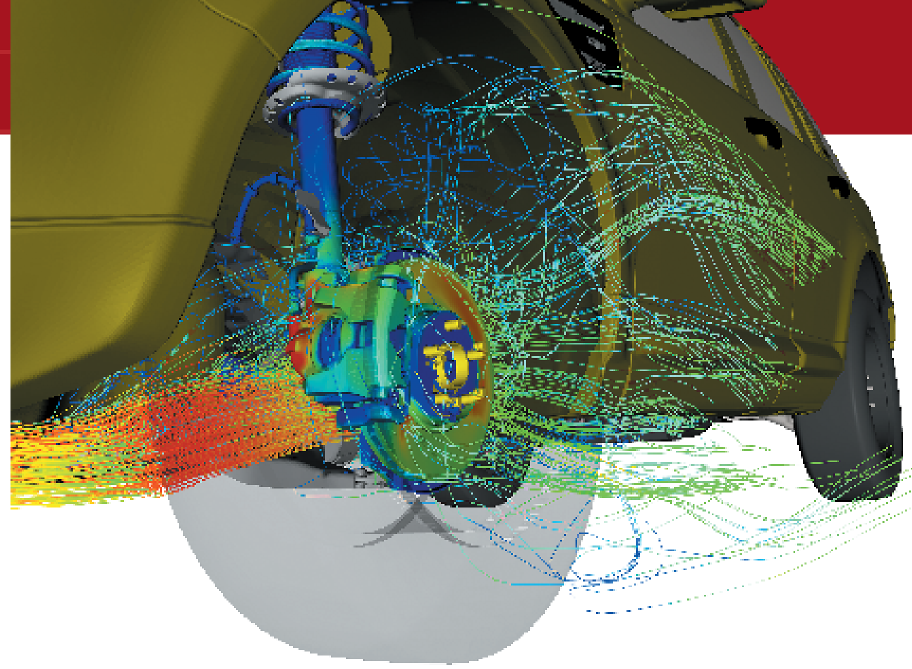
THERMAL MANAGENT

BRAKE COOLING

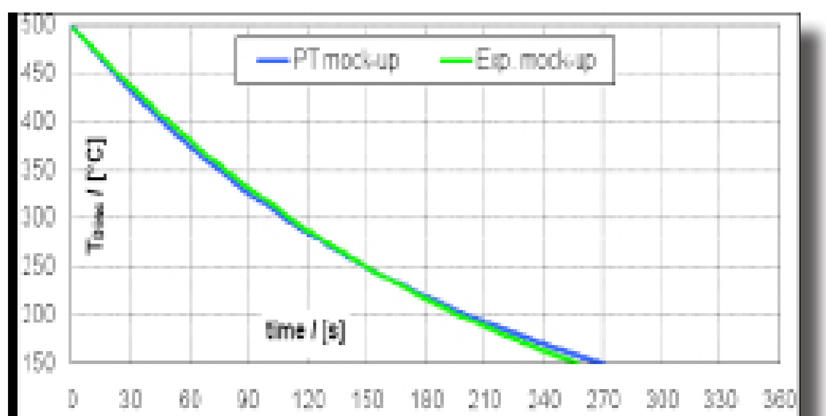


Above: Simulation of airflow through brake assembly on vehicle. Comparison between the measured and predicted brake-disc temperature during the cool-down.

KEEPING COOL UNDER PRESSURE

The brake system is a critical part of any vehicle and its failure could endanger passenger safety. Brake performance must be guaranteed with extensive testing under extreme conditions. Brake system design needs to be highly optimized to prevent the disc from overheating, which reduces braking efficiency or could lead to complete system failure. Aerodynamic cooling of the brake disc through convection is the key mechanism for maintaining the brake within acceptable operational temperature levels. You can apply additional cooling devices like brake air ducts to provide more cooling airflow to the disc, but these add to vehicle weight, increase aerodynamic drag, and increase both production and consumer costs. Moreover, brake operation is increasingly controlled through regulations that call for prediction of performance over a standard brake duty cycle. Manufacturers must be able to accurately predict brake performance at an early development phase to avoid expensive overdesign or late-stage design changes, and to reduce or eliminate expensive prototype testing.

