HOW THE TORQUE SENSOR CONTROLS THE DRIVE UNIT AS E-BIKE SENSOR

MagneticSense

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Bicycles with an electric motor to assist the driver are becoming increasingly popular among various consumer groups. In Germany, sales of E-Bikes have doubled within 5 years until 2016. Bicycles of this type not only support the pedaling power of the driver, but also allow a higher speed. These properties require reliable measurement of torque.

Measuring Challenge: Torque Sensor Pedelec

The sophisticated drive control of an e-Bike is a great challenge. On the one hand, the drive unit should support the cyclist when it is necessary and, on the other hand, it should switch off as soon as the driver no longer needs the support. The transition between human treading power and motor power should therefore be fluid, so that people and bike form a unit. To ensure this, simple sensors are not enough. The torque released by the pedaling force of the driver must be determined by other means. Torque sensors have the necessary conditions to solve this problem. So far, the applications of torque sensors have been limited. The introduction of the magnetoelastic torque sensor opens up completely new areas, such as e-Mobility.

Functioning of the toque sensor in the pedelec

Which torque sensors are available today for use in Pedelecs

There are already some technologies on the market with which previous Pedelec or e-Bike systems have realized the torque measurement.

- ✓ Strain gauges
- ✓ Passive magnetostrictive sensores
- ✓ Optical sensors
- ✓ Acoustic sensors

The Strain Gauges

The strain gauge, the most popular technology for use in force or torque measurement until now, has been established for the first systems on the market. The use of strain gauges on rotating shafts means that a great deal of effort for the integration has to be made. There are basically two ways to measure a DMS on a rotating shaft:

1.) The strain gauge is applied to the measuring shaft - welded or glued. This assembly process makes the manufacturing very expensive, complex and prone to errors because the alignment and stability of the mechanical interface are critical. Furthermore, the strain gauges must be electrically connected to an evaluation in this assembly. These are usually connected either via bonding or copper wires. The power supply and transmission of measuring the electrical signals must be realized to the sensor on the measuring shaft and back again. This challenge is usually made via slip rings or telemetry. This method has been found to be impractical because of the manufacturing costs.

2.) The second possibility is based on the fact that the measuring shaft is interrupted and a torque sensor is used, which introduces the power flow of the shaft to a DMS, which can, for instance, be about a storage. This bearing absorbs the forces due to the torque on the shaft and acts on the strain gauge. This type of torque measurement is also called secondary measurement, since not the direct torque, but the force in a bearing, which is proportional to the torque, is measured. This method has been found to be impractical due to the necessary mechanics and associated space requirements.

The Passive Magnetostrictive Sensor

Passive magnetostrictive technology, which is basically very similar to the Active Magnetic Inductive Technology, requires that the target is made of special hard-magnetic steel alloys with a special magnetic signature. This „special treatment" of the wave makes the procurement in the supply chain of a series production a complicated process and hence more costly.

Furthermore, the imprinted magnetic signature of the shaft creates a field in the range of the earth's magnetic field. Thus the signal is sensitive to both rotations of the sensor with respect to the earth's magnetic field and changes of the earth's magnetic field itself. Peripheral irradiated magnetic fields can also severely disturb the very small and susceptible measuring signals and thus the measuring capability of the torque detection.

Another problem is that the applied magnetic textures degenerate with the time. This degeneration is forced by temperature and possibly high loads on the shaft. A very strong overloading of the shaft can end up in a complete destruction of the shaft.

Optical and Acoustic Torque Sensors

These sensors are still in their premature phase and it is questionable whether they will ever qualify as a real alternative. Optical sensors are always subject to the necessity that the optical light path from the sensor to the measurement object is not interrupted or disturbed. Fats are used in a shaft and its shaft bearings in the Pedelec. These partially thin layers of fat are already sufficient to disturb the measurement sensitivity. During its functional life, the Pedelec needs this fat to protect itself against the dust, rust or other deposits, which contribute to devalue this alternative. Acoustic sensors have not been able to prevail in the shortlist for Pedelec torque sensors. The generation and detection of the signal are very complex. In this sense, here is the distance from the sensor to the shaft or its change in the field application critical.

Active Magnetic Inductive Torque Sensors

Magnetoelastic torque and force sensors, such as those made by Magnetic Sense, are based on the physical principle of magnetostriction, or inverse magnetostriction. Ferromagnetic materials change their magnetic properties under the influence of external mechanical forces. This change in the magnetic properties causes the magnetic permeability or susceptibility of the measuring point to change. When compressed, it reduces; meanwhile, with an expansion, it increases. Magnetic Sense's Magnetic Inductive Sensors induce a magnetic alternating field into the target and measure the resulting magnetic fields with secondary inductors. A change in the susceptibility and thus the magnetic resistance results in a change in the magnetic flux. This magnetic flux change is detected by the secondary inductors and converted in a digital signal processing into a signal which is proportional to the mechanical force. This measuring principle is based on the fact that the sensor requires no mechanical contact or adhesion to the measuring point and thus can be attached without contact. This fact is a decisive advantage when it comes to measuring the torques on a rotating shaft such as a Pedelec or e-Bike.

This creates the great advantage of a non-contact torque measurement, which means that more and more applications are possible, for instance, in the e-Mobility and , in this specific case, in e-Bike drives. In this case, torque sensors can be mounted on the rear axle, on the drive unit or in the bottom bracket, near the shaft in order to detect the mechanical force applied by the driver.

The active magnetic torque sensor technology has thus a clear advantage when used in rotary torque measurements in Pedelecs.

How the torque measurement works

In a Pedelec the absolute need to measure the torque is based on legal regulations and on the control algorithm.

