Conformal Mapping technique for magnetic saliency analysis of Double-layer Interior Permanent Magnet Motor

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Abstract— In this paper, an analytical method based on Conformal Mapping technique is applied to the rotor design of Interior Permanent Magnet Synchronous Motor (IPMSM). A Single layer IPMSM is developed to a double-layer IPMSM to improve saliency ratio with design of experiment (DOE) and response surface methodology (RSM). The increased reluctance torque of the double-layer IPMSM is verified by Finite Element Analysis (FEA). With this analytical method, the estimation of saliency effect related to reluctance torque can be achieved by simple calculation of equations. Therefore, time and effort in the initial design of the model having complex geometry can be saved.

I. Introduction

The Interior Permanent Magnet Synchronous Motor (IPMSM) has advantage in high torque density, because it can utilize both magnetic and reluctance torque. Due to the rotor saliency, the reluctance torque is generated and added to the magnetic torque. The improvement of the rotor saliency in IPMSM can reduce the dependency on the magnetic torque, that is, it will lower the amount of PM buried in rotor part [1].

Through optimizing design of the PM and buried air-gap in the rotor part, the higher rotor saliency can be obtained. An analytical approach for the rotor saliency analysis is presented in this paper, which can guide the rotor part design easily and fast comparing with the Finite Element Analysis (FEA).

The rotor saliency is considered in an improved relative permanence function (1)[2]. With the help of the Conformal Mapping (CM) technique, the effect of curvature of the rotor is fully considered by transforming the cylindrical rotor into a square region, where the effective air-gap length g_{CM} can be determined. The CM region is shown in Fig.1.

$$\lambda_{Rotor-saliency} = g_o / g_{CM} \qquad [g_o = g_{airgap} + H_{PM} / \mu_r] \qquad (1)$$

where, g_{airgap} : actual gap between stator and rotor, μ_r : relative permeability.

From some researches about IPMSM design, the rotor saliency can be effectively increased through multi-layer IPM design. Here, the presented analytical approach is applied in a surface-type (S-type) IPM rotor multi-layer design.

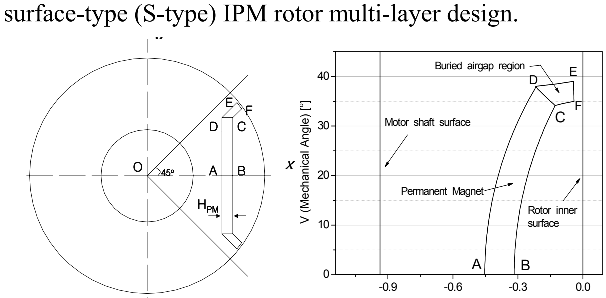

Fig1. CM of (1/8) rotor cross section region in an IPMSM

II. Analysis Model and Results

The prototype model of a single layer IPMSM, with 4 poles and 6 slots, is shown in Fig 2(a). With identical total PM volume and back e.m.f characteristic, a double-layer IPMSM is designed from the prototype model for improving the reluctance torque. The presented analytical method is used for building a higher saliency rotor structure by the relative permeance of rotor saliency calculation.

(a) (b)

Fig 2. (a) Prototype single layer and (b) Re-designed double-layer IPMSM

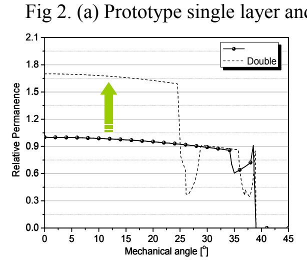

Fig 3. The relative permanence of rotor saliency variation

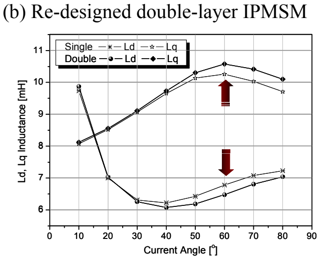

Fig 4. Improved d-axis and q-axis inductances by double-layer IPM design

In Fig.3, the improvement of rotor saliency is observed from the analytical calculation. In Fig.4, the increase of reluctance torque is revealed from the computation of d, q-axis inductances by FEA. These two results show an identical increasing tendency, so the availability of this rotor saliency analysis method is verified for using in the IPMSM rotor design for reluctance torque improvement.

III. Conclusion

The analytical method for rotor saliency analysis in IPMSM has been presented and applied in a S-type IPMSM rotor multi-layer design. A single layer IPMSM was optimally re-designed with the double-layer IPM rotor structure, in order to obtain an improved reluctance torque. This analytical approach can save a lot of computation time in designing IPMSMs having complex rotor structure.

IV. References

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