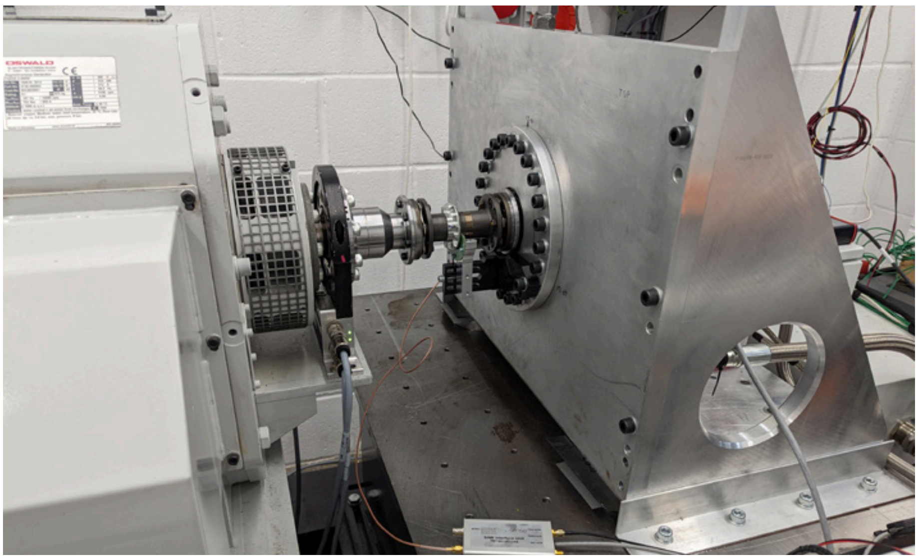
Unlocking Powertrain Density with Motor Control

Drive System Design and Transense Technologies collaborate on fully functional automotive solutions

Matthew Jaster, Senior Editor



DSD and Transense Technologies collaborated on a motor control study on high-speed, high power density traction.

An innovative technology for the next generation of high-speed, high power density traction and propulsion systems has been jointly developed by Drive System Design (DSD) and Transense Technologies. David Hind, principal engineer, DSD, presented "Unlocking Powertrain Power Density with Innovative Motor Control," earlier this year at the CTI USA Symposium 2025 in Novi, MI. The presentation built on initial simulation studies performed in MATLAB Simulink; a software tool used to design and simulate systems before moving to hardware. While simulation trials proved successful, achieving quality experimental results proved far more challenging. Hind examined these challenges and potential solutions at CTI.

Hind said in a recent interview that the growing trend towards high-speed motors as a means of increasing power density is limited by the computation time of the motor control algorithm which has been identified as a key a limiting factor in the maximum achievable motor speed.

Direct Torque Control (DTC) has a much lower computational burden than the commonly used Field Oriented Control approach and can reduce execution time by >50 percent, enabling control at higher motor speeds.

However, DTC suffers from torque accuracy and ripple because of the torque and flux estimators used and the interdependence between the two. An Improved DTC approach was proposed using measured torque feedback in place of the torque estimator. This approach eliminates the interdependency between the estimators and can significantly reduce torque ripple.

Surface Acoustic Wave Torque Sensor

DSD has experience in motor control solutions. "We've developed our own platform in-house and we're able to develop custom controls," Hind explained. "Recently, we developed a new type of motor control with Transense Technologies."

Founded in 1991, Transense Technologies, headquartered in the UK, is a leader in the development and supply of specialized sensor technology and measurement solutions for use in demanding, high growth markets. Transense created a sensor for the accurate measurement of torque, pressure and temperature based on Surface Acoustic Wave (SAW) technology.

"Transense created a really neat torque sensor, and they were looking for new market opportunities, particularly in automotive, so they came to us to help find new innovative ways to utilize the sensor," Hind said.

This technology is a wireless, passive, sensing system consisting of three main elements: SAW sensing elements connected to antennas known as RF Couplers mounted on the part to be measured and an electronic interrogation unit called a reader, connected to its stationary RF coupler. The reader generates and transmits an interrogation signal across the RF Coupler to the sensing element. The sensing element is excited by this RF signal creating a surface acoustic wave on the surface of a piezoelectric substrate between the fingers of an interdigital transducer (IDT). The IDT reflects the SAW back to the reader. The frequency of this reflected signal is affected by the physical measurement of either strain or temperature in the sensing element. The reader analyses the received signal and calculates the value of the physical measurement.

