Mobility

The topic of "mobility" is a constant companion for us at the Fraunhofer ITWM – be it for the automotive industry, in construction and agriculture or even for aerospace. Our focus is on our simulation methods, which optimize products, often before a costly prototype is built. However, we also test components with our terahertz research. We can boast a large number of projects in this area and are constantly adding new ones that improve mobility for suppliers and users.

Virtual Worlds for Vehicle Engineering

Autonomous driving functions and driver assistance systems such as parking or lane departure warning systems are considered pioneering technologies in the automotive industry and are already an integral part of modern vehicles. However, before they can be put on the road, they need to be tested and validated. Our "Dynamics, Loads and Environmental Data" department has developed a new module in the VMC® (Virtual Measurement Campaign) tool suite for this purpose: The VMC® Road & Scene Generator.

Current methods often fail to reflect the diversity and complexity of the real world. For example, in manually created simulation models, there are often only simple basic intersections that rarely occur in the real world. However, modern assistance systems must ensure safety at all times – even in complex traffic situations. This requires realistic models of the environment.

Left: Real scene (photo)
Center: 3D scan
Right: Virtual 3D scene

Multi-Level Generation of Environment Models

The VMC® Road & Scene Generator focuses on the creation of virtual worlds that depict public roads or test sites as required. The generation can be based on high-precision measurement data, such as measurements from the department's own "REDAR" measurement vehicle. However, the software package also offers another special feature: the module delivers valuable results even without detailed measurement data. "Thanks to the VMC® database, which contains worldwide, georeferenced data on roads, topography, land use and traffic, we can create digital 3D maps without having to carry out measurements on site. If required, we merge this data with other available information, such as that provided by surveying offices," says expert Tim Rothmann. If individual attributes are missing from the process, such as the number of lanes or width of a road, our researchers supplement these with customized prediction models based on regional or typical road conditions. Although this does not result in an exact representation of reality, it produces sufficiently realistic approximations for many applications. Thanks to the efficiency of the approach and its global availability and diversity, the Fraunhofer ITWM makes a significant contribution to the effectiveness and feasibility of scenario-based safeguarding concepts.

One Module, Many Applications

The VMC® Road & Scene Generator always offers the right solution depending on the requirements: for simulations based on simple abstract information such as road network descriptions, as well as for more complex applications that require detailed and photorealistic 3D models or an exact replication of the real environment. "We offer the optimum balance of variability, degree of realism and effort," explains Rothmann.

www.itwm.fraunhofer.de/vmc-road-scene-generator_EN

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VMC® Web Services – Cloud-Based Analysis of Vehicle Data

The collection of usage data plays an important role in many areas. In the automotive industry, for example, it helps to determine relevant driving conditions or to record energy consumption. The VMC® Web Services developed at the Fraunhofer ITWM are available to interested vehicle manufacturers and fleet operators in order to utilize the data in a meaningful way. Thanks to highly automated, data-driven analysis options, they provide an important additional building block in the value chain of vehicle development.

One focus of our "Dynamics, Loads and Environmental Data" department is on modeling the usage variability of vehicles while taking environmental data into account. They developed the versatile software and service package VMC® ("Virtual Measurement Campaign"). It supports vehicle manufacturers in gaining deeper insights into vehicle stress and use and extrapolating measurement data to the entire life of the vehicle.

Every vehicle collects data, every kilometer driven is recorded in real time – whether for cars or heavy trucks. This is information on how we use the vehicles, which routes we travel and much more. Vehicle manufacturers and fleet operators typically transfer this data to a cloud-based filing system, where it is available for comprehensive analysis. As the availability of vehicle data from ongoing operations increases, so do the possibilities for analysis.

Another Building Block in Vehicle Engineering

"This is where our new tool – VMC® Web Services – comes in. It combines the collection of real usage data with the derivation of specific customer models and supports vehicle manufacturers in integrating this information into their product development," explains expert Thorsten Weyh. The web services correspond to the modules of the VMC® desktop software. However, the modules can be individually combined to realize highly automated, statistical evaluations for specific usage groups.

