TIRE SIMULATION AND VIRTUAL TESTING

Get the Future of Sustainable Tires Rolling

DASSAULT SYSTEMES

"We can reduce the time required to develop the tire. And I can say that using the platform we were able to shorten this time by 25%."

Masayuki Kanai, Director, Vice President & Senior Corporate Officer, Division General Manager of the Digital Innovation Division at Toyo Tire

READY FOR A CHANGE?

The tire industry is undergoing several major upheavals. In particular, the urgent demand for more sustainable products is driving innovation. Both consumers and manufacturers recognize the need for change. Increased regulations and compliance, driven by climate change targets, influence supply and demand, resulting in new business models. The trend towards **CASE** (Connected, Autonomous, Shared and Electric) mobility is becoming mainstream:

- **Electric vehicles** are being rapidly adopted, and their weight and torque require much stronger tires than other passenger cars, while their quietness compared to internal combustion engines (ICE) mean that there is growing demand for acoustic dampening of tire noise.
- **Carsharing** and the boom in delivery services mean that the demand for the **Tire as a Service** (TaaS) model is increasing. Fleet managers look to tire manufacturers to maximize their fleet's performance, particularly with increasing mileage, and minimize downtime.
- **Connected vehicles require connected tires**, with sensors to monitor tire conditions and antennas to transmit this telemetry data.

Tire product ranges therefore are becoming wider to meet increasingly varied customer demands. To manage this diversity, tire manufacturers are now working on **modular tire designs**.

The environmental impact of tires is also coming under growing scrutiny, in particular, the impact of particulate matter generated by wear, which is included in the proposed Euro 7 standards. Finding new materials that are more resistant to wear and less problematic in the environment is recognized as being fundamental to reaching sustainability goals. Recent studies have shown that over half of small particle pollution from road transportation comes from tires and brakes. In addition, companies are having to innovate and develop some radically new concepts for their tire designs, including airless, self-healing, and lightweight tires.

This e-book demonstrates the benefits of **unified tire design and simulation** and the advantages of creating a **virtual tire twin**. Simulation is helping tire manufacturers to meet and exceed their targets faster, reducing development and testing time by as much as 25%, and giving them a crucial edge in the race to market.

