HOW INNOVATIVE SENSORS ARE REVOLUTIONIZING TORQUE AND FORCE MEASUREMENT

MagneticSense

Content

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Here is a preview of highlights from the fields of steering systems, e-bikes and torque sensors.

The challenge of E-mobility

E-Mobility covers a wide spectrum of topics, from electrification of motorcycles to autonomous driving. The efficient operation of the engine of today's electric or railway vehicles requires permanent monitoring and diagnosis of the engines by means of intelligent sensors. In the future, the demands on sensors in terms of measurement ranges and dynamics will increase significantly, due to technological advances in power electronics. Today, sensor manufacturers focus heavily on equipping vehicles with intelligence so that they can drive autonomously. Less attention is being paid to drive efficiency and dynamic driving comfort. Significant progress could be made with small, intelligent sensor solutions.

A major difference between means of transport based on conventional internal combustion engines and electronic mobility vehicles is the way in which the necessary torque is applied, which is ultimately responsible for the actual locomotion. While the torque of an internal combustion engine depends on the range of engine speeds and the speed of the turbocharger, the torque of an electric motor is available instantaneously. This brings some advantages, for example, the driver of an electric car can accelerate in a very short time, but there are also dangers. In the field of e-Mobility, there are situations that have never occurred before with the combustion engine. One of these scenarios is to stop and accelerate in a curve. While in the combustion engine it is necessary to generate a previous rotation movement, which is initially small, to generate the impulse movement, in the electric motor this impulse is instantaneous. The danger of sudden acceleration when the wheel loses contact with the asphalt in a curve is much greater in the electric motor than in the combustion engine. Measuring pairs and their need for efficient and dynamic motion is an aspect of sensor technology for electronic mobility. Another aspect revolves around dynamics and driving comfort. Force and torque sensors are also used in vehicle dynamics applications. For example, the torque sensors in wank stabilizers can determine the position of the vehicle and intervene by control to increase driving comfort.

Electric mobility is also often associated with autonomous driving. For autonomous driving, the number of sensors used increases exponentially. The trend in steering systems is clearly in the direction of "Steered by Wire", also to prepare the car for use in autonomous vehicles. With "Steered by Wire" steering systems, the steering column is no longer directly

connected to the steering shaft and the signals transmitted from the driver to the steering wheel are recorded electronically (e.g. with a non-contact torque sensor) and the steering angle of the vehicle is adjusted on the basis of this information.

Another use is real-time axle load measurement for trucks. A new guideline requires that, in the future, a police officer be able to detect an overload on a truck through a weighing device that would carry the truck on board. This weighing device can be implemented by means of force sensors on the axles of the truck. A connected load management system can also be used to determine the centre of gravity of the load and issue a warning in case of danger.

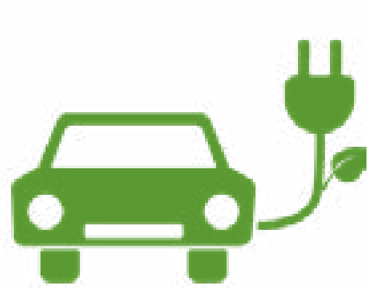
Improving steering behaviour with E-Torque vectoring

With the electric torque vector systems and the new torque sensors contained in them, the drive torques are specifically transmitted to the individual wheels in order to be able to actively steer the vehicle. This is done by correcting the angle of rotation around the vertical axis. The driver gets an improved and more natural driving experience. This actively prevents the vehicle from understeering or oversteering. Especially in electric vehicles that do not have a cardan shaft, the driving torque can be controlled by several electric motors.

The possibilities in sensors for electric mobility applications are very wide. The emergence of new application possibilities and new standards are the driving force behind innovation in this field. Magnetic Sense's magnetic-inductive force sensors are designed to meet these new requirements.

Electric cars

Comfort and driving



An increasing demand for torque information is needed not only in internal combustion engines for map control, but also in electric vehicles. On the one hand, the torque is the power factor of the vehicle, but on the other hand it is also a decisive factor for driving comfort.

In electric car drives, the power of the electric motor will in future be connected almost directly to the drive shaft. Therefore, in many cases there is no or only a very rudimentary gearbox in the middle. This direct connection results in an electric torque that acts directly on the drive shaft, i.e. a direct power flow. This direct power flow must be taken into account in the safety aspects. A failure of the electric motor or unwanted output power has a direct effect on the driving behaviour of the vehicle. It is therefore necessary to install many additional sensors for series use in order to intercept or plausilize faults and initiate appropriate emergency stops.

