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CHASSIS

Trends for New Conditions in Chassis and Axle Components



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Chassis Trends from Lightweight Design to Validation

The transition from combustion engines to battery-electric drives is leading to new vehicle platforms with altered mass distribution, higher total weight, and integrated battery packs. This transformation has a direct impact on the design, dimensioning, and virtual validation of chassis components. Hirschvogel highlights the trends in materials technology and forging processes for chassis and axle components under new boundary conditions.



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The profound transformation in the automotive industry is reshaping the requirements for chassis and axle components and thus their development. Electrification, global platform strategies, and increasing cost pressure are influencing vehicle architectures as well as changes to subsystems, such as those made necessary by brake-by-wire and steer-by-wire technology. At the same time, requirements for ride comfort, vehicle dynamics, crash and functional safety, and efficiency continue to increase. As a result, chassis and axle systems are gaining importance as function-critical assemblies within overall vehicle development, also for the Hirschvogel Group.

Battery electric vehicles in particular are placing new demands on chassis design compared to conventionally powered cars. Higher vehicle masses, altered mass distributions, and new packaging constraints lead to higher load spectra and more stringent boundary conditions. The axle is increasingly evolving from a primarily mechanical structure to a highly integrated assembly that combines mechanical and functional aspects.

In this article, key trends in the development of chassis and axle components will be highlighted. In addition to developments in materials and manufacturing technology, methodological approaches to virtual design and validation are examined to dem-

onstrate interactions between design, simulation, system integration, and manufacturing for lightweight forging [1].

SYSTEM-LEVEL REQUIREMENTS FOR MODERN CHASSIS SYSTEMS

Modern chassis and axle assemblies today must meet a wide range of conflicting requirements. In addition to classic target values such as stiffness, strength, and durability, comfort and NVH properties are becoming increasingly important. At the same time, aspects such as weight, installation space, costs, and sustainability are coming to the fore. These requirements can no longer be optimized in isolation at the component level; instead, they require a holistic, system-level approach.

A key driver of this development is the increasing electrification of the powertrain. Compared to conventional passenger cars in the same segment, battery electric vehicles have significantly higher overall vehicle masses in average. Review work of current lightweight-design strategies estimate this effect at around 20 to 30 % additional mass, primarily attributable to the battery pack. For example, the VW ID.7, currently the 2025 best-selling electric vehicle in Germany, has a minimum curb weight of 2180 kg in its basic version. In contrast, the VW Passat with combustion engine in its basic version weighs only 1672 kg. The additional mass has a direct impact on wheel loads, axle loads, and thus on the design of load-bearing chassis structures.

The increased vehicle mass not only raises overall energy demand but also results in significantly higher road and rolling loads. For chassis and axle development, this means investigations in higher structural loads from special and misuse events, changed fatigue strength requirements, and increasing demands on elasto-kinematics and NVH tuning.

In addition to the absolute mass, the altered mass distribution also plays a key role. The positioning of the high-voltage battery in the vehicle underbody shifts the center of gravity and the axle load distribution, which has a direct impact on vehicle dynamics. In particular, rear axle loads increase significantly. Systematic comparisons to conventional or electrified drives

