ON THE FAST TRACK

Ferrari pushes the limits of simulation in improving aerodynamic performance of racing cars.

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Aerodynamics plays a key role in motorsports. Ferrari S.p.A. has made dramatic improvements in its racing cars' aerodynamic performance by combining computational fluid dynamics (CFD) simulation and wind-tunnel testing. Ferrari engineers have extensively automated the simulation process and run many design iterations to explore the design space and improve speed, reliability and safety. It takes about three to four weeks to arrange a session in the wind tunnel, while company engineers can perform more than 100 CFD simulations in the same time period. Simulation dramatically increases the number of different

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Simulation enables substantial performance improvements that have played a key role in Ferrari's many track victories.

aerodynamic alternatives that can be evaluated, enabling substantial performance improvements that have played a key role in Ferrari's many track victories. "The contribution of simulation is huge," said GT Driver Gianmaria Bruni, winner of the 2012 24 Hours of Le Mans in a Ferrari 458 Italia.

GT2 RACING

Ferrari has been involved in racing since the company began, competing in a wide range of categories. Ferrari's current GT2 entry is the 458 Italia GT2, which is based on the 458 Italia production model. Aerodynamics plays a major role in the design of these cars because the shape of the upper part of a GT car body generates lift, so the underbody must be designed to create down-force. This increases the tires' gripping capabilities during braking and cornering, without increasing drag. Ferrari improves down-force in GT2 cars by smoothing out the underbody and adding diffusers at the rear to intensify air speed and mass flow under the car. A diffuser ejects air from the underside of the car, causing an increase in velocity and a reduction in pressure of air below the car. The slower-moving air above the car generates a higher pressure, and the resulting pressure differential pushes the car onto the ground.