Not only from the electric motor to the drive, but also the effects of road force have a direct effect on the electric motor. These bi-directional force flows must be measured, monitored and evaluated in the functional safety circuits in serial applications. With a torque sensor that can measure the force directly on the drive shaft, it is possible to collect this safety-relevant information and transmit it to the controller. This is still easy when electric motors are used for the entire vehicle. When wheel drives are used, it becomes more difficult. Each wheel drive has its own performance behavior, which can be calibrated to each other, but can be misaligned by aging effects. The adjustment of these electric motors determines the driving behaviour of the vehicle. Without a direct measurement of the parameters at the output of the electric motor, it is almost impossible to determine the driving behaviour of the vehicle. With the use of torque sensors in these electric motors, the behaviour of each individual electric motor can be measured instantly and used as a nominal value input in the control unit to control the motors.

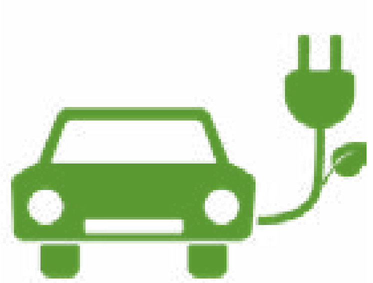
Not only the direct drive, but also the driving comfort can be improved by means of force sensors. For example, torque sensors in the limited slip differential can be used to precisely adjust the torque in the individual wheel, resulting in optimum cornering performance for the car. The information required for torque vectorisation can not only improve driving dynamics. In principle, they can also be used to measure wheel slip and serve as a control variable for anti-slip control.

In addition to these classic applications for torque sensors, there are other fields of application in the field of electric mobility. For example, sensors can be used to directly measure the weight of the vehicle and determine how much additional load has been absorbed. This information is important for determining fuel consumption or as an input variable for the acceleration and deceleration behaviour of the vehicle. There are other possible applications in the steering area for measuring steering forces.

"With a torque sensor (...) it is possible to collect this safety-relevant information."

Electric cars

Steering systems



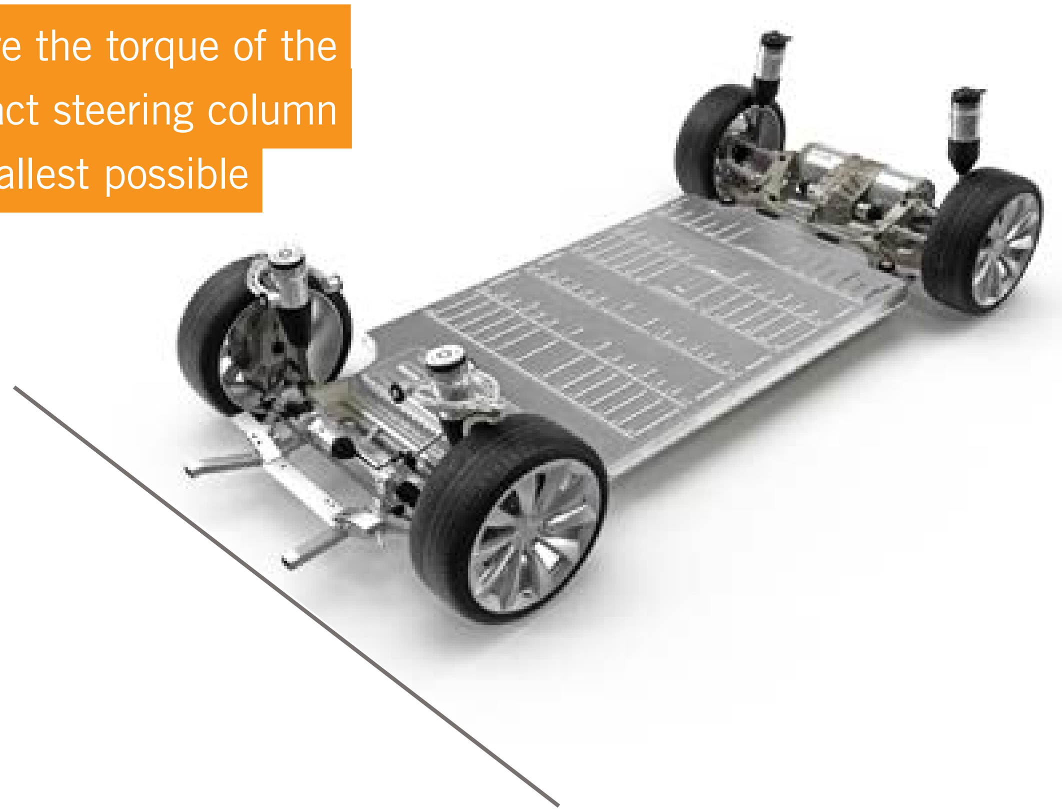
Car steering systems consist of a large number of subsystems, which together form a well-coordinated unit. Almost all new cars have power steering systems that support the steering power of the driver and are therefore relevant to steering comfort. To determine this force applied to the steering wheel, there is a torque system that registers the torques directly in the steering and acts as a control variable for hydraulic or electric steering assistance.