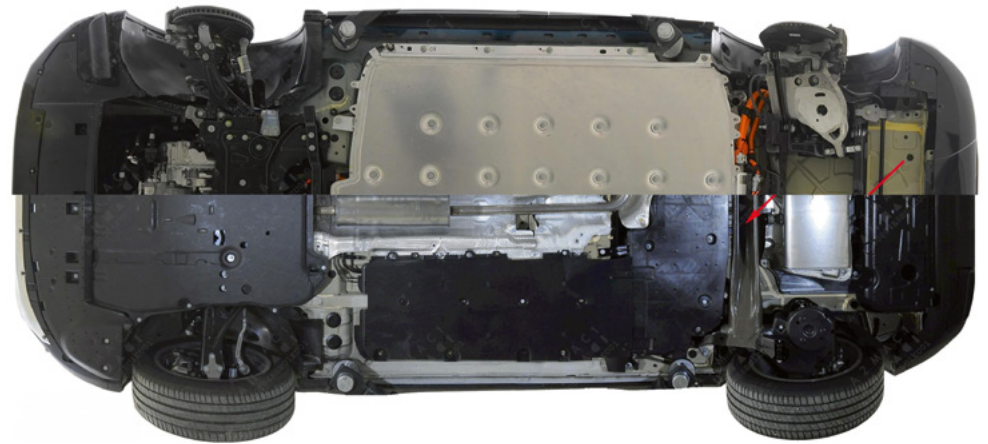


FIGURE 1 Different underbody designs using the example of a Peugeot 3008 depending on the type of drive: electric drive of the eGT model variant from 2024 (top) and combustion engine drive of the 1.2 PureTech Allure model variant from 2016 (bottom) (© A2Mac1) (Source: A2MAC1, A00004KSBUEU01)

show that these effects must be taken into account early on in the development phase in order to resolve target conflicts between vehicle dynamics, comfort, and efficiency.

To ensure that the battery can be optimally positioned in the underbody and contribute effectively to a 50:50 axle load distribution, sufficient installation space must be available. **FIGURE 1** shows, using the Peugeot 3008 SUV as an example, the underbody with a trailing arm axle compared to one with a multi-link axle. The multi-link axle provides significantly more space for the battery, which is why it is increasingly preferred even in compact class battery-electric vehicles.

In addition, functional integration within the axle is constantly increasing. Components such as wheel carriers, control arms, and axle carriers not only perform load-bearing functions today, but also serve as interfaces for sensors, actuators, and brake systems. This multifunctionality increases design complexity and requires close coordination between design, simulation, and manufacturing. As a result, the axle becomes a central component in the overall vehicle system, whose properties have a significant influence on vehicle dynamics.

Another aspect is the increasing variety of models. Platform strategies mean that axle assemblies have to be designed for different vehicle derivatives and drive variants. This requires scalable concepts that can be adapted to varying boundary conditions with reasonable effort. Modu-

larization and a building block thinking are therefore playing an increasingly important role in axle development.

MATERIAL AND MANUFACTURING TRENDS IN AXLE DEVELOPMENT

The increasing system-level requirements for chassis and axle assemblies have a direct impact on the selection of materials and the design of manufacturing processes. While classic cast iron or sheet steel constructions continue to play a central role, high-strength and ultra-high-strength steels or aluminum components are being used more frequently; these materials enable high load-bearing capacities with reduced material usage. The task of component suppliers is to resolve the conflict between weight, stiffness, and service life as efficiently as possible.

In **FIGURE 2**, **FIGURE 3** and **FIGURE 4**, it is illustrated, using the example of a damper fork, how different material choices affect component properties. Three variants are compared here: the conventional aluminum casting alloy EN AC-ALSi7 T6, the typical aluminum wrought alloy EN AW 6082 T6 (forging), and the material 38MnVS6, a forging alloy frequently used for steel components. The same geometry is deliberately chosen to ensure that material-related differences can be compared under identical conditions. Both aluminum variants, each weighing 802 g, offer significant advantages in terms of the unsprung mass compared to the heavier

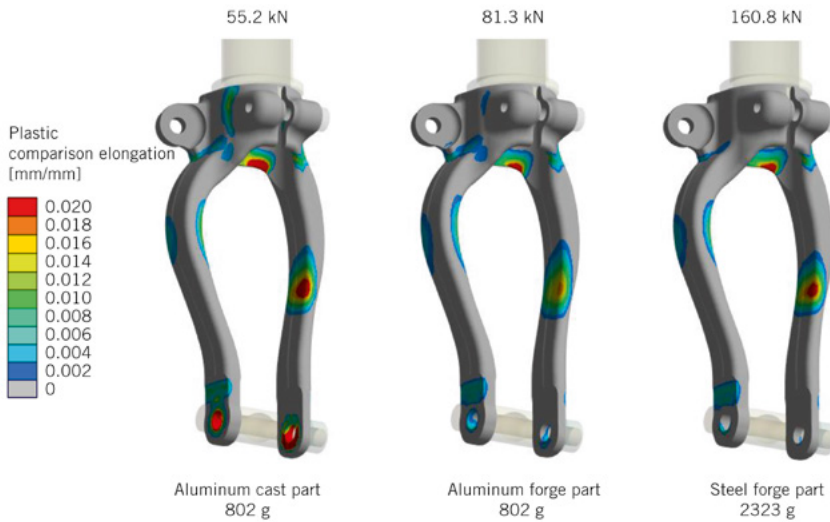


FIGURE 2 Damper fork as an example: Comparison of plastic elongation for one cast part and two forged parts at 2.2 mm displacement (© Hirschvogel Umformtechnik GmbH)