MEET CLASSIC CHALLENGES WITH TIRE SIMULATION

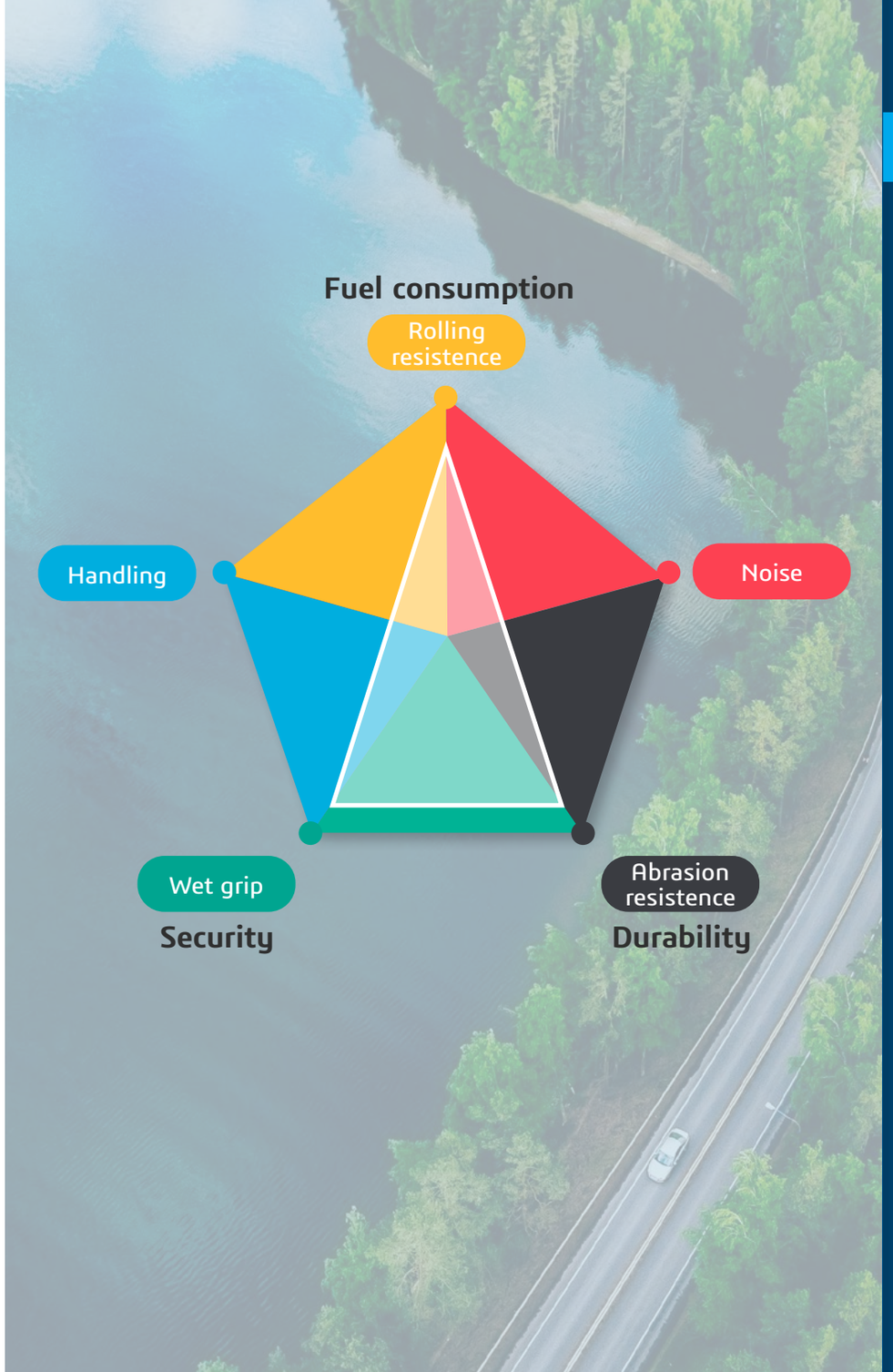
Tire engineers typically speak of the "Magic Triangle" of three key performance indicators (KPIs): rolling resistance, wet grip and wear resistance. Conventionally, these were thought of as part of a trade-off as improving one would degrade the performance of the others. However, tire companies are increasingly finding ways to improve all corners of the triangle at once:

- Improve rolling resistance to increase fuel efficiency.
- Improve grip (wet and dry) to improve safety and handling.
- Improve wear resistance to make tires longer lasting and more sustainable.

All this needs to be achieved while maintaining a good ride experience and performance in terms of noise and handling to meet customer expectations.

> The shift-left concept, with early analysis and optimization of a design, is becoming widely adopted in the industry. By integrating simulation early in the design process, even during the modeling stage, engineers can see, for example, what impact the design of the "green" tire has on the performance of the final cured tire.

The Magic Triangle is no longer enough. Tire Simulation and virtual testing needs to be connected with Material Science as new formulations must also be tied to product performance.



NEW ENGINEERING CHALLENGES

MODULARITY

With so many varying customer requirements, tire manufacturers are finding their product ranges have to expand rapidly, with more stock-keeping units (SKUs) on offer than ever before. It is becoming unfeasible to design every tire from scratch, and companies are increasingly dependent on modular designs. This can mean common green tires, common carcass, common treads, or a combination of these. OEMs also increasingly demand entire corner modules, integrating not just the tire but the whole wheel, hub and other components. **Simulation can verify the performance of different combinations of modular designs, and store the various common components in an easy-to-use form**.