The legal requirements direct that the Pedelec or e-bike is only allowed to move if the driver operates the vehicle by applying power to the pedal and when it is clear that he wants to move it purposely. This means when the bottom brackets are turning.

Often, the concept of e-bike and Pedelec are bedevilled. While the e-bike can only drive by pressing a „throttle", the Pedelec needs the driver's input described above.

The way in which this driver information in shape of a torque signal and a bottom bracket speed (cadence) is detected and utilized by the control system depends on the end customer market of the OEM. There are as many different approaches as there are OEM bikes that are equipped with a Pedelec drive.

The basic operating mode of this torque or treadmill control is explained below.

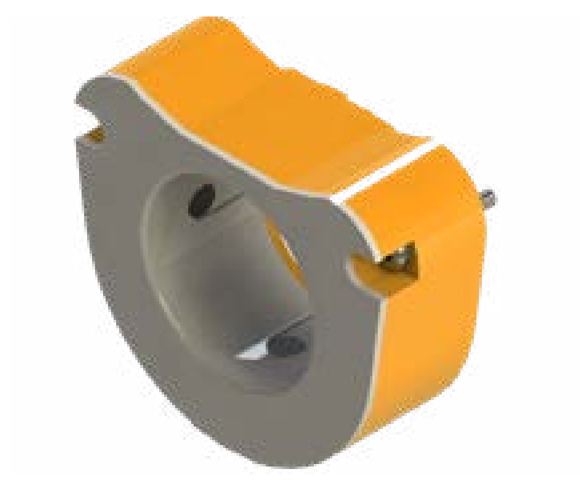
The applied pedaling torque of the driver is detected by the sensor and transmitted in a digital signal to the Pedelec or E-Bike control.

Many Pedelecs or E-Bikes need not only the information of the torque, but also the cadence for their control. By simply integrating Hall sensors that detect either a magnetic texture on a flywheel or a ferromagnetic texture in the form of a gear rim on the shaft, the speed of the pedal or cadence can be determined.

The performance of a pedelec perceived by the driver depends crucially on the quality of the control and thus on the quality of the sensor signals. The detection of the torque is here a key component of the input to the control. The largest error contribution of a torque measurement on a rotating shaft in the pedelec is the measurement error caused by the rotating shaft - short RSN (Rotational Signal Nonuniformity). This measurement error is due to inhomogeneities in the wave structure that affect the sensor signal when the shaft rotates.

By an additional integration of an angle sensor to the torque sensor, a location-dependent compensation of this RSN can be carried out, which contributes decisively to a very small measurement error of the torque sensor and thus to driving behavior. In addition, this angle information may be provided to the driver as a pedal crank angle and so forth. High performance athletes serve to gather information as the tread homogeneity of both legs varies over the orbital angle.

The integration of the torque sensors from Magnetic Sense into customer projects can be implemented relatively easily due to the modular design, and it is possible to address various interface requirements with regard to the mechanical and electrical design. The modular platform, including the electrical interface options, contributes to the rapid implementation in samples and market introduction.



Magnetic Sense Torque Sensor Advantages

- ✓ Contactless measuring principle
- ✓ Insensitive to mechanical overload
- ✓ Digital literate output signal
- ✓ Robust against magnetic and electrical interference fields
- ✓ No mechanical or magnetic machining of themeasuring point necessary
- ✓ No specific requirements for the shaft's material
- ✓ Modular kit that can be applied to custom requirement

What are the challenges of measuring torque on the E-Bike?

Many questions regarding torque sensors in pedelec or E-Bike applications can be found in several forums. Most questions give quickly a very clear picture of the challenges of torque measurement. Probably, the biggest challenge in torque measurement is the rotating shaft.

What difficulties are there in measuring torque?

Many sensor principles are designed in a way that the measuring point does not change. A sensor converts a physical quantity into an electrical quantity. If, in addition to the physical quantity, other influencing factors, which affect the measuring signal, change on the sensor , then the measuring signal is no longer clear and receives therefore a corresponding measuring error. For the functionality of a sensor, it is important that this disturbance is very small in relation to the measurement signal. If this is not the case, then the sensor is unable to resolve the physical measured variable in a defined manner and thus is unusable for use.
One of the big challenges for torque sensors in pedelec applications is the rotating shaft. Due to the rotation of the measuring shaft, the position of the measuring point for the torque sensor changes for each angle of rotation. This rotating shaft creates a very special challenge for every torque sensor in the E-Bike.

What is to consider when developing torque sensors in E-Bikes?

The most important criterion in the development of a torque sensor for e-Bike applications is therefore to minimize this inability to measure due to the rotating shaft. This measurement error is commonly referred to as „RSN, Rotational Signal Nonuniformity" or „RSU Rotational Signal Uniformity". There are many factors influencing the RSN of a spinning shaft. The torque sensors currently available on the market are generally based on the magnetostrictive or inverse magnetostrictive measuring principle. This measuring principle is based on the fact that due to the mechanical stress on a ferromagnetic measuring body, its magnetic properties change.
The change of the magnetic properties of a wave depends on various factors. It is, for instance, important which material alloy is used, which hardness the material has and which intrinsic magnetization is present. These properties can vary around the circumference of the wave and are thus responsible for different measurement conditions. Likewise, they can therefore be responsible for the above-mentioned RSN.

It is therefore very important to properly dimension the measuring wave from the very beginning. This means to choose the right material alloy, the right hardness and, above all, the production methods of the shaft. Those who work with torque sensors have to get involved very deeply into the material sciences and build up a broad understanding of the magnetic properties in addition to the mechanical properties of the materials.

The company Magnetic Sense has a competent team, which deals intensively with these measurement error behaviors, and can hence help in the dimensioning of the correct measuring shaft from the beginning.

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