E-bikes for Micromobility – Compact Integration of the Drive into the Frame

The mobility transformation toward greater sustainability can succeed with the use of smaller vehicles. Electric scooters and e-bikes are part of micromobility. The partners ZF and Raymon Bicycles have developed an e-mountain bike with the CentriX 90-Nm drive, HSC composite frame and 48-V architecture that overcomes the previous compromises between power output and installation space. The result is the Tarok model with one of the best weight/performance ratios for full-assist drives.

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The electrically-powered-mountain-bike (e-MTB) segment is developing dynamically. End-consumer demands for high maneuverability and agile handling combined with high performance and a long range present e-bike manufacturers with challenges while also offering opportunities to position themselves in the premium segment with innovative concepts. However, lightweight design, which would above all meet the agility requirements of the end consumers, must function in the overall system of a full-power e-bike. The drive unit plays an important role here because it influences the weight and – via integration – other factors such as frame design, wiring routes and battery connection.

According to the German Bicycle Industry Association (ZIV), more e-bikes than conventional bicycles were sold in Germany for the first time in 2023: 2.1 million e-bikes sold accounted for more than half of all four million two-wheelers sold [1]. At the same time, the differentiation between different types of e-bikes is increasing, both for everyday use and for sporting purposes.

The premium bike manufacturer Raymon Bicycles has developed an e-MTB with a new drive system from ZF (see also article in MTZworldwide 9/2024 [2]), that overcomes the previous obstacles between performance and installation space. The result is a high-power full-assist e-mountain bike that turns rider and bike into a single unit. The system impresses with one of the best weight/power ratios for a full-assist drive that are currently available.

TECHNICAL FEATURES OF THE ELECTRIC MOUNTAIN BIKE

The drive specialist ZF has developed a 90-Nm high-torque and at the same time especially compact full-assist electric drive, which will be used for the first time in a e-MTB with full suspension ("fully" for short) from the bicycle manufacturer Raymon Bicycles. This bicycle model, called Tarok, has a HSC composite frame and a suspension travel of 160 mm; it is especially designed for use on trails. It will be the first production e-MTB with the newly developed drive system

"ZF Bike Eco System" and its centerpiece, the ultra-compact ZF mid-mounted motor CentriX. The Tarok bicycle, which was presented for the first time at Eurobike on July 3, 2024 [3], should be available on the market in early 2025.

The development goal was to support the special advantages of a fully, that means better traction, greater control and more precise riding stability even in rough and obstacle-laden trail terrain as well as full performance, but in return to minimize weight and maintenance work.

With a system weight of just 22.9 kg, the fully developed by Raymon Bicycles is well below the mean value in this segment of full-assist e-MTBs in the performance class up to 90 Nm with maximum battery size. The German bike manufacturer from Lower Franconia has utilized design freedom in the bottom bracket area to improve handling and agility: such as a functional connection between the down tube and motor area, where complex interfaces normally must be used, which add to the weight of the already heavy motor. The 88 mm diameter of the electric drive contributes to its compactness, **FIGURE 1**. The design has also succeeded in creating a shorter rear triangle, which is directly reflected in significantly better maneuverability.

Space was gained in the down tube thanks to the specially adapted battery holder, the so-called battery rail. Here, the battery is docked firmly to the rail at the lower end only. This not only ensures the battery sits firmly in place, but also makes it easy to remove.

The wiring of all electric drive components has also been significantly simplified in the new ZF drive system, **FIGURE 2**. Only one cable harness needs to be laid between the ZF Core Controller on the top tube and the battery terminal. The control and operating unit and if applicable the touch display on the handlebars and the front light can be controlled and supplied with power from the core controller. Meanwhile, the drive unit, the rear light and the charging socket are connected with the battery terminal. There are also free ports available to supply electrical circuits or other components with power and information via CAN bus system, for example.

