New ways to measure torque may make your current method obsolete

This may seem like a bit of an overstatement. But if you need to measure torque and you have not looked at new technologies lately, you may be in for a big surprise.

New ways of mounting, installing, sensing, controlling, actuating, collecting data and reporting data abound. And, if you have not upgraded your torque measuring and controlling apparatus recently, be prepared to find new systems that are fast, accurate, flexible, inexpensive, require less maintenance and are simpler to install.

First, let's revisit what torque is and why it's important. Torque is a measure of the forces that cause an object to rotate. Reaction torque is the force acting on the object that's not free to rotate. An example is a screwdriver applying torque to a rusted screw. With rotational torque, the object is free to rotate. Examples include industrial motor drives and gear reducers. Torque and RPM determine horsepower, and horsepower determines system efficiencies, so being able to monitor and control torque can be critical in optimizing overall system efficiency. Here is the equation:

$$hp = T * \omega / 63{,}025$$
$$\xi = hp_o / hp_i$$

where,

T = torque (in.-lbs.)
ω = revolutions per minute
ξ = efficiency
hp_o = output horsepower
hp_i = input horsepower

Torque measurement is paramount in engine and transmission testing, turbine testing, pump testing and testing of gear trains and power measurement within propulsion systems. Monitoring torque can be critical to the performance of axles, drive trains, gear drives, and electric and hydraulic motors. Other in-plant applications include gas and steam turbines. Really, torque is an important factor in anything that rotates or spins on a shaft, spindle or axle. A lumber mill might use a predetermined maximum torque to initiate blade changes. This saves wear on the drive system and increase product quality.

How torque-measuring technologies evolved.
So, what's new and how did we get there? A brief history of what has been used and how torque measuring has changed may help illustrate the benefits of the latest technologies.

Digital telemetry is the latest technology, and so far, seems to have a number of benefits over older systems. But before digital telemetry was viable, there were several other methods, starting in recent history with the slip ring signal transfer method.

<u>The slip ring</u>
The slip ring is a simple means of getting a signal transferred from the rotating element to the stationary element. It has low speed limits. Ring wear and dust generated by the brushes can quickly impede signal transfer, so you must routinely maintain the rings and the brushes to ensure clean signal transfer. As testing requirements became more demanding, so evolved the rotary transformer.

<u>The rotary transformer</u>
Compared to the slip ring, the rotary transformer method tolerates higher speed, is non-contact and typically more accurate. However, it is less tolerant to extraneous loading conditions like bending moments and thrust loads. It also requires more sophisticated signal conditioning instrumentation using an AC carrier excitation. So as testing demanded more and more so

evolved the total non-contact solution of using analog telemetry.

Analog telemetry
Analog FM wireless telemetry systems use a sensor with a built-in radio transmitter module, a power supply and a receiver. Low voltage signals from the strain gauges are amplified and modulated to a radio frequency signal by the transmitter. This radio signal is picked up by a hoop antenna and decoded into analog voltage by the receiver. This voltage is amplified and scaled to show the torque value on an LED display. This signal is routed to an external connector for interfacing with a data acquisition system.

While this form of telemetry is an improvement over other mechanical methods, it is bulky and requires additional receivers for multiple channels. The frequency response is limited to about 1,000 Hz with an analog signal output. The antenna, straps and battery-powered systems can be difficult to install and tune. As technology and electronics advanced, digital telemetry became practical.

Early generation digital telemetry
The first generation of digital telemetry systems frequently used a hoop antenna, a bulky receiver and had limited data processing capability. A coil acted as the rotary transformer. The coil is excited by the radio frequency that is transmitted via the antenna. These early systems did allow two-way communication flow, but because they had no microprocessors, data processing was very limited. All the discrete components added to the cost and design limitations.