NEW CONCEPTS

Experimental ideas such as airless tires, connected tires and sustainable tire materials offer the potential to unlock new markets, but these relatively untested concepts need to prove themselves for mass adoption. Research and development teams can **use simulation to explore** the practicality of a new concept early on and fine-tune the idea before committing to an expensive R&D project. In order to meet these new engineering challenges faster, more efficient business processes and greater collaboration is necessary.

DIGITAL TRANSFORMATION

The engineering definition of the tire is not the final product that rolls off the manufacturing line. Manufacturing tolerances, material variance and safety margins are just some of the factors that affect the mold design and lead to differences in the tire. Can the final engineering design be closer to the manufactured tire? **Simulation can offer a more precise understanding of the behavior of the final tire under different tolerances before manufacturing begins, reducing the need for additional margins**. Manufacturing can trust that the design sent to them is one that can be realized, and engineering can trust that their design will be accurately replicated.

"Manufacturing plants are multi-million dollar investments, and their output can be very sensitive. Simulation on the 3DEXPERIENCE platform offers a single source of truth for all the data from the manufacturing plant to identify the cause of possible problems. As just one example, rubber mixing can be optimized, helping engineers select the right ingredients and mixing blades, and resolving quality issues in extrusion."

John Lewis, Industry Process Expert, Dassault Systèmes SIMULIA®

ELECTRIC VEHICLES AND TIRE NOISE

Compared to their ICE counterparts, electric vehicles (EV) tend to be heavier (due to the batteries), quieter and more powerful. This changes the game for tire manufacturers: even a small electric city car can require high-performance tires. Simulation is helping EV start-ups and established manufacturers to develop innovative new tires for this market.

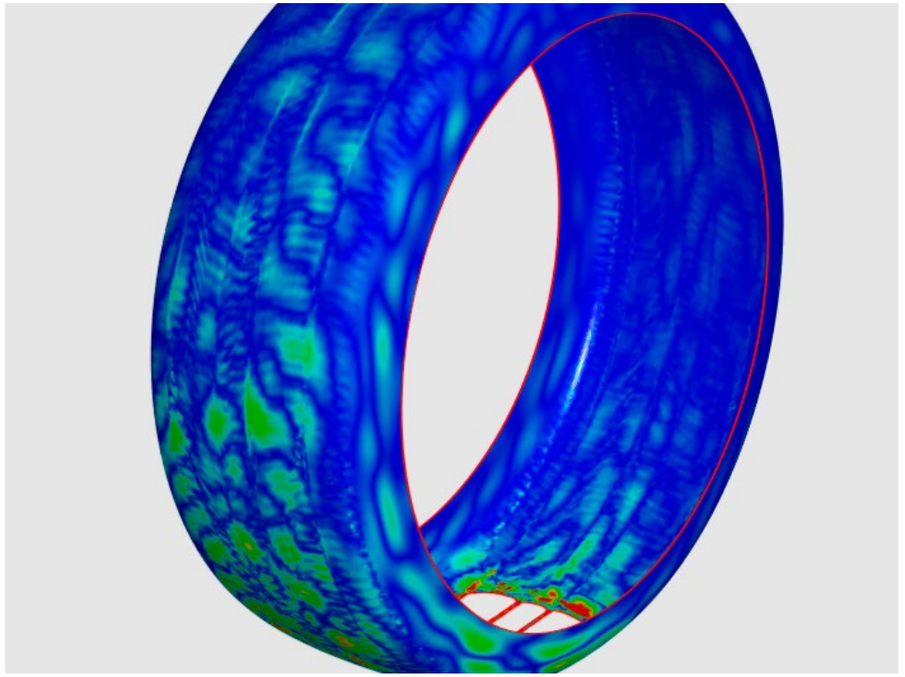
CABIN NOISE AND PASS-BY NOISE

One particular topic of interest is noise. For most ICE markets, tire noise was not considered a major concern—the engine would drown out tire noise in most scenarios. Electric vehicles however produce very little motor noise—instead, wind noise dominates at high speeds and tire noise at low speeds. This affects both the passenger experience and the pass-by noise experienced by the local community.

