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Brushing up on the available methods and tools for measuring torque will help you improve your accuracy, as well as protect your wallet.

Torques can be divided into two major categories: static or dynamic. The methods used to measure torque can be further divided into two more categories: reaction or in-line. Understanding the type of torque to be measured, as well as the different types of torque sensors that are available, will have a profound impact on the accuracy of the resulting data, as well as the cost of the measurement.

Static vs. dynamic

In a discussion of static vs. dynamic torque, it is often easiest to start with an understanding of the difference between a static and a dynamic force. To put it simply, a dynamic force involves acceleration, while a static force does not.

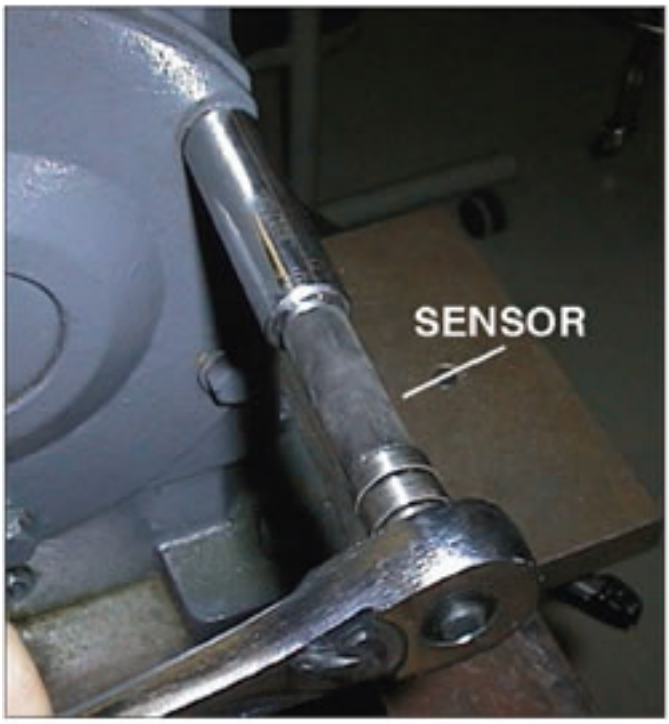

Fig. 1. Inline torque measurement, wherein a torque sensor is inserted between torque-carrying components.

The relationship between dynamic force and acceleration is described by Newton's second law; F=ma (force equals mass times acceleration). The force required to stop your car with its

substantial mass would be a dynamic force, as the car must be decelerated. The force exerted by the brake caliper in order to stop that car would be a static force, because there is no acceleration of the brake pads involved.

Torque is just a rotational force–or a force through a distance. From the previous discussion, torque is considered static if it has no angular acceleration. The torque exerted by a clock spring would be a static torque, since there is no rotation and, hence, no angular acceleration.

The torque transmitted through a car's drive axle as it cruises down the highway (at a constant speed) would be an example of a rotating static torque. In such a case, even though there is rotation, at a constant speed there is no acceleration. The torque produced by the car's engine will be both static and dynamic, depending on where it is measured. If the torque is measured in the crankshaft, there will be large dynamic torque fluctuations as each cylinder fires and its piston rotates the crankshaft. If the torque is measured in the drive shaft, it will be nearly static since the rotational inertia of the flywheel and transmission will dampen the dynamic torque produced by the engine.

The torque required to crank up the windows in a car (remember those?) would be an example of a static torque, even though there is a rotational acceleration involved, because both the acceleration and rotational inertia of the crank are very small and the resulting dynamic torque (Torque = rotational inertia x rotational acceleration) will be negligible when compared to the frictional forces involved in the window movement. This last example illustrates the fact that for most measurement applications, both static and dynamic torques will be involved to some degree. If dynamic torque is a major component of the overall torque or is the torque of interest, special considerations must be made when determining how best to measure it.

Reaction vs. inline

Inline torque measurements are made by inserting a torque sensor between torque carrying components, much like inserting an extension between a socket and a socket wrench. The torque required to turn the socket will be carried directly by the socket extension. This method allows the torque sensor to be placed as close as possible to the torque of interest, preventing possible errors in the measurement such as parasitic torques (bearings, etc.), extraneous loads and components that have large rotational inertias that would dampen any dynamic torques.

According to the above example, the dynamic torque produced by an engine would be measured by placing an inline torque sensor between the crankshaft and the flywheel, thus

avoiding the rotational inertia of the flywheel and any losses from the transmission. To measure the nearly static, steadystate torque that drives the wheels, an inline torque sensor could be placed between the rim and the hub of the vehicle, or in the drive shaft. Because of the rotational inertia of a typical torque drive line and other related components, inline measurements are often the only way to properly measure dynamic torque.

A reaction torque sensor takes advantage of Newton's third law that "for every action there is an equal and opposite reaction." To measure the torque produced by a motor, we could measure it inline, as described above, or we could measure how much torque is required to prevent the motor from turning,which is commonly called the reaction torque.Measuring the reaction torque helps us avoid the obvious problem of making the electrical connection to the sensor in a rotating application (discussed later). This method, however, comes with its own set of drawbacks.

