Mobility

Mobility determines a major part of life, globally and locally. Appropriate technical and conceptual solutions are needed to guide traffic, make it safer and conserve resources. With our partners in the automotive industry, we focus our activities on vehicle-environment-human interaction and develop software tools for virtual product development and product creation in the digital factory.

The ITWM Technical Center – Experiments and Simulations Consolidated

Simulations have long played a major role in mobility research and are becoming increasingly important, especially in virtual product development in the vehicle sector. This is the focus of our "Mathematics for Vehicle Development" division, which combines the necessary technical testing facilities in its technical center. Here, we develop our own measurement and simulation techniques, which are built hand in hand with the modeling and simulation methods as well as software tools.

Hardware and ssoftware as the technical bedrock of our research

The simulator center includes the robot-based driving simulator RODOS® (RObot based Driving and Operation Simulator), the static driving simulator VI-Grade compact DIM and the virtual reality laboratory. The measurement technology is provided by REDAR (Road and Environment Data Acquisition Rover) – a 3D laser scanner vehicle – and the highly automated measurement machine MeSOMICS® (Measurement System for the Optically Monitored Identification of Cable Stiffness). It is used to determine cable stiffness.

Virtual environment for cars and commercial vehicles

The RODOS® driving simulator represents the largest of the facilities at the technical center and allows the exploration of situations right up to the moment before a crash in a detailed, highly reproducible and risk-free environment with the aid of interactive simulation. With a payload of 1000kg, the robot arm allows the use of standard tractor and excavator cabs as well as real car bodies. Inside a spherical projection dome measuring ten meters in diameter, 18 projectors create a seamless projection of an interactive scene, whereby, for example, driver-vehicle-environment interactions are studied. RODOS® is currently the most powerful driving simulator of Fraunhofer society. We also use the static simulator VI-Grade compact-DIM for model development as well as for cooperative driving simulation and mapping of complex mixed traffic situations. This system is optimized for the interactive simulation of passenger cars and is used in particular for the development of our CDTire/Realtime software

VR Lab for people in complex environments

The Virtual-Reality Lab opens up the possibility of placing people in complex environments and scenarios. Applications can be found in driving simulation, production and factory planning as well as visualization. One or more people can experience a virtual reality as a pedestrian in our laboratory, on a surface of ten by six meters. Human reactions can also be studied in highly complex traffic situations by interfacing with the simulation environments of RODOS® and VIGrade compact DIM via a real-time data interface.

More information at www.itwm.fraunhofer.de/technikum_en

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CDTire – Reinventing the Tire with Simulation

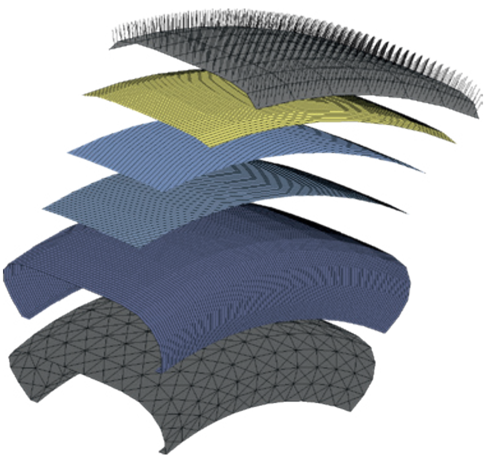
The tire modeling software has long been an integral part of the product range in the field of "Mathematics for Vehicle Engineering". In an interview with Dr Manfred Bäcker, head of the "Tire Modeling" group, we wanted to find out the unique selling points of CDTire:

CDTire is a tool for the simulation and development of tires. What does it do and who works with it?

Historically, tire simulation models such as CDTire were first used by the automotive industry. They were needed to enable full vehicle simulations on digital (measured) test tracks in the virtual vehicle development process in order to obtain statements about comfort, operational stability and driving dynamic properties of a development status early in the development process and to further improve it. The tire industry, on the other hand, uses detailed tire models, which, however, are not applicable due to their very high computational simulation cost. Moreover, they are not readily made available to third parties, i.e. not even to customers in the vehicle industry, because they also contain design details which are regarded as proprietary know-how. That is why the automotive industry has always has always been dependent on tire models developed outside the tire industry. Because of the demand for low computational cost, these very much simplified models were inferior to the finite element (FE) models of the tire industry.

And this is where CDTire comes into action?

