Customer Success Story

Simulation-based Development of Functional Oil Distribution in Electric Axle Systems

Shorter Development Cycles through Virtual Prototyping

Reaching Targets using PreonLab

The Challenge

OEMs who quickly bring electric vehicles (EVs) or hybrid vehicles (HEVs) to the market are dominating the industry. The same applies to Tier 1 suppliers providing powertrain systems and components.

Electric axle systems play an important role in vehicle electrification. Due to their compact design, they can be used in all vehicle segments with hybridized or all-electric powertrains.

To push these complex systems to the market as quickly as possible while maintaining high product maturity, an integrated simulation approach is essential during development.

The AVL Approach

The Computational Fluid Dynamics (CFD) solution PreonLab supports Schaeffler in analyzing and optimizing the oil distribution in its gearboxes. This is a significant contribution to the development of functional and high-performance electric axle systems.

With its meshless approach and extremely fast solver, PreonLab enables design-related investigations of various lubrication concepts. The short turnaround times and modern post-processing allow a quick and thorough evaluation of the oil distribution in the gearbox.

Benefits

Some of the benefits of Virtual Prototyping using PreonLab are:

- User-friendliness and intuitive user interface
- Short pre-processing, no meshing, superior simulation time
- Powerful visualization and post-processing of results
- Qualified, task-oriented support and method development by experienced AVL engineers
- Reduction of cost-intensive hardware tests enabled by focus on relevant design variants

Schaeffler Group

The Company

The Schaeffler Group is a global automotive and industrial supplier. The Schaeffler Group is already making a decisive contribution to "Mobility for Tomorrow" today with its high-precision components and systems in engine, transmission, and chassis applications, in addition to rolling and plain bearing solutions for a large number of industrial applications. Since its beginnings, the Schaeffler company has been characterized by groundbreaking innovations and global customer orientation.

Technologies for Hybrid and Electric Drive Systems

The consumption and emissions targets of the future can only be fully met through electrification of the drive train. As a result, Schaeffler offers products across the full bandwidth of electrification options - from 48-volt hybrids and plug-in hybrids to drives for purely electric vehicles.

This broad spectrum of knowledge makes Schaeffler an expert partner to the various markets and customers it serves - such as with components and systems for hybrid modules, entry-level hybridization, electric axle drives, and electric wheel hub drives.

Customer Success Story

This case study deals with the development of functional oil distribution in the gearbox of electric axle systems. Lubrication is one of the major challenges in gearbox development due to high rotational speeds, wide temperature ranges, as well as the transverse and longitudinal acceleration.

Schaeffler analyzes and optimizes the oil distribution in the gearbox by virtual prototyping using the innovative simulation solution PreonLab and thus ensures the robustness of the concept. At the same time, the testing effort and associated costs are reduced significantly.

