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DRIVE SYSTEMS

## for Micromobility from E-bikes to Light Electric Vehicles

# Drive Systems for Micromobility from E-bikes to Light Electric Vehicles

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WRITTEN BY

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The effects of climate change and the scarcity of space, resources, and energy pose major challenges for the urban mobility of tomorrow. Electric small and light vehicles offer one solution. As Hirschvogel shows in the following, experience and know-how from automotive development can be used in the development of robust and cost-effective drive components for these applications.

To date, there is no universal definition of the term “micromobility”. It often refers to electric micro-vehicles used as a small and light means of transport for covering the so-called first or last mile. At Hirschvogel, the scope of the Micromobility Business Unit ranges from electrically assisted bicycles or cargo bikes to small and light vehicles of the L6e or L7e classes. A variety of innovative approaches and concepts exist that have the potential to significantly influence personal mobility and delivery traffic of the future [1]. One of the biggest challenges here lies in the technical and industrial implementation of micromobility. The intensive dialog with manufacturers and users shows that small and light vehicles are not robust enough, are too expensive compared to conventional vehicles, and are not very attractive, thereby making it difficult to extend their reach. There is a lack of suitable vehicle components. To address this need, Hirschvogel is combining its experience and industrialization expertise with the agility, flexibility, and speed of the development team in the Micromobility Business Unit. The aim is to develop robust and cost-effective products and systems for small and light vehicles and offer them under a brand created specifically for this purpose. AXIMO is thus intended to support the mobility shift toward lighter, smaller and altogether more sustainable vehicles.

**FIGURE 1** Drive axle for a three-wheeled e-cargo bike (© Hirschvogel)

## DRIVE AXLE FOR E-BIKES

With the drive axle, **FIGURE 1**, for a three-wheeled e-cargo bike, which was brought to market by a renowned German manufacturer in May 2023, the first series product of the Micromobility Business Unit was launched at the end of 2022 at Hirschvogel E-Solutions in Kaufbeuren. Within a development time of just under 18 months, a drive axle that is characterized by a special tilting mechanism, a constant-velocity joint, and a specially devised differential gear was designed and brought to series maturity. The design enables natural and safe driving behavior that is on par with that of a regular e-bike and ensures that the transported load does not tilt when cornering and at low speeds. The differential gear provides speed compensation between the drive wheels. This prevents spinning wheels and allows the load wheel to still be steered precisely and safely even at higher speeds and when navigating tighter curves.

As part of the industrialization process, essential knowledge was acquired with regard to assembly-oriented product design, the procurement of complex component volumes, and the process development of assembly systems including collaborative robots, **FIGURE 2**. A suitable assembly system was developed inhouse. The new processes as well as the experience from the automotive environment formed the basis for this. As a result, the assembly system is efficient, flexible in terms of variants, scalable as required and, thanks to the collaborative robots, has a high level of process reliability even for small volumes.

Assembly, **FIGURE 3**, takes place in a so-called one-piece flow, where the less complex joining of individual