Exactly! With the CDTire model generation, developed between 2010 and 2012, we have provided simulation models of tires for the first time that are accepted and used as development tools in both the automotive and tire industries. The key to this success is a model framework which simulates tire geometry and structure with similar accuracy as the tire industry's FE models – but at hundred times the computational speed.



CDTire/3D: Functional layer concept

What does CDTire do in the virtual pre-development of tires? What do the individual process steps look like?

Since CDTire/3D is suitable for all applications from driving dynamics to comfort to "Noise Vibration Harshness", the software suite allows evaluations for these development criteria at a very early stage. In addition, since 2018, we have established a new method for the subjective evaluation of tires on driving simulators in cooperation with the tire manufacturer Goodyear via corresponding pilot projects with vehicle manufacturers such as Maserati. For this, we use the real-time capable CDTire/

Realtime, which is derived from CDTire/3D. This innovation is so important because the subjective evaluation of a tire by professional test drivers is still the pinnacle of the development process: Only their OK releases the tire. However, this usually requires many iterations and a corresponding tire prototype must be produced in each iteration. Vehicle prototypes must also be available, of course. The goal is to complete 90 percent of this time-consuming and cost-intensive process on the driving simulator using virtual tire and vehicle prototypes, so that ideally only the final acceptance has to take place on the real test track. This can save immense costs and development time.

What were the biggest challenges in software development in recent years?

We have consistently designed the new generation of CDTire as a "multi-physics tool". Thus, the actual structural mechanical tire model has been extended in recent years by a thermodynamic model (CDTire/Thermal) for the simulation of temperature propagation within the tire and also by a model for the air flow within the tire – the so-called cavity model. These different physical sub-models require a high degree of modularity in software development and also pose a challenge to the numerics of the overall model, because the structural model, temperature model and internal air model naturally interact with each other. The overall model thus becomes a so-called "multi-scale model". The computational step sizes of the sub-models are on different scales and must be coordinated against each other to achieve good overall performance. The modularity and extensibility in the sense of a multi-physics tool with simultaneous high computing speed is the greatest challenge.

CDTire contains a whole family of tire models that are used by both tire and vehicle manufacturers. What new properties will be considered in CDTire in the future?

We achieved the greatest development progress and at the same time the greatest success in attracting new customers by adding the dynamic inner air model. The new application allows a good prediction quality for full vehicle simulations in a frequency range up to 300 Hz. Pilot users were Audi and Maserati, which we were able to win as customers. In the near future, the prediction quality is to be further increased by linking the tire model to a flexible rim model. Furthermore, CDTire is to be extended for the "Air-Borne Noise" application. Here, we simulate the transfer of structural vibrations of the tire surface into the outside air and their feedback via the body into the vehicle interior.

More information at www.itwm.fraunhofer.de/cdtire_en

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Making Better Use of Data – AI and ML in Vehicle Engineering

Whether measured in test vehicles or recorded in modern vehicles during operation: In the automotive sector, the availability of data has been increasing for years. This also applies to quantity and quality of environmental data: digital maps, climate, topographical data and even socio-economic information are flowing into the growing data pool. The technologies used to collect and process this data are also constantly being improved, which is why methods of artificial intelligence (AI) and machine learning (ML) can be used very efficiently and effectively today, to extract valuable information from the sheer volume of data.

Modern vehicles are bubbling sources of data. AI methods help to use and understand the flood of data.