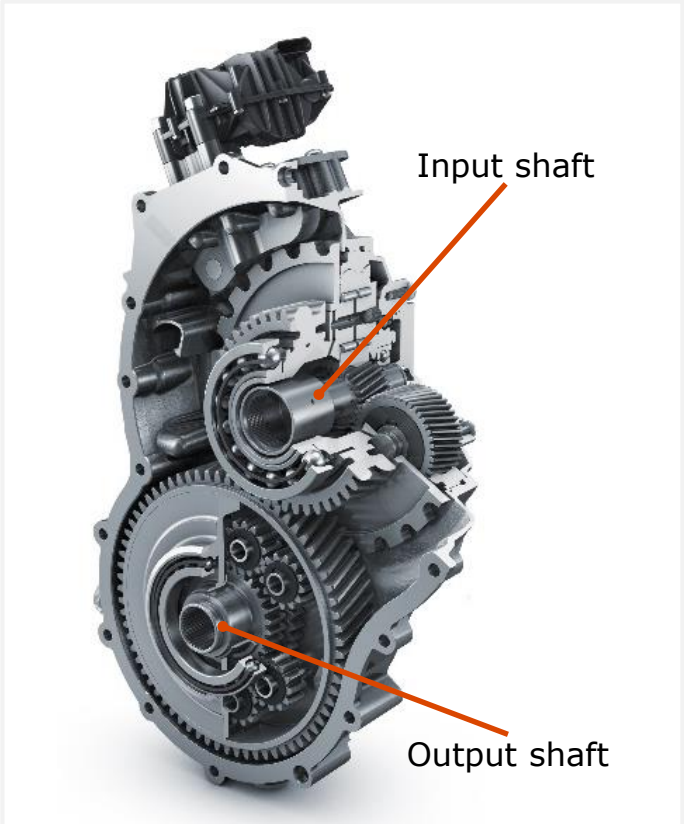
Source: www.schaeffler.de

Development Challenges in Passive Lubrication Concepts

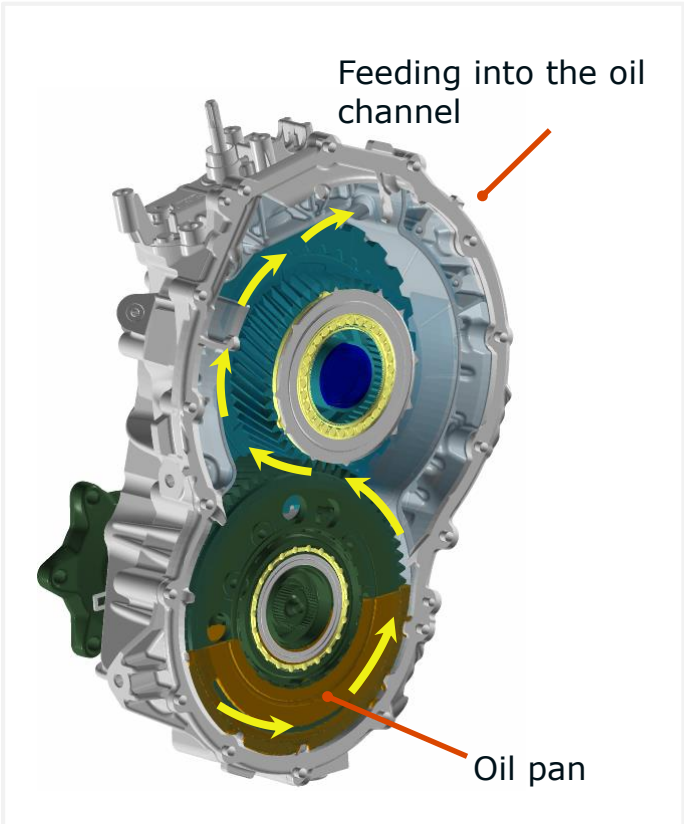
In addition to component load capacity and the NVH behavior of the e-axle system, gearbox lubrication and cooling poses a major challenge for developers. The selection of the lubrication concept impacts the cooling and lubrication of relevant locations and the overall weight and efficiency of the system.

This design features a vertically-oriented offset design relying on passive cooling and lubrication. Due to the compact design and the limited oil pan volume, the risk of foaming might appear. The multi-axis accelerations in real driving mode influence availability of oil in the lower pan. Oil viscosity may vary by orders of magnitude when considering temperature ranges from cold start through a loaded operating state. Oil supply to the upper oil channels has to be ensured under the above conditions.

The robustness of the lubrication concept is essential for all operating temperatures, conditions and speeds. It is essential to analyze and validate it as early as possible in the development process.



Offset design with vertical offset of gear shafts in installation position



Passive oil cooling and lubrication in the gearbox due to moving components

Source: C. Dassler, C. Vinci, Schaeffler Technologies AG & Co. KG

Experimental Analysis of Gearbox Lubrication

While some experimental methods exist to understand e-axle systems on the testbed, measurement capability is limited.

Thermocouples placed in the gearbox housing provide understanding of system thermal inertia and provide temperature data.

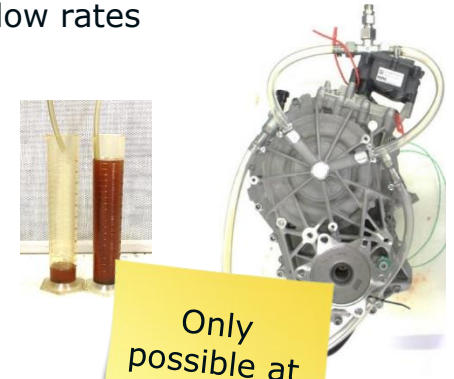
Volumetric flow rates can be determined by instrumenting bypasses, which relies on the availability of a channel at which to measure.

Volumetric distribution of the oil through the case cannot be directly measured. However, for some test conditions, transparent housings combined with high-speed camera recordings can give a qualitative understanding of the lubricant distribution. Dynamic oil levels can be visualized with small viewing windows.

