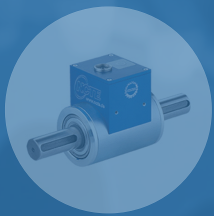
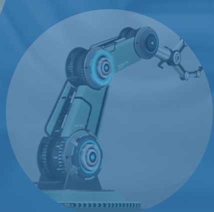








RELIABLE
NON-MAINTENANCE
NON-CONTACT

The future of torque and force measurement is magnetic

Table of contents

1. Sensors for industry 4.0 and smart serial products

For decades the applications of sensors measuring torque and force changed rather little. In recent years new challenges arose which require new innovative solutions for sensors and large volumes in sensor production. Conventional torque sensors on the basis of strain gauges are still very useful for very precise measurements in test applications, for instance. However, they are very expensive and also their maintenance is very costly. This prevents their use in large numbers and they are therefore not suitable for the new requirements.

Apart from this the conventional technical solutions are not suitable for applications in industry 4.0, big data and serial smart products. There is a new technology that offers a solution to this issue which is suitable for serial production: non-contact torque sensors based on magnetostriction.

The shaft itself is turned into the “transmitter” of a sensor by magnetic encoding in a magnetising process patented for NCTE.

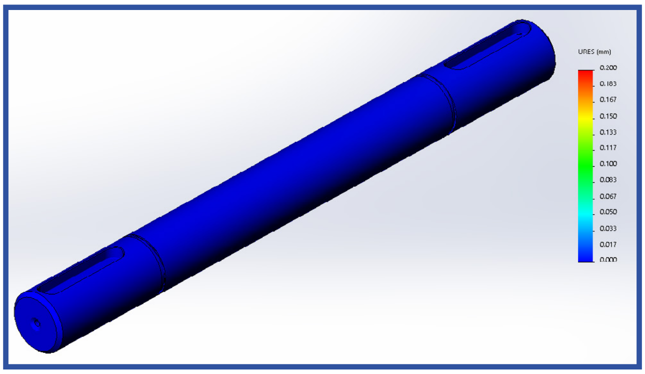
Without touching the transmitter, the “receiver” senses the changes of the magnetic field at a distance of several millimetres - even through a layer of dirt and/or lubricant and at very high numbers of revolutions - and processes these changes. This magnetic field-technology uses the shaft as it is. There is no need to change its design. The receiver unit can be designed as required by the application and thus offers entirely new opportunities for defining measuring points and use cases.

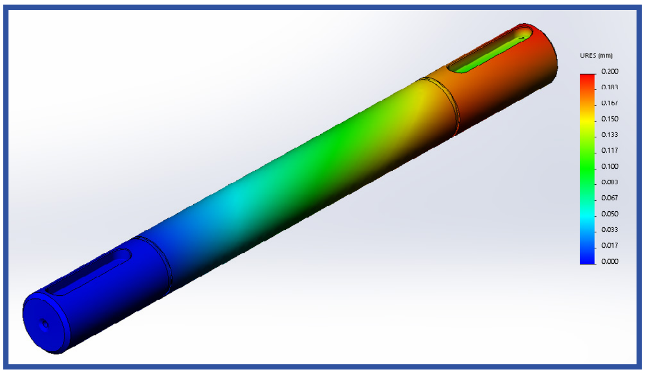
This magnetic technology is already used in many smart products like e-bikes, torque measurement in robotics or drive shafts in industry. The solution is both non-contact and compact and - compared with other measuring technologies - it is cheaper by a factor of up to 10.

