Reduction of torque ripple in Ferrite-assisted synchronous reluctance motors using asymmetric flux barrier arrangement

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Summary

Ferrite-assisted synchronous reluctance motors (FASRM) provide high torque density and a wide range operation speeds for many applications, ranging from electric vehicle and electric home appliance. However, the main drawback of the FASRM is the high torque ripple. This paper is propose a method of reducing total ripple by changing the opening angle of flux barrier. The key of this method is to consider the reluctance torque ripple because it is the main source of torque ripple in ferrite-assisted reluctance motors. In addition, the ferrite magnet insertion part is not changes compared with original design, and it is expected that the average torque does not decrease with this design.

In the proposed FASRM, low-cost ferrite PMs are inserted in a central position within the rotor flux barrier. Moreover, it contains three different kinds of poles which are named M and numbered. In the proposed arrangement, the relative angle between the edge of flux barrier and the center of the ferrite magnet is changed based on the flux barrier of M1.

In this way, a sort of compensation of torque harmonic was achieved. Since, it reduces the amplitude of torque ripple greatly. However, they are related with additional drawbacks concerning the torque capability and production costs.

Methods

In this paper, a new design with asymmetrical rotor structure has been presented in order to reduce the torque ripple.

By adopting asymmetrical rotor structure in FASRMs, a sort of compensation of torque harmonic is achieved.

Due to the optimized opening angle of the flux barrier, torque performance has been improved as compared with the original design. Moreover, it is easy to implement, while the average torque is not sacrificed.

Results

The key of the proposed FASRM is to minimize the reluctance torque ripple, which is the main source of the total torque ripple. Due to the adopted asymmetric flux arrangement, the reluctance torque ripple reduced effectively. The reluctance torque ripple reduced from 80% to 20% approximately.

In addition, reluctance torque has two main harmonics, including the 6th and 12th harmonics. It can be seen that the 2nd main harmonic has been eliminated greatly after changing the opening angle of flux barrier. Moreover, the 1st harmonic also has been affected.

Cogging torque

The interaction between the rotor magnets and the stator teeth of the motor will produce coggging torque inevitably. Thus, the coggging torque is another source of torque ripple in the FASRM. The coggging torque can be reduced obviously. The 12th harmonic is the main harmonic and has been eliminated greatly due to adopting the proposed asymmetric flux arrangement. The coggging torque became insignificant and ignoreable.

Total torque

The total torque ripple has been reduced from 68% to 17% after changing the opening angle of flux barrier and their harmonics. Original torque is mainly fundamental average torque component. Also, it has two main harmonics, including the 6th and 12th harmonics. It can be seen that based on the proposed asymmetric flux arrangement, the 6th harmonic 12th harmonic have been successfully eliminated. In addition, it is easy to find that the total average torque does not sacrifice with the proposed design.