DESIGN FEATURES OF BRUSHLESS DC MOTOR

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Brushless DC motors (BLDC motors) are electric motors that use permanent magnets to generate a magnetic field in the rotor and are controlled electronically.

Because the BLDC provide magnetic flux in the rotor rather than electromagnetic excitation, these motors can achieve higher efficiency while being lighter and smaller in size than collector DC motors. This makes them ideal for use in electric bicycles, electric scooters, hoverboards, quadcopters, industrial robots, and other electromechanical systems that require efficient motors with precise control and a high specific power output [1].

However, for the highly efficient BLDC design process, a number of tips and features that are present for these concentrated windings machines must be followed:

1. These machines require a number of slots per pole and phase (q) that is greater than 0.25 but less than 0.5. If $q > 0.5$, using a concentrated winding becomes ineffective because a rotor pole will cover multiple teeth. Instead, a distributed winding system would be used. Therefore, it is highly recommended to exclude these combinations for these machines.

2. The number of stator slots should not be equal to the number of permanent magnets ($Ns \neq Nm$). If the number of slots (Ns) matches the number of poles (Nm), the motor will generate significant cogging torque and lose its ability to self-start. This pairing should also be avoided in BLDC design.

3. Slot and pole combinations resulting in unbalanced windings and lacking symmetry should be excluded. Ideally, a BLDC motor should possess a symmetry of at least 2, meaning it has two repeating sections. This minimizes unbalanced radial forces and noise during operation. In other words, a motor lacking symmetry generates torque on only one side of the rotor, therefore each BLDC motor should be with balanced winding.

Of course, these are not all recommendations for BLDC design, but the main ones that provide guidance for determining the number of slots and poles for a BLDC motor with concentrated windings. For instance, if your motor has a diameter below approximately 60 mm and a maximum RPM under 10,000, combinations like 10s14p, 10s12p or 12s14p could be a better choice for the BLDC design. For larger diameters or motors rotating at speeds 3000-6000 rpm, opting for a higher slot and pole count, such as 24s26p, along with fewer turns per tooth and thinner steel laminations, would be more advantageous. However, motors with higher pole counts exhibit increased electrical frequency, leading to higher losses, but in that case, they will have lower mass due to the use of thinner back-iron. In this case, lamination steel with a thickness less than 0.5 mm is preferable.

References:

1. Brushless Permanent Magnet Motor Design. Hanselman, Duane C. Published by The Writers' Collective; 2nd edition (March 1, 2003) (2003). ISBN 10: 1932133631 ISBN 13: 9781932133639.