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

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Presented at the MT-25
RAI-Amsterdam
Session number: Wed-Af-Po3.05-14 [65]
Program I.D. number: 214
2017 Aug. 30 (Wed) 13:15

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 to 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.

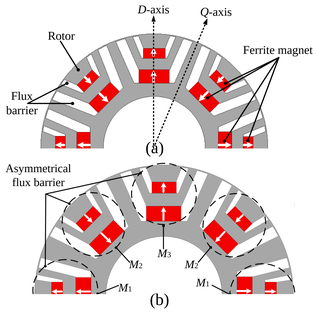
Conclusion

- 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.

Proposed FASRM

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 angel between the edge of flux barrier and the center of the ferrite magnet is changed based on the flux barrier of M_1.

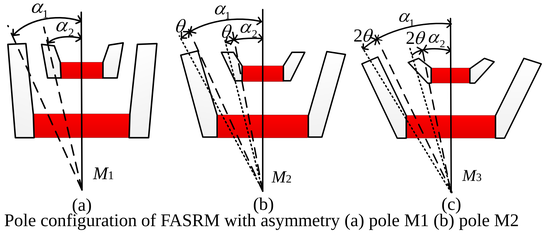
In this way, a sort of compensation of torque harmonic was achieved. Since, it reduces the amplitude of torque ripple greatly. However, they are related with additional drawbacks concerning the torque capability and production costs.



Existing and proposed FASRMs rotors. (a) Existing one. (b) Proposed one.

Methods

Three kinds of rotor poles are adopted in the proposed FASRM the pole. M_1 is used as a baseline, pole M_2 enlarged a particular angle and pole M_3 enlarged double based on the pole M_1. In addition, it is worth mentioning that the center of ferrite magnet does not move because the ferrite magnet insertion part does not change compared with the conventional design. The phase of torque waveform will change when opening angle of flux barriers are optimized in rotor. Thus, torque harmonic will get compensation and be weaken.



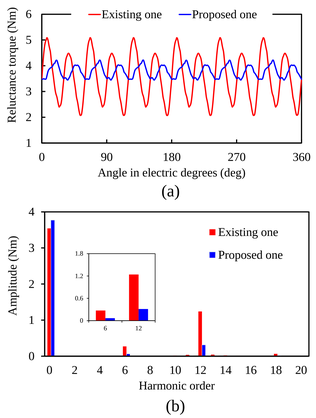
Pole configuration of FASRM with asymmetry (a) pole M1 (b) pole M2 (3) pole M3

Results

Reluctance torque

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.

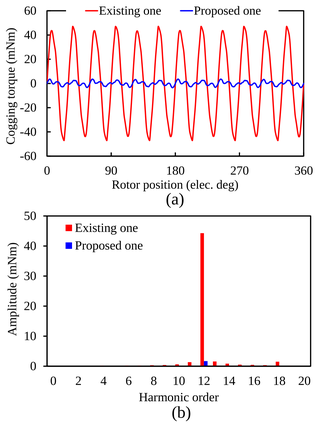
In addition, reluctance torque has two main harmonics, including the 6th and 12th harmonics. It can be seen that the 2nd main harmonic has been eliminated greatly after changing the opening angle of flux barrier. Moreover, the 1st main harmonic also has been affected.



Comparison of reluctance torque in both FASRMs. (a) Reluctance torque. (b) Harmonic order.

Cogging torque

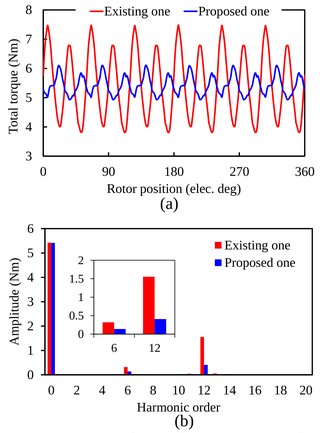
The interaction between the rotor magnets and the stator teeth of the motor will produce cogging torque inevitably. Thus, the cogging torque is another source of torque ripple in the FASRM. The cogging torque can be reduced obviously. The 12th harmonic is the main harmonic and has been eliminated greatly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



Comparison of cogging torque in both FASRMs. (a) Cogging torque. (b) Harmonic order.

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 harmonic12th harmonic have been successfully eliminated. In addition, it is easy to find that the total average torque does not sacrifice with the proposed design.



Comparison of total torque in both FASRMs. (a) total torque. (b) Harmonic order.