Performance of Doubly salient Permanent Magnet Motors for Parallel and Tapered Rotor Poles

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Abstract-- **This paper presents the results of a finite element (FE) analysis carried out to study the effects of variation of rotor pole arc and rotor pole shapes on the performances of a doubly salient permanent magnet (DSPM) motor; based on which a clear comparison can be done on two types of rotor pole geometries namely, the parallel and tapered. Two-dimensional (2-D) FE models of a 8/6 DSPM motor for parallel sided and tapered rotor poles with rotor outer pole arcs varying from of 15°to 38° have been analyzed with appropriate phase excitations. It is observed that in all the cases, the tapered rotor pole gives higher average torque. The maximum average torques in both the cases, occur for an outer pole arc of 22°, where the maximum torque in tapered case is more by 1.8%. The average torques in both the cases varies similarly for rotor outer pole arcs above 22° and up to 30°. This is also true in case of torque ripples. For outer rotor pole arcs of less than the optimum 22°, it is observed that the tapered case is better; at 15° pole arc, the average torque developed by the motor is 14.8% higher than the corresponding value of parallel-sided case. The magnet utilization in case of the tapered poles is found to be better for rotor pole arcs up to 26°.**

Index Terms-- **Doubly Salient Motor, DSPM, FE Analysis, Motor, Permanent Magnet Motor.**

I. INTRODUCTION

Doubly salient permanent magnet (DSPM) motor is an advanced variety of brushless motors that inherits the merits of both permanent magnet brushless motor and switched reluctance motor (SRM). In these motors, the permanent magnets are located in stator, eliminating the problems of irreversible demagnetization and mechanical instability while remaining the merits of high efficiency and high power density. The corresponding rotor is same as that of the SRM hence the advantage of mechanical robustness and simple construction is also available. Also the speeds attainable in this motor are in the same order of that of the SRM. Therefore, a keen interest is developing among the researches to consider this motor as a replacement for the conventional as well as above mentioned motors like SRM and PMBLDC. However, as the motor is in its early stage of development, there is no literature available on the effect of rotor pole tapering on the performance of DSPM motor. This paper presents the results of a finite element (FE) analysis carried out to study the effects of rotor pole arc variation and rotor pole tapering on the performance of the DSPM motor.

II. FINITE ELEMENT ANALYSIS OF THE DSPM MOTOR WITH PARALLEL SIDED AND TAPERED ROTOR POLES

The design data of the 8/6 DSPM motor [1] is used in this work. 2-D FE model of the motor for various rotor pole arcs considering the parallel sided rotor pole and keeping the stator pole arc constant to original value of 22° have been made and analyzed for various performance parameters considering the two phase excited mode of operation in which at the same time all the four phases of the motor will be excited. Fig.1 and Fig. 2 shows the PM flux linkage and phase A inductance variation for various rotor pole arcs respectively. It is observed from Fig.1 that with the reduction in rotor pole arc the PM flux linkage characteristic becomes stepper, while from Fig. 2 that higher rotor pole arc gives steep inductance characteristics and higher unaligned and aligned inductances. It is also observed from Fig. 2 that the phase inductance in case of the tapered pole is higher when rotor pole arc is less than the stator pole arc lower when rotor pole arc is greater than the stator pole arc.. Fig. 3 shows the developed torque profiles and Fig. 4 shows the average torque and torque ripple variation with rotor pole arc from which it is observed that the rotor pole arc of 22° is giving the maximum torque, while the rotor pole arc of 15° is giving the minimum torque ripple and the rotor pole arc in the range of 25° to 30° will

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give good average torque with reduced torque ripple.

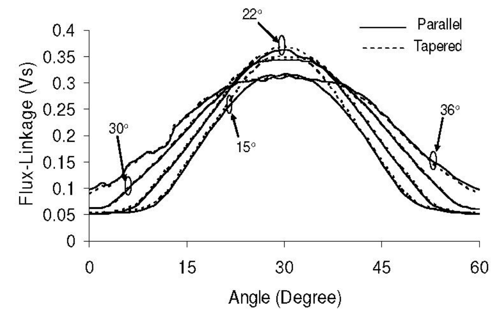

Fig. 1. Flux-linkage vs. rotor position characteristics of the 8/6 DSPM motor when stator phase excitation is absent.

