

POWERFLOW FOR COOLING AIRFLOW



3DEXPERIENCE®

Adequate cooling airflow through heat exchangers is an essential element of vehicle thermal management. Many other vehicle systems, such as engine cooling, transmission, HVAC, and power steering have significant cooling requirements and their thermal efficiency has a direct impact on the fuel economy, performance, and comfort aspects of a vehicle. The design of a cooling airflow management system should also account for the constraints and design issues related to front-end appearance, as well as the trade-offs with other vehicle performance characteristics (such as aerodynamic performance).

Recent trends in the industry towards more powerful engines with higher heat rejection requirements and ever tighter underhood packaging pose significant challenges in the design of efficient cooling airflow systems. To comply with warranty requirements, the OEM must also ensure that supplier-provided components such as engines and transmissions will operate within the specified temperature ranges. Accurate prediction of the cooling of thermal components and systems early in the product development process is essential.

Technical Challenges

Accurate prediction of cooling airflows is required to reliably predict the performance of thermal management systems under realistic vehicle operating conditions. The flow patterns and air temperature distribution in the underhood area are highly complex and transient due to the intricate interaction of the ram air and cooling fan flows, along with variations in air density and temperature as a result of heat from the thermal systems. In addition, they are very sensitive to vehicle operating conditions and fine geometric details. Therefore, a high-fidelity simulation is necessary to capture the relevant physics associated with cooling airflow prediction.

Vehicle thermal management is a system design problem. There is a complex interaction between multiple heat exchangers commonly found in modern vehicles and with other underhood components such as cooling fans, shrouds, and the engine block, as well as with system-level controllers. The entire system must be analyzed in order to optimize system-level performance.

SIMULIA Solution

PowerFLOW's unique, inherently transient Lattice-Boltzmann-based physics enables it to perform simulations that accurately predict real-world transient conditions in the most complex geometry. Each simulation predicts time-accurate evolution of the airflow around the vehicle and through the engine bay and underbody. Air density and temperature variations and their effects on the velocity field are fully accounted for. This is particularly important for idle conditions where buoyancy effects are significant. The ability to simulate with fully detailed geometry makes it possible to investigate the effects of geometry details (such as seals to prevent leakage and recirculation) on the local flow field. Cooling fans are an important mechanism to drive the cooling airflows, especially at low vehicle speed. PowerFLOW features true rotating geometry, providing fully accurate simulation of moving cooling fans.

The heat rejection from heat exchangers is calculated using PowerCOOL — a fully coupled heat exchanger modeling tool. PowerCOOL uses the precise airflow distribution provided by PowerFLOW as its input, then calculates the coolant side temperature distribution, top-tank temperature, and heat rejection information. PowerCOOL handles various types of compact cross-flow type automotive heat exchangers including radiators, charge-air-coolers, oil coolers, and condensers.

Using this coupled simulation approach, you can:

- Estimate heat exchanger and fan performance under vehicle installed conditions (including multiple heat exchangers, fans, shroud, and blockage effect) for a wide range of vehicle operating conditions (including high and low vehicle speeds, and idle).
- Improve the design of individual components of the cooling package for better efficiency.
- Analyze various cooling system layout concepts against thermal design limits.
- Identify the relationship between vehicle front-end design (grille opening size, location, and texture) and the cooling airflows.
- Optimize the underhood component layout to minimize the system resistance to cooling airflows, which contributes to the overall drag of a vehicle.

Using the PowerFLOW cooling airflow solution can significantly reduce the need for prototype testing in thermal wind tunnels. You can perform the design and testing of the cooling package well before prototypes are built. This results in a significant reduction in design cost, and drastically improved quality of the first prototype. Renault reported an approximate 30% reduction of the time spent in the thermal wind tunnel. Significant improvements of the cooling performance were also reported by AGCO (for off-road vehicles) and Bentley (for performance cars).