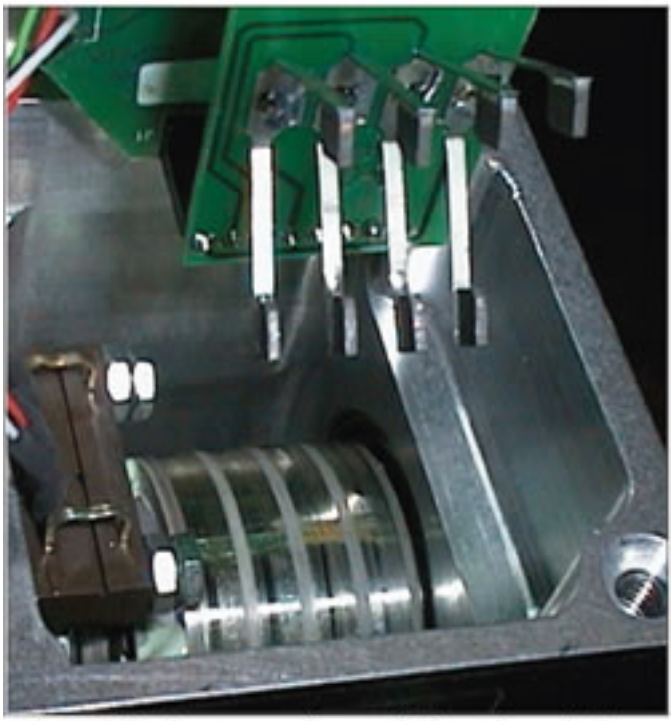

Fig.2. Slip ring example consisting of a set of conductive rings that rotate with the sensor and a series of brushes that contact the rings and transmit sensor signals.

A reaction torque sensor often is required to carry significant extraneous loads, such as the weight of a motor or, at least, some of the drive line. These loads can lead to crosstalk errors (a sensor's response to loads other than those that are intended to be measured), and sometimes to reduced sensitivity, as the sensor has to be oversized to carry the extraneous loads. Both of these methods–inline and reaction–will yield identical results for static torque measurements.

Making inline measurements in a rotating application will nearly always present the user with the challenge of connecting the sensor from the rotating world to the stationary world. There are a number of options available to accomplish this, each with its own advantages and disadvantages. They are:

Slip ring…

The most commonly used method to make the connection between rotating sensors and stationary electronics is the slip ring. It consists of a set of conductive rings that rotate with the sensor and a series of brushes that contact the rings and transmit the sensors' signals.

Slip rings are straightforward and economical solutions that perform well (with only a few minor drawbacks) in a wide variety of applications. The brushes, and to a lesser extent the rings, are wear items with limited lives that don't lend themselves to long-term tests or to applications that are not easy to service on a regular basis. At low- to moderatespeeds, the electrical connection between the rings and brushes are relatively noise-free. At higher speeds, though, noise will severely degrade their performance.

The maximum rotational speed (rpm) for a slip ring is determined by the surface speed at the brush/ring interface. As a result, the maximum operating speed will be lower for larger, typically higher torque-capacity sensors by virtue of the fact that the slip rings will have to be larger in diameter, and therefore have a higher surface speed at a given rpm. Typical max speeds will be in the 5,000 rpm range for a medium-capacity torque sensor.

Finally, be aware that the brush ring's interface can be a source of drag torque. This can be a problem, especially for very low-capacity measurements or applications where the driving torque will have trouble overcoming the brush drag.

Rotary transformer…

Rotary transformer systems were devised in an effort to overcome some shortcomings of the slip ring. They use a rotary transformer coupling to transmit power to a rotating sensor.

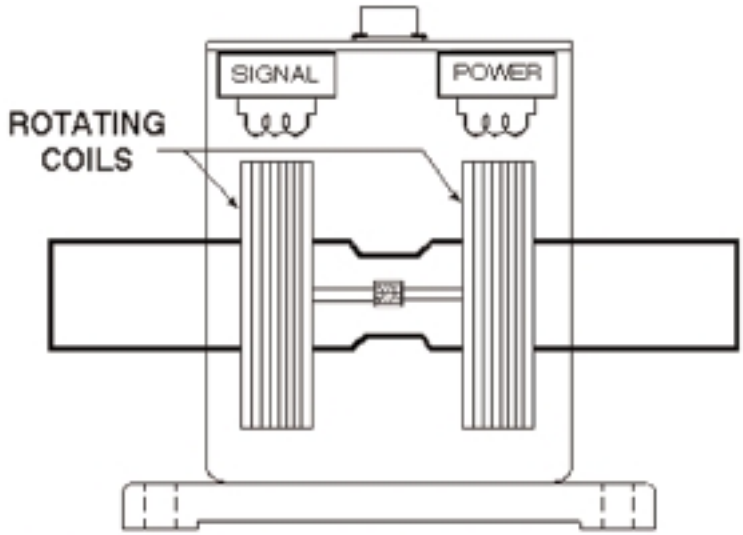

Fig. 3. the rotary transformer system uses a rotary transformer coupling to transmit power to rotating sensor.

