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Postertitel: „Traction-X – a Patented Combination of Power Transmission and Wheel Suspension for the Scooter of the Future“

Konferenzthema: Fahrzeug – Fahreigenschaften motorisierter Zweiräder

1 Reinventing the wheel

Conventional motor scooters have comparatively small wheels due to limited space, which leads to significant disadvantages in terms of driving stability, rolling comfort and tire grip compared with motorcycles. The technically widespread accommodation of engine and transmission within a powertrain lever results in comparatively large unsprung, i.e. tire-sprung masses of the wheel suspension, with corresponding losses in comfort.

The patented Traction-X® system solves these problems by combining the swing arm and drive wheel in a single compact unit (see [1]).

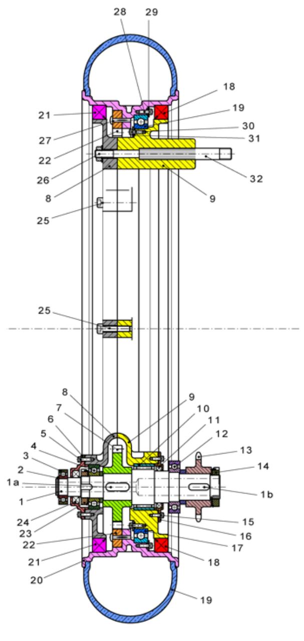


Figure 1: Cross Section View from the German Patent

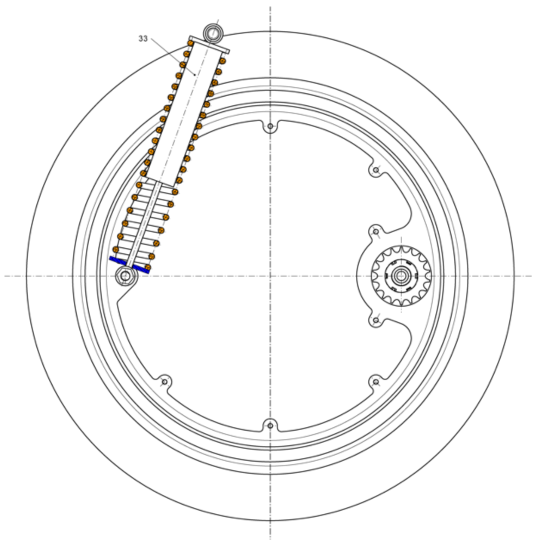


Figure 2: Axial View

The Traction-X® system comprises a hubless wheel that is driven internally by a gear stage via an eccentric drive shaft, which is also the swingarm axle. The wheel thus performs the dual functions of power transmission and suspension flexibility. Figure 1 is a sectional drawing and Figure 2 an axial view of this invention marketed under the Traction-X® brand name.

After subtracting the oscillating motion of the wheel, a free space remains inside it, allowing space-saving and frame-fixed accommodation of aggregates therein without increasing the tire-sprung masses. In this compact assembly, the diameter of the wheel can be increased to a value typical for motorcycles. Additionally, the Traction-X® hubless wheel enables interesting new design aesthetics.