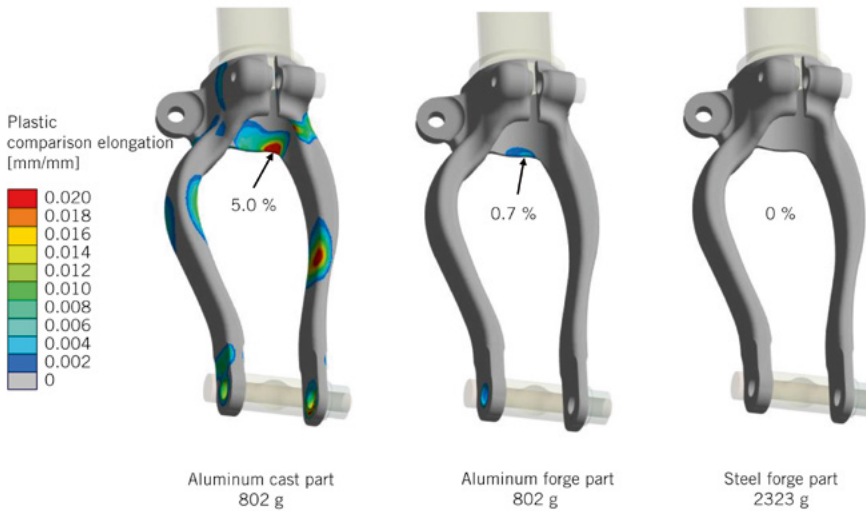


FIGURE 3 Damper fork: Comparison of plastic elongation for one cast part and two forged parts at 55 kN force (© Hirschvogel Umformtechnik GmbH)

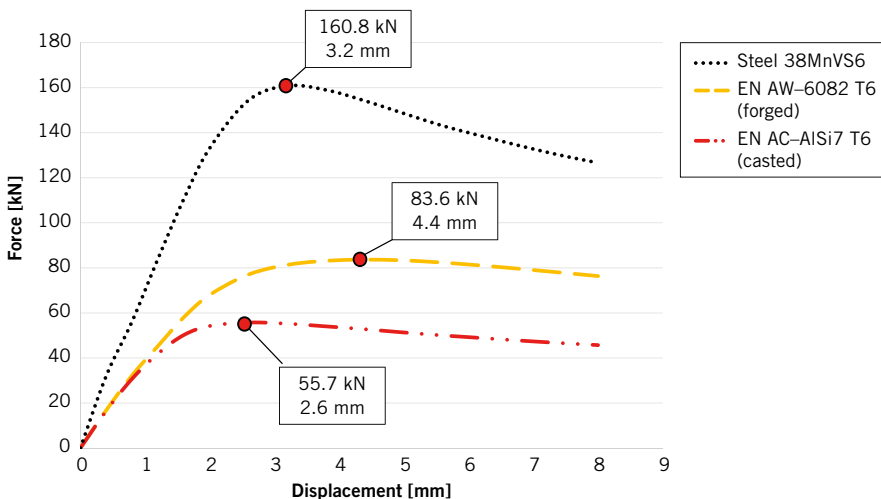


FIGURE 4 Force-displacement diagram of the various manufacturing processes in comparison to steel (© Hirschvogel Umformtechnik GmbH)

steel version at 2323 g. With regard to stiffness, and consequently ride comfort properties, the steel version performs better. When it comes to buckling behavior and service life, the forged aluminum part provides an excellent compromise at minimal weight. The deformability of the aluminum forging prior to fracture is particularly noteworthy. It reaches maximum load at a significantly higher deformation displacement than the other two manufacturing variants. Both aluminum components show good corrosion resistance under the demanding adverse environmental conditions of chassis applications, without the need of additional corrosion protection.