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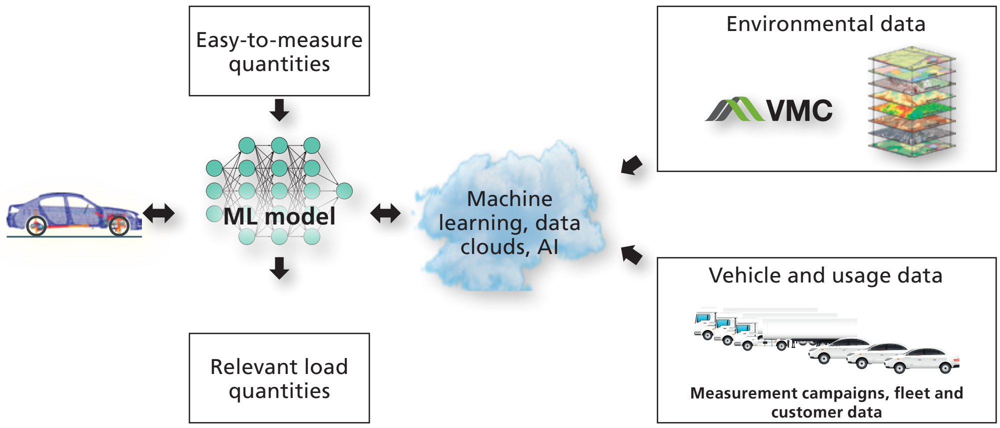
In our department "Mathematics for Vehicle Engineering – Dynamics, Loads and Environmental Data", such methods are used to incorporate the knowledge gained in the process into the vehicle development process at an early stage. For example, in the form of the Virtual Measure Campaign VMC® software suite: Its aim is to compile and maintain environmental data in a geo-referenced database covering as much of the world as possible and to link it with mathematical analysis tools. With the help of driver, vehicle and environment models, VMC® can predict traffic-dependent speed profiles thanks to efficient simulation technology and – based on this – derive statements about vehicle loads and energy demands.

Another profound benefit for the entire development and safeguarding process arises in the next step through the combination of usage data on the one hand and vehicle and environmental data on the other hand.

From the vehicle directly in the cloud

Modern vehicles reveal a lot about their use because they record numerous condition variables; commercial vehicles are also often equipped with a telematics system that sends the collected data to a cloud at regular intervalsFor commercial vehicles, especially for agricultural and construction machinery, the usage



Environmental data, vehicle data and models support the development process of modern vehicles and their operation.

variability is very high, depending on the customer group and region of use: For example, a truck in the mountainous regions of the Caucasusis exposed to very different loads than a truck that transports its load mainly in mainly in central Europe. Or an excavator in a sand pit compared to an excavator that crushes construction debris and separates it into “metal” and “concrete”.

For the development process, it is therefore of particular interest to know as much as possible about the actual use of a vehicle in order to set the right design and testing criteria.

AI recognizes type of use

To draw the right conclusions from the data at hand, AI and ML come into the game. “At this point, we use an ML-based detection algorithm that recognizes the type of use, for example ‘digging’ in the case of an excavator,” explains Dr. Michael Burger, deputy head of the “Dynamics, Loads and Environmental Data” department. “Once an appropriate ML model is trained, we can derive very accurate and very efficiently usage profiles, specific to groups of people and their respective regions of use. However, equipping a large number of commercial vehicles with sensors that are precise and sensitive requires a lof of effort and a robust operation is usually costly and time-consuming. “As an alternative or complementary approach, we also use data-based and hybrid models that predict relevant internal quantities, such as internal component forces. For this purpose, we use easily measurable external quantities such as accelerations at axles or on the frame,” says Michael Burger. This makes it possible to avoid numerous sensors and complex measurement technology.

Further information is available on our website at www.itwm.fraunhofer.de/environmental-data

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DEFACTO – E-Mobility Gains at the Cellular Level Are Picking up Speed


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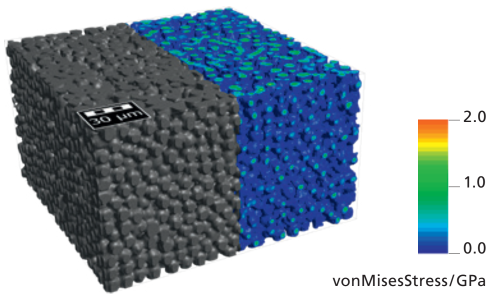
Revolutionizing european battery cell production

The EU's DEFACTO project has set an ambitious goal: to develop a modeling toolchain for e-mobility batteries that describes all relevant aspects ranging from battery materials, the manufacturing process to the macroscopic cell behavior. These tools are expected to improve understanding and lead to faster, more favorable development processes for novel cell types and to extended lifetime of the batteries. The ITWM team under Dr. Jochen Zausch is focusing on the modeling and simulation of cell performance and aging mechanisms.