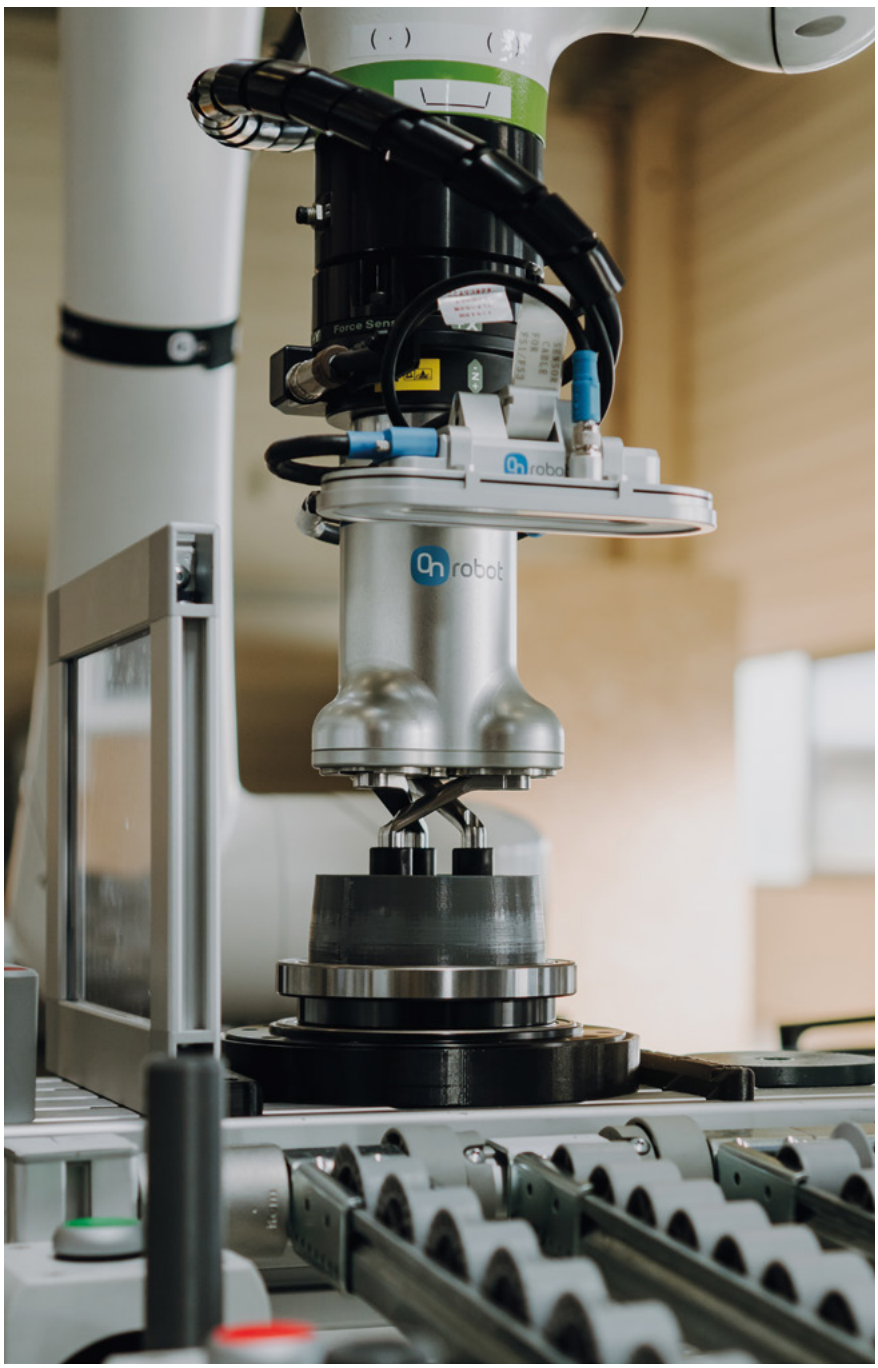


**FIGURE 2** Collaborative robot (Cobot) (© Hirschvogel)

subassemblies is automated, allowing the worker to focus on completing the complex overall assembly. Artificial intelligence is used to check that all components are in place. Each assembly undergoes an End-of-Line (EOL) test and is traceable by means of a product label.

Further variants of the drive axle for three- and four-wheeled cargo bikes with ready-to-assembly differential gears will go into serial production in two size classes (maximum/rated torque 350/100 Nm and 600/350 Nm) from the beginning of 2024 and at the end of 2024 respectively. The integrated bevel gears made of case-hardening steel will undergo warm forging at the lead plant in Denklingen. This will be followed by machining and case hardening. The cover is a cold forged part, allowing strain hardening to be taken advantage of; the housing will be produced by a warm forging process. The cover and housing are made of heat-treatable steel and will undergo machining after forging. The other parts will be purchased. The validation of the drive axle and differential gears is carried out on the basis of inhouse standards (differential testing) and by means of external testing service providers (fatigue test, torsion test, salt spray test).

**FIGURE 3** Assembly of bellows (© Hirschvogel)

## DRIVE SYSTEM FOR E-BIKES

The drive system for pedelecs, e-cargo bikes and speed pedelecs developed by Hirschvogel E-Solutions at the Piusheim site, **FIGURE 4**, is about to take its final step towards serial production. The system is a direct drive hub motor that delivers a maximum torque of 60 Nm at the wheel and supports up to 45 km/h in the speed pedelec version. **FIGURE 5** shows the test set-up. With a motor weight of just under 5 kg, the AXIMO drive has the highest power performance (torque/weight) on the market, with a maximum efficiency of 83.3 % at the speed pedelec operating point (45 km/h on level ground).

The power electronics are built into the motor, with a patented solution for integrated torque and cadence measurement ensuring intuitive control. The motor is integrated into the drive system via a CAN bus; the other system elements – such as the battery, cable harness, as well as the operating and display elements – are supplied in cooperation with a system provider. The design of the motor allows installation in standard frame dropouts and the use of standard cassettes, belts, brake disks, and commercially available thru axle systems.

The motor is extremely robust and – thanks to its gearless design – maintenance-free, rendering it suitable for commercial use. For servicing purposes, the motor can be opened with the spokes assembled and quickly replaced in the event of damage.

