Enhancing Motor Performance Through Innovative Rotor Designs

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Brushless direct current (BLDC) motors are widely used across medical, aerospace and industrial automation applications. Their specific design plays a significant role in the motor's performance, with optimizing the motor's design for specific applications ensuring that OEMs achieve optimum performance and reliability. Research and development efforts also play a vital role in refining these design options.

Portescap R&D engineers, Chetan Kale and Smitesh Vangalwar discuss outer rotor design.

BLDC motors are often specified to maximise efficiency and torque density, and open rotor designs can further extend these capabilities. Heat build-up can limit performance, but specific designs can be achieved to aid heat dissipation. Not every OEM project requires this level of analysis, but developments achieved by Portescap's R&D team help to drive forward new technology across all miniature motor applications.

Boosting performance advantages

Compared to their brushed design counterparts, brushless motors can achieve higher efficiency, as well as greater torque and power density, and this is particularly true of outer rotor BLDC motor designs. In this configuration, the rotor and magnet assembly spins around the outside of the stator and its windings, which form the centre of the motor.

In contrast to the traditional motor design, which places the spinning rotor at the centre of the motor, the outer rotor setup can achieve higher torque, resulting from the larger rotor diameter. Importantly, an outer rotor motor can also optimise efficiency. This is largely thanks to the increased rotor surface area, combined with its external position, which enable it to dissipate heat more easily.

While energy losses through factors such as vibration should also be considered in BLDC design and specification, heat losses are the most common, and usually the most significant, challenge. Not only do heat losses decrease efficiency, but they are also a major contributor to premature motor failure.

Heat build-up

Mechanical losses, including bearing friction, as well as aerodynamic drag resulting from the outer rotor, are among contributors to heat accumulation. However, the most significant factor is copper losses, resulting from the resistance of the stator's copper windings. The other major contributor to heat comes from the motor's iron core losses, caused by harmonic flux or alternating magnetic fields, including hysteresis and eddy current losses.

To combat the effects of heat build-up, external rotor design techniques that increase heat dissipation can be considered. In fact, this was a project the Portescap R&D team worked on and was typical of the development of new motor designs, as well as answering specific customer challenges.

To test and identify the optimum approach, the team compared a traditional, closed external rotor design, alongside an open slot rotor that would introduce additional air ventilation. A third design was also considered and included an integrated fan combined with an open slot rotor, which could potentially improve ventilation further still.

Testing rotor designs

While the stator's copper losses are the main contributor to motor heat, all other types of losses contribute to the thermal resistance of the motor. This is mathematically determined by motor construction and speed variables. If speed is constant and the load increases, the iron and mechanical losses will tend to be constant with the temperature rise, primarily due to copper losses only.

With equivalent thermal resistance, the maximum torque can be calculated at any speed based on data at a specific load point. After recording the temperature and equivalent resistance at various data points, an accurate power graph, including speed compared to torque, could be created.

To compare the performance characteristics of the closed rotor, open slot rotor, and integrated fan open rotor designs, the research team applied torque to the motor with a dynamometer. The temperature rise of the coil was monitored until each motor reached its steady state, thermally stable temperature.

Torque increase

Tests of the three motor designs were carried out at speeds ranging from 0 to 8,000 RPM, at increments of 2,000 RPM. Power loss and thermal resistance of each motor at the set speeds were then calculated based on the measured resistance, current and stable coil temperature.

The study showed that the thermal resistance of both the open slot rotor and the integrated fan rotor decreased rapidly with an increase in speed. Instead, while the thermal resistance of the closed rotor decreased slightly at first, at speeds up to 3,000 RPM, thermal resistance then increased drastically from 5,000 RPM onwards.

The result this thermal resistance impact had on torque generation was significant. Replacing the closed rotor with the open slot design increased the maximum torque from 54 mNm to 80.5 mNm at 8000 RPM, which represented a 47% increase in torque capacity. The test showed that the integrated fan rotor design pushed the maximum torque capacity further still, achieving 113 mNm at 8,000 RPM, a further 40% increase compared to the open rotor alone.