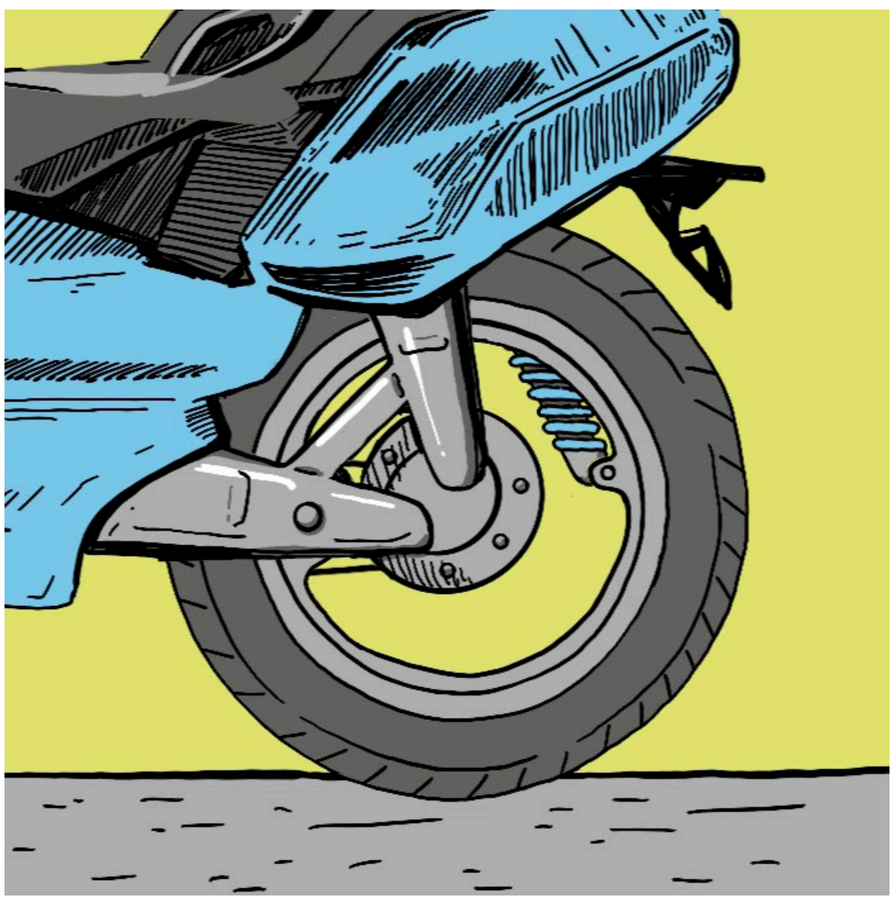
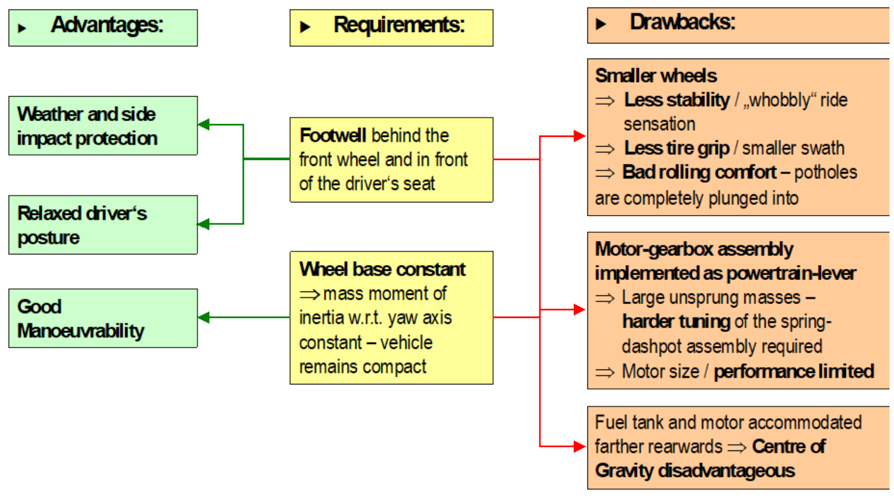


Figure 3: Traction-X® functional animation

Figure 3 shows a functional animation of the Traction-X® scooter wheel, while traversing a road unevenness. It is provided with a propulsive torque by and is pivoting around the combined transmission shaft and swing arm axis. Note that the electric motor is mounted within the chassis and does not contribute to the unsprung masses. On the left-hand side of the vehicle, i.e. in the background of the image, a toothed belt for power transmission can be distinguished.

2 Scooter versus motorcycle: Technology comparison

So far, a motor scooter is the technically unsatisfactory solution to conflicting requirements, as the following diagram illustrates. The starting point is a comparison with a conventional motorcycle.



The aforementioned customer wishes for a relaxed seating position, a protective and comfortable footwell as well as a maneuverable vehicle come at the price of a number of disadvantages with conventional scooter design. This dilemma was the motivation for the development of Traction-X®.

3 Increased driving safety through the symbiosis of motorcycle and scooter

The unsprung mass moment of inertia of the Traction-X® system is actually about an order of magnitude lower than that of designed powertrain levers. This is indicated in Figure 4 that compares the suspension masses of a Piaggio scooter top model with 12 inches wheels with that of a Honda motorcycle with 18 inches wheels, and with a Traction-X® wheel of the same size. A reduced suspension inertia allows for lower spring stiffness and reduced viscous damping, both yielding a more sensitive suspension response. It also reduces the dynamic wheel load, thus optimizing the force generation in the tire contact patch.

