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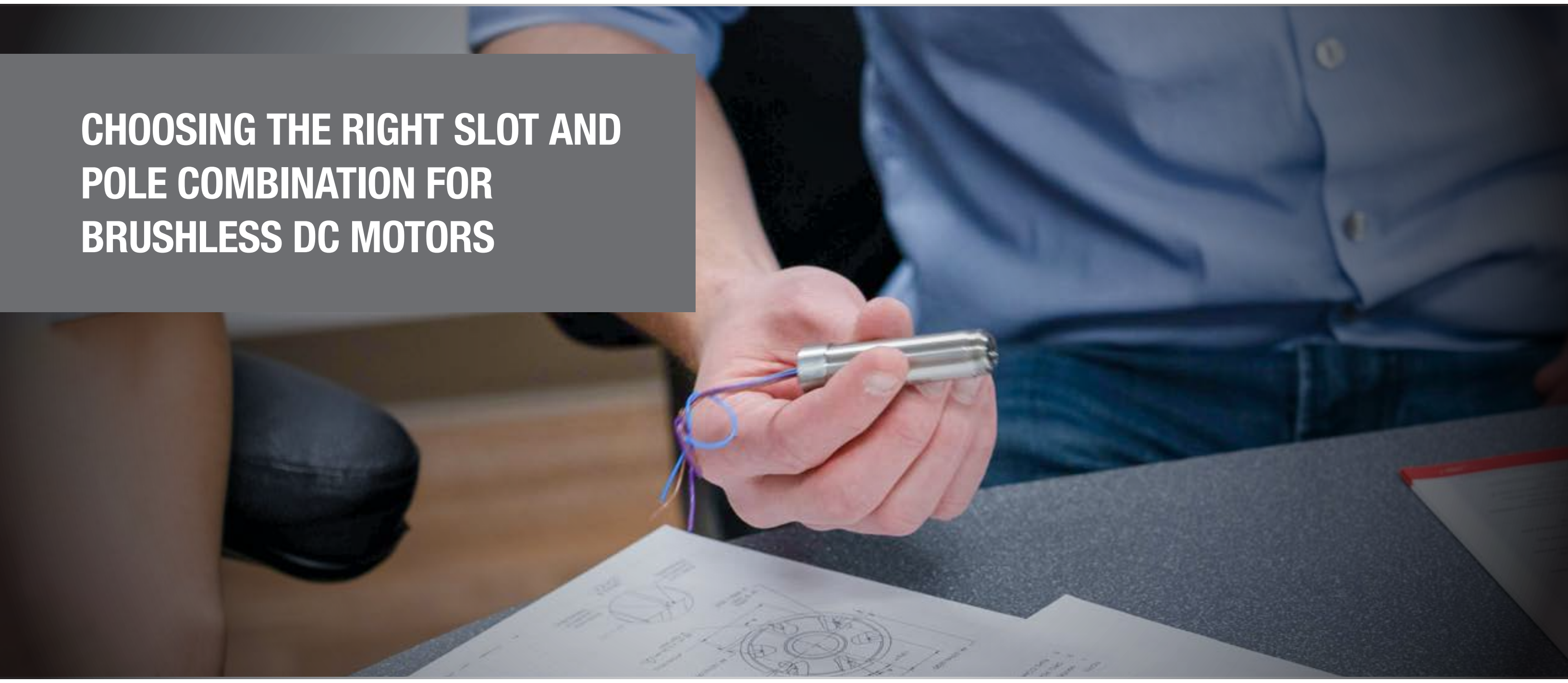
WHITE PAPER

CHOOSING THE RIGHT SLOT AND POLE COMBINATION FOR BRUSHLESS DC MOTORS



Selecting the appropriate slot and pole combination for a brushless DC (BLDC) motor has implications for its speed and torque output. The choice of pole, slot and winding configurations can also impact the smoothness and control of torque delivery, as well as efficiency. As these factors can strongly contribute to the overall performance of a given application, it's vital to make the right choice of slot and pole designs when choosing a BLDC motor.

The advantage of brushless DC motors includes higher efficiency, lower maintenance, and longer lifespan. This is due to the absence of brushes and commutators in a design that reduces wear and friction. A BLDC motor, combined with its external electronic control, also provides precise speed and torque modulation, making it ideal for applications requiring accurate motion. BLDC motors are compact and lightweight, enhancing their suitability for space-constrained environments. To optimize these advantages, an important consideration is the specification of their slot and pole combinations.

WHAT ARE SLOTS AND POLES?

In a BLDC design, the stator forms the outer ring of the motor. The internal circumference of the stator includes grooves in specified intervals, known as 'slots' that channel copper windings. When an electric current passes through the windings, a series of magnetic fields is created. It's the interaction between these magnetic fields and the magnets on the rotor, or the central rotating part of the motor, that generates rotational motion.

