Improving Efficiency of IPM By Different Geometry of Rotors

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Abstract- *In this paper, the performance of an inside permanent magnet rotor has been analyzed and findings on how to increase its efficiency has been documented. Initially, analytical calculation is performed to generate the first model of the IPM (INTERNAL PERMANENT MAGNET) during the development stage. The method of analytical calculation is used as it offers the initial parameters based on the kinds and materials utilized in the machine design which provides a scientific way to compare and contrast the efficiency of the IPM. The outside and inner stators contain 12 and 9 slots, respectively, and the inside permanent magnet rotor has 6 poles. To achieve the design objective functions of high output torque, low torque ripple, low cogging torque, and low total harmonic distortion, four main input motor parameters, namely outer stator slot opening, rotor angle, rotor geometry, thickness are varied and optimized so to achieve the maximum efficiency.*

Keywords- Rotor, permanent magnet, induced electromagnetic force, synchronous motors

I. INTRODUCTION

The internal permanent magnetic synchronous motor (IPMS) is, the most reliable and efficient machine widely used in industrial applications and electric vehicles due to its high efficiency, good dynamic performance, high torque and high power density. As a rule in the IPM design, it is important to determine the type of winding used in Polances. Fountain slot combinations represent engine windings that do not overlap, and unusual combinations will show overlapping windings.

In the proposed model, the space is weakened and the overload capacity is merged into a promising candidate with performance benefits. This contributes to the high coefficientof copper packaging,high efficiency ofand interfacing of copper packaging, not to distinguish production benefits.InternalPermanent (IPM) MachineMagnets have receivedbroad research benefits because they have advantages such ashigh torque compared to ordinary disposable PMSMs. They are utilised in the work of magnetic collaborators, incorporated in electric cars (EVs). The internal constant magnet is designed in such a way to reduce the manufacturing cost of mechanical engineering based on the relative position of stator slots. The IPM uses a wind system where it places two spatially independent stators for the cooling system.

II. PROPOSED MODEL

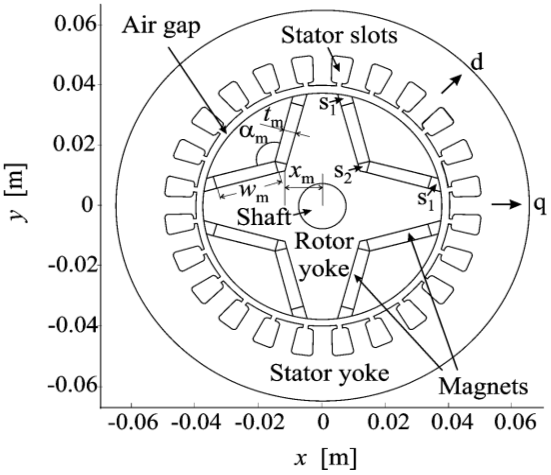


Fig. 1. FEM geometry of the stator and rotor yoke

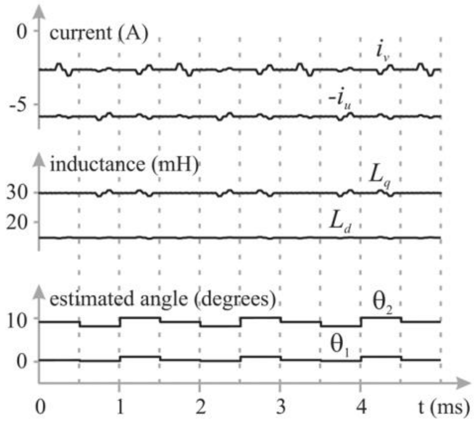


fig. 2. For a IPM at standstill and rotor angle zero degree, (a) phase currents, (b) inductances of d-and q-axes, and (c) estimation of the rotor angle in case of saturation without cross saturation(θ_1) and with cross saturation (θ_2)

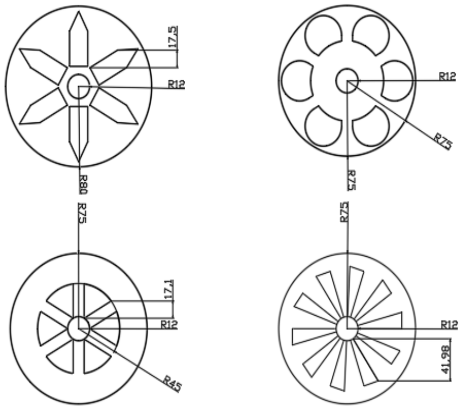
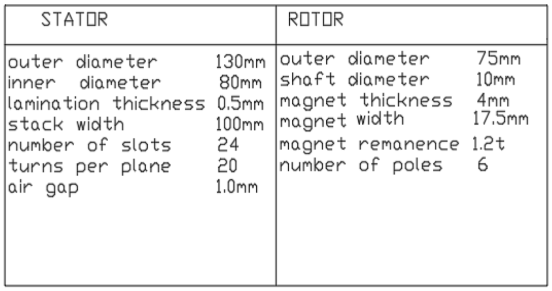