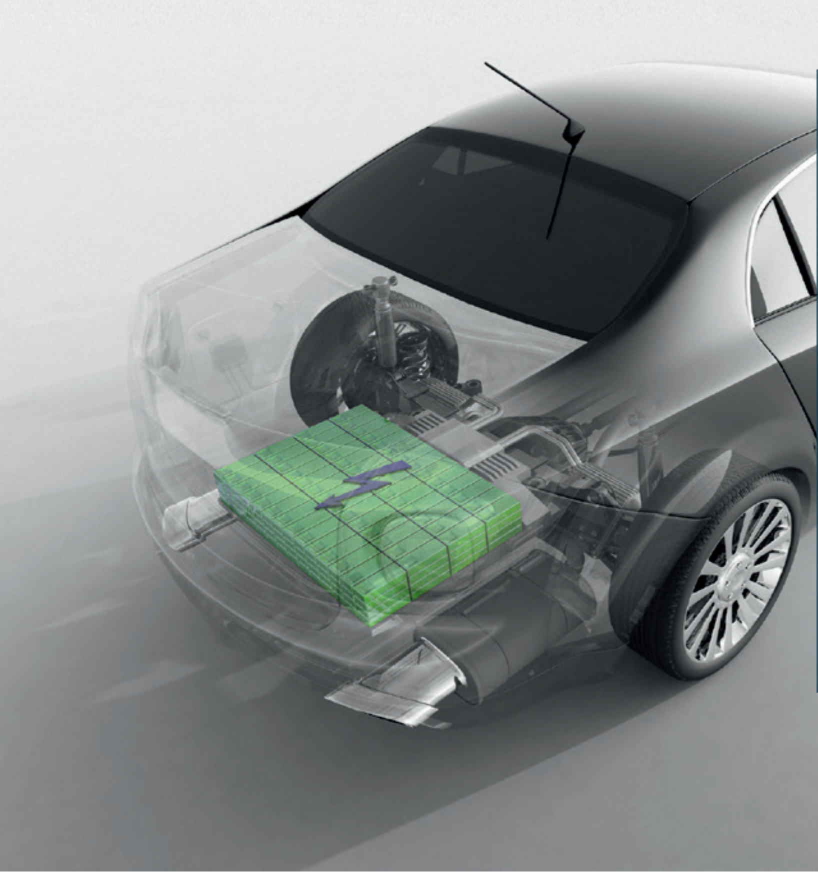
The basic components of batteries for e-mobility are complex electrochemical cells. "In our contribution to DEFACTO, we are concentrating on the mechanical aging of the cells, which is caused by volume changes of the battery electrodes," says Dr. Jochen Zausch, head of the "Electrochemistry and Batteries" team in the "Flow and Materials Simulation" department.

The promising, high-capacity, silicon-containing anodes degrade quickly after only a few charging cycles. The reason for their short cycle-life is the silicon particles in the anode, which expand and contract. This process, which is called "cell breathing," increases wear due to



Simulation: Calculated mechanical stresses in a compression experiment of a virtual battery electrode

cracks and damage. The mechanical stability of the electrodes and thus the charging capacity are gradually reduced. Simplified, these



"Structure.e": Faster Charging

Another current e-mobility project that involves the BEST simulation software from ITWM is "Structur.e". Its goal is to put an end to long waiting times for electric vehicles at charging stations. In this project, which is funded by the German Federal Ministry for Economic Affairs and Energy, Zausch and his team are researching methods that improve the performance and charging capability of lithium-ion batteries. In a large project consortium coordinated by Volkswagen AG, ten companies and research institutions are not only working on the development of new electrode concepts, but also on suitable characterization methods. The work is supported by computer-based simulations, which are developed at ITWM.

new materials increase the range of the electric vehicle, but at the same time the lifetime of the cells is less than a typical car would require.

Understanding cell material behavior with ITWM simulations

Zausch and his team get to the root of such problems with the ITWM tool "BEST", which they use to simulate the electrochemical behavior of the cell. "The big challenge isn't only about calculating the ideal battery behavior,. We also want to provide for more realism by predicting how the battery properties change over the cell's lifetime," says Zausch. This will be achieved by linking and enhancing two ITWM software tools: BEST (for electrochemistry) and FeelMath (for structural mechanics). "Ideally, this microscopic view can then be transferred to the macroscopic scale. We want to deepen our understanding with regard to material selection, electrode production and processing at the European level." To promote innovation in e-mobility, the European Commission is funding the DEFACTO project with a total budget of around six million euros. The initiative's consortium of 13 companies and research institutes from Belgium, France, Germany, Greece and Spain will pursue this ambitious goal through June 2024, with the aim of increasing the competitiveness of European industry.

For more information, visit our website at www.itwm.fraunhofer.de/defacto_en

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