On the latest 458 Italia GT2 model, Ferrari engineers performed hundreds of CFD simulations with ANSYS Fluent to optimize the aerodynamic performance of the car. In general, the process begins when the design team provides a proposed design in the form of a computer-aided design (CAD) file. An analyst then manually generates the surface mesh, the only part of the process that is done manually. Then an automation script takes over and executes the entire simulation process, starting with generating a volume mesh based on the surface mesh, specifying boundary conditions, and running the CFD solver. In early stages of the design process, analysts typically evaluate one proposed design at a time and closely examine flow speed and direction as well as pressure around the body to understand the performance of the design and how it might be improved.
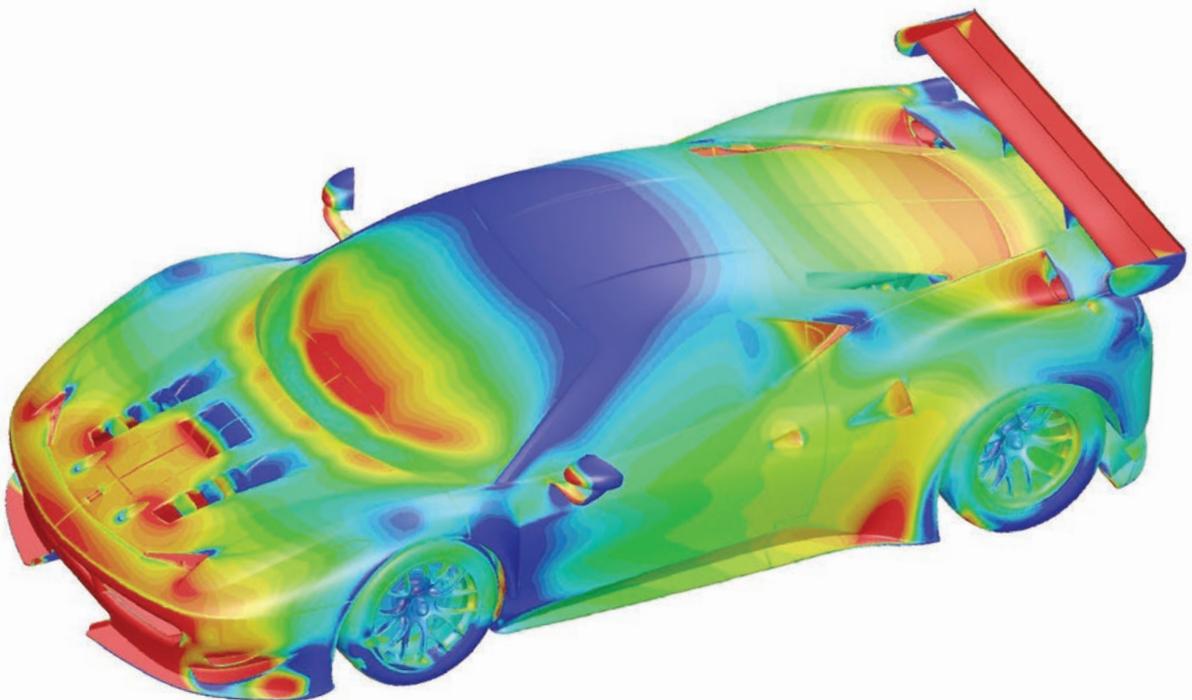
▲ High down-force configuration of F458 GT2
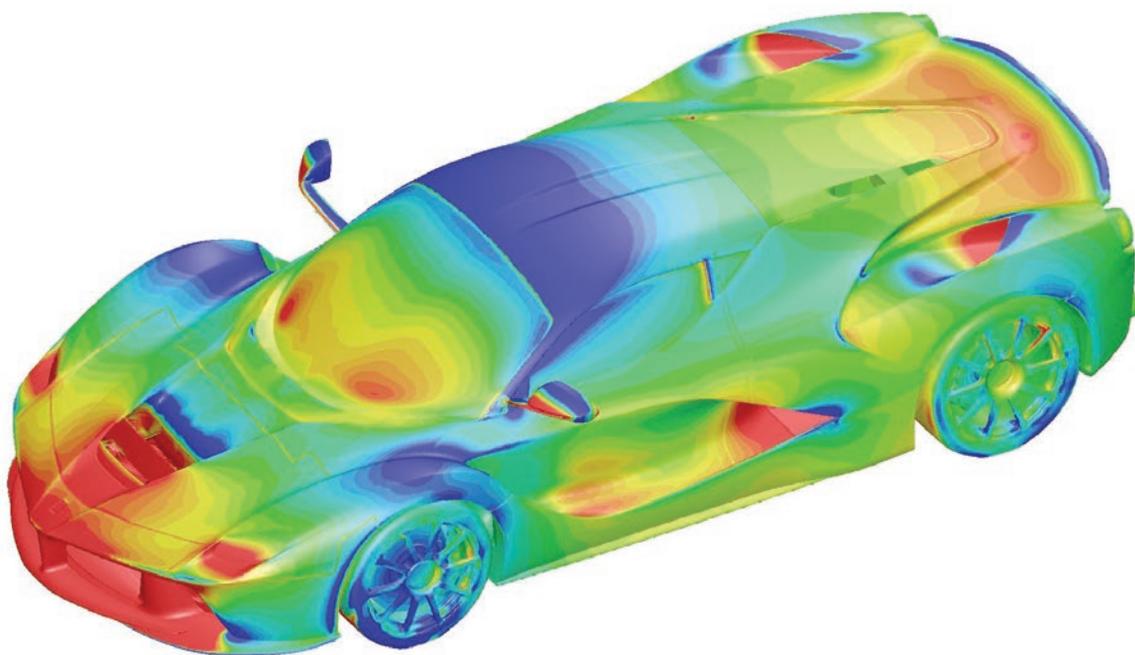
▲ Low down-force configuration of LaFerrari

The ModeFRONTIER optimization tool runs tens to hundreds of simulations without user intervention to evaluate the design space. ▼

OPTIMIZING THE DESIGN

Once analysts gain a general understanding of flow patterns and which design parameters have the most impact, they set up a design of experiments (DOE) using the ModeFRONTIER® optimization tool, which runs tens to hundreds of simulations without user intervention to evaluate the design space. ModeFRONTIER provides several different optimization algorithms, including the response-surface method (RSM) that is fitted to the data points revealed by the DOE. This technology allows Ferrari to explore the design space with minimal computational effort. ModeFRONTIER also provides genetic algorithms to evolve a group of candidate designs toward better solutions. The simulation is run on a high-performance computing (HPC) compute cluster. ANSYS Fluent splits up the mesh and data into multiple partitions, then assigns each mesh partition to a different compute node.

The position of the car's components often constrains the aerodynamic design. For example, if engineers are working on the rear diffuser, that part's maximum expansion is limited by the presence of the frame and the muffler. So they configure the optimization tool to examine only expansion angles and curvatures of expansion for the diffuser that can be accommodated without interference. Sometimes the aerodynamics team removes constraints to determine if a large improvement might be achieved in the absence of a constraint. In that case, the aerodynamics team meets with the design department to see if the design can be altered to remove the constraint.

