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DESIGN AND ANALYSIS OF A NEW PERMANENT MAGNET BRUSHLESS DC MACHINE

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Purpose

A new permanent magnet (PM) brushless dc machine with a unique feature of flux regulation is proposed in this paper. It is essentially a hybrid of the multiphase reluctance machine [1]-[2] and the conventional PM brushless dc machine. The originality is that the air-gap flux of the machine is generated by both the PM excitation and the specially controlled stator currents under the same PM pole. The machine possesses advantageous characteristics of both the PM brushless dc machine and the dc series machine, namely the powerful PM torque and the controllable reluctance torque. It offers the merits of high power density, high efficiency, high starting torque and wide constant power speed range. A 3-phase 10-pole prototype is designed and built. The magnetic field distribution and steady-state performance are analyzed by using the finite element method (FEM). The theoretical calculation is also verified by experimental measurement.

Design

Fig. 1 shows the schematic diagram of the proposed machine whose configuration is similar to that of the multiphase reluctance machine except that ten pieces of PM in the width of one half of the pole pitch are inserted in the sunken space of the rotor. The dovetailed shape of these PM can improve the mechanical robustness of the rotor during high-speed operation. The eccentric surfaces of salient poles are purposely designed to reduce the armature reaction.

Field Analysis

Two-dimensional FEM is used to analyze the magnetic field of the proposed machine at different load conditions. Fig. 2 shows the flux distribution at full load of 51 A.

Steady-state Performance

The steady-state performance can also be obtained from FEM. Fig. 3 illustrate comparisons between the theoretical and experimental EMF waveforms of the proposed machine. It can be seen that there is a good agreement between the theoretical and experimental results. The characteristic of torque versus rotor position changes with the phase current I as shown in Fig. 4. The variations of the torque and its two components with respect to the phase current are shown in Fig. 5. To compare the variation of each torque components with respect to the phase current clearly, Fig. 6 shows the normalized torque-current characteristics. As the reluctance torque is approximately proportional to the square of the phase current, it rises up faster than the PM torque. Particularly at over-current start-up, this reluctance torque component can significantly improve the normalized total torque.

References

[1] R. Mayer, H. Mosebach, U. Schröder and H. Weh, "Inverter-fed multiphase reluctance machines with reduced armature reaction and improved power density," Proceedings of International Conference on Electrical Machines, 1986, pp. 1138-1141.

[2] J.D. Law, A. Chertok, and T.A. Lipo, "Design and performance of field regulated reluctance machine," IEEE Transactions on Industry Applications, vol. 30, no. 5, 1994, pp.1185-1192.

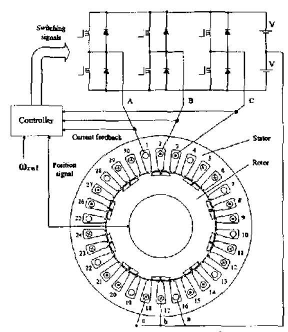

Fig. 1 Schematic diagram of PM brushless dc machine.

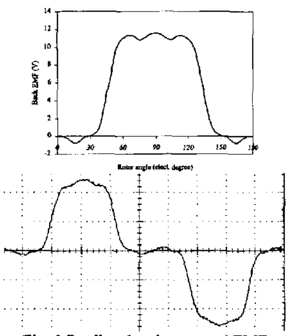

Fig. 3 Predicted and measured EMF waveforms.

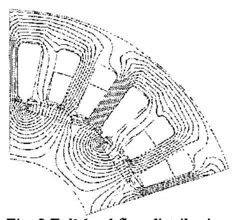
Fig. 2 Full-load flux distribution.

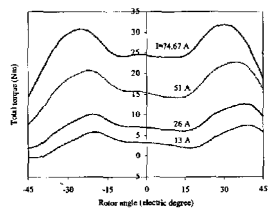

Fig. 4 Torque versus rotor position.

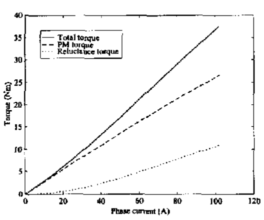

Fig. 5 Torque-current curve.

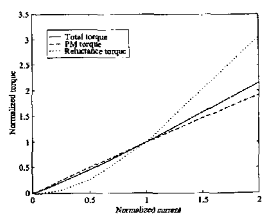

Fig. 6 Normalized torque-current curve.