A Novel Disc Machine with Axial Biased Flux and Complementary Salient Rotors

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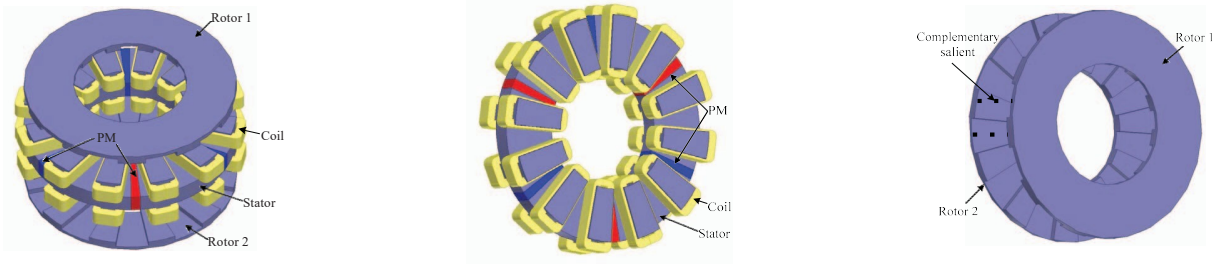
Disc machines are promising candidates for direct drive in-wheel machines due to the inherent merits such as short axial dimension, high torque density and high efficiency. Currently, most of disc machines have the permanent magnets (PMs) employed on rotor, which can contribute to improved torque but also results in many undesired limitations. Definitely, these structures have large space to install PMs, suitable for pursuing higher torque density. However, with PMs on the rotor also cases some disadvantages. Firstly, the rotors with PMs on have more risk of been damaged since the rotary wheels usually experience the bumps and vibrations. Secondly, PMs would cause the axial force even with bilateral rotors, which may accelerate the aging process of the bearings.

To avoid aforementioned problems, the stator-PM axial flux machines derived from the flux switching permanent machines (FSPMs) are investigated in recent years [1-2]. The torque density of these machines could be high because of the magnetic congregate effect. However, the utilization rate of the PMs is relatively low, since the exciting flux linkage is shorted when the rotor tooth is aligned to the PM.

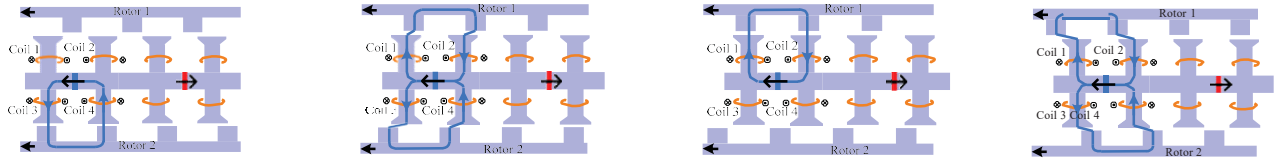
In this paper, a new disc machine with axial biased flux and complementary salient rotors is proposed, as shown in Fig.1. The stator has 24 slots and concentrated windings, and each rotor has 11 salient teeth. The PMs are installed in the yoke of the stator with two stator teeth between the adjacent ones, and the magnetizing direction of the adjacent PMs is opposite. Different with conventional disc machine, the bilateral rotors Rotor 1 and Rotor 2 are complementary, namely the rotor teeth are staggered with 180 electrical degrees. This design contributes to reduced copper losses, increased PM utilization rate as well as enhanced torque per PM volume ratio.



(a) General machine structure (b) The stationary parts (c) The complementary rotors

Fig. 1 The proposed disc machine with axial biased flux and complementary rotors

The basic operation principle of this machine is shown in Fig.2. When the rotor at 0 electrical degree, all the PM excitation flux goes through Coil 3, Rotor 2 and Coil 4. Noticeably, no PM flux in rotor 1 for the rotor salient is complementary. Then, when the rotor moves to 90 electrical degrees, the PM flux passes both of the rotors and goes through both airgaps, while the rotor moves to 180 electrical degrees, the PM flux goes through Rotor 1 totally. Last process, when the rotor moves to 270 electrical degrees, the flux goes through both sides again. So during this whole period, the flux in Coil 3 and Coil 4 changes from maximum to zero and then back to maximum while the flux in Coil 1 and Coil 2 experiences zero to negative maximum and back to zero. There are three distinguish characteristics with this special machine design and operation. Firstly, the PM flux is switched smoothly from one coil to another in the whole period, without shorted flux path. Therefore, the PMs utilization rate could be improved comparing to the FSPM disc machines. Secondly, the armature flux is parallel with the PMs flux. For example, when at 90 or 270 electrical degrees position, the injecting current gets maximum so the armature flux goes through the stator and rotor teeth to form a circuit. The paralleled flux can reduce the armature flux reluctance and avoid the risk of PMs demagnetization. Thirdly, the coil fluxes in outer side windings and inner side windings are biased with DC components. For example, the flux in Coil 3 and Coil 4 is positive biased while the flux in Coil 1 and Coil 2 is negative biased. Using this feature, An innovative flux weakening control strategy can be realized by a novel way of injecting the DC components to the stator windings. For instance, with negative and positive DC current is injected in Coil 3 and Coil 4 respectively, the PM flux could be weakened.



(a) Rotor at 0 electrical degree (b) Rotor at 90 electrical degree (c) Rotor at 180 electrical degree (c) Rotor at 270 electrical degree

Fig. 2 The operation principle diagram of the proposed machine

The proposed disc machine removes the PMs from the rotor to the stators, strengthening the robust of the rotor and eliminating the axial force in the bearing, which may finally improve the reliability of the direct drive wheels. Meanwhile, with the stator-PM design, this machine could realize higher PM utilizations, exempt the PMs being demagnetized and perform a novel flux weakening control.

References

[1] Lin, M., Hao, L., Li, X., Zhao, X., & Zhu, Z. Q. "A novel axial field flux-switching permanent magnet wind power generator." Magnetics, IEEE Transactions on 47.10 (2011): 4457-4460.

[2] Hao, L., Lin, M., Zhao, X., Fu, X., Zhu, Z. Q., & Jin, P. "Static characteristics analysis and experimental study of a novel axial field flux-switching permanent magnet generator." Magnetics, IEEE Transactions on 48.11 (2012): 4212-4215.