# DOUBLE

Digital twins are virtual replicas of real-world assets, dynamic simulations of physical behavior in facets ranging from a single tire to a whole factory

By **JACK ROPER**

Tire companies are investing in digital twins as a means to develop and test products and ideas without building prototypes. Furthermore, they're being utilized to trial transformations to tire production lines in-situ, which can then be commissioned with confidence in the final result.

Each digital twin has a unique purpose for differing design and production application areas, as Dr Mathias Oppelt, head of simulation center for Siemens, explains. He employs the analogy of a human twin to describe how the technology works.

"All human twins have an order of birth. [In the tire development world] the digital twin naturally comes first. A CAD workflow with drawings enriched by models that represent physical behavior bring this twin alive."

Peter Haan, Siemens' global head of vertical market management tire, notes that 'digital twin' is the new term for a complete simulation. A digital twin uses infinite mathematics and the latest computing capabilities to run a model in real-time, with CAD data providing the basis for an asset's facsimile.

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The process of building a digital twin is said to be both quick and efficient. Creating a digital twin of a curing press including its many facets from a CAD model, for example, can take as little as one week. Siemens can perform the so-called 'dynamization', which involves defining the limits of the behavior of each parameter to feed the simulation.


ACT

"The digital twin is undoubtedly a key enabler for efficiencies across the whole engineering chain," echoes the head of digital engineering – R&D technical center, Bridgestone EMIA, Paolo Filetti, who notes that a digital twin is usually built before its corresponding physical entity has been created. "Reducing prototypes, physical testing, lab trials and industrialization loops drives down the cost and time-to-market as well as the environmental footprint of the development."

According to Filetti, the tech is proving particularly beneficial on OEM programs, enabling Bridgestone to exchange virtual representations of a product with its automotive partners for analysis and approval.

André Colom, simulation and data science director for Michelin, gives another explanation of what a digital twin is: "CAD and simulation combine to enable numerical continuity between stages and engineers to predict performance using first principles or data-based models."

The French firm applies digital twin technology to simulate design changes, model operations and predict equipment maintenance by testing any hypotheses on a virtual system.

### Double duty

More specifically, Michelin employs physics-based models to analyze wet traction degradation. "We rely on fluid dynamics simulation to test worn tires on wet roads and trial complex evolutions of tread patterns," says Colom.

Over at Siemens, Haan reveals that in one particular application, digital twin tech was used for a hydroplaning simulation to measure water dispersion of a tire built for a leading manufacturer. "We are able to simulate not just the profile but the complete tire behavior from the sidewall deformation to the forces on the surface plate and at the contact patch.

"We can also mount four virtual tires onto a virtual car and test them on a virtual street. We can change road surface parameters to test tire behavior in rain or snow or during summer," Haan continues.

**ⓘ BY THE NUMBERS**

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Paolo Filetti, head of digital engineering, Bridgestone EMIA

**Right:** Behavior simulation of every element of a tire is possible, from changes in the profile to shifts in the contact patch loads and deformation of the tire's sidewall

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> Dr Matthias Oppelt, head of simulation center, Siemens

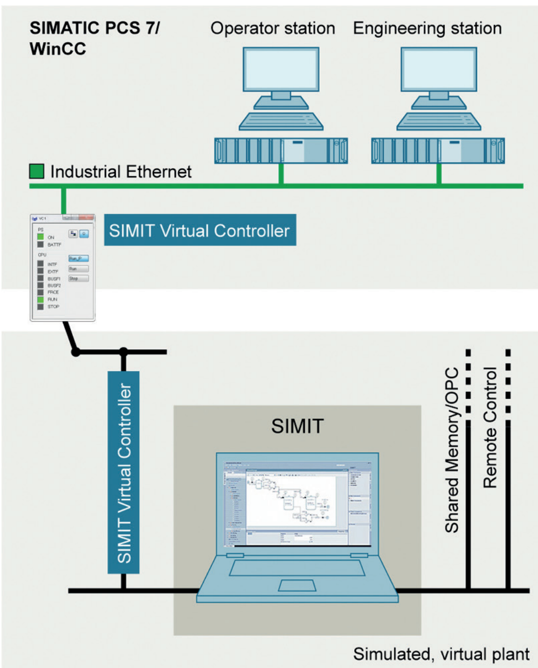
"Models are being elaborated to become holistic and capture more phenomena," comments Edwin de Vries, account manager and former senior vehicle dynamics engineer at simulator supplier Cruden. "To simulate handling 10 years ago, we focused on lateral force generation and ignored or simplified the vertical dynamics. However to undertake a complete driving simulation, these behaviors had to be merged in a model that could perform in six directions."