Extensive Functions

The new web services offer several advantages. It is now possible to create specific routes including potential stopovers, project routes on VMC® map material, evaluate routes according to road type, curvature or mountainousness and combine and simulate speed profiles for different vehicle, driver and traffic models. As a cloud-based online service, no costly and resource-intensive local IT infrastructure is required. The hardware requirements on the customer side are reduced to a minimum, thus enabling low-threshold access to the web services. In addition to the geo-referenced analysis options already mentioned, the services also provide information on consumption and emissions over the selected route.

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Particle Simulation for Construction and Agricultural Machinery

The Demify® module is part of the IPS software family and offers, with the "Demify® for Heavy Machinery and Vehicles" toolbox, a particle simulation for various applications at the interface between granular materials and tools. The particle solver enables force prediction in the interaction between the ground and the tool of a construction and agricultural machine. Through Machine Learning, in particular recurrent neural networks (RNN), our researchers significantly accelerate the simulations.

Real-time tests in the RODOS® driving simulator are now also possible. Further research is being funded by the Fraunhofer-Gesellschaft as part of a PACT project. "Over the next two years, we want to develop further features, implement our ideas and establish Demify® on the market," says Dr. Sebastian Emmerich. In addition to AI models to increase efficiency, new methods for coupling particle systems and multi-body models as well as the co-simulation of flexible components are planned.

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Realistic Tire Model for Precise Rolling Resistance Prediction

The rolling resistance of tires is the result of energy losses. It is part of the EU tire label, which divides them into efficiency classes from A to E. It allows new tires to be compared under laboratory conditions. Lower rolling resistance improves fuel consumption and therefore also energy efficiency. In practice, however, the situation is quite different, which means that the efficiency classes cannot be achieved in everyday life due to many short journeys with "cold" tires. However, this is particularly important for electric vehicles, as it affects the range. Researchers in the "Mathematics for Vehicle Engineering" division are tackling this problem. The tire simulation software "CDTire", which enables physical modelling of all elements of a tire such as a steel belt – including temperature and pressure variations – has been further developed so that it now also takes internal friction losses into account. By coupling the internal friction with the temperature model, a realistic simulation of the rolling resistance is possible.

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Terahertz for Space Travel

Our modern terahertz systems measure non-destructively and precisely layer by layer– even with complex structures such as foams and their adhesions – thereby preserving the integrity of the materials. The terahertz technology we use is completely non-contact and non-destructive and does not use any harmful radiation. In a new project, we are now supporting “MT Aerospace” in examining the new tank for the “Ariane 6” launch vehicle.

The aerospace company ”MT Aerospace” specializes in the production of lightweight constructions, particularly those made of metal and fibre composites. They are currently investigating the potential further development of the cryogenic liquid tanks of Ariane 6 for AriResaneGroup in the PHOEBUS project. This latest European launcher currently uses classic metallic tanks and is currently in the final preparations for its first launch.

The aim of ”PHOEBUS” is now to reduce the overall weight and costs of the rocket by switching the tank material by replacing the aluminum tank material by carbon fiber-reinforced plastics (CFRP). In a specialized process, hard foam panels are bonded to the CFRP tanks to provide mechanical damping and thermal insulation during flight. This process must not result in any defective glued joints or air pockets, as otherwise the stability of the entire structure is at risk.

Between Infrared and Microwave Radiation

Terahertz refers to the range of electromagnetic radiation between infrared and microwave radiation with frequencies of around 0.1 to 10 THz. This radiation enables non-destructive penetration of objects, on the one hand for investigations using 3D imaging and on the other for material characterization.

Optimized Material Bonding Through Terahertz Measurements

This is where the experts in our "Material Characterization and Testing" department come into play. With their terahertz technology, they examine complex components for internal, structural damage or production defects. This is because the measurement techniques they have developed are ideally suited to examining many non-electrically conductive materials – including the foams used in the PHOEBUS project. As soon as our robot-controlled terahertz scanners are integrated into the production system, they analyze the entire surface of the tank, including the glued-on rigid foam, and detect irregularities in the glued surface.