Production of the individual components and assemblies is scheduled to be carried out in cooperation with various partners in Germany and Asia. Assembly will be performed at the Kaufbeuren site. Calibration and EOL testing will also take place there before the drives are supplied to the vehicle manufacturers.


**FIGURE 4** E-bike drive system (HMI: Human Machine Interface) (© Hirschvogel)

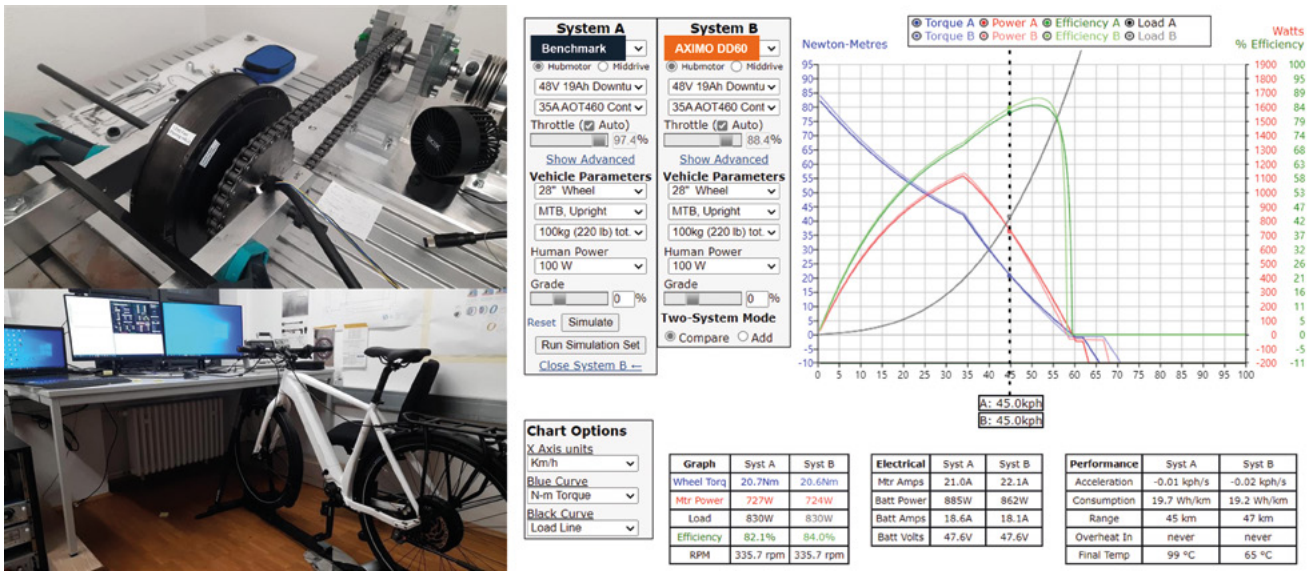


**FIGURE 5** Performance test bench (left) and comparison benchmark versus AXIMO DD60 (right, screenshot) (© Hirschvogel)

## AXLE SYSTEM FOR SMALL AND LIGHT VEHICLES

The rear drive axle combines the functions of axle structure, suspension/damping, drive (motor and controller), as well as brake/recuperation in one unit. Thanks to its modular concept, it can be used for a variety of Light Electric Vehicles (LEVs) in the L2e, L6e, and L7e ranges. Hub motors with three power ratings offer a maximum torque per axle of 120, 240, and 600 Nm at a maximum axle load of 450 kg. A track width of between 900 and 1250 mm can be selected, the axle offers between 50 and 70 mm of suspension travel, and the vehicle's ground clearance can be easily adjusted. Steering knuckles made of forged aluminum will be used in serial production, thereby guaranteeing low weight and high strength in a very limited assembly space. Trials are currently underway on the A-test bench. The corresponding steered and suspended front axle is at the concept stage and will complete the axle system shown in **FIGURE 6** by the end of 2025.