Real-time capability is a prerequisite for integration [of a model] with a driver-in-the-loop simulation, the expert explains. For a human to interact with a digital twin, its state must be calculated every millisecond.

Formula 1 teams have long been exploiting digital twins technologies to their full potential by using their comprehensive capabilities in observational research, de Vries reveals. "We can measure the temperature of a rolling tire with a 3mm tread depth, for example. On a real tire that's impossible, but we can dig into this parallel model cleanly and flexibly."

By eliminating prototype builds, which would typically be three rounds of tires, Haan at Siemens estimates a cost saving in the region of US$117,500 (€100,000). He adds that the manufacturing of test tires usually requires a dedicated production line or the flexibility to build one set of pilot tires in between mass production.

"You need a special compound batch in the mixer and you have to retool the curing presses and pulling machines. That costs a lot of money for four tire [rounds]," Haan underlines.




**Above:** Digital twin technology allows the element of a physical plant to be modelled, from curing presses to handling equipment

**Left:** The digital twin of the manufacturing plant runs in parallel with the physical entity, this allows for potential efficiency gains to be found and implemented

## Two of a kind

Colom, of Michelin, notes that production facilties can be streamlined on a global scale through utilization of worldwide manufacturing and flow simulations. He says, "Each process step is represented as well as finished and semi-finished products and their interaction with plant elements. Hypotheses can be tested for impact on tooling, agility, throughput, waste, quality and costs. Plant architects can optimize system design and layout. Predictive models can be progressively included in real-time operations management."

Notably, functionalities and equipment can be automated and their operations fine-tuned virtually. A digital replica of a machine can be combined with a plant's real automation and control systems, for example. Oppelt from Siemens explains: "We can emulate our physical programmable logic controllers and all the communication [systems]. We can connect the original program to a digital twin of the instrumentation with sensors, actuators, motors, and drives, which are all digitally represented."

Siemens, for example, was able to carry out tests of a Mesnac curing press in the computer, employing a digital twin of the machine, which was integrated with automation systems and a human machine interface.

Furthermore, software programming and testing can get underway before construction has begun. Finally, as Filetti at Bridgestone says, operators can be trained on digital machines. This notably reduces the risk of mishandling, and accelerates ramp-up when a real asset comes online.

For the future, Michelin's Colom believes the potential of the digital twin can be fully realized through collaboration between industry players to bring together data and capabilities. "We must share development in ecosystems beyond our own organization to improve digital twin capabilities through exposure to a diversity of needs."

The digital twin will continue to flourish as an engineering tool, Haan at Siemens predicts, as the mathematical models beneath are developed. This will enable more complex phenomena to be simulated. Haan gives the example of a curing bladder used in the production of green tires as one element that is particularly hard to simulate.

Furthermore, Haan reveals, "Today, mathematical models assume that all hydraulic curing press cylinders behave the same, but we're working to connect kinematic simulation with hydrosimulation of fluid behavior to fully differentiate older cylinders."

Bridgestone, meanwhile, believes that digital twin technology will be a key enabler in the development of future intelligent transportation systems.

"For connected, autonomous, shared and electric vehicles, tires must sense the tire-road interaction, capture events and communicate continuously with vehicles. This will be possible by combining digital twins, embedded sensors and artificial intelligence," comments Filetti.