The existing torque shafts in the steering systems are designed to meet the highest safety requirements. Some of today's systems have been in use for years and are based on established technologies.

The trend in steering systems is clearly in the direction of "Steered by Wire". This is mainly due to the fact that future generations of cars must be prepared for autonomous driving. In "Steered by Wire" steering systems, the steering column is no longer directly connected to the steering shaft. This means that in these steering systems the signals transmitted from the driver to the steering wheel are recorded electronically and the vehicle steering angle is adjusted on the basis of this information.

The trend of these systems shows the need for good integration between the sensor systems, which are necessary to pick up the driver's signals. It is also necessary to record an overlay of driver signals with force feedback. Force feedback is necessary because the driver needs haptic feedback when the handlebar is no longer connected and there is no torsion in the steering column. Conventional torque sensors are not suitable for these applications, new solutions need to be created.

"...Measure the torque of the non-contact steering column in the smallest possible space."



Magnetic Sense's new technology for the development of magnetic-inductive torque sensors opens up new application possibilities in this field. Our sensors can be dimensioned in such a way that they can even be integrated into tight spaces to measure the steering column torque without making contact. Its technology allows redundant signal processing and, depending on application requirements, can be used in safety-relevant applications.

Other applications are also emerging in the agricultural sector, with fully automatic harvesting machines. Non-contact torque measurement can be used in all applications where motors move machines.

E-Bike
Drive control

Bicycles with electric motor to support the driver are becoming increasingly popular among various consumer groups. Sales of e-bikes in Germany have doubled in 5 years until 2016. Bicycles of this type can not only withstand the pedalling power of the cyclist, but also allow higher speeds. These properties require reliable torque measurement.

The driving control of an e-Bike is a great challenge. On the one hand, the drive unit must support the rider when necessary and, on the other, it must be switched off as soon as the driver no longer needs the support. Therefore, the transition between human pedal force and engine power must be smooth, so that people and the bicycle form one unit. To do these, simple sensors are not enough. The torque released by the driver's pedaling force must be determined by other means. Torque sensors have the necessary conditions to solve this problem.

Until now, applications of torque sensors have been limited. The introduction of the magnetoelastic torque sensor opens up completely new areas, such as e-Mobility.

Magnetoelastic torque and force sensors, such as those manufactured by Magnetic Sense, measures changes in the electrical inductance and convert these data into measurement results. This gives a great advantage to non-contact torque measurement and there are more and more fields where it is possible to apply these sensors. This is also the case for applications in electric mobility and, in this specific case, in the motors of e-Bikes. Torque sensors can be mounted on the rear axle, on the drive unit or on the pedal axle.

The e-Bike sensor can pick up the torque accurately and without contact. As soon as the pilot steps on the pedals, the forces act on the shaft and the magnetic field of this ferromagnetic material changes. These changes are recorded by the torque sensor and transmitted to the sensor electronics for evaluation. The Magnetic Sense's sensor can also measure torque at low speeds, such as on pedals. In addition, the torque sensor can be used in a temperature range of -40 °C to 85 °C and operates with high measurement accuracy. This means that the torque sensor not only guarantees non-contact measurement, but also precise measurement results under difficult conditions.

" The Magnetic Sense's sensor can also measure torque at low speeds (...)."

Trucks

Safety and efficiency

Time is money and that applies to many services. But, above all, also in the transport sector. The pressure of time and costs are external factors that define the future of the freight transport sector on the railways, in the air, in the water and on the road. The greatest factor of uncertainty in this interaction is the state of operation of the machine and the people needed to operate it.

The truck of the future can drive very efficiently and quickly from A to B and dispatchers have all the information about the operating status and loading of the vehicle at all times. This is the vision of many transport companies and drivers of innovation in this field. Sensor manufacturers are needed to turn these visions into reality. The autonomous driving of cars is still in its infancy. In the case of trucks, this step is not far off either. Electric mobility and associated autonomous drives and steering systems are already being tested by many original equipment manufacturers on the road. The market for sensors for driver assistance systems is very competitive and is the focus of many strategic meetings.

In addition to these electric mobility systems, there are also requirements for sensors in the truck of the future. For example, in addition to functional safety in the drive, load monitoring and overload protection must also be developed. The motors of the future will be electric motors. The electric motors available on the market today are designed in such a way that many interference sensors are required to control the drive unit and thus guarantee its functional safety. Direct control of the drive torques of truck engines (electric motors and combustion engines) would allow many additional systems to be dispensed with. Torque sensors directly on the output drive can also help to improve the efficiency of the entire system and thus save energy. Torque sensors on the wheels or drive unit directly in combination with an absolute angular signal are also able to detect tyre slippage, allowing the control system to react directly to such events.