The advantages of this drive system design are less effort during assembly and maintenance work: Not only the motor, which is fixed to the frame with a full-surface clamp and only requires two plug connections, but other com-

FIGURE 1 The free installation space in the bottom bracket area was utilized: CentriX drive unit from ZF with a diameter of only 88 mm, installed in the Tarok e-mountain bike from Raymon Bicycles (© Raymon Bicycles)

FIGURE 2 The ZF Bike Eco System only requires a single cable routing in the down tube between the core controller ❶ and the battery terminal ❷. All electrical components at the front of the e-bike are connected via the core controller, while all components at the rear are connected via the terminal. This significantly simplifies the installation and retrofitting of components. (neutral bike) (© ZF)

ponents also can be installed and removed much more quickly. This makes the newly developed bike not only easier to assemble but also easier to maintain.

ADVANTAGES OF THE ULTRA-COMPACT DRIVE UNIT WITH INNOVATIVE STRAIN WAVE GEAR

The CentriX drive unit from ZF is designed to be so compact that it disappears completely behind a 34-tooth chainring. This makes it virtually indistinguishable from an e-light drive. Right from the start, ZF broke new ground to achieve the development goal of accommodating the torque strength of classic full-assist mid-mounted motors (90 Nm) in the installation space of so-called light-assist motors (up to 60 Nm). This resulted in significant unique selling points for the drive unit, for example in terms of weight, torque density and compactness thanks to the single-axis design. With a weight of just 2.5 kg, the drive unit is extremely light compared to similarly powerful drives.

Feature/torque class	ZF CentriX 75	ZF CentriX 90
Diameter	88 mm	
Mass	2500 g	
Q factor	175 mm (depending on crank)	
Frame interface	ZF CentriX	
Spline interface	ISIS	
Maximum torque	75 Nm	90 Nm
Supported maximum speed	25 km/h	
Coaster brake option	No	
Rated continuous power	250 W	
Peak power	450 W	600 W
Nominal voltage	48 V	
Gearbox type	Strain wave gear, single speed	
System name	ZF Bike Eco System	
Ride mode	Off, Eco, Active, Sport, Boost	

TABLE 1 Specifications of the CentriX drive unit from ZF (Q-factor: It is measured on the same level from the mounting point of the left pedal on the crank arm to the mounting point of the right pedal on the other crank arm) (© ZF)

The CentriX drive unit is available in two torque classes (75 and 90 Nm) and consists of the actual electric motor and an innovative gear stage, **TABLE 1**. The electric motor is a brushless direct current motor and is designed with an external rotor. This allows stronger lever forces to be generated. The motor can therefore generate higher forces from a standstill and thus provide more torque than assistance power, **FIGURE 3**.

The gear stage is not designed as a spur gear, as is often the case in this e-bike performance class. ZF relies on an innovation in the form of a strain wave gear, which ZF has adapted to the requirements of a bicycle wheel drive. Until now, strain wave gears have mainly been used in robotics, where their advantage is their high precision due to backlash-free operation. These properties create a very direct feeling of assisted power transmission in the bicycle drive – this matches the good riding experience of the entire Fully E-MTB.

A torque limiter, designed as a friction-locking multi-plate separating clutch, protects the mechanical strain wave gear from excessive torque in particular and is therefore a key reason for using this type of gearbox in a wheel drive. In addition, the rider receives constant motor support and there is no noise when driving downhill in a decoupled state.

The combination of the electric motor and the strain wave gear on a two-part shaft is mainly responsible for the compact design of the drive. The cylindrical design with a diameter of just 88 mm is essential for the easy integration into the bike and for the constructive freedom in bike design already described and implemented by Raymon Bicycles.

The drive unit can be combined with both derailleur gears as well as hub gears. Cranks with ISIS standard are used, and special direct-mount solutions or a spider with a 104-mm standard bolt circle can be used as chainrings.