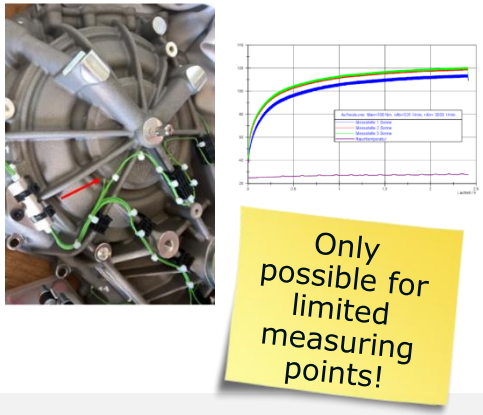
This method has limited applicability. At higher rotational speeds, splashing and foaming of the oil fully occludes windows and visualization is not possible. Transparent housings and windows also require specialized manufacturing.

The high level of system complexity creates a challenging testing protocol which ultimately provides only limited information. Considering multiple design variants in this environment is cost-intensive and requires a lot of time.

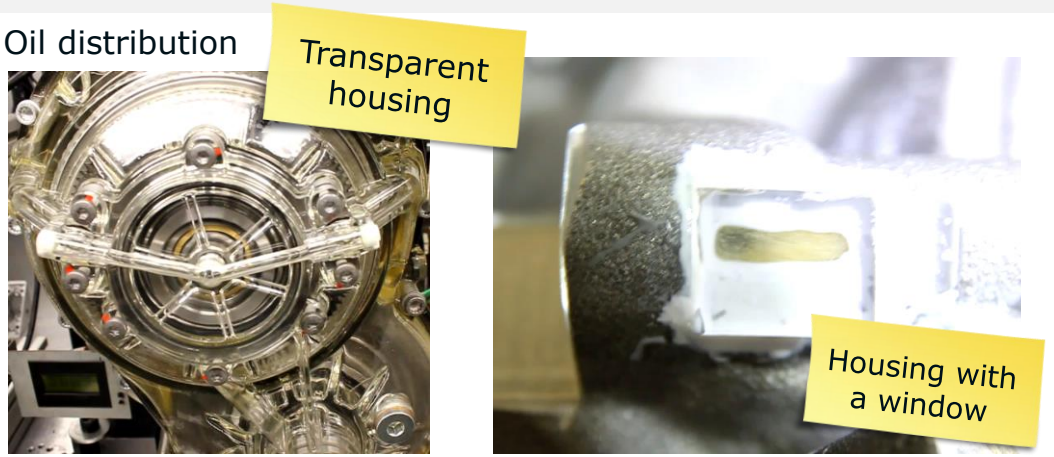
Flow rates



Warm-up curves



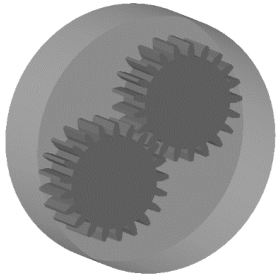
Oil distribution



Source: C. Dassler, C. Vinci, Schaeffler Technologies AG & Co. KG

Simulation of Gearbox Oil Flow

Subsystems are already covered with classic CFD methods



Particle-based methods (SPH) are used to simulate entire gearboxes

Analysis and illustration of gear contact

Gearbox system behaviors can be deeply understood through CFD.

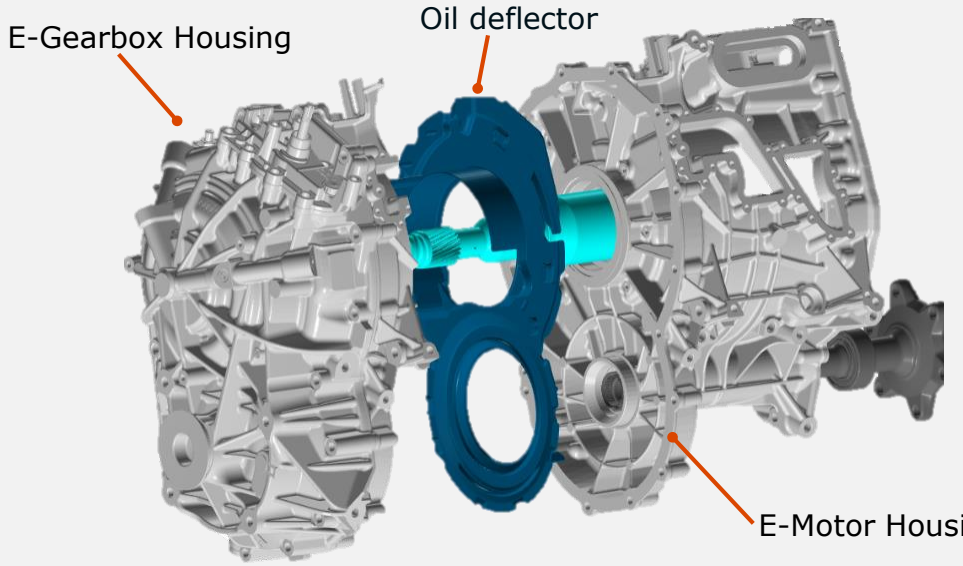
Simulation of the overall system is possible using classic Euler-based CFD methods. But in the case of product development it is unfeasible due to high resource and computational time requirements. One such resource requirement is meshing of the simulation domain. Therefore, only selected subsystems are simulated at reasonable expense. Since these do not represent the overall system, their value is limited.