1.1 The technology behind non-contact measurement

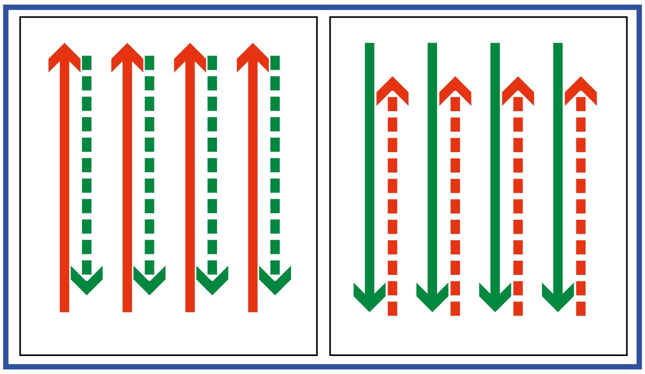
NCTE's measuring principle is based on the effect of inverse magnetostriction. This is based on the fact that an object's magnetic field changes when it is subjected to mechanical forces.
If an object is magnetised, this leads to a distortion of its crystal structure and thus to magnetostrictive deformation. Inversely this effect can be used by measuring the change of magnetisation induced in magnetised material by mechanical loads.
Figure 1 shows a magnetised shaft with schematic field lines.

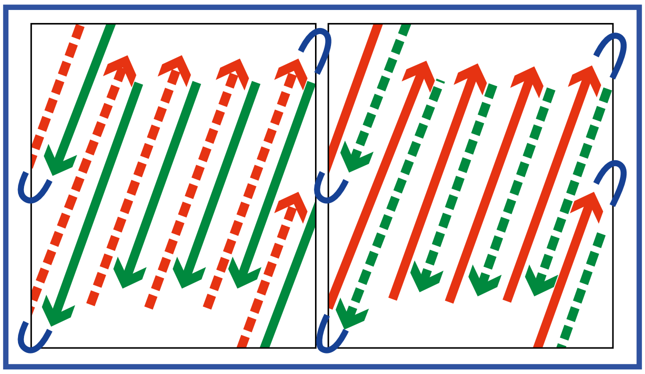
When an external force is applied to the shaft (shown by the colour changes in the image) the orientation of the previously existing magnetisation changes. This effect is called inverse magnetostriction and it is the basis of NCTE's measuring principle. The magnetic field is circular and after deformation or vibrations it always returns to its original shape and orientation.





The crystal structure changes under the impact of a force as shown in the CAD-simulation.

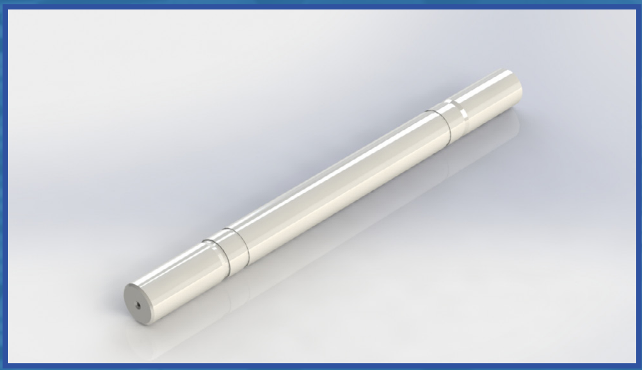




The magnetic field changes accordingly.

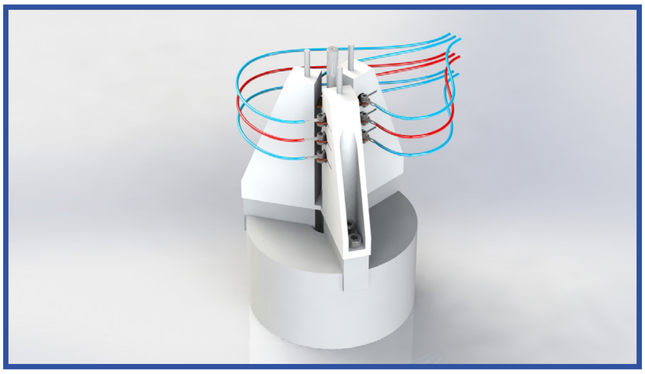
Figure 1: A force impacting the shaft changes the orientation of the induced magnetisation.

