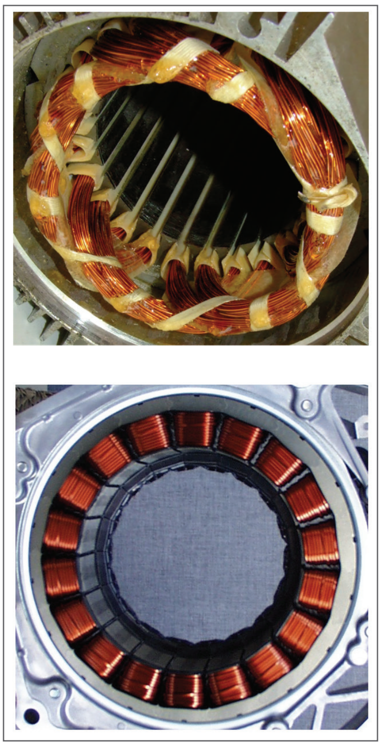
OPTIMISING NEW ELECTRIC MOTOR DESIGNS

-Yokogawa power analysers play key part in efficiency tests on motors for electric vehicles -



Comparison of conventional (above) and concentrated (under) winding. (Photo by Universität der Bundeswehr)

Yokogawa power analysers are playing a key part in tests designed to optimise the efficiency of a new generation of motors for electric vehicles being developed by German drives specialist FEAAM in co-operation with the Institute for Electrical Drives & Actuators of the Universität der Bundeswehr (University of the Federal Armed Forces) in Neubiberg, near Munich.

The new motors are being developed as part of a research project to examine ways of increasing the efficiency of induction motors with the aim of challenging two perceived limitations that are hampering the market acceptance of electric cars: namely, the short range and the high purchase price. The research project is looking at the components of the drive train, and is basing its tests on driving cycles: the same concept that is used in efficiency and emissions tests on internal combustion engines. An important element of this approach is that the results do not depend on the efficiency at maximum load conditions, but on the efficiency at partial load operation.

Single-tooth winding

A promising approach for the optimisation of the electric motor efficiency is the concept of asynchronous motors with concentrated windings. Unlike a conventional induction motor with distributed winding, where the coils are wound around multiple lamination teeth, the windings use only a single tooth. Although this technique has been known about for some time, it has not previously been practically applied because of the interfering harmonics that can occur.

In the joint research project, FEAAM and the university team analysed the magnetic fields in the motor very precisely by a combination of simulation and practical experiments. As a result, they were able to devise various measures to suppress unwanted harmonics. The closer these harmonics are to the working wave, the more they can interfere with the motor's operation, causing electrical losses or acoustic noise.

The damping of the harmonics is achieved by a special winding technique in which adjacent tooth coils are wound in opposing directions. With the correct configuration of the number of wires in each coil, the harmonics can be reduced. In the research project, the structure of the coils is first simulated using mathematical models, and the effects are then verified by measurements.

At the test bench

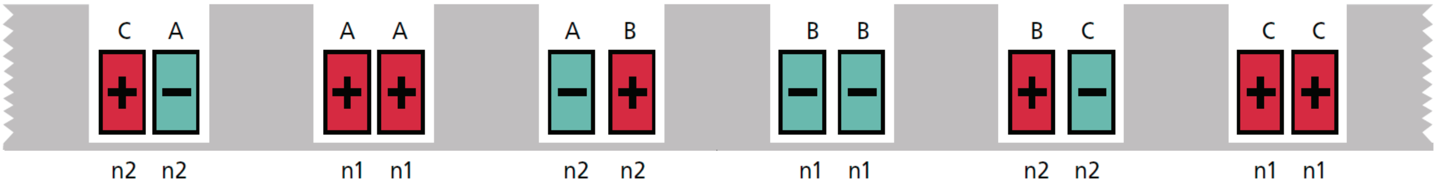
The University's Institute for Electrical Drives & Actuators has several test facilities for electric motors with an output of up to 220 kW and a peak torque of 2000 Nm. The test benches are designed for four-quadrant operation, and are equipped with high-precision speed and torque-measuring devices, power analysers and oscilloscopes. They are used for student projects as well as research and collaborative work with industry.