The simulation tool PreonLab, which employs the Lagrangian approach, is an innovative alternative. PreonLab's Smoothed Particle Hydrodynamics (SPH) method, like conventional CFD methods, is based on the same physical description of the Navier-Stokes equations. The Lagrangian particle-based approach eliminates the need for meshing. As such, direct simulation of complex, moving structures as part of the fully-defined system becomes possible. The advantages are enormous in terms of pre-processing and process time.

Source: C. Dassler, C. Vinci, Schaeffler Technologies AG & Co. KG

Sample Simulation of Gearbox Oil Flow

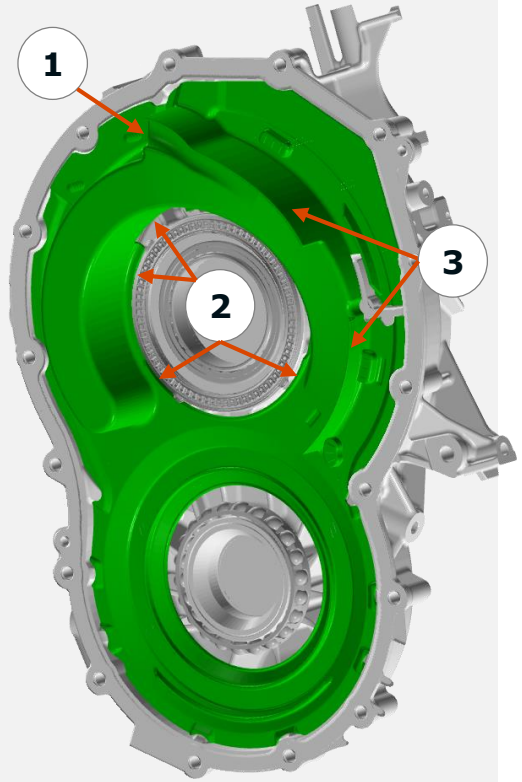
Schaeffler relies on a passive lubrication concept in the gearbox of an electric axle system. In order to specifically influence the oil flow and to ensure the oil supply at the upper channel, a plastic insert (deflector) is integrated into the gearbox housing.



The plastic insert also offers the possibility to decouple the oil flow from the ribbing at the electric motor housing and thus enables targeted oil supply to the gearbox. CFD simulation with PreonLab optimized its shape with regard to flow losses.

Baseline oil deflector

Optimized oil deflector



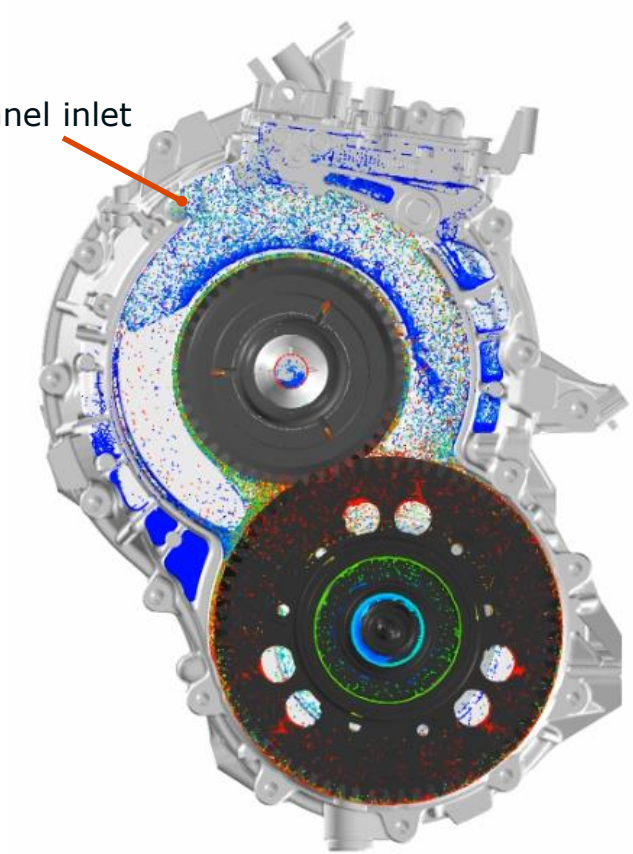
Design optimization of the oil deflector resulting from simulation insights:

1. Optimized contour for targeted oil supply to an upper oil channel
2. Adjustments to avoid oil volume flows behind the depositor
3. Wall + contours optimized for high rotational speeds

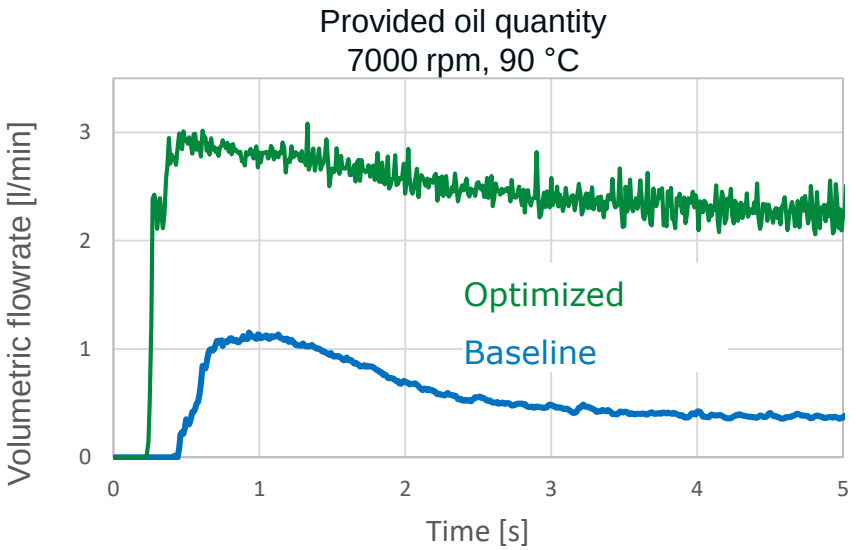
Source: C. Dassler, C. Vinci, Schaeffler Technologies AG & Co. KG

Sample Simulation of Gearbox Oil Flow

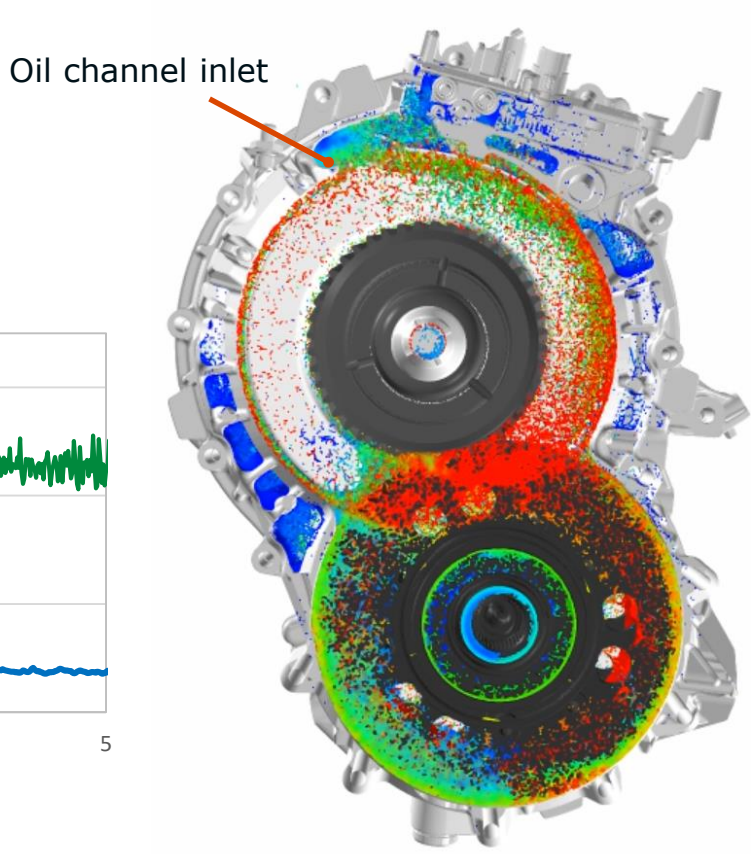
Baseline configuration



Volume flow increased 5 to 6 times!