1.2 Smart up the metal: design of a non-contact sensor

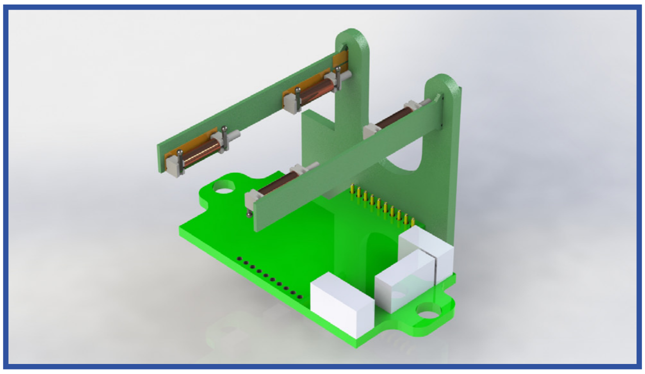


A non-contact torque and force sensor consists of the magnetised existing shaft (primary sensor) and a reading unit (secondary sensor) whose design depends on the application. This paragraph explains the sensor design in detail based on the phases of its production (1-5 in figure 2).

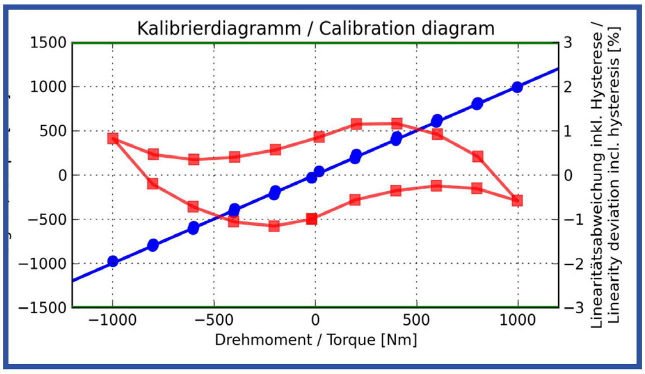
1st step: Ultra-sound cleaning and demagnetisation of the shaft.



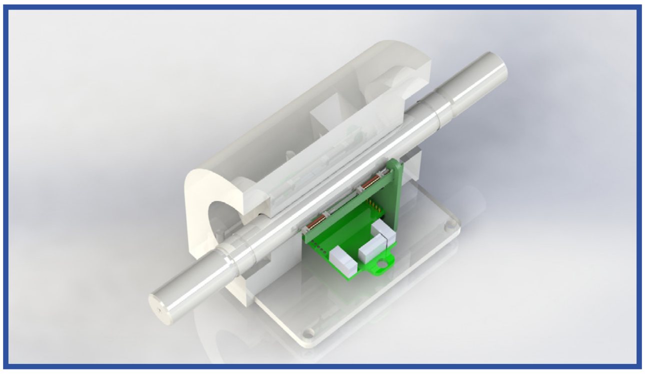
2nd step: Induction (only once) of the magnetic fields