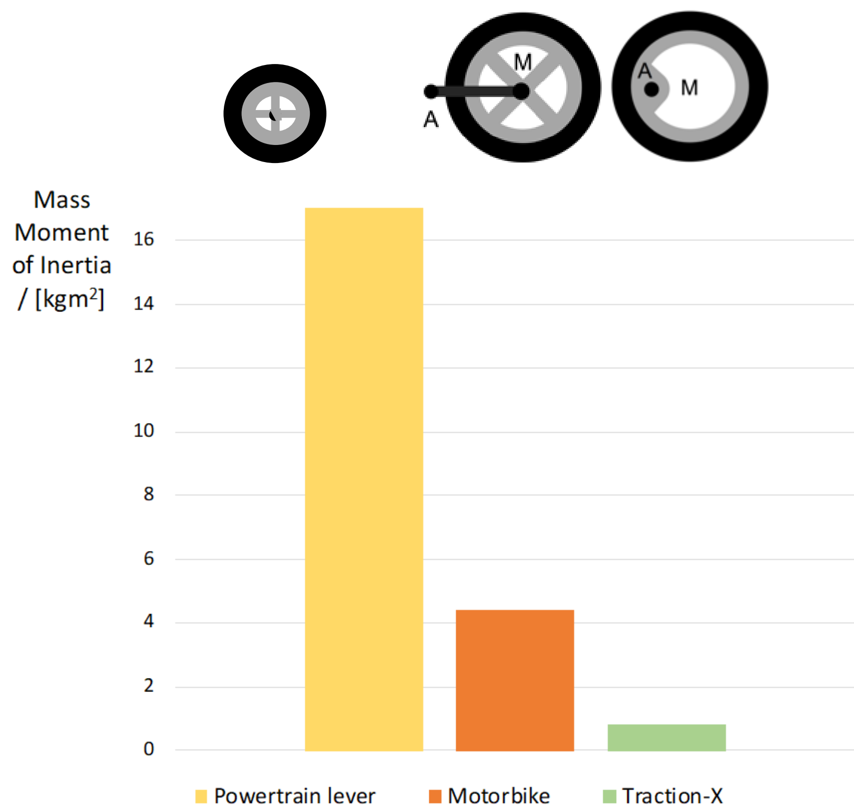


Figure 4: Suspension mass moments of inertia in comparison

The larger wheel diameter increases both the rolling comfort, as indicated in Figure 5, and the driving stability.

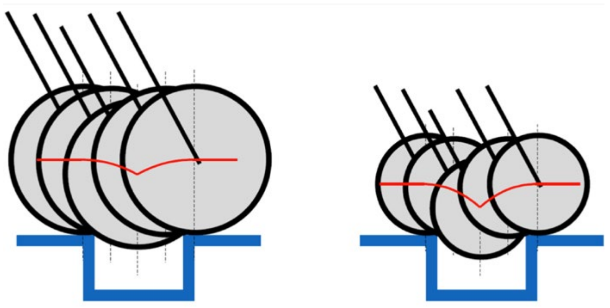


Figure 5: Effect of wheel size on sensed unevennesses [2]

In Figure 6 the angular momentum at a velocity of 50 km/h of the 12 inches scooter wheel is compared with those of the conventional motorbike wheel and the Traction-X® wheel torus, both of 18 inches diameter. Although not the only influence on a vehicle stability, it can be derived that the stabilizing contribution from the rear wheel can be increased to almost that of a motorcycle wheel.