Radiated tire noise can be analyzed with simulation, with Design of Experiments (DoE) enabling users to quickly optimize tire design to reduce noise. Tire noise simulation can use the same tire model as the other virtual tests, meaning there is no need to re-build the tire model in the new simulation environment.

"Electric vehicles have a high torque and as a result the lifetime of the tire gets shortened. This means our tire development has to react and needs to build more durable tires."

Masayuki Kanai, Director, Vice President & Senior Corporate Officer,
Division General Manager of the Digital Innovation Division at Toyo Tire



VIRTUAL PROTOTYPING | TIRE PERFORMANCE & REGULATORY COMPLIANCE

Tires need to undergo significant testing in order to fulfill regulatory requirements for certification, which is a lengthy and expensive process. Simulation can replace rounds of testing with virtual tests on a digital twin prototype of the tire. The number of check tires needed in the prototyping process can be reduced by as much as 85% with simulation, cutting development time and costs while reducing waste.

During certification, OEMs and regulators increasingly accept validated simulation results alongside or instead of measurement data. In some cases, the tire testing workflow can take place entirely virtually. Accurate material calibration means engineers can fully capture the behavior of materials (including hysteretic effects) and ensure that the simulation model is an accurate digital twin of the real tire.

The 3D visualization enabled by simulation allows engineers to identify exactly which components are contributing to non-compliance, thus providing insight that physical testing will not provide.

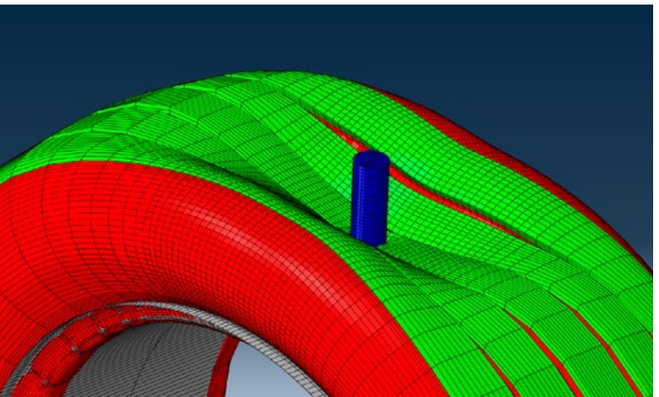
TESTS REPLICATED WITH SIMULATION

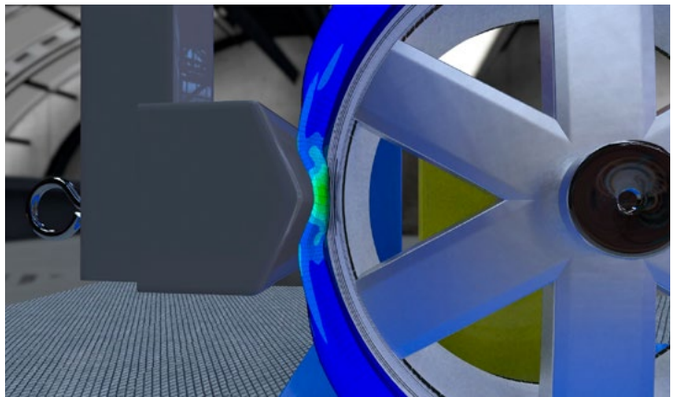
Plunger test: A plunger is pressed into the tire to measure its strength. Structural simulation can replicate the entire test set-up.