BATTERY SYSTEM AND 48-V ARCHITECTURE

The removable batteries with 504 or 756 Wh energy content were harmonized with the basic characteristics of the drive unit as part of the development project. The decision in favor of the 48-V system architecture for the traction energy played an important role because

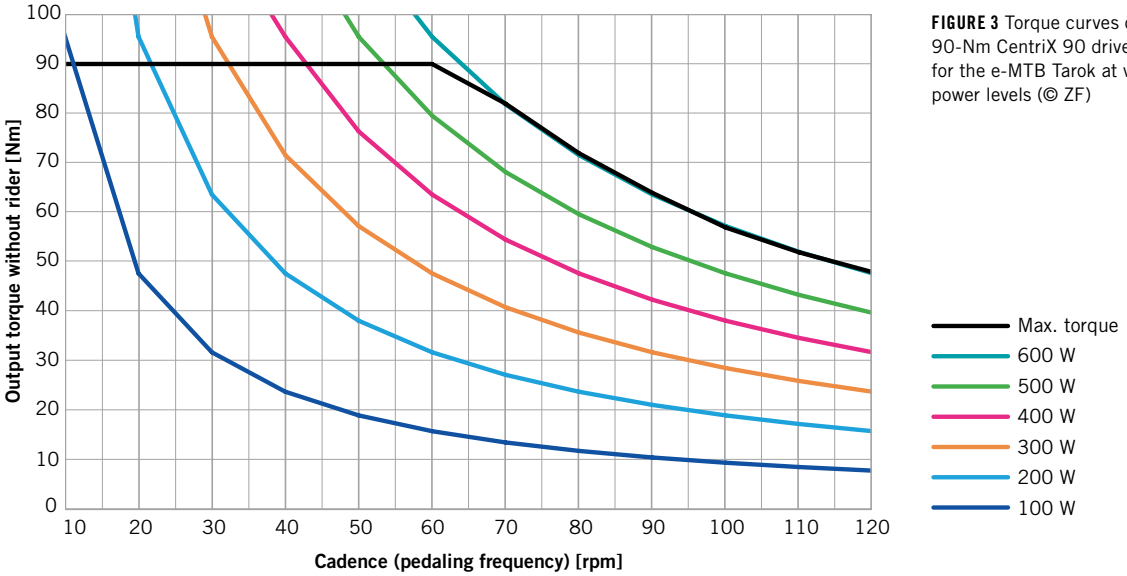

FIGURE 3 Torque curves of the 90-Nm CentriX 90 drive unit for the e-MTB Tarok at various power levels (© ZF)

it shows clear advantages compared to the already established 36-V architecture. The voltage architecture has an influence on the required amperage, especially when a peak power of up to 600 W is called for on the CentriX 90 torque class. The higher the voltage, the lower the amperage. This has a positive effect on the service life and the energy efficiency of the components, slows down the ageing process of the battery cells and benefits the overall system, as no active cooling system is used due to costs, weight, maintenance work and complexity.

At 60 °C, lithium-ion batteries interrupt the power supply to prevent damage to the system. The intelligent e-bike drive system reduces the peak power draw in good time by means of a so-called derating. The peak power and the maximum supporting torque are reduced as required by the control software. Due to the higher voltage level, the cable cross-sections can be reduced, which is a clear advantage when mounting in the frame. In the 48-V architecture, smaller cross-sections of the current-carrying conductors and lighter components are also used in the motor. This was essential for the development of the ZF Bike Eco System.

The ZF battery system also comprises the battery terminal including battery rail, battery holder and locking device. It provides an integrated power supply for internal devices (core controller, remote control, and touch display) and for external devices including third-party devices (lights, grip heating, hubs, etc.).

USER-FRIENDLY OPERATION

The central control and operating unit, the ZF Core Controller, is integrated into the top tube, **FIGURE 4**. It displays system information such as the battery charge status to the rider and is kept simple and intuitive with a circular LED display. The connection options via Bluetooth Low Energy or via a magnetic universal click socket (Apple Lightning, Android USB-C) are diverse, allowing system data to be transferred to smartphone apps.

OUTLOOK

As a countermovement to the development of ever more powerful but also heavier drives for e-mountain bikes, more and more models with light-assist drives have come onto the market in recent years. These models with less powerful motors and batteries with a lower capacity enable an e-bike design that comes close to a classic bike design. Now, the premium bike manufacturer Raymon Bicycles and the drive specialist ZF have created a symbiosis of high torque assistance and compact wheel and drive design and presented it to the public for the first time at Eurobike 2024, setting a new benchmark for full-assist e-bikes.

FIGURE 4 View at the control and operating unit of the ZF Bike Eco System with the core controller in the top tube, remote control, and touch display on the handlebars (© Raymon Bicycles)

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