Looking at power, plotting the maximum torque versus speed also showed that the open rotor design could increase total power, while the integrated fan design significantly extended the total generation of watts.

R&D achieves optimum design

Frequently, OEMs require customised motion solutions to optimise the performance of their specific application. Yet even in these cases, special test projects, such as the analysis of thermal resistance and heat dissipation, may not always be required. Often, the accumulation of years of R&D already confirms the ideal motor and motion solution design for the given conditions.

However, test situations like this show that specific designs can be analysed in bespoke projects, delivering the optimum outcome for the given conditions and work points. Moreover, the findings from these kinds of projects permeate across all motor technology development at Portescap, to the benefit of all customers. This is the advantage of working with a trusted miniature motion expert with decades of experience in customized motion control solutions.

Image captions:

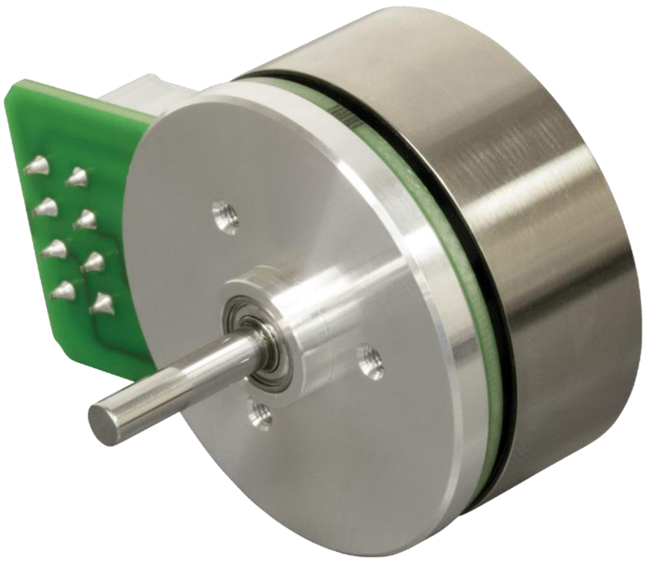

Image 1: Portescap's Brushless direct current (BLDC) motors are often specified to maximise efficiency and torque density, and open rotor designs can further extend these capabilities.

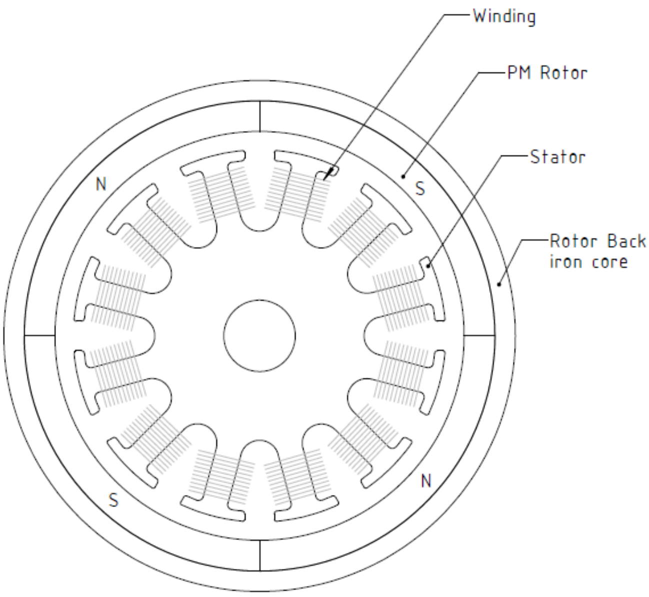

Image 2: Outer rotor motor.

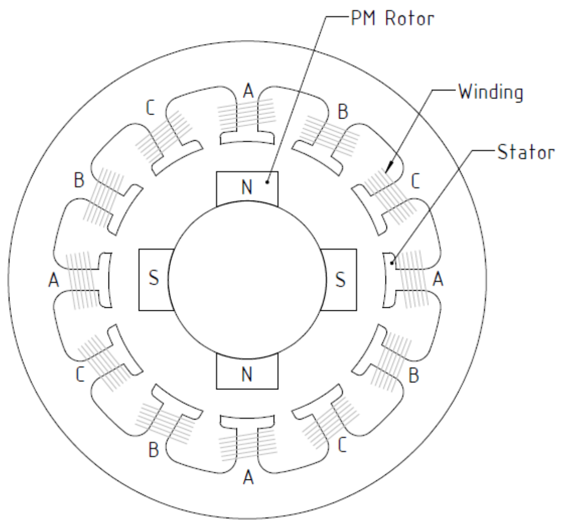

Image 3: Inner rotor motor.