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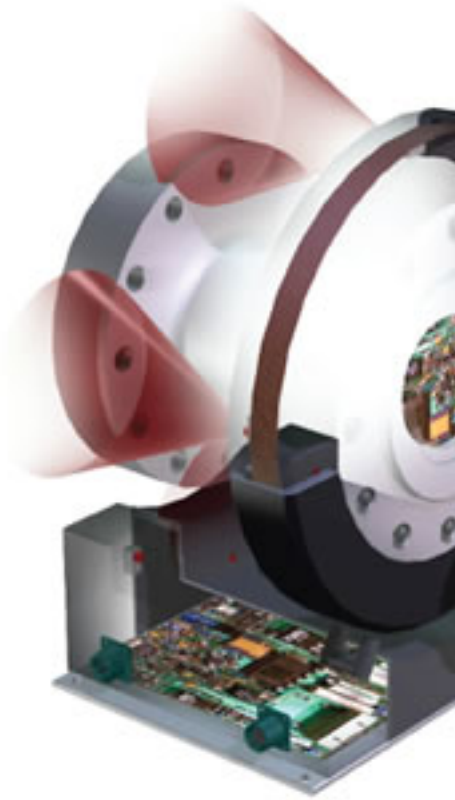

Fig. 4. IR torque sensor utilizing co
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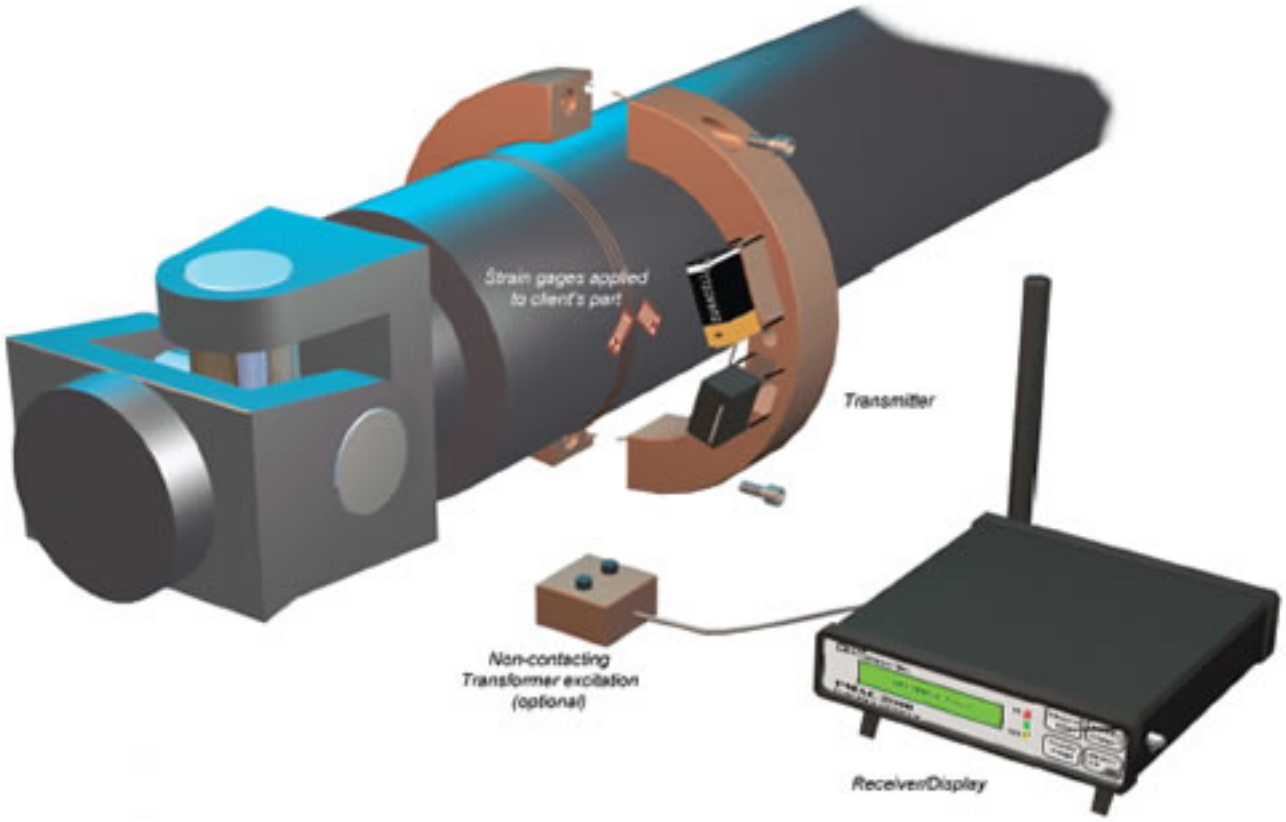

Fig. 5. FM transmitter devices connect force or torque sensors to remote data-acquisition systems.