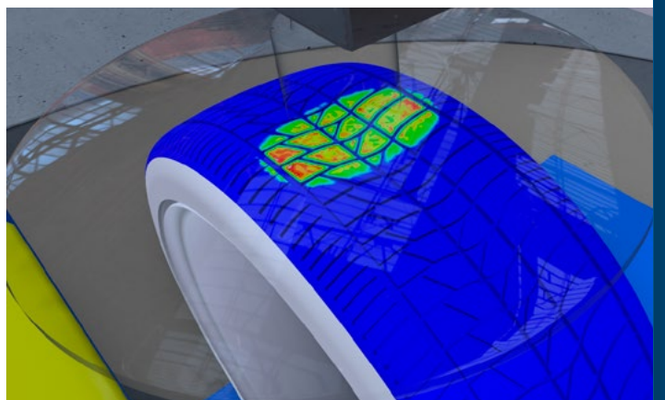
Rolling resistance: Virtual testing does not just calculate the rolling resistance—it also allows engineers to visualize precisely the contribution of different parts of the tread to rolling resistance, which physical testing cannot.

Footprint: Fully automated DoE allows users to quickly see the footprint for any tire and to find optimal designs.

Noise: The rise of electric vehicles means tire noise is now an increasingly important concern. A pass-by noise test analyzes the community noise as well as the noise experienced by passengers.







REDUCING WEAR, INCREASING SUSTAINABILITY

When people think about pollution from motor vehicles, they usually think of the gases and soot from the internal combustion engine. There are however many other sources of environmental pollution from vehicles, and tire particles have come under special scrutiny in recent years. The EU Commission, in their proposed EURO 7 standards, note that tires are becoming "the major sources of particle emissions from vehicles" [1].

When tires wear down, the abraded material is released in the form of fine particles. Some enter the air and become particulate emissions, while others enter watercourses and cause microplastic pollution. Both routes risk damage to the environment and to public health. There is now growing pressure on tire manufacturers to reduce the pollution caused by their tires.

One way to achieve this is by reducing tire wear, but there are trade-offs between wear, grip and rolling resistance to be considered. As simulation can help achieve better trade-offs, tire manufacturers can find new designs that increase the durability of the tire without compromising other aspects. Simulation also unlocks the potential to innovate new tire designs, using new materials that are more hardwearing or less polluting. Multiphysics analysis including thermal simulation can also help understand and improve tire thermal performance and durability. Multiphysics simulation can also potentially be used to model mitigation technology—for example, filters or electrostatic dust catchers that trap particulate matter released by the tire.

[1] EU Commission proposal on the new Euro 7 standards

IMPROVING ENERGY EFFICIENCY

The tire plays a part in the overall efficiency of a vehicle. **Decreasing the rolling resistance of a tire improves the range of an electric vehicle or reduces emissions from an ICE vehicle**. This makes tire design a key part of developing more sustainable vehicles.

Up to 20% of the aerodynamic drag of a vehicle is associated with the tires, and the worldwide harmonized light vehicles test procedure (WLTP) standards require tire drag be taken into account. Fluid simulation can model the aerodynamics of tire designs to reduce drag and improve fuel efficiency.