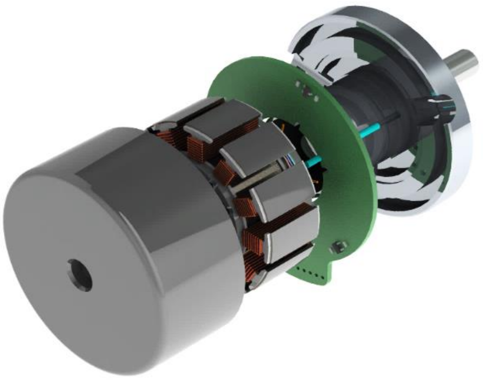

Image 4: 3D Exploded model of a closed rotor type motor.

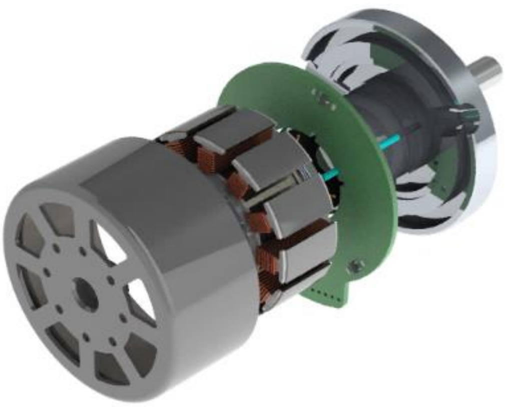

Image 5: 3D Exploded model of an open slot type rotor motor.

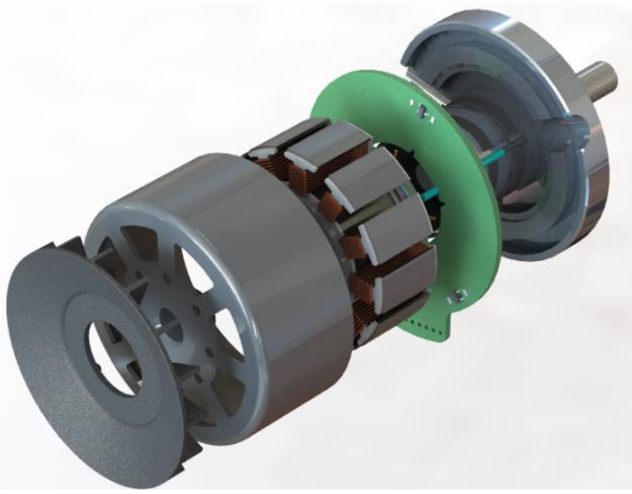

Image 6: 3D Exploded model of an integrated fan type rotor motor.