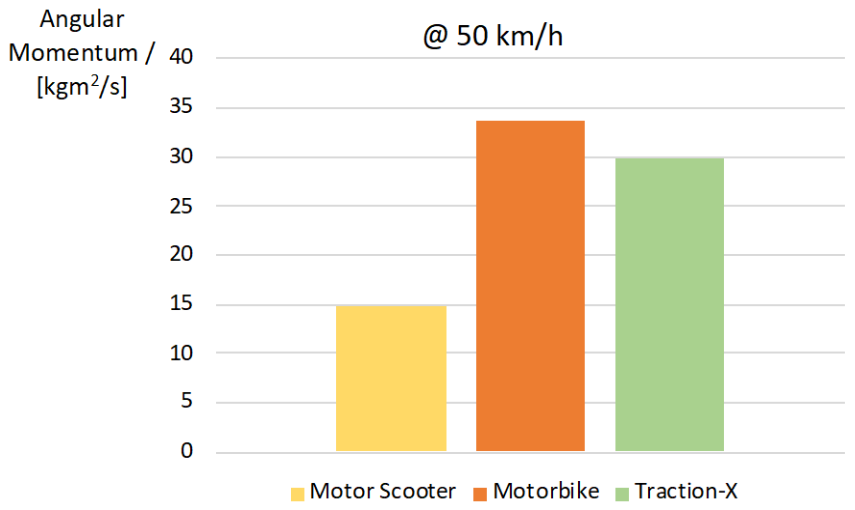


Figure 6:Wheel angular momentum in comparison

In good approximation the rolling resistance is inverse proportional to the wheel radius. This yields an approximately 27 % resistance force reduction of the 18 inches wheels w.r.t. that of the 12 inches small scooter wheel. This comparison is indicated in Figure 7. Although this resistance force is generally low in comparison to the air resistance, it becomes non-negligible in urban transportation.

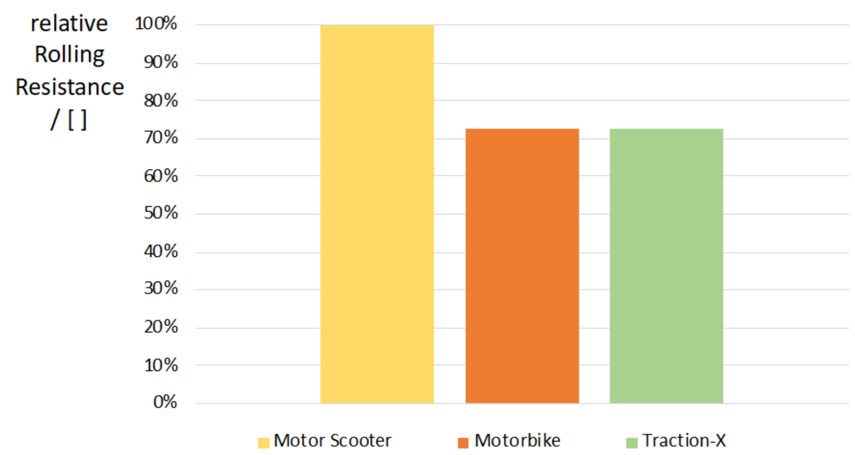


Figure 7: Wheel rolling resistance in comparison

The compactness of the Traction-X® system facilitates to maintain the footwell of the scooter, which increases comfort and safety.

4 The best of two worlds

Traction-X® thus combines "the best of both worlds", i.e. the favorable characteristics of the scooter, which include seating comfort and protected footwell, with the advantages of the motorcycle, i.e. superior riding stability, rolling comfort, tire grip and suspension comfort.

The anticipated advantages and potential of a scooter with Traction-X® are overall:

- Large wheel diameter
  - increased tire swatch and "grip" ✓
  - increased rolling comfort ✓
  - reduced rolling resistance ✓
  - quadratic increase in mass moment of Inertia
  - linear decrease in wheel revolutions per minute

  } ⇒ linear increased gyroscopic stability ✓
- Small unsprung masses ⇒ Sensitive actuation of the suspension system ✓
  ⇒ Reduced dynamic wheel load ✓
- Protective footwell maintained

5 Predevelopment

In a cooperation with two Universities of Applied Sciences of Cologne and with Ostfalia Wolfsburg a pre-development was carried out from 2020 to 2022. To this end, a partnership has been formed with the Department of Automotive Engineering at Cologne University of Applied Sciences and with the Faculty of Automotive Engineering at Ostfalia University of Applied Sciences. The preliminary design was developed as a classical win-win situation with a team of automotive engineering students. Altogether 13 bachelor theses and student research papers have investigated a.o. the improved driving dynamics, and two Traction-X® variants have been designed and verified by structural analysis a.o. with the finite element method. The Autodesk Fusion360 CAD and CAE tool chain with the solver Nastran was used and modern methods of networked teamwork were resorted to. Some 3000 hours of supervised engineering work have thus been dedicated to the new technology development.