"We use our sensor to check the entire foam layer and observe the reflected terahertz signal on the CFRP surface," explains project manager Dr. Maris Bauer. "This allows us to record the interface between the two materials in great detail. In the terahertz images generated in this way, differences in contrast indicate faulty bonding. Based on these findings, we provide our project partner with precise information on how successful the bonding is and which areas may require further attention."

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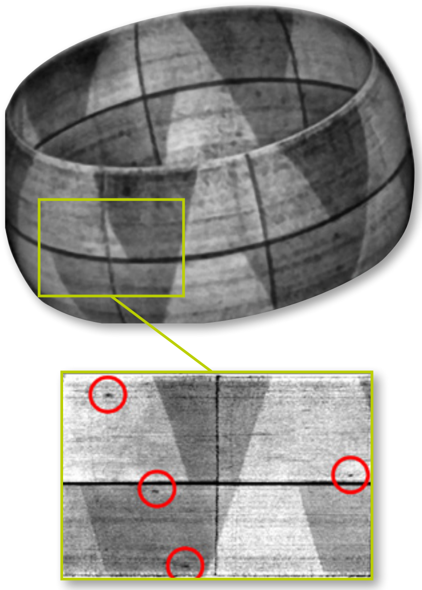

Top left: Concept study of a potential upper stage with CFRP liquid fuel tanks
Top right: Terahertz image of the bonding surface of foam sheathing and cylindrical CFRP tank

Line by Line for Quality Assurance

The department's researchers are not only responsible for the actual measurement technology. They are also developing the system integration into a complete testing system. During the measurement process, a robot positions the terahertz sensor at a single point on the fuel tank, while the tank itself rotates on a rotary axis. This results in the analysis of exactly one measurement line along the surface of the foam-covered tank. Once a line has been completely scanned, the robot then moves the sensor a few millimetres further to capture the next line. The result is a 3D image of the entire structure of the foam and tank. The structure is thus analyzed systematically, layer by layer and millimetre by millimetre, over a period of several hours. The rotational speed of the tank is the decisive factor that defines the total measurement time of a complete tank. At present, this is still a few hours. However, improved mechanics are being planned to significantly reduce the recording time of the terahertz measurements.

"As the rocket tanks are just a few individual pieces, the measurement time is not the only decisive factor. With these extremely safety-relevant constructions, it is much more important that the bonding surfaces are inspected precisely and, above all, without gaps. This is where we differ from other point-by-point testing techniques, such as manual ultrasonic testing. Our method enables us to detect problems in production in good time and therefore offers reliable and guaranteed measurement technology," explains Bauer. "Through this thorough analysis, we not only ensure the quality of the end product itself, but also identify potential weak points in the manufacturing process, allowing corrective action to be taken at an early stage."

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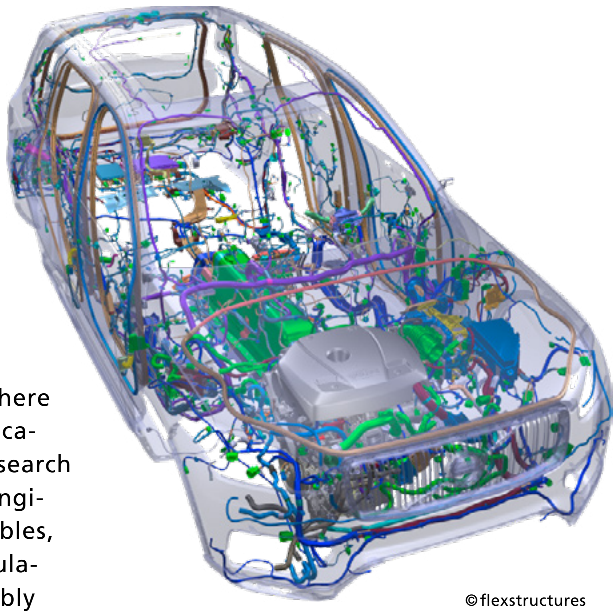
How Long Does a Cable Last?



A look inside a vehicle: cables and hoses are everywhere.

They can be found almost everywhere in vehicles – we are talking about cables. This is why a core topic of research in our "Mathematics for Vehicle Engineering" division is the field of cables, hoses and flexible structures. Simulations help to optimize their assembly position long before hardware comes into play. But the ultimate question is: how long will the cable last?