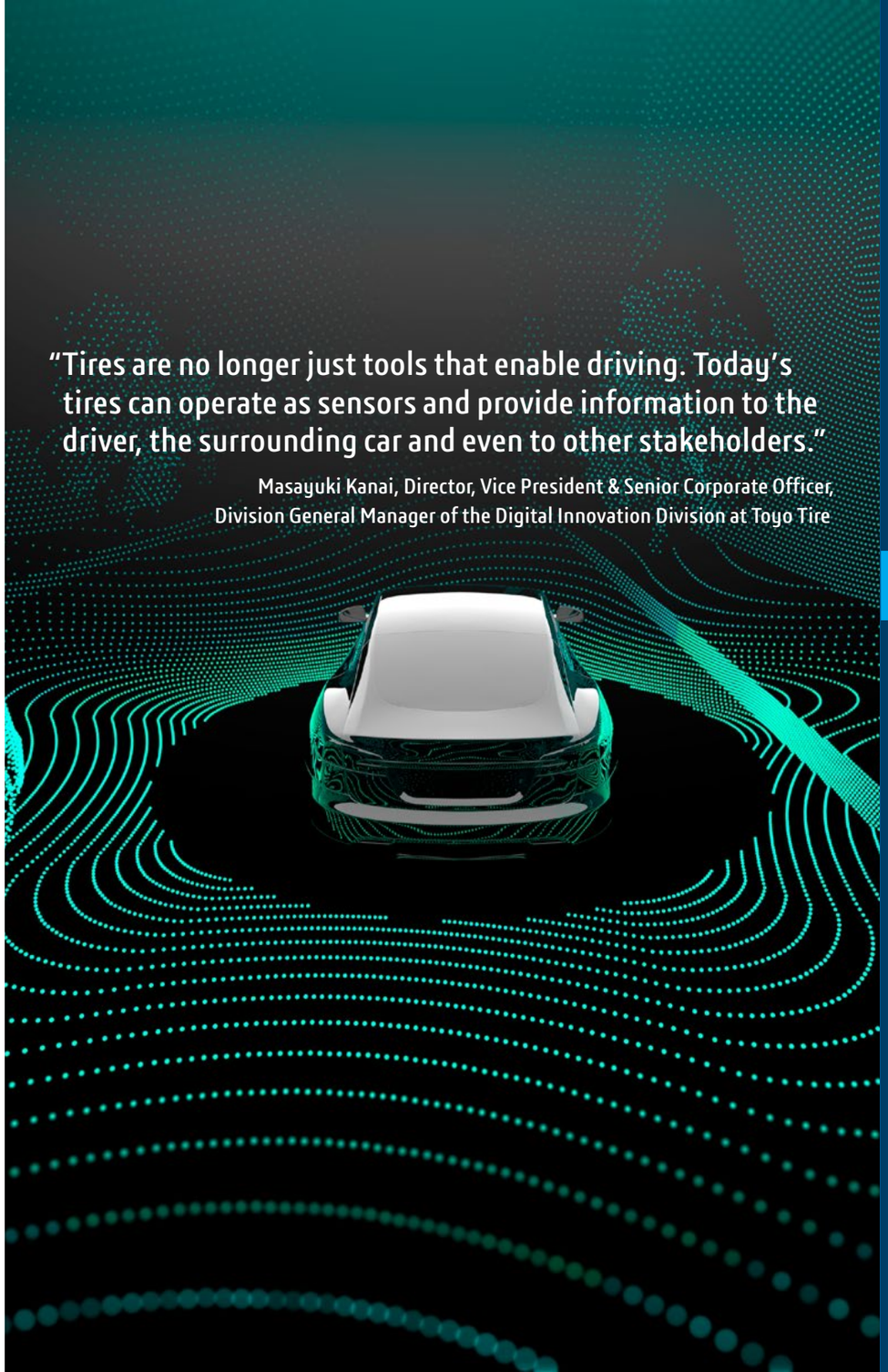
THE CONNECTED TIRE AND TAAS

Tire management has always been an important part of fleet management for delivery, logistics and transport companies. Traditionally, this would mean regular inspections of all tires across all vehicles, which were expensive and time consuming.

Modern logistics and ridesharing companies are increasingly moving away from old-fashioned fleet management strategies, towards flexible digital oversight of the fleet on fully connected platforms. Tire manufacturers need to be a part of this ecosystem, and many major manufacturers are already producing "connected tires" that monitor tire status using sensors and transmit this information to the driver or to a central system. This supports the Tire as a Service (TaaS) model and the CASE vehicle tire market.

Developing a connected tire adds electromagnetics to the list of disciplines required by a tire engineering team. Sensors need to accurately measure tire KPIs such as pressure, wear and mileage, while antennas need to transmit data in challenging conditions.

