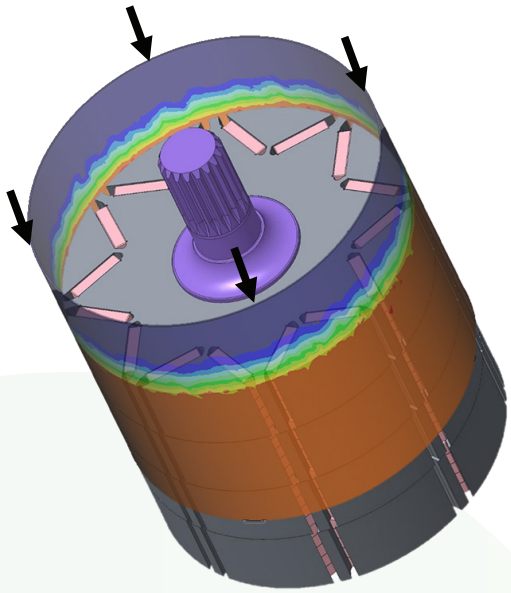
DRIVE SYSTEM DESIGN

Vehicle Electrification:

Increasing eMotor Power Density by up to 37% Using a Novel Composite Rotor Sleeve

Increasing the spin speed of the electric machine is widely believed to be one of the most attractive ways to improve power density, with the goal of increasing efficiency and therefore the range of electric vehicles without increasing the size, cost and mass of the battery pack. The challenge is to develop high-speed machines that meet automotive durability requirements and can be manufactured in high volumes, at a price that is commercially attractive.



As part of an Innovate UK project funded by the Office for Low Emission Vehicles (OLEV), Drive System Design (DSD) and the National Composites Centre have recently developed a solution to this challenge by developing a composite rotor sleeve to replace the traditional magnetic bridge. As well as optimising the design and validating the resulting efficiency improvements, the programme has developed a design that is scalable to high volume manufacture.

For a machine operating at up to 30,000 RPM, DSD's analysis shows a potential power density increase of up to 37% compared with a typical machine, together with significant savings in magnetic materials. Substantial efficiency improvements were also demonstrated for motors running at lower speeds.

In separate programmes, DSD has developed complementary technologies for ultra-high speed, very high precision control, for high-speed single and multi-speed transmissions, for the optimisation of system architecture choices and for the test and validation of high-speed machines.

Technology Development: New press fit carbon sleeve enables affordable spin speeds up to 30,000 RPM

The construction of Interior Permanent Magnet (IPM) motors allows assembly processes that typically offer high potential for volume production, providing traction motors with attractive functional characteristics at affordable cost. An increasingly popular strategy for increasing the efficiency of these motors is to increase their operating speed, but the potential is limited by a number of factors, notably the stress limitations of the standard lamination material as part of the construction of the magnetic bridge.

In a conventionally constructed rotor, the "magnetic bridge" is the thin section on the circumference of the steel rotor that is necessary to mechanically retain the buried magnets against the centrifugal forces - but its very presence compromises the magnetic performance due to the stray magnetic

paths it provides. The carbon composite sleeve provides a means to retain the magnets and eliminate these stray paths, improving the performance and efficiency.

This study generated four novel IPM motor concepts each utilising a carbon composite sleeve, a component which retains the rotor magnets, replacing the traditional magnetic bridge. An evaluation of the differing grades of composite indicated the optimum cost/performance point, and processes could then be developed for both manufacture of the sleeve and for press fitting it onto the rotor (pictured). The proposed process uses a filament winding technique for the manufacture of the sleeve, allowing production target volumes to be achieved.

Significant work is underway to deliver an affordable system for the press fit due to the limitations presented in composite layup (i.e. manufacturing), as the loads the material is required to withstand in-service are incompatible with the loads the material is needed to comply under during manufacture. This can be overcome by utilising a novel layup, enabled by extensive simulation of in-service and installation loads, as well as service temperature extremes.

Outstanding price and durability of high-speed IPM rotors manufactured in volume

The superior mechanical properties of the new technology provide rotor speeds validated up to 30,000 RPM, allowing a smaller, lighter machine with lower material costs.

The novel construction allowed a significant reduction in flux leakage, providing improved magnetic efficiency at base speed, reducing energy consumption and therefore increasing range, and allowing further cost and weight savings in associated systems. The 30,000 RPM concept is anticipated to deliver a cost saving when manufactured in volumes of 20,000 units per year. Substantial benefits are also anticipated at lower speeds, with a 12,500 RPM system particularly benefiting from the larger diameter associated with motors of this specification, allowing a significant improvement in torque density and supporting cost, mass and packaging reduction targets.

Technology Readiness
Composite Sleeve technology in IPM motors is ready for further development and implementation for next-generation electric machines.

With thanks and acknowledgement to: NATIONAL COMPOSITES CENTRE, UKRI Innovate UK, Office for Low Emission Vehicles

Follow the latest vehicle electrification research from Drive System Design

Drive System Design is one of the world's most trusted specialists in the accelerated development of electrified driveline and transmission systems. Our engineers are experienced in all key phases of production programs, from strategy to launch and beyond, working in partnership with our clients to deliver highly integrated technologies that combine light weight and compact architectures with refinement, high efficiency and confidence.

In-house R&D allows DSD to identify and develop new ways of maximising driveline efficiency, new tools for accelerating product development, and new areas of value for automotive, commercial, off-highway, defence and aerospace applications. Our specialists attend many of the major conferences and look forward to meeting you.

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