FIG:3 PROPOSED MODELS
*THE PERMANENT MAGNETS OCCUPY THE INNER VACCUM



STATOR		ROTOR	
outer diameter	130mm	outer diameter	75mm
inner diameter	80mm	shaft diameter	10mm
lamination thickness	0.5mm	magnet thickness	4mm
stack width	100mm	magnet width	17.5mm
number of slots	24	magnet remanence	1.2t
turns per plane	20	number of poles	6
air gap	1.0mm		

Fig.3. proposed rotor models

III. SIMULATIONS

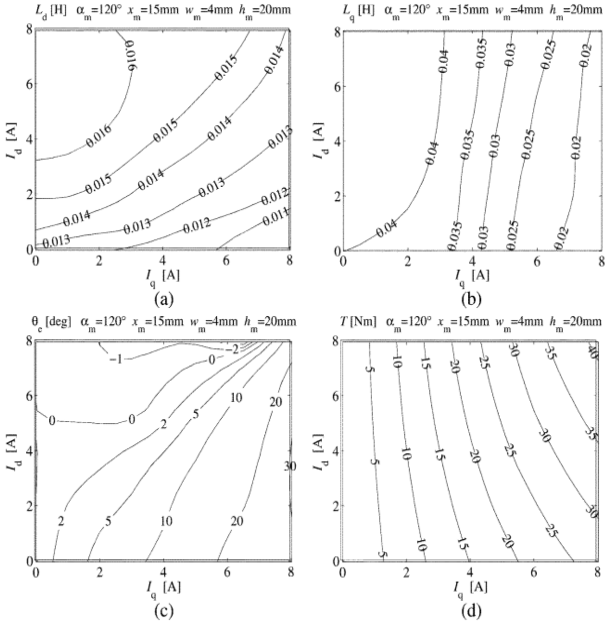


Fig. 4. For a IPM with $\alpha_m = 120°$, (a) inductance L_d, (b) inductance L_q, (c) rotor position estimation error, and (d) torque T as a function of the d- and q-components of the stator current, obtained by FEM.

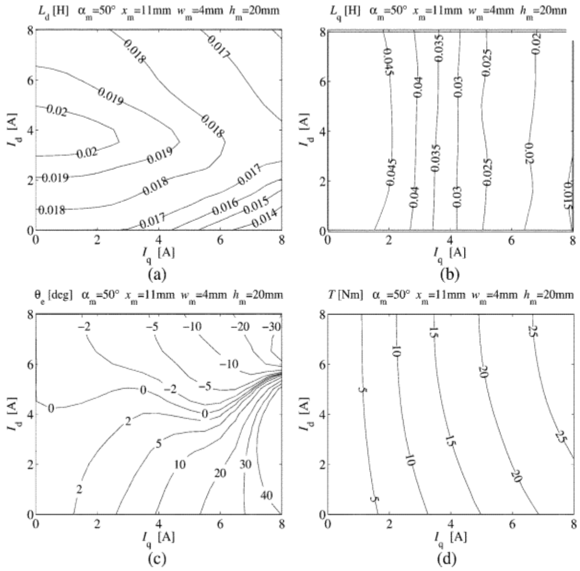


Fig. 5. For a IPM $\alpha_m = 50°$, (a) inductance L_d, (b) inductance L_q, (c) rotor position estimation error and (d) torque T as a function of the d- and q-components of the stator current, obtained by FEM.

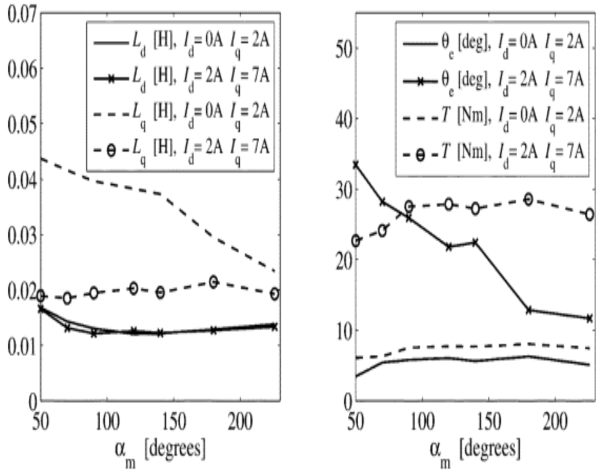
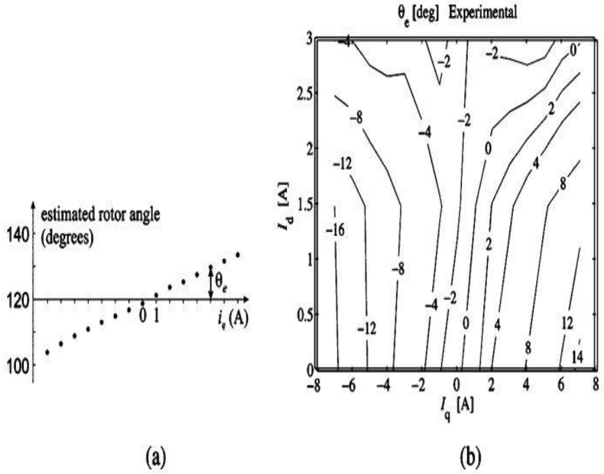