Next generation digital telemetry
As microprocessor and surface mount technologies progressed, multiple chips were added to the next generations of systems to vastly improve data management and control. A rotor electronics circuit board module is embedded in the sensor and is potted and sealed. Signal conditioning and digitizing is done on the rotating sensor using this module. Antenna and caliper-style coupling modules eliminate the need for hoop antennas and are more immune from vibration problems. Antennas are limited to a few select sizes and are matched to the caliper modules at the factory. This eliminates the need to tune the system in the field. Outer protective layers on the antenna and caliper module give outstanding protection against moisture and oil. A signal-processing module acts as the receiver unit, handling the communications with the rotor electronics.

Resolution, stability and accuracy are all improved over the early digital telemetry systems. The new systems transfer digital data at very high speeds, providing a frequency response up to 3,000 Hz.

More than stand-alone sensors, these are complete torque measurement systems, with standard analog, frequency and digital outputs. Fully software- driven, these digital telemetry systems can be changed “on-the-fly” without affecting calibration. They can be designed with clear upgrade paths for custom software, developments and future requirements. It is also where the “fit and forget” concept can be used to lower maintenance costs of existing solutions.

If you are measuring torque “the old fashioned way,” you may be unaware of some inherent inefficiencies. Here are a few headaches digital telemetry can potentially eliminate.

The setup headache
A common setup when one measures torque (or electrical current for that matter) the “old” way is to use a torque sensor or transducer that converts torque into an electrical signal. This conversion requires some method to transfer the signal, which requires more equipment and more work. Common signal transfer methods include a slip ring or transformer. To operate properly, both methods need standalone signal conditioning equipment. This means more setup and configuration, involving potentiometers and switches, which can be problematic. This sensor is interconnected with cabling to the strain gauge instrumentation or amplifier.

Let’s say you are measuring torque on an axle and you need a range of 1000 foot-pounds. However, you also want to measure at lower range of 500 foot-pounds and would like a voltage output at full scale for both. Both the “old” way and “new” way require you to calibrate the sensor and connect it to your instrument with cabling. Making these adjustments using analog potentiometer pots or switches can be time consuming and labor intensive. You normally have to set both a zero and a known load point. During the process, you need to read it and verify that you are in the range. It takes a lot of "back and forth" to manually dial the pot so you are in the right range. More importantly, all this adjusting will work only for the original range of 1000 foot-pounds. You *cannot* scale for different ranges, including the desired 500 foot-pound scale in our example.

The new generation of digital systems eliminates the headache of adjusting potentiometers and switches. These systems are completely software-driven, and output range is factory-set. However, the software allows this range to be changed, within certain limits, to any output level. They are almost plug and play.

You can order separate calibration runs that are stored on a disk that you can upload into the signal-processing module using the *Toolkit* software. While these separate calibrations are an additional cost, it may be money well spent. Scale ranges for these separate calibration runs are typically limited to between 50% and 150% of the full scale range. It is important to note that the resolution for separate calibration runs will be different from the resolution of the factory calibration.

With this new generation of digital telemetry, you can adjust your voltage output to interface with your existing data acquisition system through the software and also make changes "on the fly" during a test. You can also upload a new scale from your software "on the fly." You can establish multiple scales to create a library of scales and corresponding output voltages. When you want to change scales, you just upload and reset it. For instance, if you are measuring 0-1000 foot-pounds, you can set up your system so 10 volts is equivalent to 1000 foot-pounds. There is minimal set up.

<u>The mounting headache</u>

Torque measuring systems should be flexible and install easily on standard mounting configurations, such as DIN drive shaft yoke flange patterns, SAE drive shaft yoke flange patterns, integral couplings, or circular keyed shafts.

You can use smaller and more discrete components when you mount a digital telemetry system. Using a caliper coupling module style receiver instead of an analog hoop antenna receiver avoids the cumbersome installation and alignment headaches associated with hoop antennas.

<u>The wiring headache</u>

Digital telemetry is a self-contained system with fewer connections and fewer moving parts. There is no need for wiring to connect an antenna, amplifier or other signal conditioning equipment.

