Automotive and transportation

Renault F1 Team

Racing team uses Simcenter STAR-CCM+ and Fibersim to support continuous innovation

Products

Simcenter, NX

Business challenges

Design a high-performance race car within the constraints of complex regulations

Facilitate performance, reliability and safety

Maintain a disruptive innovation cycle

Keys to success

Integrate CFD with wind tunnel testing and simulation programs

Provide design engineers with CFD capability

Use Fibersim to integrate design, analysis and production of composites

Results

Improved performance by simulating complex fluid flows

Enhanced understanding of how tire shape and deflection affect flow

Gained consistency and repeatability with CFD templates

Enabled agile response to competitive pressure

Expanded capability to respond to new regulations

Siemens Digital Industries Software solutions enable aerodynamic efficiency and accurate production of composite components

Driving with downforce, drag and danger

The dynamic between grip and drag dictates design preparation for each race in the Formula One calendar. A large rear wing creates the downforce required for tight cornering at Monaco. For Monza, where too much downforce would slow the car on fast straights, a slender rear wing is needed.

"Good grip enables the car to go faster but downforce also produces drag, which must be overcome by engine power," says Peter Machin, head of aerodynamics at Renault F1 Team. "The ultimate goal is to generate a vertical force and push the tires into the ground while minimizing drag."

The workflow of a Formula One car design is a 365-day-a-year process. Throughout the season, surfaces are continually being adjusted to accommodate the track, the driver and climate conditions.

"Our car could be seen as an aerospace prototype," says Luca Mazzocco, head of technological partnerships, Renault F1 Team. "We need to deploy innovation race-by-race if we want to be a credible challenger, and that can be on a weekly basis and on 21 different tracks around the globe."

Seventy percent of a car's performance stems directly from its aerodynamic behavior.

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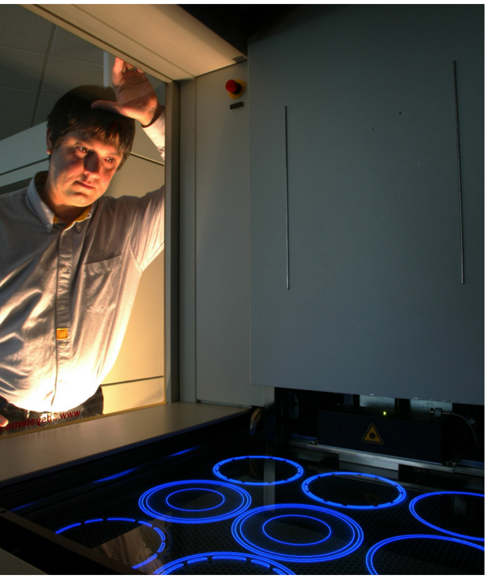
Ian Goddard
Head of Technical Partnerships
Renault F1 Team



Incremental improvements are made on a day-to-day basis as stiffness, weight and cost effectiveness are balanced. Not surprisingly, aerodynamics is the largest department at Renault F1 Team; it commands the biggest budget and its supercomputer produces 60 terabytes (TB) of data each week.

Aerodynamics involves both physical testing and simulation. Aside from the inherent limitations of a wind tunnel, the nature and extent of physical testing is restricted by Formula One regulations. The use of computational fluid dynamics (CFD) software is critical and, for over 15 years, the company has been using Simcenter™ STAR-CCM+™ software from product lifecycle management (PLM) specialist Siemens Digital Industries Software.

As the use of strong, lightweight carbon fiber is critical to a racing car’s aerodynamic performance, Renault F1 Team also uses the Fibersim™ portfolio of software for composites engineering from Siemens. This is used to manage the design, analysis and manufacture of fiber-reinforced composite parts.

Correlating data from different sources

Paul Cusdin, head of CFD for Renault F1 Team, says, “Our challenge is to ensure that the computational domain correlates with data captured from the wind tunnel, so we can ensure that every design upgrade will actually match up with reality.”

The focus is not only on speed; CFD is used for thermal simulation because an overheated car is a potential danger and must be called into the pits. On the other hand, there are clear restrictions on how much cooling can be applied to the engine during a race. CFD is also used to simulate the action on the track, particularly when another vehicle directly in front is creating turbulence that not only makes it difficult to overtake it but could lead to a critical loss of downforce in one part of the car.

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Paul Cusdin
Head of CFD
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Another major question for the CFD experts at Renault F1 Team is how to get the most from the tires. It is not easy to model the geometry and wake behavior of tires in a wind tunnel, especially in high-speed corners when tire shape fluctuates. Another consideration is that within a tunnel, wind moves over the car rather than the car moving over ground.

"This area is where we have the least correlation between the physical and the computational," says Cusdin. "Yet we need to extract more from the tires, for example, by placing geometry around the floor of the car in the best way possible for aerodynamics performance."

Revealing the physics of flow

CFD offers a design team insight into what happens in the wind tunnel. "It shows the precise airflow over the car and tells us why we are getting certain results," says Cusdin. "For example, simulation shows whether a vortex is above the wing or below it. It can introduce heat, which we cannot do in the wind tunnel, and illustrate thermal interaction. It tells us more about a specific design, indicating if it is close to optimal. In short, the computational domain not only augments the physical domain, it also improves it."

