The Basics of Torque Measurement

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Torques can be divided into two major categories, either static or dynamic. The methods used to measure torque can be further divided into two more categories, either 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 dynamic force. To put it simply, a dynamic force involves acceleration, were a static force does not. 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 involved. 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 IN-LINE

In-line 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. Measuring the reaction torque avoids the obvious problem of making the electrical connection to the sensor in a rotating application, but does come with its own set of drawbacks. A reaction
torque sensor is often 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 may dampen dynamic loads of interest, as the sensor has to be oversized to carry the extraneous loads, thereby reducing sensitivity. Both of these methods, in-line and reaction, will yield identical results for static torque measurements.

Making in-line 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.

SLIP RING

The most commonly used method to make this 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 and Brushes

Sliprings are an economical solution that perform well in a wide variety of applications. They are a relatively straightforward, time proven solution with only minor drawbacks in most 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 moderate speeds the electrical connection between the rings and brushes are relatively noise free, however at higher speeds 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 will 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, the brush ring interface is a source of drag torque that 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

In an effort to overcome some of the shortcomings of the slip ring, the rotary transformer system was devised. It uses a rotary transformer coupling to transmit power and receive the torque signal from the rotating sensor.

An external instrument provides an AC excitation voltage to the strain gage bridge via the excitation transformer. The sensors strain gage bridge then drives a second rotary transformer coil in order to get the torque signal off the rotating sensor. By eliminating the brushes and rings of the slip ring, the issue of wear is gone, making the rotary transformer system suitable for long term testing applications. The parasitic drag torque caused by the brushes in a slip ring assembly is also eliminated. However, the need for bearings and the fragility of the transformer cores still limits the maximum rpm to levels only slightly better than the slip ring. The system is also susceptible to noise and errors induced by the alignment of the transformer primary-to-secondary coils. Because of the special requirements imposed by the rotary transformers, specialized signal conditioning is also required in order to produce a signal acceptable for most data acquisition systems, further adding to the systems cost that is already higher than a typical slip ring assembly.

INFRARED (IR)

Like the rotary transformer, the infrared (IR) torque sensor utilizes a contactless method of getting the torque signal from a rotating sensor back to the stationary world. Similarly using a rotary transformer coupling, power is transmitted to the rotating sensor. However, instead of being used to directly excite the strain gage bridge, it is used to power a circuit on the rotating sensor. The circuit provides excitation voltage to the sensor’s strain gage bridge, and digitizes the sensor’s output signal. This digital output signal is then transmitted, via infrared light, to stationary receiver diodes, where another circuit checks the digital signal for errors and converts it back to an analog voltage.
Since the sensor’s output signal is digital, it is much less susceptible to noise from such sources as electric motors and magnetic fields. Unlike the rotary transformer system, an infrared transducer can be configured either with or without bearings for a true maintenance free, no wear, no drag sensor.

While more expensive than a simple slip ring, it offers several benefits. When configured without bearings, as a true non-contact measurement system, the wear items are eliminated, making it ideally suited for long term testing rigs. Most importantly, with the elimination of the bearings, operating speeds (rpm’s) go up dramatically, to 25,000 rpm and higher, even for high capacity units. For high speed applications this is often the best solution for a rotating torque transmission method.

The transmitter offers the benefits of being easy to install on the component as it is typically just clamped to the gaged shaft, and it is re-usable for multiple custom sensors. It does have the drawback of needing a source of power on the rotating sensor, typically a 9V battery which limits the test time, or with an inductive power supply that can be cumbersome to install on a vehicle.

**SUMMARY**

Understanding the nature of the torque to be measured, as well as what factors can alter that torque in the effort to measure it, will have a profound impact on the reliability of the data collected. In applications that require the measurement of dynamic torque, special care must be taken to measure the torque in the proper location, and to not effect the torque by dampening it with the measurement system. Knowing the options available to make the connection to the rotating torque sensor can greatly affect the price of the sensor package. Sliprings are an economical solution, but have their limitations. More technically advanced solutions are available for more demanding applications, but will generally be more expensive. By thinking through the requirements and conditions of a particular application, the proper torque measurement system can be chosen the first time.

**FM TELEMETRY**

Another approach to making the connection between a rotating sensor and the stationary world utilizes an FM transmitter. These transmitters are used to remotely connect any sensor, whether force or torque, to its remote data acquisition system by converting the sensor’s signal to a digital form and transmitting it to an FM receiver were it is converted back to an analog voltage. For torque applications they are typically used for specialty, one of a kind sensors, such as when strain gages are applied directly to a component in a drive line. This could be a drive shaft or half shaft from a vehicle for example.