<u>The variable torque range headache</u>

It might take considerable time to set up your potentiometer for a 0-1000 foot-pounds scale. But now, let's say you are changing tasks, and you need to measure 1500-3000 foot-pounds. You may have to disassemble your system, and send the sensor back to the manufacturer for recalibration. Not only is this expensive, it could take weeks. Meanwhile your measuring station is completely down, unless you have another sensor that you can reinstall and reset to the new scale. To recalibrate the sensor in-house, you will need a set of reference standards for comparison. After calibration, you will still need to change out the sensor calibrated to the old range and replace it with the new sensor. Every time you change range scales, you must repeat this process.

Without digital telemetry, if you want to measure 10 ranges, you might need 10 sensors. And, you will need to set up the new ranges on your instrumentation and adjust the scaling factors. This could easily be several hours of time. Surely you have heard a colleague say "Oh, yeah! This is all true! I spend 2 hours the other day recalibrating a sensor."

With the digital telemetry system, you can order a sensor with multiple calibrations that can be changed out during different test sequences without long cumbersome setup or configuration changes. For example, you can have the torque ranges of 0-2000 foot-pounds, 5000 foot-pounds and 10000 foot-pounds preset. When you want to change the range, there is no need to change the sensor or any other component of the system. You just upload the new scale file. So you can cover various test ranges using one sensor.

The output headache that only goes one way.
With digital telemetry, you can also change the scaling output parameters. In our earlier example, we had a 10-volt output at 1000 foot-pounds. You can change the software to rescale to a 10-volt output at 500 foot-pounds. With the "old" way, this is difficult to accomplish. There is no two-way communication and interaction between the sensor and electronics.

Digital telemetry allows for two-way communication. It accommodates programming and scale input and output. The "old" way is fixed output only. You cannot change it. There is no input feed. This is true even with analog telemetry. That too is a one-way communication system.

Digital telemetry systems allow you to choose from multiple standard outputs. You can choose from voltage or current and one of two different frequency outputs. You can choose from either an RS232 or 485 standard. You can change output ranges "on the fly" and it is completely selectable and scalable. If you want to read volts at one test stand and current at another, you just change the output on the software. You can randomly switch between outputs.

Doing this the "old" way, you would need a new instrument, new sensor; new calibration or the whole system would need to be reconfigured. Most traditional sensors will have a fixed parameter or output that you can't change or rescale.

This ability is desirable because, say you want to verify or compare different values. If one station has instrumentation that reads volts and another station has instrumentation that reads frequency, there would be no way to compare. You would need to change out the instrumentation to read the same parameters. With digital telemetry, you don't need multiple instruments, nor do you have to switch out any components. It saves on expensive data acquisition equipment and the labor to make the change.

The accuracy headache
With the "old" way, there are many areas for errors to stack up, such as slip ring wear, dust from brushes, the instrument, the cables and outside electrical interference or noises.

Quick Check
Digital Telemetry…

…is much simpler to setup. It's a self-contained system without individual components to connect. There is no hoop antenna. There are no other sensors, instruments, elaborate wiring, installation or safety concerns.

…is much easier to mount. It mounts using small, discrete components. It fits all standard mounting configurations and can be customized to non-standard mountings.

…has fewer sensor and instrumentation wiring issues.

…lets you choose from a wide range of sensing ranges that you can change on the fly.

…not only lets you choose your sensing range, it let's you choose sensor *output type* and *range* that you can change on the fly.

…is very accurate and has significantly less error than slip ring strain gauge type sensors.

…requires much less maintenance.

…can be smaller and lighter.

…permits multiplexing for expansion and upgrading.

…gives you two-way communication

With digital telemetry, you can get a lot more resolution and capability. You can use one sensor for several torque ranges. This greatly reduces sensor error. Most likely, you will need only one sensor, even over a broad torque range. Using the "old" way, you need to switch sensors more often and you are very limited in the range of coverage.