Figure 8: Traction-X variant 1 (see [4] and [5])[4]

Figure 8 depicts the variant 1 of the Traction-X design, which features an oil lubricated gearbox that is completely encapsulated via rotary shaft seals. The design allows for power transmissions of up to approx. 40 kW and maximum vehicle speeds of 170 km/h, the latter being limited by the sliding velocity of the seals. The deceleration is accomplished via a small disk break, the forces of which are transmitted and increased via a gear with ratio of approx. 6. A wheel bearing of a lightweight wire design by Franke GmbH is implemented [6], which reduces component costs w.r.t. conventional slim-ring bearings. Automotive application of this type of bearing have been verified by the Dutch Formula Student Team and their successful DUT 17 electric racing car (see [7]). Design details like groves for fitting balancing weights and plastic cover rings to protect the seals from road contamination have been taken care of.

Figure 9: Traction-X® variant 2

The current technical baseline is depicted in Figure 9 and a cross-section of it in Figure 10. This second variant of Traction-X® has a comparatively small number of components, as shown in Figure 11, and does not require any high-priced parts (see [8] and [9]). The ring gear inside of the outer rim is comparatively broad and with inclined teeth of large modulus so that it can be made from glass fibre reinforced plastics. It thus does not require any lubrication. The large ball bearing is replaced by four track rollers, which run within a circular grove of the outer rim. All bearings are sealed and life lubricated. The inside of the wheel therefore is only encapsulated by non-contacting plastic labyrinth seals.

Figure 10: Traction-X® drivetrain suspension cross-section

This makes the Traction-X® variant 2 design an ideal solution for power transmission and suspension for the new type of urban electric motor scooter, as a sustainable alternative to conventional means of commuting. The anticipated major improvements in driving safety and comfort will ideally match an evolving market.

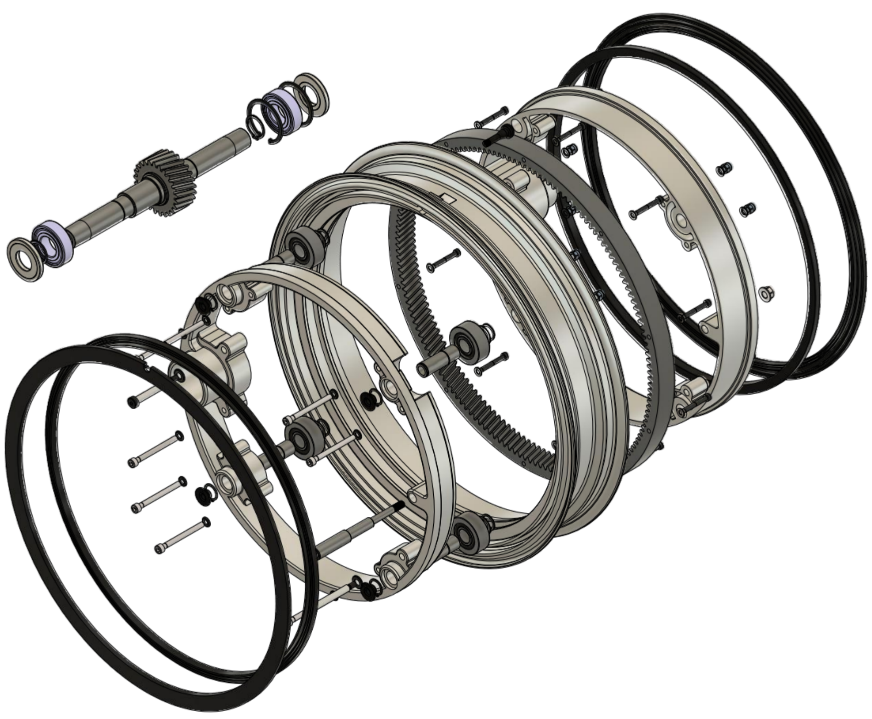


Figure 11: Traction-X® exploded view

6 Proof of concept

A demonstrator of the Traction-X® system has been developed in collaboration with the Institute of Automotive Engineering at the Technical University of Cologne (see [3]). This completely animated model was produced by additive manufacturing technologies and is controlled via a micro-PC. The demonstrator depicted in Figure 12 represents an important functional proof of concept.