3rd step: Setting up the electronic equipment and positioning the coils

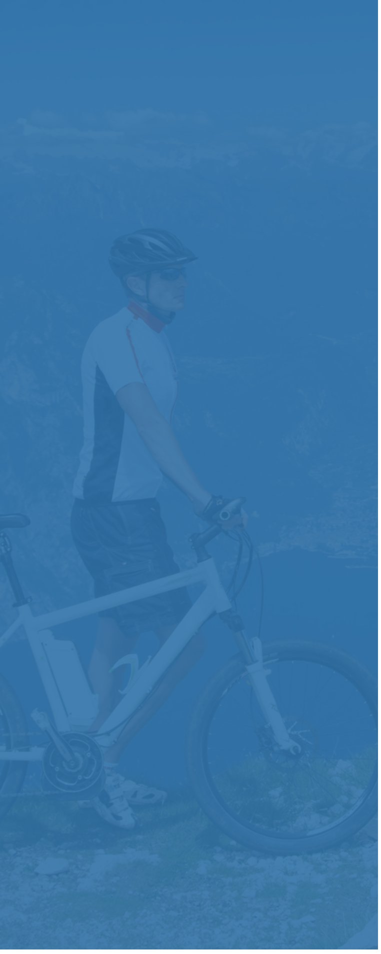


4th step: Calibrating the sensor



5th step: System inside housing

Figure 2: Five steps to the finished sensor



The shaft as primary sensor

The central element of the non-contact sensor is the component transmitting the torque or force. This may be a shaft in an extruder, a steering wheel or a car's gearbox.
Since shafts go through various steps in production they may have been magnetised already, for instance by induction hardening or magnetic clamping fixtures. For getting a uniform basic state for later magnetisation the shaft will therefore be cleaned first and then demagnetised (step 1).
Then the shaft will get magnetic encoding by means of a process called Pulse Current Magnetic Encoding for which NCTE holds the patent.
This encoding turns the shaft into the primary sensor. For creating the permanent magnetic field, a current impulse is sent through the shaft equalising the orientation of all magnetic moments. The current usually has a strength of several kiloamperes and depends on the shaft's diameter. It lasts few milliseconds. The induced magnetic field has long-term stability (step 2).

Secondary sensor unit and pairing

The reading unit is a static mini-sensor measuring the changes of the magnetic field without contact at a distance of several millimetres. The torque-induced changes of the magnetic field are very small (ca. 150 µT - 200 µT), therefore they are measured with a very precise measuring unit. This unit consists of magnetic field sensors as well as electronic components and a non-magnetic casing (step 3).
The last step is sensor calibration. The calibration of the entire sensor system takes only a few seconds and is very suitable for serial production (step 4).
In the last step both primary and secondary sensors are integrated in the product (step 5). The entire design can be adapted to the case of use. The OEM-design allows the system's use even in the smallest spaces. The electronic parts can even be placed inside hollow shafts.

1.3 Which material for the primary sensor?

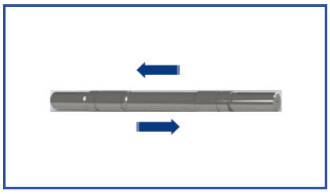
If a steel can be used as primary sensor or not, depends neither on its remanence nor its permeability but on its magnetostrictive properties (e.g. how much does its magnetic field change when exposed to torsion). In a nutshell: the harder a steel the more suitable it is for use as primary sensor. One reason is that harder steels are “more magnetic”. Secondly, hardness reduces the material’s distortion. This means that there is less hysteresis in the material after applying and removing forces.
There is no list showing the magnetostrictive properties of all steels. However, we at NCTE can rely on our experience to select the suitable steels. Most suitable as sensor steel are 5NiCrMo16 (1.2767), 15NiCr13 (1.5752), X20Cr13 (1.5032) or S155/300M, for instance.
The magnetic properties also depend on the thermal and mechanic “history” like tempering and production techniques. For these reasons we will test and assess each material for its suitability and the potential precision of the measuring results that can be achieved by using it.

1.4 The right precision for each application

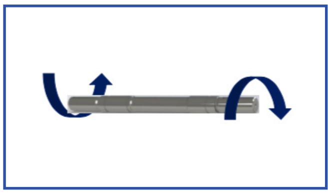
The standard accuracy of measuring results that can be achieved with the non-contact torque and force sensors ranging from 0.1 % to 2 %. This accuracy can be adapted to the application and the desired profitability.
The potential accuracy and adjustability of the sensor signal depend mainly on the material used for the primary sensor. The more homogenous the heat treatment the better.

2 Advantages of non-contact sensors

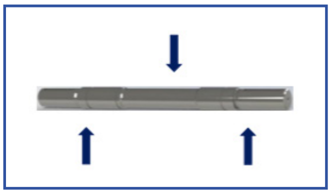
Magnetostriction technology allows for non-contact measurement of torque, force, shear or bending (static/dynamic) in test rigs or applications. Magnetic field technology can also be combined with conventional measuring techniques like rotational-speed measurement or active temperature compensation.



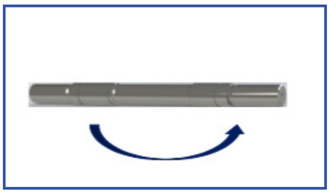
Pressure and tension



Torque and rotational speed



Bending



Bending

Below we summarise the main characteristics of non-contact technology:

- The existing shaft becomes the primary sensor, the secondary sensor can be designed as needed.
- Measurements are performed non-contact without cables or wear.
- The patented magnetic encoding has long-term stability.