"Engines from the future are electric"

In addition to torque sensors, force sensors are also increasingly popular in the truck sector. Truck axle load sensors can not only detect whether the truck is overloaded or within the normal range, they can also detect when the truck has been loaded or unloaded. This allows shippers to monitor their trucks online and use the received data for plausibility checks.

EU regulatory laws even oblige truck manufacturers to implement such systems on the truck to inform the police of the direct loading status of the truck during an inspection. This is to prevent truck overloading from causing traffic accidents or damage to the road.

Many other possible applications for force sensors in trucks will enable more innovations and sensor concepts in the coming years for the solution of tomorrow's applications.

Trains

Safety in braking systems

The train is considered one of the safest and most comfortable travel options today. It is common for a railway engineer and his suppliers to deal on a daily basis with sensors for operation and safety, since in recent decades, it has undergone significant development in terms of safety and efficiency.

Sensors in braking systems can measure the axle load and regulate the braking force accordingly. Railway braking systems are divided into several stages. From light braking to actual stop, there are several systems that support each other. A few decades ago, it was common for passengers to have to hold on to each other in order not to fall, but this went down in history when multi-stage braking systems came into being. Force or torque sensors installed on the brakes or wheel axles can measure the forces acting on the mechanics during the braking process and regulate the braking force according to these forces. In this way, closed-loop brake controls can be implemented.

In addition to the control of the braking force, sensors are also used in the field of load management. For example, force sensors in the boarding area can count how many people have boarded or exited the train. If you are interested in this topic, you can read our article on sensors in electric cars where these topics of safety and comfort while driving are discussed. Force sensors can also determine the weight of the load on the axle of the wagon and how it changes during loading. This is especially interesting in freight transport, where the transport cost is calculated from the weight of the load and the volume. In this way, the rail operator can check the data of his customers.

Force transducers are also used in the field of pantograph axis transducers. The contact force of the pantograph with the overhead contact line defines the quality of the electrical connection. If it is too weak, it is possible that the electrical contact resistors are too high and that a drop in power occurs. If the load is too high, malfunctions may occur. High forces and loads also occur in the area of the couplings in trains. The force transducers in these positions can determine the train loads and issue a warning in the event of overload or unintentional disconnection.

There are many possible applications for torque and force sensors in the railway sector. The integration of sensors into the railway infrastructure is also an exciting topic. There are systems that control how many trains have crossed the rails or how many axles have passed through a point. This information can be used, for example, to make emergency stops in the event of a wagon stopping to avoid a collision. Some of these sensors are based on optical and ultrasonic technologies. By integrating force sensors into the rails, the signal quality and reliability of this measurement method can be improved. Thanks to the technology of magneto-inductive force sensors, which can be easily integrated at any measurement point, these measurement methods can be adapted to existing track sections.

"The application possibilities for torque and force sensors in the railway sector are very diverse."

Our sensors

Torque sensor

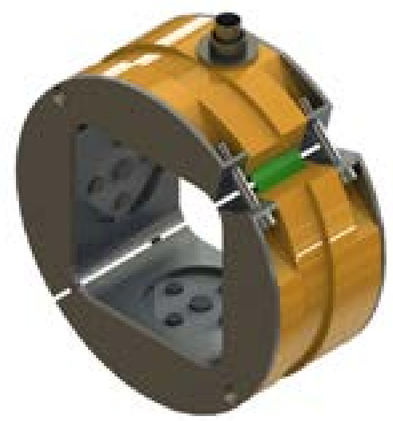
Direct torque measurement: unique technology for the measurement of mechanical forces in axes. The sensor forms a shaft-coordinated measuring system that can also be economically produced in large quantities. Our technology creates a unique torque sensor for serial applications.

Advantages of the torque sensor

- ✓ Contactless measuring principle
- ✓ Resistant to mechanical overloads
- ✓ Digital literalised output signal
- ✓ Robust against interference
- ✓ No mechanical/magnetic treatment of the measuring point required
- ✓ No specific requirements for shaft material
- ✓ Resistant to deterioration

Force sensor

Force sensors (also known as force transducers) measure the various forces acting on an object. These include bending and axial forces (tensile and compressive forces). Based on the principles of active magnetic torque, our sensor technology can measure these forces accurately and without contact. The force sensor works with any ferromagnetic test object.



Advantages of the force sensor

- ✓ Contactless measurement
- ✓ No treatment of the measuring point is necessary
- ✓ Compact and custom design
- ✓ Extremely robust under harsh conditions
- ✓ Maximum long-term stability
- ✓ Works with any ferromagnetic material
- ✓ Resistant to overloads

Conclusion

Non-contact torque and force sensors are cost-effective and are the future. With our magneto-inductive measuring principle, we have created something completely new for the measurement of torsion and forces in series applications. This is a decisive step for the development of intelligent electric mobility solutions in the future.

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