Optimized deflector

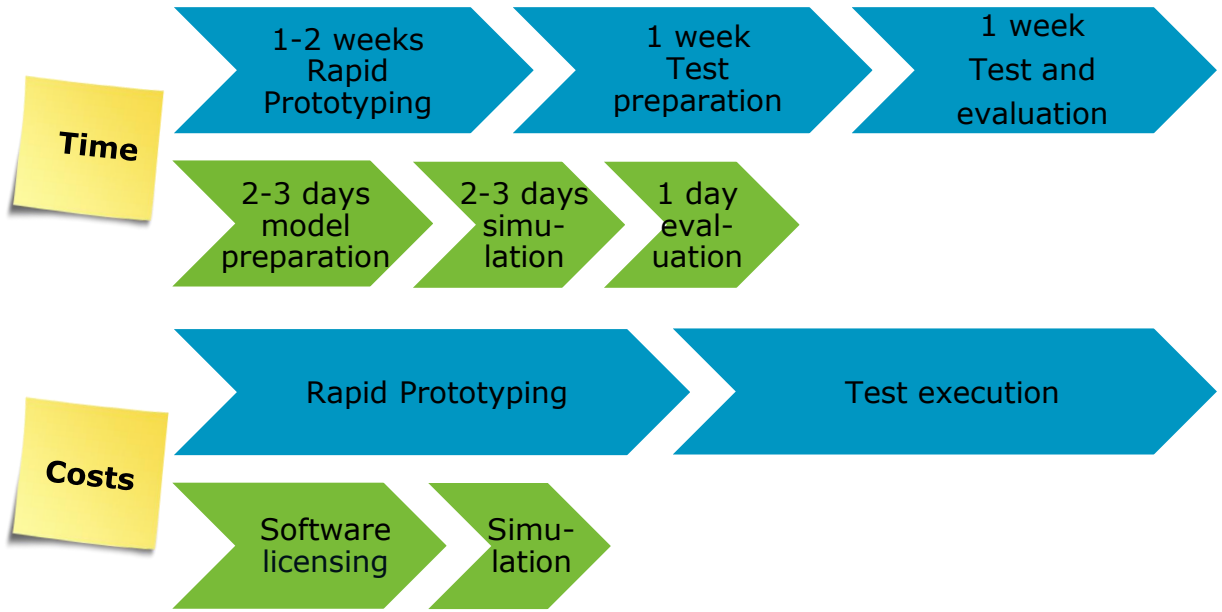


Simulation results confirmed by tests!

Source: C. Dassler, C. Vinci, Schaeffler Technologies AG & Co. KG

Benefits of Simulation-Based Development

Design Evaluation Workflow



PreonLab

- Simulation supports the design engineer
- Easy and fast evaluation of design variants
- Reduction of cost and time intensive hardware tests

The simulation of oil distribution with PreonLab enables significant cost and time advantages for each design variant. In addition, PreonLab offers extensive possibilities for displaying simulation results in post-processing. This in turn enables an in-depth system understanding for the optimal design. Virtual sensors can be placed at any location, even inaccessible to experiment, to obtain quantitative statements.

Virtual prototyping offers enormous potential for shortening development cycles through the use of innovative simulation methods. The meshless SPH approach and the high-performance solver enable PreonLab to carry out design-related investigations of various lubrication concepts. The short turnaround times and the modern post-processing allow for efficient and confident evaluation of the oil distribution within the gearbox.

„The combined use of virtual prototyping using PreonLab and testing is an efficient approach in the development of lubrication and cooling concepts for e-axles. It efficiently supports us in achieving our goals in terms of functional design as early as possible. *Christian Dassler, Head of R&D, Product Line E-Axle Transmission, Schaeffler Technologies AG & Co. KG*

Source: C. Dassler, C. Vinci, Schaeffler Technologies AG & Co. KG

AVL CAE
Added Value Through Engineering Competence!

With more than 10,000 employees, AVL is the world's largest independent partner for the development, simulation and testing of powertrains for passenger cars, commercial vehicles, stationary engines, large engines and their integration into the vehicle.

AVL's simulation solutions and respective tools and methods represent the only market options that have emerged from the challenges of real product development processes. AVL is the exclusive distributor of PreonLab and partners with FIFTY2 on continuous development of this innovative tool.

Thanks to this unique combination of engineering expertise and tools for virtual product development, we can increase your product quality at an early stage of development and thus significantly shorten your development times.

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