The above results in the following advantages for the user:

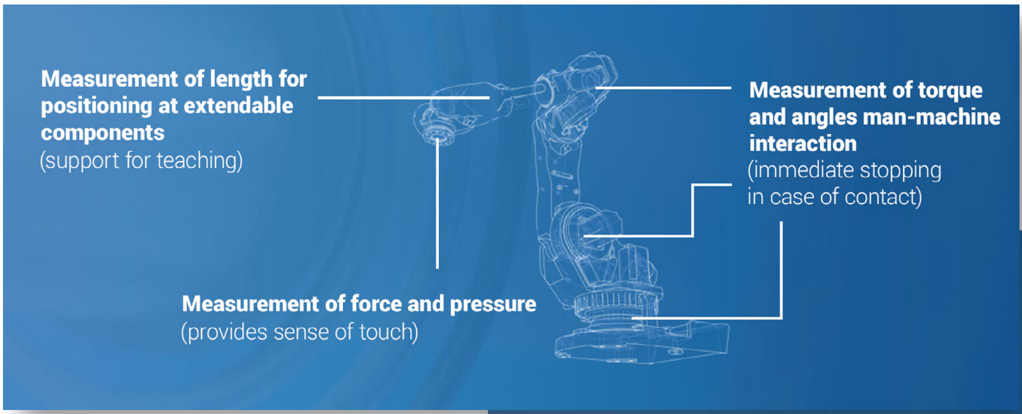
- No need for adapting the original shaft design; the client keeps full control of the mechanical properties and saves the cost for adaptation.
- The secondary sensors occupy very little space; they can be adapted to the use case and find room even in hollow shafts.
- With its cost structure and scalability, the technology is suitable for use both in test stand and in serial production.
- The sensors deliver precise measurements even when exposed to strong vibrations, temperatures up to 125°C and under permanent temperature load with externally mounted electronics and rotational speeds of more than 40,000 rpm. Even the presence of oil or water will not compromise the sensors' functioning.
- Magnetic field measurement is non-maintenance and even overloads will not damage the sensors.

The strengths of magnetic field sensors become most obvious especially in applications in the automotive industry, industry 4.0 or mechanical engineering, e-bikes, motor sport, medical engineering and off-highway vehicle engineering.

Two examples for the smart use of non-contact torque and force sensors by NCTE are:

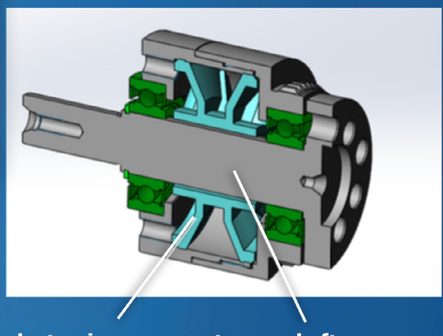
3.1 Sensitive robots in industry 4.0

Robots have become an integral part of the factories of the future. They need new abilities when working together with humans. They have to "learn" new processes and respond to touch with enormous sensitivity. Collaborative robots acquire these abilities by means of intelligent sensors. Torque and force sensors give them the sense of touch.
For achieving this, torque transmitting shafts are magnetised in each of their joints. When occurring forces are measured in hollow shafts, these shafts may even be placed in control and pneumatic conduits. There is no need to alter the original design. The secondary sensors (very compact as required in robotics) capture any change of forces very precisely with sampling rates of more than 10 kHz. The sensors deliver real-time data, thus allowing very dynamic movements of the robots. Ongoing feedback on the forces allows the robot to learn. The work cycle's framework parameters are recorded in each position.
Moreover, the magnetic field sensors can combine torque measurement and simultaneous bending measurement in two axes in a single sensor array. For this purpose, several secondary miniature sensors are combined. This solution is used especially for applications where complex movements take place.