In one instance, members of the CFD team were looking to incorporate the power of the fast-moving air from the exhaust to enhance downforce, but results on the track were disappointing. By further analyzing the physics, they discovered that modeling the exhaust as a steady jet rather than a series of pulses had inadvertently led Renault F1 Team designers down the wrong path. CFD solved this engineering challenge by simulating the pulse aspect and allowing engineers to visualize its repercussions on the airflow.

Enabling speedy innovation

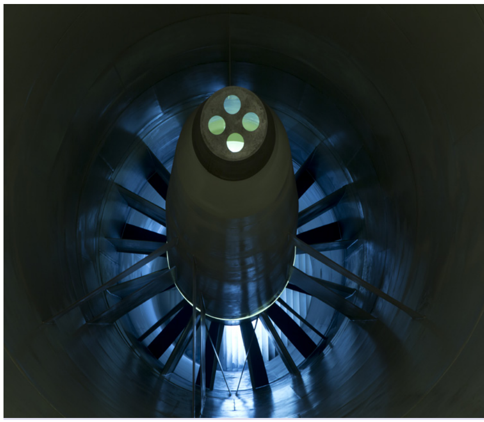
"When we test different geometries in the wind tunnel, we learn whether they are better or worse than the prior design, but we only rarely understand exactly why," says Cusdin. "Understanding the vortex created by the front wing is particularly important because the rest of the car depends on that; yet CFD has been rather poor at capturing the wake structure at the front of the car.

"However, Siemens introduced a turbulence model within the latest enhancements for Simcenter STAR-CCM+ and now we can look at all the vortices shed off the front, side and rear and clearly see how these react with the field downstream."

The CFD team aims to calculate and recalculate design changes within a few hours so that clear information is available for designers.

"Our simulation pipeline is very simple," says Cusdin. "Other CFD software requires extensive coding, but we only write code for each new set of environmental parameters. This is the unique advantage of Simcenter STAR-CCM+ and it means that we can create templates for the design team."

As a result, design engineers can replace any surface and continuously re-run the same simulation. By accessing templates from within the system, they do not even have to open Simcenter STAR-CCM+ or see the solver. In this way, the CFD team iterates in step with the design department as aerodynamic shapes are assessed for performance. Promising geometries are sent to the wind tunnel and possibly reassessed through CFD. Designs are released for manufacture only when results from the wind tunnel match those from simulation.
In accordance with Formula One regulations, the wind tunnel car is a 60 percent scale model. Because of the fast testing cycle and shape complexity, most wind tunnel model parts are made using additive manufacturing, a technology that is also involved in making several full-scale car parts. In some cases, this process can be completed overnight, though more complex parts may take several weeks.



Using composites for lightweight strength and stiffness

Composite components are formed when pre-impregnated materials are layered into a mold and cured in autoclaves at high temperature and pressure. The result is an extremely strong, light and stiff material that contributes to both performance and safety: Composites account for 85 percent of the volume of a racing car, but only 25 percent of its mass. The low mass of composite material enables engineers to alter the position of a car's center of gravity, and this can have a significant influence on handling characteristics.

When aerodynamic surfaces are released they lack structural properties, so the first stage of manufacture involves a close liaison between stress engineers and laminate

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Solutions/Services

Simcenter STAR-CCM+
siemens.com/simcenter

Fibersim
siemens.com/fibersim

Customer's primary business

Renault F1 Team consists of the Renault R.S.18 chassis, developed and manufactured in Enstone, Oxfordshire, England, while the Renault R.E.18 power unit is developed in Viry-Châtillon, France.
renaultsport.com

Customer location

Enstone, Oxfordshire
United Kingdom

design engineers. They work together to optimize the structure of a part, determine the type of composite material to be used and organize the layers of laminate.

"Fibersim ties departments together through one single digital model, which becomes the baseline for how data migrates through design and ultimately to manufacturing," says Ian Goddard, head of technical partnerships at Renault F1 Team.

There are over 1,000 pieces of composite material in a race car, and Fibersim was first used by Renault F1 Team for the most complicated parts, such as the chassis. Goddard continues, "Having evolved the process over many years to gain control of things like the chassis, we decided to apply the same mindset to everything and introduce control methodologies on all components, from the tiniest little bracket up to aerodynamic wings and right through to our crash structures. Having that level of confidence and control through a single 3D Fibersim model, we can really improve the overall quality of the parts we manufacture."

Fibersim enables complete precision during the manufacturing process. It is used to determine the optimal way to overlap layers and send precise instructions to the machine that cuts flat patterns. It also drives a laser projection guidance system in the clean room. This projects a green laser light into molds, indicating to the laminators exactly how and where to position and cut individual pieces of material in order to create each ply.

"With Fibersim, we really get repeatability and consistency beyond what we could achieve with simple measures and dimensions," says Goddard.

Efficiency through repeatability and consistency

"Our pipeline is a huge shortcut. It saves time, gives repeatability and the use of templates provides consistency," says Cusdin. "CFD gives us significant direction and I anticipate expanding our use of Simcenter STAR-CCM+. Whereas physical testing is both expensive and time consuming, there are far fewer limits on digital experimentation."

Machin adds, "CFD software is absolutely critical; without it we would not know how to use wind tunnel testing to improve performance. Simcenter STAR-CCM+ feeds decision making by enabling us to assess where the biggest performance gain is."

With constant technological and regulatory change, the development cycle at Renault F1 Team is both dynamic and relentless.

"We need technical partners who really want to embrace our challenge to innovate under pressure and we truly value the relationship we have with Siemens Digital Industries Software," says Mazzocco.

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