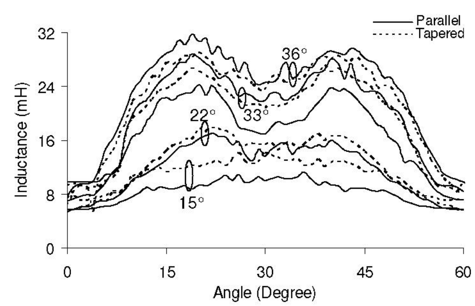

Fig. 2. Phase inductance variation at the excitation of 270 AT/phase.

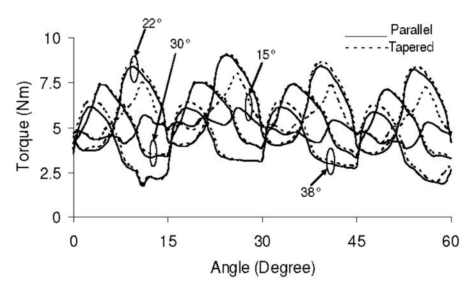

Fig. 3. Developed torque characteristics of the motor at the stator excitation of 270 AT.

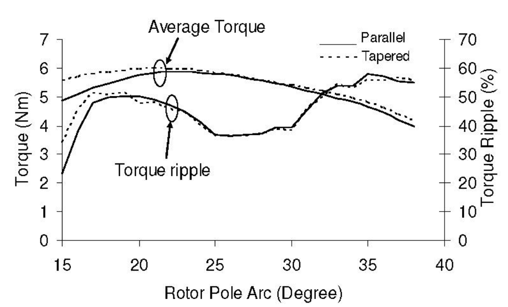

Fig. 4. Comparison of the average and ripple torques of the motor at the stator excitation of 270 AT/phase.

Similarly keeping the rotor pole base arc constant to an original value, rotor pole outer arc is varied in steps from 15° to 38° and various performance characteristics are obtained and shown in Fig. 1 to Fig. 4. It is observed from Fig. 2 that, for both types of rotor poles, the maximum average torque occurs when the stator and rotor pole arcs are equal, but with higher value of the torque ripple. At the rotor outer pole arc of 15°, the torque ripple is the minimum. It is also observed that the tapered rotor pole gives more average torque compared to the parallel rotor pole of the same pole arc, but with more torque ripple if the rotor outer pole arc is less than 19° or greater than 33°.

Fig. 5 shows the magnet leakage factor, a ratio of the total flux coming out of the magnet and the sum of the total airgap flux of all the phases, from which it is observed that higher rotor pole arc has lower magnet leakage factor or better utilization of magnet flux for both kind of rotor poles.

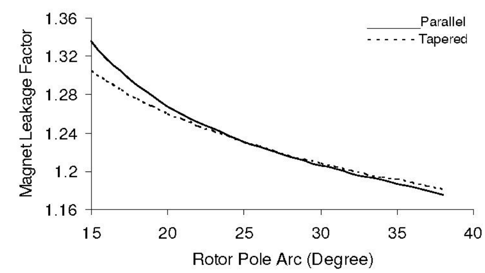

Fig. 5. Variation of the magnet leakage factor with rotor outer pole arcs.

It is inferred from this paper that the tapered rotor pole gives higher average torque than the parallel sided rotor poles. The maximum average torques in both the cases, occur for an outer pole arc of 22°, where the maximum torque in tapered case is more by 1.8%. The average torques in both cases varies similarly for rotor outer pole arcs above 22° and up to 30°. This is also true in case of torque ripples. For outer rotor pole arcs of less than the optimum 22°, it is observed that the tapered case is better; at 15° pole arc, the average torque developed by the motor is 14.8% higher than the corresponding value of parallel-sided case. The analysis has also revealed that the DSPM motor is immune to the type of restrictions of certain stator and rotor pole arc combinations prevalent in switched reluctance motors for having non-zero torque zones.

REFERENCES

[1] M. Cheng, K. T. Chau, C. C. Chan, and Q. Sun, "Control and operation of a new 8/6-pole doubly salient permanent-magnet motor drive", IEEE Trans. Ind. Applicat, vol. 39, pp. 1363-1371, Sept./Oct. 2003.