Electromagnetic simulation models the performance of components in realistic conditions—for example, a structural antenna deformed by the weight of the vehicle, or a sensor in a tire covered in mud—in order to allow engineers to develop a reliable connected tire. In a true MODSIM approach (see page 9), electromagnetic simulation is integrated with the other design and simulation tools, meaning that sensors and antennas can be designed together with the rest of the tire.



BUSINESS PROCESS TRANSFORMATION

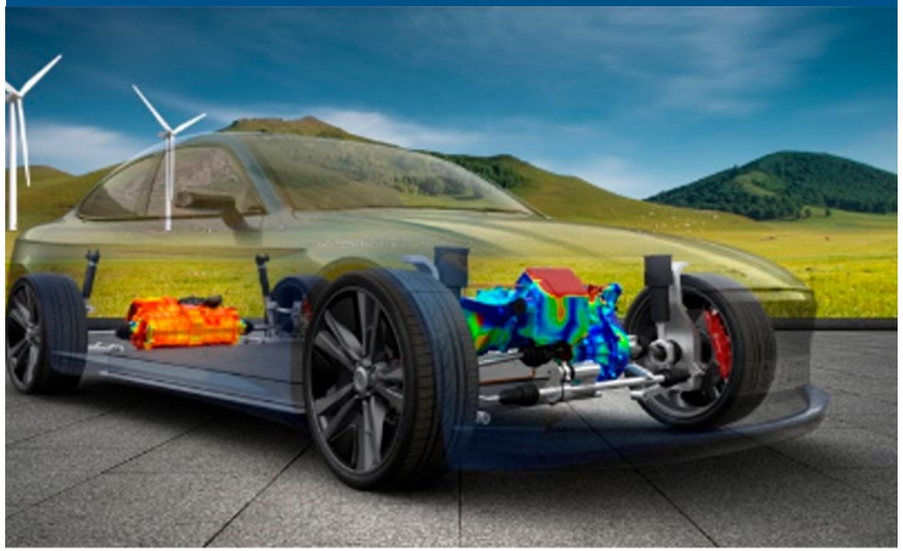
A successful tire cannot be developed in isolation. There are many stakeholders for a tire design. MODSIM enables internal stakeholders—materials scientists, tread pattern specialists, testing engineers, mold designers—to contribute to the tire design, building a coherent workforce with a common purpose.

Because all the data relating to the tire is stored in a shared database, so that everyone working on the tire design can be confident that they are working on the latest model, ensuring a single source of truth. Changes in the design are automatically propagated downstream to other users, preventing time and resources being wasted through poor communication.

The different types of simulation—mechanical for footprint and wear, thermal for heating, acoustic for ride noise, aerodynamic for drag and soiling, electromagnetic for antennas and sensors—can all use the same geometry files as their basis. Templates and **3D**EXPERIENCE® apps make simulation more accessible, extending it to users beyond software experts—evolving the roles of designers and expert analysts.

All this means that simulation can significantly increase productivity and accelerate development, while helping companies ensure their tires meet and exceed the expectations of the customer.

MODSIM unifies modeling and simulation on a common data model within a single user experience on the **3D**EXPERIENCE platform. It accelerates the efficiency of simulation-based tire design.



WHY SIMULATE: CUT COSTS, REDUCE RISK, BE SUSTAINABLE

Dassault Systèmes offers solutions for tire manufacturers to meet the needs of new markets while cutting development costs, time to market and reducing risk.

Collaboration

Break down silos between stakeholders with seamless integration of data from all parts of the organization via a common data model.

Democratization

Simulation templates and automatic processes allow non-specialists to use simulation tools.

Sustainability

Reduce waste and physical prototypes. Explore new materials at the start of development for innovative new designs.

Cost Savings

Cut costs and development times using virtual twins. Avoid the risk of costly late stage design changes.

Avoid Risk

Simulate to test and validate performance before committing to expensive and time-consuming physical testing.