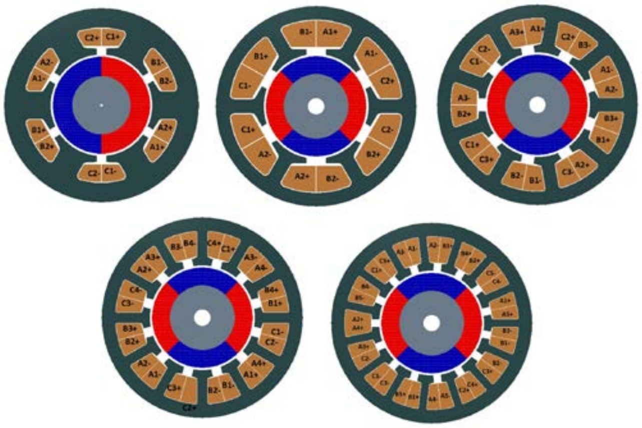


Figure 1: Different slot-pole combinations and winding layouts

The design of the slots, as well as their quantity and layout, affect the motor's winding configuration, and as a result, the distribution of magnetic flux, which is crucial in driving the motor. In short, slot design is vital for achieving optimal electromagnetic performance, including the motor's total amount of torque, smoothness of delivery, and overall efficiency.

However, these windings do not create the magnetic fields alone, but comprise part of the motor's 'poles'. The poles, which include pairs of north and south opposites, are located on the stator. However, they aren't actual components in themselves. Instead, the poles are areas of magnetic influence created by the interaction between the stator's laminated core and the current-carrying windings around it.

When current is applied to the windings, these areas of the stator become electromagnets, and the interaction between the stator poles creates a magnetic field. At the center of this field, the rotor, which comprises a permanent magnet, spins under the force of electromagnetism, generating the motion of its adjoining shaft.

Although the number and design of poles and slots contribute significantly to motor performance, there is no one-size-fits-all approach. Identifying the necessary combination of slots and poles depends on the required output characteristics of the motor.

POLE COUNT AND NUMBER OF SLOTS

The number of poles in a BLDC motor directly impacts its speed and torque. Higher pole pair counts generate greater torque but lower maximum speeds. Conversely, motors with lower pole counts can achieve higher speeds but generate lower torque. As a result, the right pole count choice depends on the required balance of torque and speed.

Figure 2: A BLDC motor, combined with its external electronic control, also provides precise speed and torque modulation, making it ideal for applications requiring accurate motion.

Similarly, motors with a higher number of slots generate higher torque at low speeds, making them ideal for applications where high starting torque is required. Instead, motors with fewer slots generate lower torque at high speeds, but they are generally capable of a higher torque density overall and can also generate higher motor speed.

WINDINGS

The design of the slots' windings is also important, and the starting point is the winding factor. This reference is the fraction of current used to produce torque, and as such, it plays a vital role in determining the motor's efficiency.

To calculate the winding factor, the coil span factor must be identified. This number defines the ratio of voltage generated between the winding configurations, and it affects the distribution of magnetic flux. The winding factor is also dependent on the distribution factor, a reference that quantifies the actual voltage obtained, relative to the potential voltage if all coils of a polar group were concentrated in a single slot.

Ensuring winding symmetry is essential too, as this impacts the motor's balance. If perfect symmetry is not achieved, it can cause noise, vibration, and irregular torque delivery. Winding symmetry relies on both specification and design, as well as precision in manufacturing techniques.

COGGING TORQUE

With similar detrimental effects, cogging torque creates vibrations and noise during operation. This impacts the motor's performance when precision control over position is required. Selecting a motor with a higher cogging frequency means that the torque ripples occur at a higher rate, leading to lower variations overall. This spreads out the torque ripples, resulting in smoother operation and improved efficiency.

Certain combinations of pole and slot counts create more uniform magnetic fields, helping to reduce the torque ripples. Concentrated winding configurations can help to mitigate cogging torque, while precision manufacturing combined with optimized design geometry of the rotor and stator is also important to enhance operational smoothness.

SPECIFYING THE RIGHT DESIGN

Choosing the right slot and pole combination for BLDC motors requires a thorough understanding of the specific application's requirements. By considering factors such as the number of poles, slots, winding factors, and cogging torque, engineers can design motors that deliver optimal performance, efficiency, and reliability. Customization based on these parameters can also ensure that BLDC motors can deliver optimum performance for the application at hand, providing efficient and precise motion control.

Dipak Mane
Engineering Manager
Portescap
A REGAL REXNORD BRAND

FOR MORE INFORMATION:

Portescap
110 Westtown Road
West Chester, PA 19382
T: +1 610 235 5499
F: +1 610 696 4598
portescap.sales.america@regalrexnord.com
www.portescap.com

CONTACT AN ENGINEER:
www.portescap.com/en/contact-portescap