With digital telemetry, electrical noise is much less of a factor. You are digitizing the signal right at the sensor by using CHECKSUM for data transfer. This means only "good" data is transferred to the system. That's one reason why the system is so accurate. It is immune to EMI and other fields of interference. Total system error is about .05%. With the "old" way, you might have a total error of over 0.15% when you stack up all the independent errors of the sensor, the instrumentation and electrical noise interferences associated with cabling and power source.

The maintenance headache
Digital telemetry may, but not necessarily, have an initial higher cost. But, it is virtually

maintenance free once installed. Mechanical and analog telemetry systems can have bearings, slip rings, hoop antennas and transformers that are easily damaged and require upkeep. Setting and recalibrating sensor and output ranges can be time consuming and repetitive. Coordinating and maintaining different instrumentation to read, record and actuate signals can be expensive. And remember, analog systems do not have two-way communications unlike digital, even though analog systems may be non-contact.

The "old" way of using analog telemetry also requires an antenna. This antenna many times is a hoop, which is typically a quarter inch brass wire that must go around the entire unit. It can be problematic when installing and doing your fixturing because antennae are easily bumped and damaged and is alignment critical. There can be signal degradation. In some cases, the unit will not work at all if the antenna is not positioned and aligned properly. They can also be dangerous; they break easily and they must be positioned and aligned just so or they don't work properly. While it is not a significantly expensive piece of equipment, nevertheless, you still need an antenna, and it needs to be purchased, installed and maintained.

<u>The size headache</u>

The "old" way uses lots of parts, requires twisted shielded type cables and hoop antennas. For older, traditional flange-to-flange mounting styles that require a slip ring or transformer as signal transfer, you may need a multi-piece design with bearings.

The "new" way is smaller, lighter and more compact, yet it configures to meet standard interfaces. It can also be customized to fit your needs. You will see higher torsional stiffness and lower rotational inertia yielding better mechanical response characteristics. With digital telemetry, you can have a simpler design with fewer backlash, size and weight issues.

<u>The lack of expansion and upgrading headache</u>

Multiplexing is the ability to adapt to multiple sensors. The architecture of a digital system allows you to expand and upgrade for more customization. For example, you can sense torque and also multiplex temperature channels at the same time. This is a sampling technique, so you can have 8 temperature readings in conjunction with your torque readings. Besides torque and temperature, other parameters can include humidity, thrust, pressure or other load factor. All you need are the proper sensor, such as adding a thermocouple. The architecture of the software and the electronics in digital telemetry gives you this sampling capability. With our open-ended architecture, you can expand your system to meet most of your needs by just adding an adapter interface and some software and circuitry.

Comparing Telemetry Systems—they are not all alike.

The differences between analog and digital torque telemetry systems should be clear by now. But some of the advantages to digital may be subtler. For instance, digital torque measurement systems do not need a hoop antenna to surround the entire rotating sensor. Rather they use a small caliper coupling module (CCM) for transmission and receiving of signal. This device can be more accurate and reliable than any antenna. Also, the analog system does not allow for two-way communications, one way only. Analog is not selectively scalable, you cannot adjust it, nor can you make any changes "on the fly" as you can with a digital software-driven system. It is not user-friendly and its setup and calibration can be time consuming and difficult.

Choosing a torque sensor system vendor.

Ideally, the vendor you select for your digital telemetry system has experience not only in torque telemetry, but in wireless networks as well. They should be experts in the sensor industry and have the capability to have measurement, instrumentation and actuation software either custom-engineered or done in house. They should have extensive system engineering experience, not only sensing or controlling expertise.

Considering calling Honeywell and ask about their new digital telemetry system called the TMS9000 Measurement System. It has flexible mechanical formats for easy mounting and is totally software-driven so there are no switches or potentiometers. It has six standard user selectable and scalable outputs, and it does not require a hoop antenna.

Key benefits of digital telemetry for measuring torque.
Digital telemetry can have a number of distinct advantages over analog telemetry and it can deliver better performance. While slightly more expensive at the outset, the increased accuracy, flexibility and reduced set up and maintenance costs deliver a very rapid payback.

For more information, please visit to www.honeywell.com/sensing.