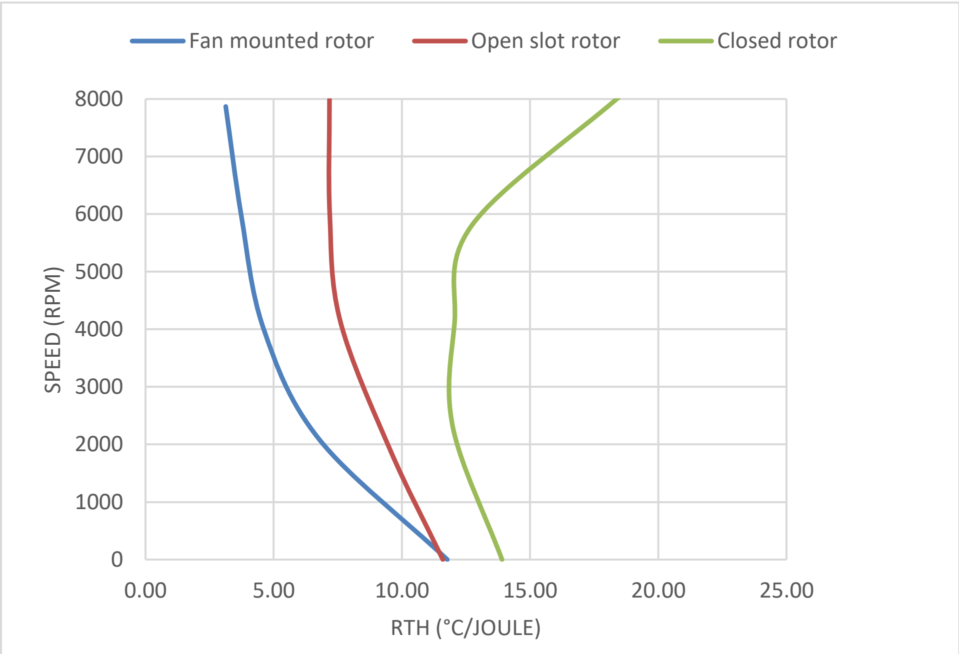

Image 7: Thermal resistance comparison of closed rotor type, open slot type rotor, and integrated fan type rotor.

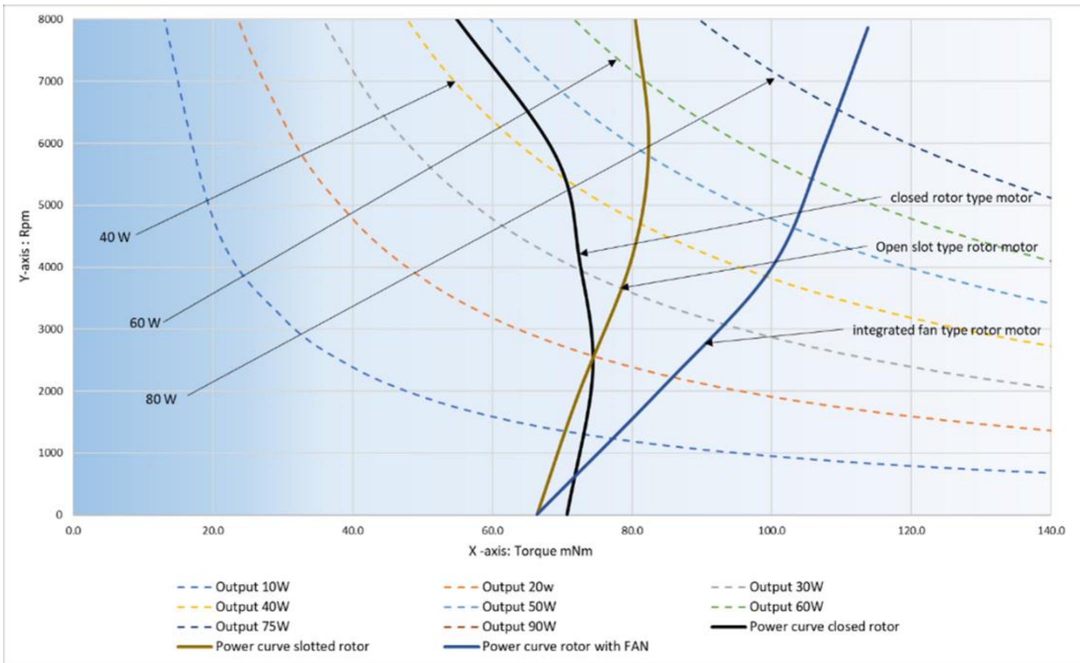

Image 8: Power comparison of closed rotor type, open slot type rotor, and integrated fan type rotor

About Portescap

Portescap offers the broadest miniature and specialty motor products in the industry, encompassing coreless brush DC, brushless DC, stepper can stack, gearheads, digital linear actuators, and disc magnet technologies. Portescap products have been serving diverse motion control needs in wide spectrum of medical and industrial applications, lifescience, instrumentation, automation, aerospace and commercial applications, for more than 70 years.

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