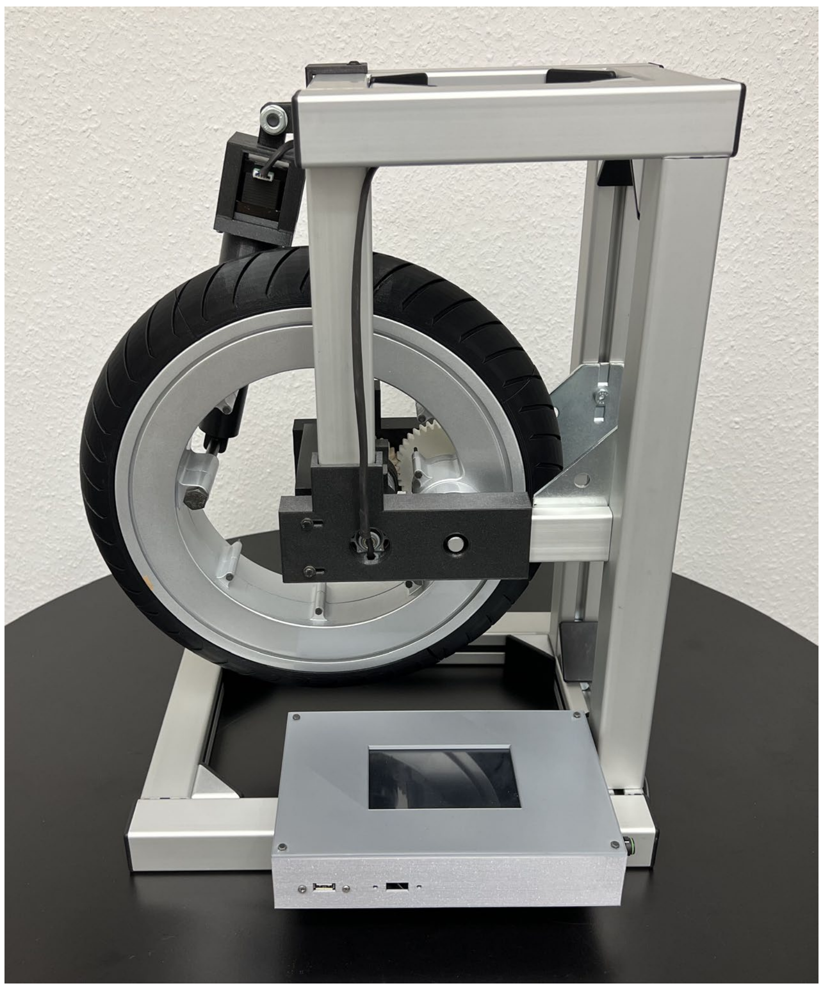


Figure 12: Traction-X® demonstrator [3]

7 Prototype development

The next major milestone in the realization of the Traction-X® scooter is the development, production, and testing of a prototype, as certain design aspects of the new mechanics and kinematics can only be verified through tests. The aim is to transfer the engineering research results from the proof of concept to a marketable product, i.e. from the current Technology Readiness Level of 4 to a TRL 9.

The prototype of a scooter equipped with Traction-X® is being developed as an electrically driven vehicle compliant with lightweight urban two-wheeler transportation. A consortium with the Institute of Automotive Engineering at University of Darmstadt and with the Institute of Vehicle Technology at Ostfalia University of Applied Sciences in Wolfsburg has recently been established for this purpose.

8 The specification of „Smart Urban Mobility“

The scooter of the future equipped with Traction-X® serves the desire for smart urban mobility embodied by young and dynamic trendsetters. Equipped with 11 kW of engine power, the scooter artistically depicted in Figure 13 can be driven with an EU class A1 driver's license.

