Torque of a motor revolution

Tony Ingham, Sensor Technology Ltd

Oxford YASA Motors is using a TorqSense non-contact speed and torque sensor from Sensor Technology to aid the refinement of its motor designs. Used in a test rig to evaluate prototype motors, the sensor provides accurate and reliable real time information in a readily accessible format.

Oxford YASA Motors is engaged in the development and manufacture of a new type of axial flux motor based on the revolutionary YASA motor developed by Oxford University's Energy and Power Group. The motor features Yokeless And Segmented Armature (YASA) topology. Compared with conventional axial flux motors, YASA configuration offer a step-change improvement in torque density, making them ideal for applications such as electric vehicles where the highest possible torque-to-weight ratio is a key requirement.

The YASA topology is based around a series of magnetically separated segments that form the stator of the machine. The step-change improvement in the specific torque of the motor, which at around 20 Nm/kg is at least twice that of the best currently available alternatives, results from a combination of patented improvements in the magnetics, cooling and packaging of the motor.

A 500 Nm YASA motor has already been developed specifically for use in electric and hybrid vehicles. This motor is compact – just 340 mm in diameter and 70 mm wide – and therefore able to fit easily in the volume normally occupied by the front or rear differential in typical vehicle, with the advantage that no differential is needed with YASA motors.

Since these motors have an output of 500 Nm per "slice", and a peak power of around 75 kW, two of them provide sufficient power for most vehicles. This has been verified in practice by the Westfield iRacer, a pioneering home-build electric racing car from Birmingham City University and Westfield Sportscars, fitted with two YASA motors, which accelerates from 0 to 60 mph in less than 5 s, and is capable of reaching an electronically limited top speed of 110 mph.

Despite the impressive performance and versatility of its existing products, Oxford YASA Motors is committed to continually refining and improving its designs. In addition, the company offers a custom design and manufacturing service for motors to suit applications that are not yet covered by its standard product range. All of this means that it has a regular requirement to analyse the performance of prototype motors.

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An essential element of this work is accurate measurement of torque and speed of the motors during an extensive programme of testing. The tests often involve linking a pair of motors back-to-back, with one driving and the other acting as a brake. While conventional torque sensors based on strain gauges could have been used in this application, this would have unnecessarily complicated the design of the test rig and, in addition, such sensors have a poor reputation for accuracy and reliability.

Accordingly, the development team at Oxford YASA Motors looked for a better alternative, which it found in the form of Sensor Technology's TorqSense non-contact wireless torque sensors. Based on surface acoustic wave (SAW) technology, these sensors essentially comprise two thin metal electrodes, which

Westfield iRacer live build at Millennium Point in 2013. Credit: BBC Filming two thin metal electrodes, which take the form of interlocking fingers on a piezoelectric substrate. When a radio frequency signal of the correct frequency is applied to this assembly, surface acoustic waves are set up and it acts as a resonant circuit.

If the substrate is deformed, however, the resonant frequency of the assembly changes. This means that if the assembly is attached to, for example, a motor shaft it can be used to measure the deformation in that shaft as the torque transmitted by the shaft changes. In other words, the assembly becomes a frequency-dependent strain gauge that measures torque.

As the assembly operates at radio frequency it requires no wired connections – signals to and from it can easily be coupled wirelessly. As a result, the patented TorqSense sensors can be used on rotating shafts without the need for the inconvenient brushes and slip rings that are often required in traditional torque measurement systems.

For the Oxford YASA Motors application, a type RWT321 sensor with integral electronics was chosen. This combines high accuracy and resolution with a large overload capacity and the ability to operate equally well with clockwise and anti-clockwise rotation. In addition to torque data, the sensor also provides information about shaft speed, power and temperature, with all of the data made available in real time.

A further benefit for Oxford YASA Motors is that the RWT321 incorporates a CANopen interface. This is directly compatible with the company's data acquisition and analysis systems and, therefore, made interfacing the sensor very straightforward.

The TorqSense sensor is in regular use as an aid to evaluating motor performance and is providing the company with the dependable and accurate information needed to ensure the continuing success of its development programme.

Seminar Report: Magnetics in Future Energy Systems

Mr Chris Riley, Dassault, 3DS/SIMULIA

Dr Hamed Bahmani, Electrical Engineering, Durham University

Dr Arwyn Thomas, SiemensGamesa

UK Magnetics Society seminar, Durham University, 30 October '19

In October 2019, the Society organised a 1 day seminar with speakers addressing a wide range of topics under the umbrella of the role of Magnetics in Future of Electric Power Generation. The meeting was held in the very impressive venue of the Durham Town Hall in the centre of the city.

The morning session was chaired by Dr Arwyn Thomas of Siemens Gamesa Renewable Energy Ltd, who introduced Prof Simon Hogg of Durham University to welcome the crowded room of delegates. Simon briefly spoke about some of the work that University of Durham is undertaking, as well as saying a few words about the lovely city of Durham. Simon was followed by Glynn Cooke of Magnomatics, whose talk *Large Scale Magnetically Geared Generator* described the development of a very efficient (>99%), large scale magnetically geared generator that currently is able produce 500 kW with a torque of 200 kN-m. After explaining the operation of the Magnomatics Pseudo Direct Drive, he explored the design simulation work that Magnomatics had performed in electromagnetic, thermal, structural and fluid dynamics to optimise the design. The machine had been manufactured at ATB Laurence Scott in Norwich and subsequently tested both at the Offshore Renewable Energy Catapult facilities in Blyth and Norvento Enerxia in Spain, with excellent results and expected performance.

Speakers (L – R): Jiawei Mi, David Collier, Stuart Bradley, Arwyn Thomas (Chair), Glynn Cooke, Jonathan Godbehere, Damian Hampshire, Hamed Bahmani (Chair), Xiaoze Pei, Seiji Okabe

Glynn was followed by David Collier from Minesto. David's talk *Tidal Stream Power* was about the exciting underwater kite technology that the company are developing to create renewable energy. After showing the resource available through tidal stream energy, David explained the design, which looks like a glider, and exploits the currents in the ocean to achieve higher speeds, compared to a conventional fixed axis turbine, as it describes a "figure of 8" path. The on-board turbine generator is connected to a flexible coupling attached to the sea bed, which then delivers power to the surface. He went on to describe the construction, assembly and testing of the prototype device off the coast of Wales. The first demonstrator project will be in the Faroe Islands, where 2 of the DG100 devices will be installed.

The final two talks in the morning covered the development of magnetic materials for generators and motors. Seiji Okabe of JFE Steel's talk *Magnetic Properties of 6.5% Silicon Electrical Steel and its Applications* covered the capabilities and advantages of the relatively new generation of 6.5% silicon steels. Firstly, he briefly described the creation of JFE from two of Japan's most prestigious steel companies, Kawasaki and NKK, before introducing the new material. Seije then emphasised the excellent properties of the new steels in high frequency electromagnetic devices.