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# The state-of-art and prospect of contactless torque measurement methods

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**Abstract.** Torsional vibration is an important factor in the transmission process of mechanical shaft. The torque is also a part of the important parameters for working state of the mechanical shaft. In recent years, research on the measurement method of contactless torque of mechanical transmission shaft has been studied by many scholars. The contactless torque measurement methods have been continuously improved to achieve high precision and high reliability.The methods of contactless torque measurement is presented. The advantages of contactless torque measurement methods are introduced. The development of contactless torque measurement methods in the industry is discussed. Finally, the prospect of contactless torque measurement methods is prospected.

## 1.Introduction

Torque is one of the important parameters of a mechanical drive shaft. The value of torque is closely related to the performance of mechanical power, energy consumption, life and safety performance. Therefore, the torque can be measured accurately, timely and reliably, and the working state of the rotating shaft can be analyzed. This is a key function for automatic detection and automatic control of mechanical equipment[1].

Torque measurements can be divided into contact and non-contact. Contact torque measurement technology was used at an early stage. However, with the development of the industry, in some large-scale work, the rotating shaft is particularly large, and the torque received is also large. At this time, the normal contact sensor cannot be used to detect the torque of the shaft. Because of the torque sensor can be damage by the large tension. If a large contact sensor is designed, which will increase the cost. [2]RG Karpov（1966）[3] used existing contact torque measurement technology to achieve the goal of contactless torque measurement technology.A new measurement field for torque is being developed by RG Karpov.

The main aim of this paper starts classifies the contactless torque measurement technology, and then

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briefly describes the state-of-art of contactless torque measurement in recent years. Finally, this paper summarizes the future development trends and provides a reference for further optimization of design and practical use of contactless torque sensors.

## 2.Contactless torque measurement method

Contactless torque measurement techniques can be divided into two categories: tension measurement torque and twist angle measurement torque.

### *2.1. Tension measurement torque*

tension measurement is a conventional measure of torque .When the shaft is subjected to torque, the stress and strain values on the surface of the shaft will changes. At this time, the stress and strain values on the surface of the shaft are measured.Then the corresponding measured values are substituted into the corresponding mechanical formulas to calculate.Finally, the value of the torque on the rotating shaft is obtained.

New torque sensor can detect rotational speed and torque at the same time is designed based on amorphous alloy by Shi Yan-ping in Huaihai institute of technology (2011)[4], as shown in figure 1. Excitation current of a certain frequency flows through the sensor excitation winding. When there is no twist, the reluctance of the surface DE1 is equal to the reluctance of DE2, and the magnetic flux passing through the winding N2 is equal to them. Since the two coils are connected in reverse, the value of the sensor output is zero. When there is load torque, tensile stress and compressive stress of the alloy surface are generated. According to the piezomagnetic effect, the change in the magnetic resistance of the magnetic circuit causes a change in the magnetic flux, which Causes the induced voltage of the sense winding to change. The induced voltage of the E1 pole coil N2 increases, and the induced voltage of the E2 pole coil N2 decreases. Because the two coils are differentially connected, the output voltages are added to each other. After calibration, there is a corresponding formula that can be used to calculate the torque.

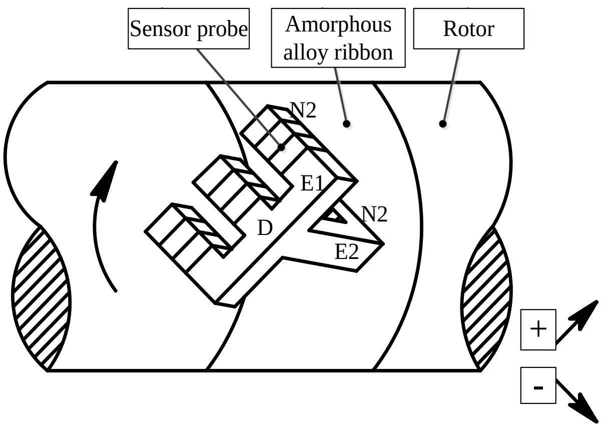


**Figure 1.** Structure schematic diagram of amorphous alloy torque sensor

An improved dynamic torque measurement method based on strain gauge is designed by Hilal Muftah(2013) [5]. The working principle of the metallic strain gauge torque transducer is to measure the strain in a flexible section of the shaft. In this improved method, a solid square element is used instead of a solid circular element as the sensing element. In this case, four strain gauges are attached into the rotating shaft as a Wheatstone bridge circuit. The first two strain gauges are fixed at ±45° on one side of the shaft axis and the other two strain gauges are also prepared at the same way on the other side of the shaft. In this case, shear strain occurs when torque is applied to the shaft. Shear strain occurs when the torque is applied to the shaft. Therefore tensile strain, which is measured by one pair of gauges, will increase the circuit resistance which, on the other hand, will be decreased by the other pair due to compression strain. Formerly the measured torque can be read from a measuring device as output voltage.

Shengnan Fu(2014)present a torque measurement method based on fiber Bragg grating (FBG) sensor [6]. The two gratings FBG1 and FBG2 are pasted in parallel on the surface of the shaft, as shown in figure 2. When the shaft is subjected to torque, the same strain occurs in both gratings. But the magnitude of their strain is the opposite. The wavelength will also change correspondingly when the grating is strained. Torque can be measured based on the wavelength changes of the two gratings FB1 and FBG2.