Our "IPS Cable Simulation" software package allows the simulation of cables and hoses in real time. This means that users can interactively carry out, modify and validate the 3D mechanical design of cables and hoses in the vehicle. This allows them to find the optimum design even before the first hardware assemblies are created. This saves time and costs and reduces prototypes and further iterations.

We Continuously Enhance the Software

Although "IPS Cable Simulation" is already successful and is distributed by our spin-off "fleXstructures", our researchers are striving for continuous improvements and new functions. In current projects, for example, they are looking at the question: How long will the cable last?

The simulation already provides information about the locally occurring loads. But what do these loads mean for the cable lifetime? "A suitable cable SN Curve, which represents the relationship between local load amplitudes and the number of load cycles until failure, is crucial to the answer," explains expert Dr. Fabio Schneider-Jung.

Comparative and Absolute Lifetime Predictions

Comparative statements are already possible with a generic SN curve. This means that although users do not know the absolute lifetime, they can compare different variants of an installation in terms of their lifetime. To additionally predict the actual lifetime, a specific cable SN curve is required.

However, determining this is no easy task. The researchers require a number of test specimens in various tests – whereby the test effort must always remain proportionate. Another hurdle is the almost impossible measurement of local loads along the cable. Here, they enrich the experimental data with simulations. Using the maximum likelihood method, they then search for the SN Curve that best matches the collected lifetime data.

"We have already determined cable SN Curves for some cables – with promising results, as the predicted lifetime was confirmed in further experiments," concludes the researcher.

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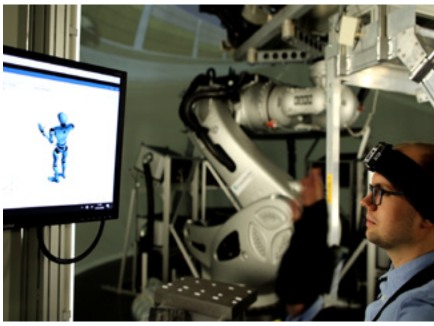
Autonomous Driving: Safe and Comfortable Thanks to Our Innovative Human Model

In the EMMA4Drive project, the "Mathematics for Vehicle Engineering" division is investigating the effects of various driving maneuvers on people, including their reaction behaviour and seat load, in order to calculate new body postures and movement sequences. A digital twin of vehicle occupants helps to investigate scenarios in the simulation and to analyze new seating concepts in terms of safety and ergonomics. Various studies are currently underway.

If a person does not drive themselves and does not pay attention to the traffic, it is hardly possible for them to prepare for driving maneuvers – they merely react to perceived accelerations and forces. In order to reproduce such reactive behavior in a simulation, our researchers use optimal control. This provides realistic movements, with the human optimally compensating for the driving maneuver. However, they are also testing approaches such as nonlinear model predictive control.



The RODOS® driving simulator in use – investigations during autonomous driving

Safe in Autonomous Buses

There are strict regulations for autonomous buses and shuttles with regard to starting and braking. "In order not to endanger standing passengers and still comply with the time-to-collision, we use simulations to determine the optimum load on the occupants. We calculate their compensatory movements in different standing directions and braking accelerations and determine optimum braking profiles for different TTC values. We also take into account the reaction time of the occupants," explains Dr. Monika Harant.

Validate Simulations

Our researchers are also using the RODOS® driving simulator. They examine the seating position and attention of a driver during a sudden lane change. At different speeds, attention levels and positioning, they test the feeling of comfort and safety during the driving maneuvers. In addition, they record the seat pressure distribution via pressure measurement mats in order to obtain information about the mechanical driver-seat interaction.

"In order to compare our EMMA simulations with the observations from the RODOS® experiments and thus also validate the simulation, we then transfer the movements of the vehicle cabin into the simulations," says Harant. To do this, they measure the movements of the vehicle cabin using an IMU (inertial measurement unit) and enter the data into the simulation as a reference movement. Using the optimal control approach, they determine a compensatory movement for the driving maneuver and also take a reaction time into account.

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