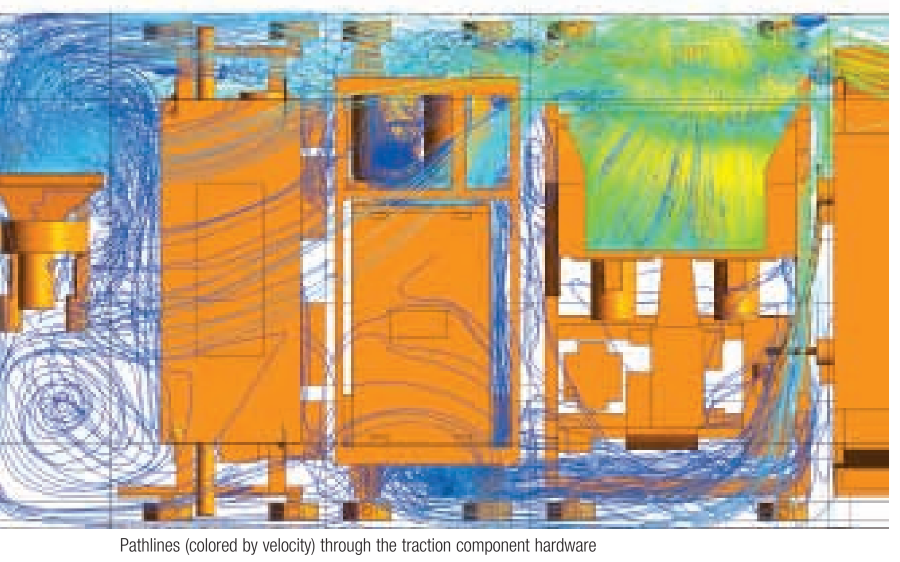
Researchers were able to specify the total flow rate at the roof inlet; however, they did not know the flow rates at the fans in the lower floor panel in advance. Only the corresponding pressure versus flow rate characteristics were available for the fan, which meant that the fan boundary conditions would need to converge dynamically within the CFD simulation.

The accurate calculation of the mass flow rates at the dynamic fan boundaries was a significant goal for this flow problem. Thus, researchers enabled the solution monitoring feature to observe the convergence of physical quantities beyond the standard solution residuals. The team then initiated the computation using 16 CPUs within an AMD Opteron™ cluster. Only 25 iterations were required to achieve initial convergence of the mass flow rates.

Complex meshes of different traction components generated by ANSYS ICEM CFD meshing software

In performing a post-processing examination of the converged results with CFX-Post, the university researchers made extensive use of the CFX power syntax, which is based on Perl™ and the CFX Command Language (CCL). With this approach, they determined precise information about the flow conditions at each traction component, including mass flow rates, pressures, temperatures, velocities and many other physical quantities. The analysis included a study of the temperature distribution for both summer and winter operation. The research group created a series of plane cuts to evaluate the effectiveness of the cooling environment under the floor of the train car. They then were able to easily generate all of the streamline visualizations that were required to provide detailed information about the flow around the traction components, which allowed for a qualitative and intuitive understanding of the cooling air pathways.

In conclusion, CFD software allowed the university research team to manage a complex problem. Simulation contributed significantly to understanding where the cooling efforts were effective and where they were not, which led to adjustments and design modifications that improved the system. With the results from the university study, Siemens was able to confirm the dimensioning of the air intake at the roof and the cooling fans, as well as the operating temperature of the underfloor traction components. ■



Pathlines (colored by velocity) through the traction component hardware