CASE STUDY

Electric drive systems

EC motor technology from ebm-papst provides a new level of driving excitement to the new BMW 3-Series

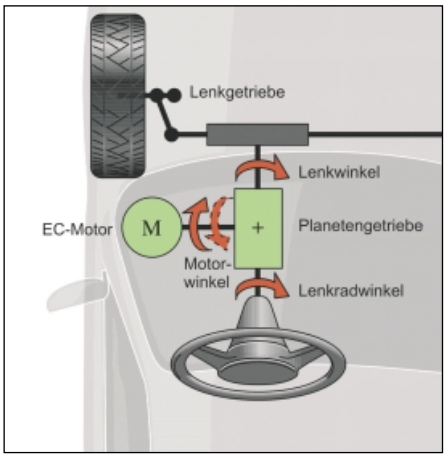
Maximum driving safety at high speeds and comfortable handling when parking: for the first time in a mid-class car, the customer can select Active Steering as an option for the six-cylinder models of the new BMW.

The core of this BMW innovation, the first of its kind in the world, is an innovative steering booster that integrates a planetary gear and an electronically commutated ebm-papst BLDC motor. In this concept the conventional servo-supported steering mechanism is extended by an interactive gearbox with two inputs: One input for manual operation by means of the steering wheel, the second one for the electric motor. The two independent input speeds are converted to one output speed. In practical use this means that the mechanical connection between the wheels and the steering wheel by means of the central gearbox input is maintained – as is the complete road surface contact for an authentic steering feedback.

Fulfills expectations of superlative comfort: the BLDC motor from ebm-papst works quietly and reliably.

In addition, an ingenious electronic control unit transmits a certain speed and direction of rotation to the gearbox, depending on the manual setting of the driver and the conditions of the vehicle. At a low cruising range the motor is activated in a way that its speed increases adding up evenly to the speed of the steering wheel: The steering mechanism reaches its max. steering deflection angle and the necessary steering movements up to a speed of 120 km/h are reduced noticeably. In contrast at high speeds the electric motor works contrarily to the direction to which the driver turns the wheel. Thus, both the output speed and the steering angle on the gearbox output get smaller leading to a safer straight run stability. In addition, the electronics enables a counter steering in certain driving situations. Several acceleration sensors measure the car's reactions resulting in stabilising steering interventions. The results are a better damping and relief of the Driving Stability System (DSC) operating via the brakes. In the unlikely extreme case of a malfunction of the steering booster, it is simply locked mechanically and the steering keeps operating safely just like a regular mechanical one.

ebmpapst



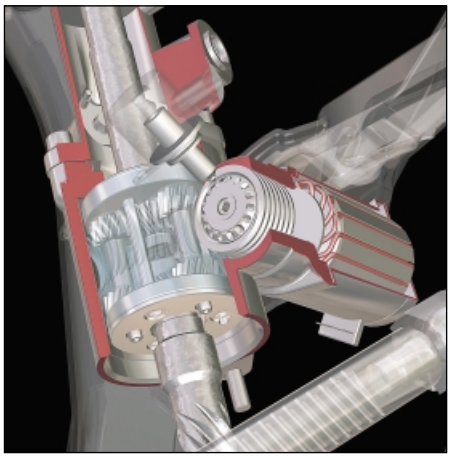


Image 1:
Principle of the differential steering system: one input for manual activation via the steering wheel, and another for the electric motor. The two independent input speeds are converted into one output speed.

Image 2:
Motor with steering gear: pressed onto the motor shaft, the worm remains in constant contact, without any play, with the worm gear of the differential gearbox.

For high class convenience requirements

Vehicle-specific customer requirements have to be met for all components of the power steering motor: reliable high performance for a variety of driving modes is a must – and must be provided in an environment that puts maximum strain on all components. The installation location in the lower area of the vehicle is known for high stress. For ebm-papst, this meant developing a high-performance electric motor that operates reliably, showing minimum torque pulsations, working at the lowest possible noise level. Furthermore, it needed to be resistant to enormous temperature fluctuations as well as to motor oil and other substances. The challenge was not only to find solutions convincing by their quality but always economically realisable as well.

Powerful drive in every situation

Speeds between 0 and 6,000 rpm have to be sustained over the entire service life. Unobtrusive power steering requires both a sensitive mode, almost like a stepper motor, as well as a rapid change mode, as demanded by rapid changes in rpm in typical parking situations, not to mention support for dynamic driving situations. While driving the motor is permanently loaded in 4-quadrant operation. Despite the arising forces, the required reliability is maintained over the vehicle's entire service life.

The ebm-papst solution is based on the principle of a permanently active synchronous motor incl. internal rotor and sinus current feed, i.e. this motor consists of a 6-slot stator and a 4-pole rotor. A concentrated stator winding provides the advantages of lower copper loss and a robust design by means of the renunciation of coil crossovers. A specific air gap extension on the rotor surface modulates the sinusoidal shape of the voltage. The cuboid-shaped permanent magnets made of high-quality neodymium iron boron material are embedded in the rotor package making the construction very robust Both, the rotor and the stator are made of low-eddy current punched and packeted electrical sheet metal.

Low torque pulsations

The foremost challenge for the motor developers was attaining the lowest possible torque pulsation, both when energized and de-energized, and a very low running noise level. The solution from ebm-papst can be described as a synthesis of electromechanical and thermal motor development. Suitable optimization algorithms were used for the solution, along with analytical and numerical calculation programs. Calculations according to the finite element method reduced the torque pulsation to a minimum.

Resistant to temperature fluctuations

The components under the engine hood must function reliably, even in greatly fluctuating temperatures. In this case, the requirements specifications prescribe a range from -40 to +125 °C. Despite the temperature-dependent expansion of the material, a gearbox in the steering area must operate without any play whatsoever. A conventional solution using expansion joints is not sufficient in this case. Therefore, the ebm-papst motor has a spring-loaded rotor shaft that can be swiveled by a few degrees. The worm shaft of the motor is in constant contact, without any play, with the worm gear of the differential gearbox. During this process, the electrical specifications must be met even in different rotor positions. This fact complicates the design and construction of this type of motor. An integrated rotary encoder with a rotation angle accuracy of 1% ensures that motor and controller receive the data they need. The external control unit both commutates the motor and monitors the steering. Sealed permanent magnets in the rotor and a special seal ensure that the required service life of at least 15,000 hours is met.