Sensor

Measuring range:	± 70 Nm
Resistance:	against fats
Compact design:	23 mm axial length

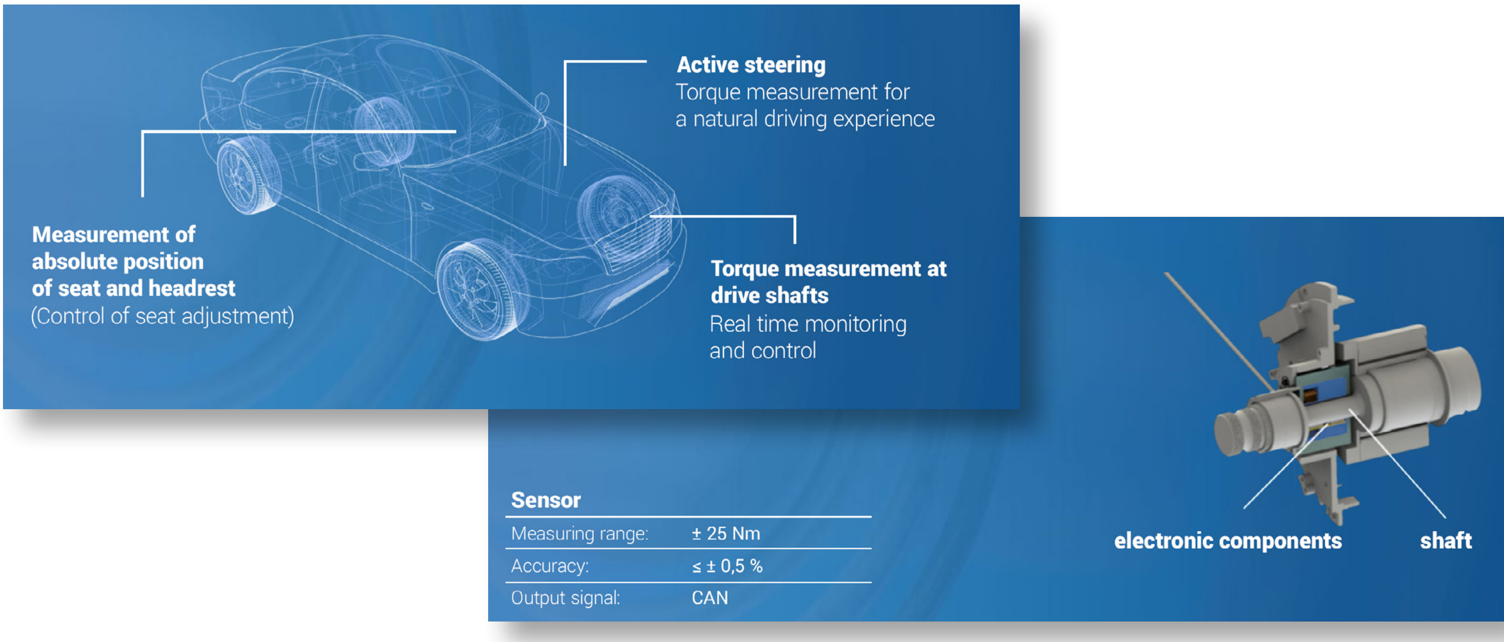


3.2 Active steering system for more dynamic driving

Active steering is a special way of steering that adapts the steering ratio to the vehicle's speed. Intelligent steering thus allows for a large steering angle with only little turning of the steering wheel when the vehicle moves at low or medium speed. When going at medium speed this makes the steering sportive and direct while requiring less turning of the steering wheel when parking. When driving at high speed the wheel's change of angle is small in comparison with the turning of the steering wheel, thus making steering indirect and comfortable.

For the sensor system the existing steering shaft is magnetised. The sensor then measures (without contact) the torque applied by the driver on the steering wheel. On this basis the electronic control unit calculates the steering support to be provided by the servomotor. Since the existing shaft is magnetised, its design need not be altered. Moreover, no additional weight is put on the steering system. The non-contact measurement delivers precise results during the steering system's entire lifetime despite being exposed to the vibrations usually occurring in vehicles.