## VIRTUAL COMPOUNDS

A new state-of-the-art technology from Hankook Tire utilizes artificial intelligence (AI) in tandem with molecular dynamics simulation to formulate tire compounds without any physical analysis work.

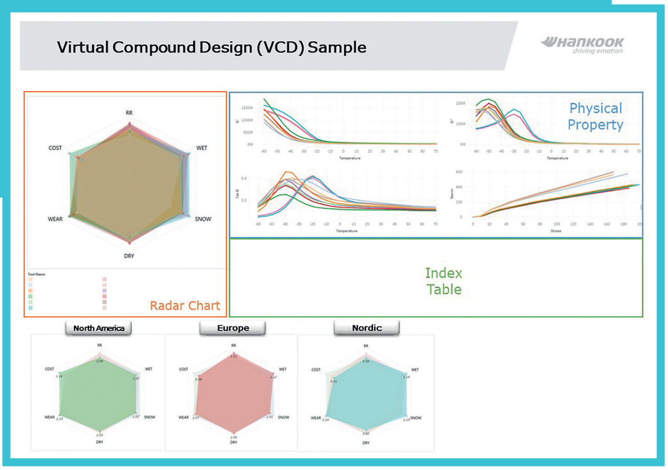
According to the tire maker, its Virtual Compound Design (VCD) system has the potential to reduce compound development cycles by 50%, forming a core element of cloud-based digital twins.

"We're integrating multiscale simulation, big data analysis and AI to optimize tire design," says senior material research project manager, Myung Shin Ryu. "Digital twins can simulate the effects of design changes, usage scenarios and environmental conditions and reduce development times. We can pre-test new equipment and materials to inform purchase decisions."

Hankook began building its VCD tool in 2015. Through joint research with the Korea Advanced Institute of Science and Technology, the OEM has been able to enhance its predictive AI component. "A tire compound consists of over 15 materials," notes chief material research project specialist, Hyoung Gyu Kim. "Its properties depend on a diversity of variables including temperature, pressure, ratio and order of combination. Integrating microstructure simulation with AI enables us to analyze compound behavior at a molecular level and select the best raw materials for specific needs."

By 2026, Hankook aims to have integrated the VCD system with finite element tire models as cloud-based digital twins. "We have analyzed tens of thousands of data units on cloud-computing platforms such as Amazon Web Service and Google's TensorFlow AI engine," notes Shin Ryu.

Hyoung adds, "We will introduce technologies based on data accumulated across the tire industry ecosystem. Digital twins of production sites based on 3D drawings will enable AI to predict possible facility failure."

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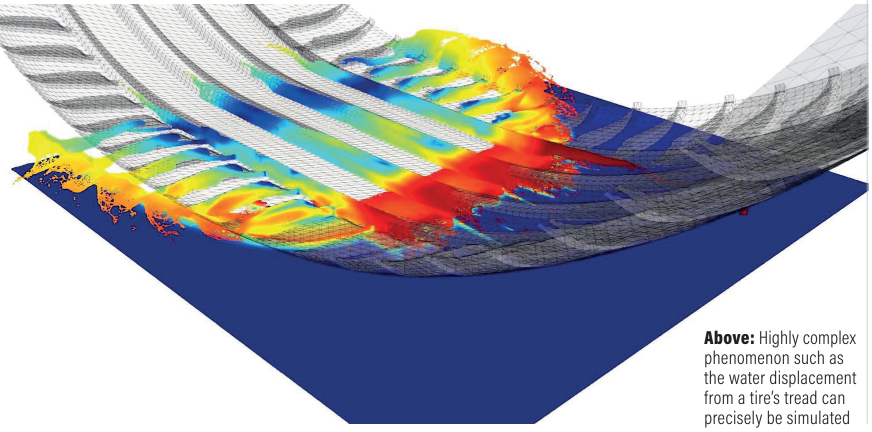

**Above:** Highly complex phenomenon such as the water displacement from a tire's tread can precisely be simulated