## CHALLENGES IN THE DEVELOPMENT PROCESS

The challenge for Hirschvogel is to evolve from a component supplier to a product or system supplier for the micromobility sector. The bicycle indus-

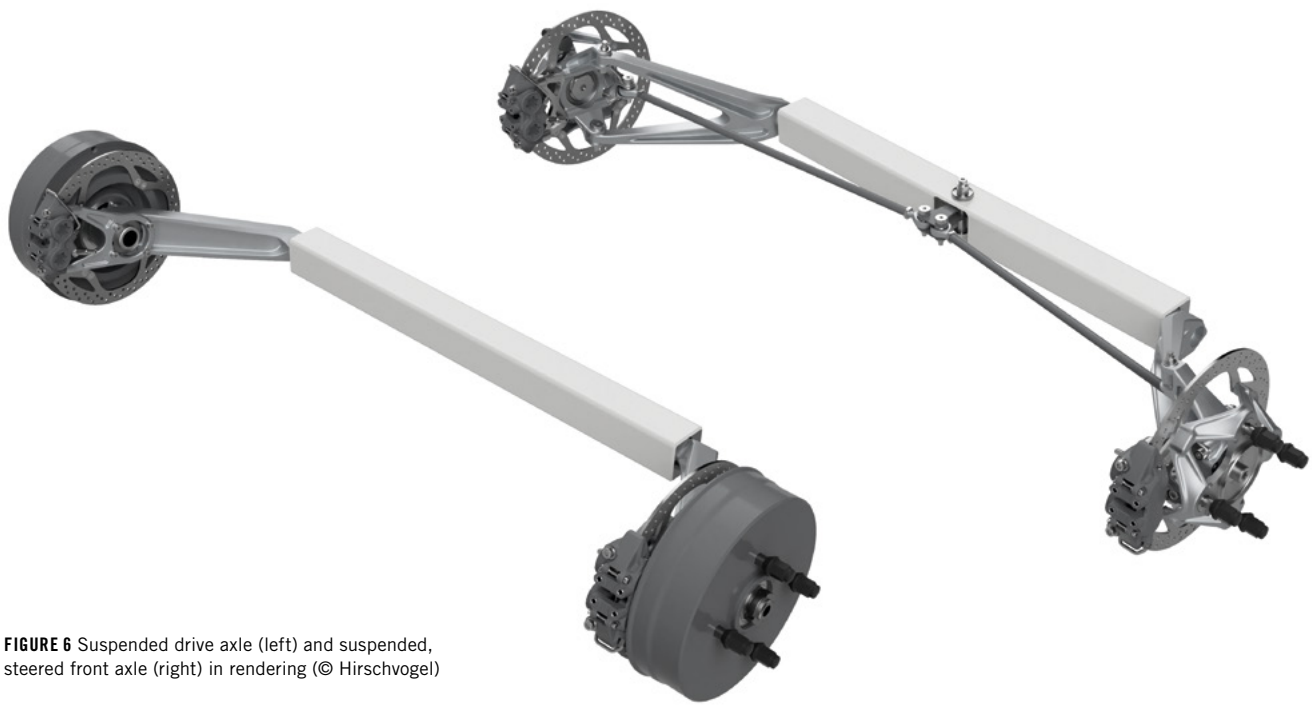

**FIGURE 6** Suspended drive axle (left) and suspended, steered front axle (right) in rendering (© Hirschvogel)

try operates differently to the classic automotive business, where, for example, there are many so-called built-to-print parts that are specified exactly by the customer. The micromobility market requires greater expertise with regard to the vehicle as a whole, since not all the requirements for the component or system are on the table at the start of the project. Instead, these are worked out together with the customer. The development process must be designed in a much more flexible way. It is very important to quickly turn interim results into prototypes and optimize them in short cycles. For this reason, agile methods for product development were introduced and successfully established when designing the e-bike drive system. Based on the Scrum concept [2], the development team works in two-week iteration cycles (so-called sprints) to complete subtasks. In addition to working with simulation tools for design and dimensioning, the feasibility of subfunctions is verified directly with the help of 3-D-printed functional prototypes. At the same time, prototype test benches are constantly being developed in order to quickly obtain testable product prototypes that can be tried out both on the test bench and in practice.

Hirschvogel's experience comes into play in serial development and industrialization. The boom in the bicycle industry is shifting the requirements away from specialized craftmanship to industrial logic. As the small and light vehicle scene evolves from small start-up companies to a growing industry, the demands on components, products, and systems are increasing. The ability to think in processes, to meet high demands in terms of quality and safety, and to deliver reliable, validated products are topics that are firmly anchored thanks to its longstanding automotive experience. And it is these strengths that will be drawn upon to achieve successful positioning in the field of micromobility.

## SUMMARY AND OUTLOOK

New mobility will require new vehicles, and new vehicles will require new components, products, and systems. With the founding of the Micromobility Business Unit, the existing competencies in the forging and machining of steel and aluminum will be complemented by new expertise and products, which will be launched on new markets in an agile and flexible manner. In the medium-term, the individual development projects will culminate in the creation of a modular component system for small and light vehicles, which will be marketed under the AXIMO brand.

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