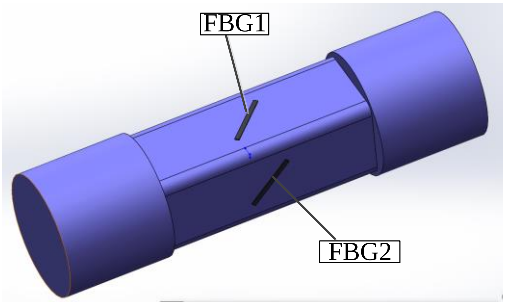


**Figure 2.** The design of the shaft and situation of FBGs bonded on the planes

Muhammad Nazar Ul Islam(2016)present a new method based on strain measurement torque [7]. There are two identical sealed chambers as chambers A and B, as shown in figure 3. Each chamber is connected to the port of the differential pressure sensor. When the shaft is subjected to torque, the torsional deformation of the shaft causes a difference in volume between the two internal sealed chambers. The value of the differential pressure measured by the sensor, The pressure difference is calculated by a mathematical formula to obtain the value of the torque.

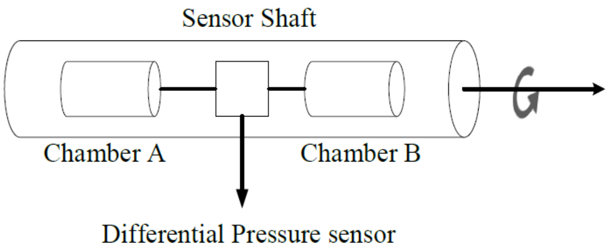


**Figure 3.** Abstract representation of the proposedmethod for torque measurement[7].

Jacques Cousteau S. Borges(2017) present a torque based on the Hall effect is measured by two self-measured magnets with two flux densities attached to the shaft[8]. The magnet is placed at an angle of 45° to the busbar on the surface of the rotating shaft, which is the maximum shear stress at the position where the shaft surface is subjected to torque. The shaft is deformed by the torque to cause a change in the distance between the magnets, and the magnetic field generated between the two magnets also changes accordingly. The equivalent moment can be calculated using the magnetic dipole model.

### *2.2. Twist angle measurement torque*

Twist angle measurement torque is also a conventional torque measurement method. When the shaft is subjected to the torque, the shaft will produce a torsion angle. At this time, two points on one of the busbars on the surface of the rotating shaft are measured. Then the relative angular difference between the two points is measured. Finally, after the data processing, the corresponding torque value can be obtained.

A contactless torque sensor is designed by RG Karpov(1966)[3], as shown in figure 4. Two soft magnetic material sprocket wheels are mounted on both ends of the rotating shaft, and the detector is also made of soft magnetic material. When the rotating shaft is rotated by the torque, the distance between the probe and the tooth tip or the root is detected by two magnetic pole detectors, and the detector generates different pulses to measure the torque value.

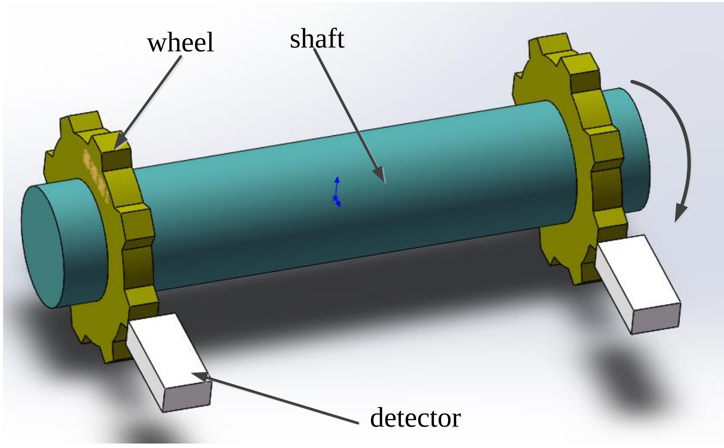


**Figure 4.** Magnetic pole detection torque sensor structure diagram

A new type of angle measurement torque sensor is designed by Yu Hong Lin(2009)[9]. A new type of non-contact torque sensor is formed by a special annular space array and a dedicated magnetoelectric detector. When the rotating shaft is subjected to the torque to generate a torsion angle, the magnetoelectric detector will move relative to the annular space array. The change in the magnetic medium between the coils causes a change in the mutual inductance, and the amplitude of the output voltage also changes. The measured electrical signal is the conversion of the torque signal.

Alberto Garinei(2017) present a non-contact torque measurement method based on laser speckle contrast method [10]. The measuring principle is that a laser beam passes through a beam splitter to obtain two beams, and the two beams respectively illuminate two different points on the same busbar on the same axis surface. The beam incident on the surface of the shaft is diffusely reflected, and the beam reflected back and diffuses forms a speckle. Speckle distribution varies with angular phase shift. The diffusely reflected beam is directed into the fiber. Electrical signal obtained by coupling an optical fiber to a photodiode. The two electrical signals are processed separately to obtain the measured torque value.

D Zappalá(2018) present a non-intrusive torque measurement of a rotating shaft using optical sensing of a zebra strip [11]. A pair of zebra strips with a relative angular phase of zero are attached to the ends of the shaft. The distance between the two measured zebra strips is as far as possible from each other. The optical sensors for detecting the two zebra strips are mounted on a fixed support. The principle of the proposed method is to quantify the shaft relative twist angle by measuring the phase difference between the two pulse signals and thence deriving the applied torque, from a known torque twist relationship.

## 3.Conclusion

The non-contact measurement of torque is moving towards digital, versatile and intelligent development. With the increasing degree of automation of various systems and the complexity of information, more and more information needs to be accessed, which not only puts higher requirements on the accuracy, reliability and response speed of the sensor. A sensor and system with standard output form needs to be developed. The torque measuring device is the following development trend:

- Torque measuring device develops to contactless measurement.
- The standardized package provides a standardized solution for the use of torque measurement.
- The production process continues to improve, and the measurement accuracy and response speed are gradually improved.
- The product volume continues to shrink, and the price ratio is significantly improved.

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