A defining trend is the function-oriented component design in close conjunction with the manufacturing process. Modern forming and forging technologies make it possible to place the material precisely along dominant load paths. Locally adapted wall thicknesses and optimal fiber orientation in accordance with the main load direction result in highly resilient axle components that also make a significant contribution to weight reduction. Manufacturing thus evolves from a mere implementation step to an active enabler of component functionalities.

With increasing functional integration, the demands on process stability and reproducibility are also rising. Axle components, such as a forged aluminum control arm, **FIGURE 5**, must exhibit consistent properties not only under laboratory conditions, but also across large quantities and, ideally, in a global manufacturing network. This requires early consideration of manufacturing boundary conditions as early as the concept and design phase. Tolerance strategies, component robustness, and control of process-related variations are thus becoming increasingly important for the overall performance of the axle assembly.

At the same time, aspects of industrialization and scalability are moving further into focus. OEM platform strategies require component solutions that can be transferred to different vehicle derivatives without the need to establish new manufacturing processes in each case – worldwide. Standardized semi-finished products, modular geometry concepts, and flexible process chains support this approach and help to shorten develop-

ment and ramp-up times.

In addition to mechanical targets, sustainability aspects are increasingly influencing the choice of materials and processes. Resource-efficient use of materials, reduced scrap rates, and the recyclability of the materials used are becoming more relevant. Modern steel grades in particular offer significant potential for reducing the CO₂ footprint of axle components without compromising safety or performance.

TRENDS FOR SIMULATION AND VIRTUAL VALIDATION

In parallel with developments in materials and manufacturing technology, methodological approaches in chassis and axle development are undergoing fundamental changes. Virtual development and validation methods continue to gain importance and are now an integral part of modern engineering processes. The goal is to complement physical testing in a targeted manner and to reduce development time and cost without compromising the quality or robustness of the components.

Simulation-based methods for designing structure, kinematics, and elastokinematics are already used in early development phases. Multi-body simulations, coupled with FEA-based structural models, make it possible to virtually evaluate chassis behavior under various load cases and driving maneuvers. This enables early identification of conflicting requirements and supports iterative optimization.

Another trend is the increasing coupling of simulation and test bench environments. Hardware-related models and real-time simulations allow axle components and assemblies to be tested on test benches under realistic boundary conditions. These so-called X-in-the-Loop (XiL) approaches form a bridge between the virtual and physical worlds and contribute significantly to maturity validation. They offer par-



FIGURE 5 Typical forged aluminum control arm (rear axle) that fits well into the available installation space (© Hirschvogel Umformtechnik GmbH)

ticularly high potential for complex axle systems with active components, where functional interactions must be reliably validated.

The consistency of the tool chains plays a central role in this context. Reliable results require coherent models and data that remain consistent across all development phases and already account for manufacturing influences. At the same time, close cooperation between OEMs, suppliers, and engineering services providers is essential to clearly define interfaces and avoid data loss. The overarching goal arises to reduce testing effort through simulation driven validation, thereby increasing development speed and lowering costs.

COLLABORATION ALONG THE VALUE CHAIN

The trends described before are leading to a shift in collaboration along the holistic value chain. Development responsibility is increasingly being shared between all companies involved. Early involvement of all stakeholders is crucial to make conflicting requirements transparent and to develop efficient solutions.

Joint development models, coordinated simulation approaches, and clearly defined responsibilities form the foundation of successful co-development projects [2]. Especially for highly integrated axle assemblies, iterative

exchange between design, simulation, and manufacturing is necessary to keep rising complexity manageable.

OUTLOOK

Chassis and axle assemblies will play a key role in future driving experience and overall vehicle performance. With the transition to software-defined vehicles, active and controllable systems will continue to gain importance. Mechanical excellence remains indispensable but must increasingly be considered in close conjunction with simulation, software, and manufacturing. End-customer-relevant functions in the overall system must also be understood by component suppliers and integrated – among other things - into simulations.

The successful development of future axle systems therefore requires suppliers such as the Hirschvogel Group not only to drive technological innovation, but also to adapt their development processes and engage in intensive cooperation of all departments from development to production.

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