The development process took about two years, and has also pursued the aims of simultaneous optimisation of ease of manufacturing, low production costs and achieving a high efficiency at partial load conditions.

Prototype unit

The end result is of interest for the automotive industry and other industrial sectors. There are now several patent applications and the first prototypes have been developed for industrial partners. The prototype of the new induction motor is equivalent to a conventional traction motor for an electric car, and has a power of about 50 kW.

Test bench for electric motors at the University's Institute for Electrical Drives and Actuators (EAA). From left: Mr. Carlo Petruschke, Prof. Dr.-Ing. Dieter Gerling and Johann Mathä (Yokogawa).



The unit is driven by three phases at up to 400 V. Using transducers in each phase, current and voltage are measured. In this way, asymmetry can be identified. In addition to efficiency measurements, a recording of torque/speed characteristics takes place, and this is used for the optimisation of the mathematical models. As the rotor resistance, and thus also the losses, increases with increasing temperature, it is held constant using a cooling liquid and is monitored using a thermal imaging camera.

In addition, measurements with different driving cycles are taken. The power and efficiency measurements are performed with the WT1600, WT1800 and WT3000 power analysers from Yokogawa. The measured values, including torque and speed and the resulting efficiency, are automatically transferred into an Excel spreadsheet.

"We have several generations of Yokogawa power meters in use, and we are very satisfied with their operability and the test results", comments Prof. Dr.-Ing. Dieter Gerling from the University: "It is particularly important that we obtain very accurate efficiency in the region over 97%, and we have found that we can rely fully on these instruments."

Mass production

Because of the easier production and the higher efficiency at partial load conditions, the new induction motor brings both advantages in terms of acquisition costs as well as the driving range of electric vehicles.

The new winding technology also opens up new advantages in production. The stamped sheet metal parts for the stator can be individually wound and then simply plugged together into a motor. This contrasts with the situation in a conventional induction motor, where the plates are assembled first, and then the winding is applied in a much more complicated fashion. Owing to this complicated production process and the associated high costs of this type of motor, the previous approach would not be ideally suited to the production of several million units per year typically found in the automotive industry.

"Previously, electric motors in this power range were produced by medium-sized companies in quantities of a few thousand per year", says Prof. Dr.-Ing. Dieter Gerling: "In the automotive industry, we are looking at quite different numbers, which means that costs become much more significant."

"This industry has a lot of experience in cost management", he adds: "In principle this, of course, also applies to power electronics and battery technology."

Currently, German companies are the leaders in the overall automotive technology sector, but the number of pure electric vehicles produced is still very small compared to the French, Chinese and especially Japanese manufacturers.

According to Prof. Dr.-Ing. Dieter Gerling, German automakers have now caught up, at least in terms of technology, so that they will soon be in a position to provide similar products.

Electric mobility

In addition to the electric motor, the FEAAM and University teams have also dealt with the optimisation of the power electronics circuitry and the motor control systems. Again, there are already proposals for optimising the efficiency at partial load operation. In addition, the powered electric wiring systems in vehicles and airplanes are being investigated. In all these areas there is, according to Prof. Dr.-Ing. Dieter Gerling, still a great potential for improvement.

With electric motors, little attention has been paid to efficiency or weight issues, but this situation has changed dramatically with the advent of electric mobility. In particular, the high production volumes inherent in the automotive industry should lead to massive cost reductions. The team at the Universität der Bundeswehr are convinced that the future belongs to vehicles equipped with electric drive trains.

figures above and under: Stator teeth (grey) and winding layout according to the patent of FEAAM GmbH in lateral view and top view. Winding direction (A, B. C) and number of turns (n)