Fig. 6. (a) Inductances and (b) torque and position estimation error as a function of the angle of the magnets.



(a) (b)

Fig. 7. Experimental results in an interior IPM at standstill $(120°)$ (a) estimated rotor position for $I_d = 1.5A$ and (b) position estimation error

IV. EFFECT OF GEOMETRY AND STATOR CURRENT ON INDUCTANCE, TORQUE, AND POSITION ESTIMATION

A. GEOMETRY OF THE MAGNET

The shape of the magnet does affect its strength. Ifa magnet has a more pointed end, that end will be stronger than the rest of the magnet. The shape affects the distribution of the magnetic energy in the space it occupies .The stereotypical U-shaped magnet is the most effective. This is due to the magnetic field concentrated between the poles thus creating a stronger magnetic field. Fig.3. shows the different angles and different geometry of magnets used in the rotor. All the proposed models contain six vacuum for the magnets. It can be seen L_d increases with increasing I_d up to a maximal value, $L_{d,max}$: the (positive) d-axis stator current reduces the flux of the magnets, so that the d-axis is less saturated and has a higher inductance I. If increased further, the inductance L decreases again because of local saturation in some of the stator teeth and in the rotor yoke regions near the magnet slots. In absence of cross saturation, the map of $L_d(I_d, I_q)$should contain horizontal contour lines (L is not dependent on I), but the contour maps show clearly that q-axis current also saturates the d-axis. For other angles, the position of L moves to higher I: up to I= 6 A for $180°$. Fig. 7(a) shows L_d as a function of α_m for two realistic working conditions (that have a high torque to current ratio): one at low load at I=0A and one at high load: $I_d = 2A, I_q = 7A$.

The inductance L_d does not change with or without the load situation.

B. THICKNESS, WIDTH, AND RADIAL POSITION OF THE MAGNETS

Increasing the width W of the magnet (with all other parameters default) increases the amount of magnet material and reduces the amount of air (domains1) in the slot, as can be seen in Fig. 1. The magnet flux increases strongly resulting in decrease of $L_d(I_d, I_q)$ and a shifting of $L_{d,\max}$ to higher $I_d$changes in L are limited. It is observed that, if the magnets fill almost the whole rotor slot (very small air zones), the regions of the rotor yoke near these air zones are heavily saturated. In the whole range of w_m, the rotor positioning error remains always acceptable: it varies between - 5 and +20 degree depending on the stator current. The contour line of 0 degree slightly shifts to higher if Iincreases. Magnets with large w are important for a high torque: the maximal T is obtained for $I_d = I_q = 8A$ and increases from 33.0 Nm (w=10 mm) to 52.3 Nm (W=22 mm). If the radial position (see Fig. 1) is small, i.e., if the magnets are relatively close to the shaft, the air zones S1 in the rotor slots are larger L_d, resulting in a larger L because of less local saturation in the region of the rotor yoke near these zones. The inductance decreases for smaller x, because the distance between air region and the nonmagnetic rotor shaft decreases. For high I_q and low I_d, this zone is saturated.

V. CONCLUSION

In this paper, the various optimization techniques on the performance of an IPM machine with six slot rotor has been demonstrated and optimised. The improvement of the machine performance using magnet angle θ_e, have been studied using simulations and FEM. Four rotor parameters have been optimized: the magnet angle, thickness, width, shape. The optimized IPM having 12 slots for the outer stator, 6 poles for the rotor has managed to reduce torque ripple, while maintaining the average output torque. The results from FEM have also confirmed the accuracy of the motor performance.

Thus it is established, in order to have a large torque, the IPM should have a magnet angle α_m of more than 90° *a large thickness* t_m, and a large widthw_m. The current component I is chosen in such a way that θ_e is small for a given machine geometry and current. It is expected that this study will prove to be beneficial in increasing the efficiency of high torque producing rotors which will have long term implications in the field of Electrical vehicles.

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BIOGRAPHY

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