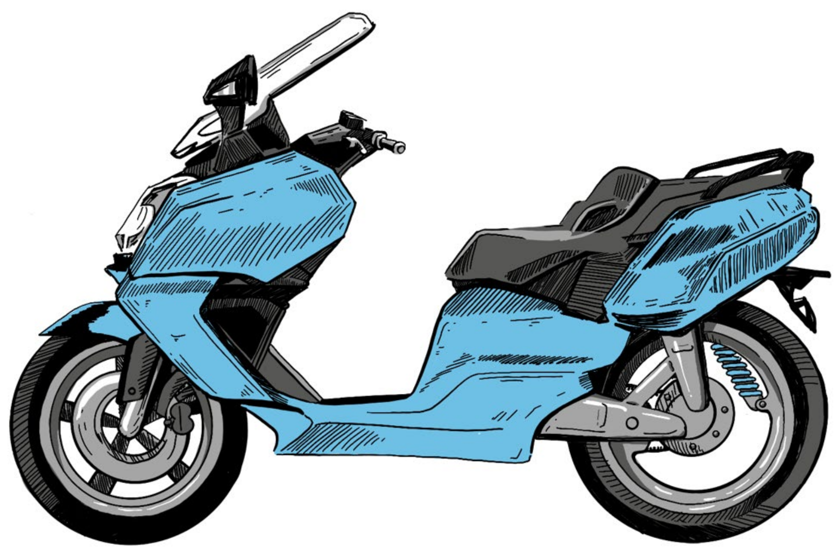


Figure 13: Concept design no. 1 of an electric scooter with Traction-X® drivetrain suspension

Other key data include

- motor power between 11 kW ... max. 20 kW
- motor torque between 30 Nm ... max. 80 Nm
- top speed of 110 km/h
- WLTP range of approx. 100 km
- axial flux electric motor Magelec M17-Cx-S20
- system voltage of max. 60 volts
- exchangeable Li-Ion batteries with 14s45p topology and LG INR18650MJ1 cells
- vehicle mass of approx. 140 kg
- Traction-X® rear wheel of 18 inches diameter

Note that the motor torque will be multiplied by a transmission ratio of approx. 6, when acting on the rear wheel itself.

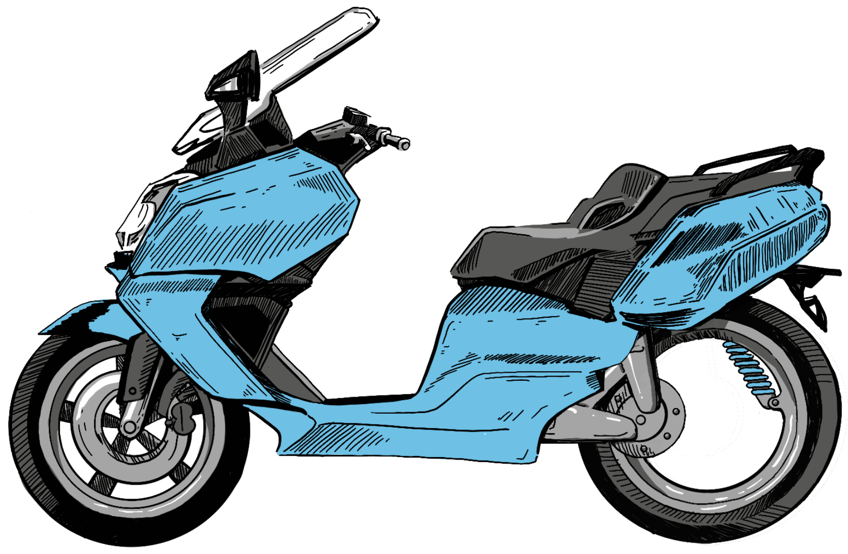


Figure 14: Concept design no. 2 of an electric scooter with Traction-X® drivetrain suspension

9 Design aesthetics

The actual design of the Traction-X® vehicle is subject to a cooperation with the Hochschule für Gestaltung in Offenbach. The shape or design language of hubless wheels in transportation vehicles shall be established in a project supported by the Frankfurt "House of Logistics and Mobility" (HOLM). Customer appeal may be enhanced by an electric motor flanged directly to the combined drive shaft and swingarm axle as depicted in Figure 14. To match with the hubless traction wheel, a non-propelled hubless front wheel is currently also being designed and verified.

10 Contact

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