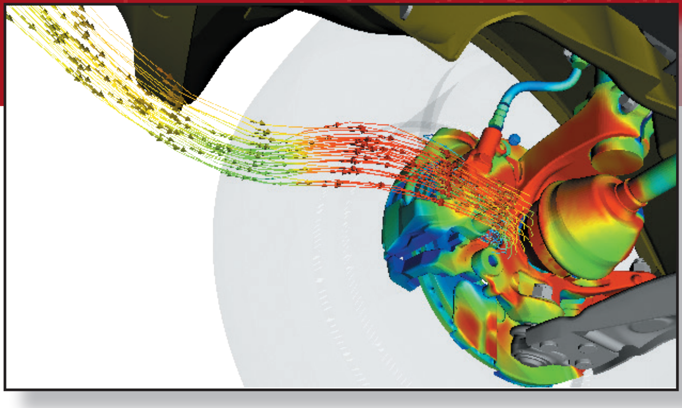
TECHNICAL CHALLENGES



Accurate testing of brake system performance traditionally requires a physical prototype for conducting extensive road or wind tunnel tests. In these tests, the brake disc is heated by braking through single or multiple braking cycles to a high temperature level. The subsequent cool-down time is measured. If the maximum temperature level exceeds the allowed range or the cooling rate is not sufficient, aerodynamic changes are the main option to improve the cooling performance. This kind of physical testing can be done only in a late design stage, when a prototype exists. In earlier design stages, the brake disc can be tested on a test bench only, but this is not representative of the actual vehicle. The brake system operates in an environment with extremely complex turbulent flow, with interaction between underbody, underhood flows, and rotating wheels. Visualizing and understanding this complex flow in detail is essential in order to assess adjustments to the geometry of the brake system — but this is virtually impossible to do with any kind of physical testing. Clearly, brake cooling must be analyzed with a simulation tool early in the design cycle.

Brake disks get very hot quickly, and their temperature is a function of the complex interaction between conduction, radiation, and convective cooling to the surrounding air. Any simulation must be able to accurately predict this interaction in an easy to use way. Furthermore, the all-important cooldown is, by definition, a transient problem occurring on a longer timescale than most fluid simulation tools can handle.

BRAKE COOLING



Thermal simulations through engine show overheated areas in baseline model which were able to be cooled though design modifications after PowerFLOW simulation & analysis.

EXA SOLUTION

Exa provides a solution to accurately predict thermal brake performance under extreme testing conditions in an early design phase. PowerFLOW's unique, inherently transient Lattice Boltzmann-based physics enables it to perform simulations that accurately predict real-world transient conditions on the most complex geometry. PowerTHERM is a fully-coupled, highly accurate, transient, conduction and radiation solver. The combination of PowerFLOW and PowerTHERM provides a complete thermal analysis, including all three heat transfer modes, and enables you to accurately predict temperatures and visualize the flow and temperature fields for the brake system. This enables you to not only identify problem areas, but provide design recommendations that eliminate problems. Rapid turnaround time for model setup, simulation, visualization, and design modification enables you to quickly make design changes to the baseline and evaluate the improvements in brake performance.

PowerTHERM can be used for long transients on the order of minutes or hours. It can also be used standalone for quick design iterations such as evaluation of additional thermal isolation. Detailed best practices methodology for brake cooling simulation is available.

Using Exa's solution for brake cooling simulations, you can:

- Accurately predict brake disc temperature rise over multiple braking cycles and the cool-down rate early in the design cycle.
- Reduce or eliminate expensive physical brake cooling tests and prototypes.
- Efficiently optimize the design with intelligent geometric modifications, preventing overdesign or unnecessary measures that increase drag, and production and customer costs.
- Perform rapid design for a wide range of vehicle operating conditions and braking cycles.

SELECTED REFERENCES:

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