Innovation

Test the viability of innovative new ideas early in development. Use DoE to explore the design space to find new potential concepts.

PRODUCT ADVANTAGES—INNOVATIVE DESIGNS FOR NEW MARKETS

The simulation technology from Dassault Systèmes empowers engineers to design, understand, optimize and validate tire performance at an earlier stage of the product development cycle. It helps to meet new market requirements faster.

New markets

Develop connected tires for the CASE vehicle market and TaaS. Produce strong, lightweight tires that can withstand the weight and torque of EVs.

Performance

Optimize all corners of the Magic Triangle for higher performance. Ensure new materials support all performance KPIs.

Sustainability

Reduce rolling resistance to improve fuel efficency. Develop more durable, less polluting tire designs.

Handling

Predict and improve ride and handling performance for any road surface.

Modularity

Use modular tire models, such as common carcass, to develop wide product ranges quickly.

Tire noise

Reduce radiated noise to improve passenger experience and community noise levels.

TIRE ENGINEERING WORKFLOWS

INTERNAL GEOMETRY

- Cross Section
- Layout

VIRTUAL 3D TIRE

EXTERNAL GEOMETRY

- Tread Engineering
- Pitch Definition
- Sidewall Marking (3rd Party)

Tire Thermal Performance

Tire Pass-By Noise

Tire-Terrain Interaction

Regulatory Testing

Cured to Green & Green to Cured

Tire Maneuverability

Dry/Wet Grip

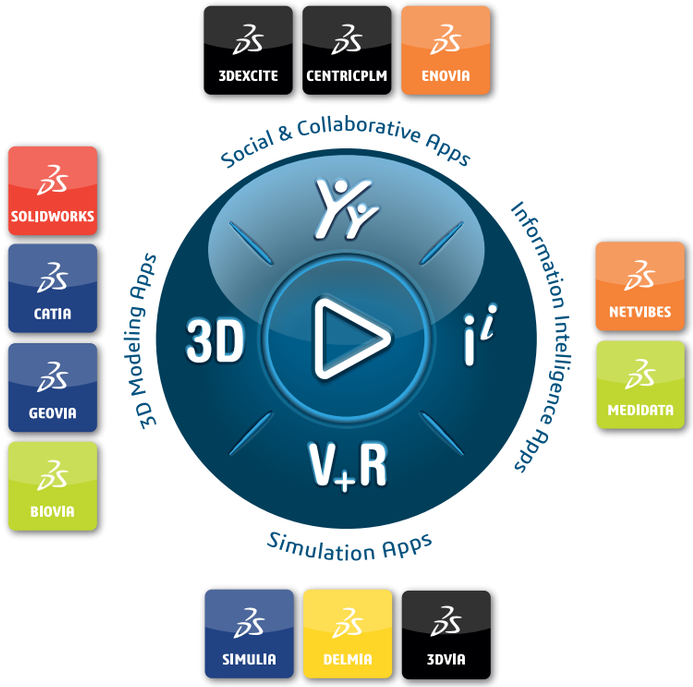
Tire Footprint & Rolling Resistance

Wear / Durability Tread Pattern Analysis

Our **3D**EXPERIENCE® platform powers our brand applications, serving 12 industries, and provides a rich portfolio of industry solution experiences.

Dassault Systèmes, the **3D**EXPERIENCE Company, is a catalyst for human progress. We provide business and people with collaborative virtual environments to imagine sustainable innovations. By creating virtual twin experiences of the real world with our **3D**EXPERIENCE platform and applications, our customers can redefine the creation, production and life-cycle-management processes of their offer and thus have a meaningful impact to make the world more sustainable. The beauty of the Experience Economy is that it is a human-centered economy for the benefit of all –consumers, patients and citizens.

Dassault Systèmes brings value to more than 300,000 customers of all sizes, in all industries, in more than 150 countries. For more information, visit **www.3ds.com**.



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