Off-Highway Vehicles:

Taking Torque Measurement from the Lab to the Production Floor and Out into the Field

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Ever since the first tractors powered by steam engines were developed in the nineteenth century, their purpose has been the same as it is today: to deliver power, high traction, and torque, with the torque provided reliably at a controllable speed. Over time, the design of that first tractor has evolved and expanded into a wide range of off-highway vehicles that perform critical functions in a wide variety of industries. Whether they are intended for use in agriculture or earth moving, in commercial or military applications, they need to keep working efficiently in a variety of challenging terrains.

In order for these vehicles to perform at their best, their wheels must stay in constant, consistent contact with the ground. This requires delivering power from the engine, along with the drivetrain, through the gearboxes and to the wheels. Pushing a heavy vehicle through uncertain terrain requires applying a known torque consistently across all of its wheels.

Rising fuel prices and the desire for more fuel-efficient vehicles have led to greater emphasis on more economical vehicles with higher efficiency. At the same time, governments around the world are pushing for higher fuel efficiency standards for both on-highway and off-highway vehicles in order to lower vehicle emissions. Attaining these goals would be beneficial for both the environment and vehicle operators.

For example, a farmer could purchase a tractor with very little wheel slip that employs an efficient engine and drivetrain system that sees very little power loss to the wheels, the power take off (PTO), and the implement. This level of operational efficiency would allow for optimum work rates, along with increased profit.

In another scenario, manufacturers of engines, transmissions, gearboxes and axles have all been focused on engineering new products that meet today's Tier 4 emissions standards. These manufacturers work in conjunction with the makers of agricultural tractors and other diesel-powered vehicles, such as wheel loaders, to ensure the final product meets both customer and governmental demands.

Over time, engineers have employed various testing methods during product development to ensure their products meet their desired performance standards. These methods include the use of strain gage-based transducer testing equipment to measure torque at the critical points within the system. Measurements can be taken at multiple points, including an engine gear shaft, flexplate, transmission shaft, gearbox, axles, wheel hub assemblies, and PTOs.

Test engineers and transducer manufacturers have employed many different torque measurement methods for precise data acquisition, such as applying foil strain gages directly to a drive shaft to measure its rotational deflection or strain. With this method, an electrical signal from a battery is passed through a strain gage, which measures the strain or force in a given direction based on a change in the gage's electrical resistance equal to the force applied, using the Wheatstone Bridge model.

Torque transducers offer another approach to measuring torque that employs the same principles as strain gage measurement. However, a torque transducer is a highly precise machined element that's installed between two components of the system at the point at which the torque is to be measured. This transducer is specifically designed to focus the rotational force and torque being applied directly at Until recently, torque measurement has been used for testing purposes only, but vehicle, engine, and driveline component manufacturers have long wanted to be able to incorporate factory-installed, production-level torque measurement on their products. By combining live torque measurements with an on-board computing system, it's possible to see power loss at various stages of the driveline, the wheels, and the implements while making adjustments on the fly. Currently, adjustments must be made using

Figure 1: HBM Torque Sensors

calculations that employ theoretical lab-tested values of the components, which are known to have a wide range of error percentages.

Significant advancements in the telematics industry and induction rings have pushed the envelope in several areas and brought production-level, factory-installed torque measurement somewhat closer to realization. The hurdles of space, technical, and cost constraints are now behind us.

Here at HBM, we are working to take advantage of these advancements. Through the use of highly engineered custom designs, our engineers can convert individual components like flex plates, drivetrains, gear wheels, axles, etc. into functional sensors to measure torque. This is made possible by embedding the telemetry board or induction ring into a cavity within the components themselves and transmitting the strain gauge torque data wirelessly to a receiver.

Figure 2: Flex Plate

This solution offers a variety of advantages:

- No need to install an additional transducer
- Linearity and reversibility error of less than 0.1%
- No change in the mechanical behavior of the drivetrain
- Continuous long-duration measurements
- Wider range of operating temperatures
- Robust transducer for continuous operation
- Immune and insensitive to electromagnetic interferences (EMC)

When autonomous vehicles move into the mainstream, off-highway vehicle engineers will once again look to implement production-level torque sensing. Without a driver at the helm to make on-the-fly adjustments, the autonomous vehicle's on-board computer system will be able to minimize wheel slip and maximize fuel efficiency by strategically transferring power to the various components.

As the demand for higher performance from off-highway vehicles grows, the industry will see breakthroughs in the advancement of telemetry technology. By allowing for the economical transmission of highly accurate and reliable rotating torque measurement data, these advances make it possible to move beyond the controlled environments of the lab or field testing and into production-level vehicles themselves. This will allow the industry to take a big step forward in the quest for lower emissions, fuel savings, and vehicle stability control.