Ferrari engineers have used these methods to optimize the down-force on the 458 in a number of areas. They have applied CFD to evaluate vortices under the body of the GT2 cars and evolve the body design to minimize the vortice's impact. In addition, they have optimized brake cooling inlet and outlet ducts with simulation. The geometry of the brake cooling ducts has a critical impact on brake performance as well as on the down-force on the car's front axle. The complexity of the brake cooling ducts' geometry makes the ducts very difficult to evaluate in a wind tunnel, so these critical areas are designed nearly entirely with simulation. CFD analysis showed that even the side mirror's design is closely related to the shape of the engine air intake. By examining the streamlines around the side mirror on the 2014
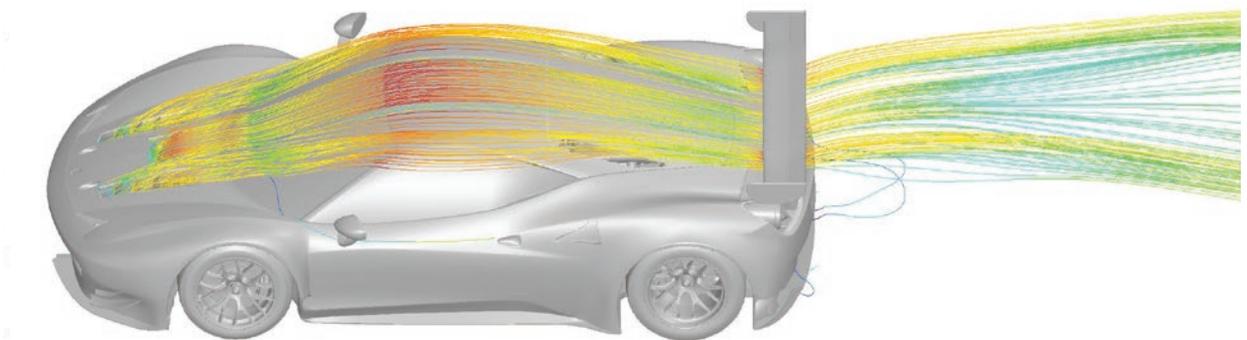
▲ Ferrari GT2 racecar

GT2 model, engineers modified the shape of the mirror to get the best performance without having a negative impact on the engine air intake.

LᴀFERRARI

Ferrari engineers used ANSYS Fluent to optimize the aerodynamic performance of LaFerrari — a limited production hybrid sports car that was officially unveiled at the 2013 Geneva Auto Show. Ferrari engineers performed more than 1,000 CFD simulations on LaFerrari, saving between 40 and 50 hours of wind tunnel testing. LaFerrari has active aerodynamics

devices in the car's front and rear, which help to increase down-force and reduce drag. The front of the car has three flaps: two lateral flaps in the front diffusers and a variable flap in the radiator. The rear of the car has a wing and an air-active rear spoiler. Ferrari engineers used CFD to optimize the aerodynamic performance of each of these devices. They ran a design of experiments that evaluated the aerodynamic performance with the car at different speeds; in different pitch, roll and yaw positions; and with the variable flap in different positions.

Time is a critical success factor, so development schedules are very tight. For this reason, Ferrari engineers need to perform simulations and tests as quickly, reliably and efficiently as possible to better drive style and design, ensure accuracy, and achieve performance targets. HPC solutions from ANSYS, including recent software advances — such as improved parallel scaling performance for very large simulations, hybrid parallelism for multicore processors within clusters and support for parallel file systems — enable the Ferrari team to improve car performance while adhering to development schedules.

Every new racing car developed by Ferrari must rise to a new level of aerodynamic performance to match the successful results it has achieved on the track over the past 80-plus years. The time required for wind-tunnel testing makes it impossible to achieve performance targets within the allotted timeframe. By combining CFD to understand the application, evaluate the design space, and iterate to an optimized design with wind tunnel testing for verification and validation, Ferrari is able to stay at the forefront of aerodynamic performance. The results are victory after victory in prestigious races. For example, the 458 Italia GT2 won the 2011 Petit Le Mans, the 2011 Intercontinental Le Mans, the 2011 Le Mans Series and the 2012 24 Hours of Le Mans. The aerodynamic technology developed for race cars is quickly transferred to road cars. "Simulation has been vital to our victories," Bruni concluded. ∧

▲ Streamlines from radiator outlet of F458 GT2