"The sensor has a small package envelope requirement and is suitable for integration into mass produced motors, meaning the technique can be applied in production EDU's and propulsion systems. DTC also removes the requirement for a position sensor (for algorithm implementation at least) which offers the potential to offset the BOM cost of the torque sensor," Hind said. "Our job was to find more value in the technology so we identified a solution that would help to increase powertrain power density using motor control."

Motor Control Enhancements

The Improved DTC approach was verified using a DSD dynamometer and test motor featuring a SAW sensor integrated into the mechanical coupling between the two motors. According to Hind, significant challenges around torque ripple feedback required additional measures to avoid this ripple being injected into the control via the closed loop.

DSD's Open Platform Inverter is utilized to interface to the SAW sensor and demonstrate the newly developed Improved DTC algorithm. Hind shared these developments in his presentation along with results from the verification testing as well as the challenges affecting the practical implementation of this new motor control approach. The presentation provided real insight into the development testing that has taken place by including the challenges faced in achieving a fully functional solution.

"One of the trends we see in motor and drive units today is increasing speeds with increasing pole counts and that allows the motors to be physically smaller. But of course, this can introduce problems for other parts of the system—one of those being the motor controls. When you push those motor speeds faster you are squashing the time you have to do the calculations to control the motor. The algorithm we produced with Transense can be executed really fast, so you can keep pushing the speed up without hitting the ceiling of the calculation time," Hind said.

They were also able to demonstrate this on a rig using DSD's in-house facilities. "We're really spoiled here. We have several test rigs where we can evaluate this equipment in real-time," Hind added.

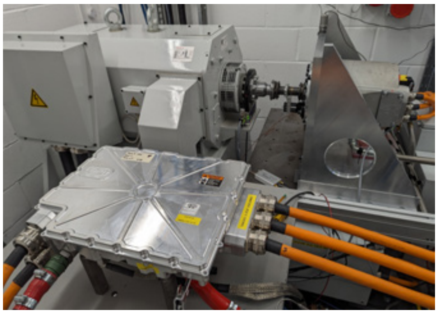
Trial & Error

Hind believes the most challenging aspect of motor control is getting something to work in both the physical and simulation space. "Simulation makes life a lot easier," he said. "The signals are always very clean. You can add noise into the signals if you want, but you are always in charge of what that noise looks like. It is when you get to the real world where it doesn't always work out."

With one algorithm, one of the problems Hind found was the dynamics of the torque feedback into the closed loop system interacting with the external systems. The dynamometer played a role in interacting with the sensor and adding an element of feedback they had not accounted for in the simulation.

"There are one or two other things in there—like bearing loss and windage loss—and those can add up to make a meaningful contribution. This made it difficult during our first attempt, but we were able to find a solution by improving the sensor implementation and where it fed into the algorithm. There is always an element of trial and error at this point," Hind remarked.

Hind credits the engineers and the equipment available to them with



making the job of refining and fixing various problems much easier. "As I mentioned earlier, our in-house test facility really helps solve the challenges associated with motor control. We also have several experienced engineers we can call on to provide feedback and different points of view on the research. This is invaluable to the work we do at DSD."

The Research Continues

Hind said the direct torque control algorithms DSD developed do not use many standard control methods like field-oriented control. "This allows you to reach those higher speeds. Typically field oriented control has an eight to 10 microsecond execution time. This is what we see without doing a load of optimization on the code—which is very time consuming itself and costly as a result."

People tend to move over to something called six step at high speed, also called 120 degrees commutation or trapezoidal control. It uses six steps or "sectors" over one electrical cycle to energize a BLDC motor. Each sector is equivalent to 60 electrical degrees, with the six sectors resulting in 360 electrical degrees or one electrical cycle. "This is a basic modulation scheme, and is poor in terms of the output quality. What we are trying to do is provide a control approach that gives the customer higher quality without the execution time penalty," Hind said.

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