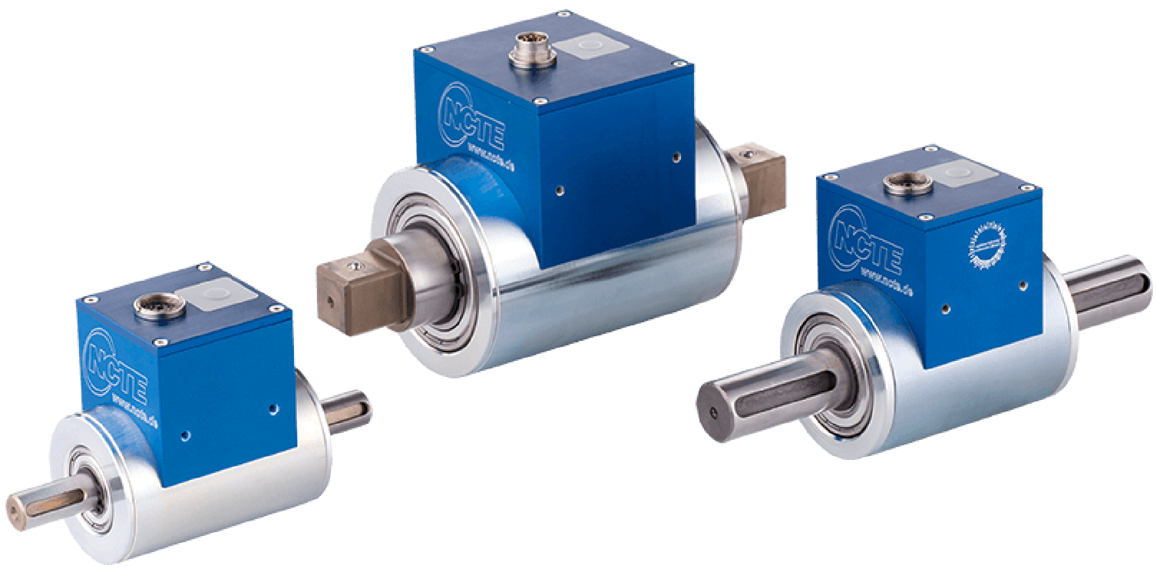
Other uses of non-contact sensors cover parts of vehicles like chassis, powertrain or interior or uses in traffic infrastructure or test rigs for engines and chassis.



4.1 Standard sensors

NCTE's non-contact standard sensors can be used everywhere without special adaptation, be it in test rigs or medical engineering products or highly complex industrial products.
All sensors are "Made in Germany". They are made at the company's seat in Oberhaching near Munich. With short delivery times from stock the sensor systems are integrated in the applications as plug & play units. Accuracy is better than 0.1 % for rotational speeds of more than 10,000 rpm and nominal torques between 1 and 25,000 Nm.

www.ncte.com/en/standard-products



4.2 Customised sensors

Apart from standard sensors NCTE develops tailor-made solutions for specific applications - from the initial idea to the design of the first prototype up to production. Because they are so economical non-contact magnetic field sensors are suitable for both single-piece and serial production.
Tailor-made solutions by NCTE are used wherever parts are rotating. To date they are used in motor sport, in test rigs for automotive systems or in e-bike motors.

https://ncte.com/en/customised

4.3 Tested safety and durability

NCTE-sensors are regularly tested under extreme conditions. Our non-contact sensors still deliver correct results after more than 2 million load cycles, 68 temperature cycles and 120 hours of vibration. Even 8 weeks of exposure to an eccentric load did not lead to a major distortion of the measuring results.

ATEX approval

As an option, NCTE offers the contactless torque sensors of 2000 series with approval for ATEX Zone II 3G Ex IC IIB T4 Gc according to the ATEX directives of the European Union.

5 Contact us!

Do you want to find out how you can use non-contact sensors in your application?
Please contact our sales staff:

Solutions for industry, robotics and aviation

Ralf Müller
Tel.: +49 89 665 619 44
ralf.mueller@ncte.de

Solutions for off-highway, agriculture and motor sport

Daniel Röser
Tel.: +49 89 665 619 38
daniel.roeser@ncte.de

Solutions for e-bikes and automotive

Marco Molino
Tel.: +49 89 665 619 39
marco.molino@ncte.de

Standard sensors and solutions for medical engineering

Akshay Vaswade
Tel.: +49 89 665 619 42
akshay.vaswade@ncte.de

NCTE AG
Raiffeisenallee 3
82041 Oberhaching
Germany