Cogging Torque Reduction by Increasing Tooth Tang Radius in Radial Flux Permanent Magnet Brushless DC Motor

Amit Kapil[1], Nil Patel[2]
[1]Dept. of. Electrical Engineering, Nirma University, Ahmedabad, Gujarat, India
[2]Dept. of. Electrical Engineering, Ganpat University, Mehsana, Gujarat, India

***Abstract* – Permanent Magnet Brushless DC (PMBLDC) motors are arises as a suitable motor for a number of drive applications in industrial and consumer products. Cogging torque is one of the main downside of PMBLDC motor which results in noises and shaft vibrations. The focus of this work is to reduce the cogging torque in PMBLDC by implementing reconstruction in design parameters. For analyzing the performance of the machine, machine is modeled using Finite Element Analysis (FEA) based software package Motor solve. It is observed that the cogging torque is influenced by tooth tang radius variation. Hence, it is very essential to select proper stator tooth tang radius to reduce the cogging torque in order to improve the performance.**

***Keywords*— cogging torque; finite element analysis (FEA); motor solve; permanent magnet motor; tooth tang radius**

I. INTRODUCTION

Permanent Magnet Brushless DC (PMBLDC) motors have advantages such as high efficiency, high power density and high reliability. These motors required minimum maintenance because of the absence of a mechanical commutator. Cogging torque is prime creator of torque ripple and it is one of the most important disadvantage of PMBLDC motor which results vibrations in shaft and noise. Cogging torque is due to the design outlook of the machine and it is created due to interaction between rotor magnet and stator teeth. There are different techniques are used to reduce cogging torque. In design improvement researchers have suggested various design modifications to reduce the cogging torque. The focus of this work is to minimize cogging torque in PMBLDC by introducing design modifications. The performance of the machine is analyzed by varying the magnet pole shape, magnet pole width and by using magnetic material with different remanance value. For analyzing the performance of the machine, machine is modeled using Finite Element Analysis (FEA) based software package Motor solve.The focus of this work is to minimize cogging torque in BLDC by increasing tooth tang radius.

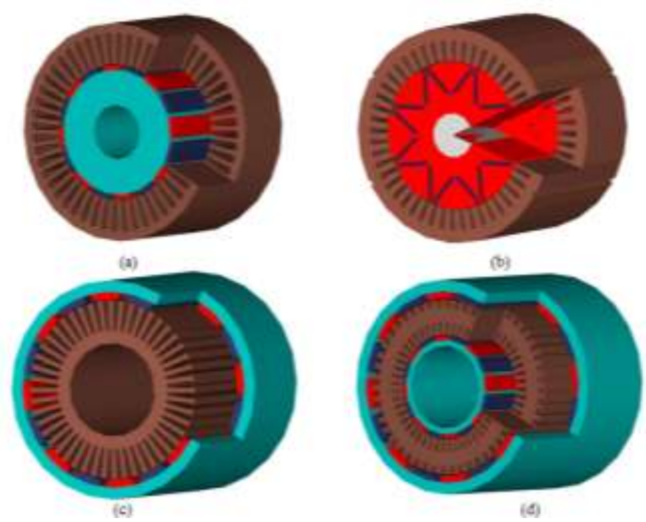

Fig.1 Radial flux PMBLDC motor

II. COGGING TORQUE

Cogging torque is defined as an interaction between the magnets of the rotor and the stator teeth. Several methods have been proposed to reduce cogging torque including teeth pairing, magnet shaping and sizing, adding dummy stator slots, shifting magnets, and skewing harmonics of the cogging torque as seen in [1], [2], [3]. Cogging torque can be represented by,

$$T_{cog} = -\frac{1}{2}\, \emptyset_g^2 \frac{dR}{d\theta} \qquad (1)$$

Where $\emptyset_g$ is the air-gap flux, R is the air-gap reluctance, and θ is the position of the rotor. To maintain uniform reluctance to minimize cogging torque many techniques are used as already referred in introduction paragraph (magnet pole width, magnet pole shape, magnetic material etc.).

A. 70 W / 24 V Radial Flux PMBLDC Motor

70 W, 24 V radial flux PMBLDC motor is designed based on sizing equations. Computer Aided Design (CAD) algorithm is developed for whole design. Model based on design

information is prepared as shown in fig. 2 to carry out Finite Element Analysis (FEA).

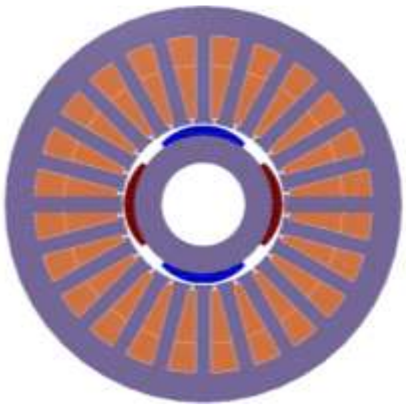

Fig.2 Model of 70 W motor with 1.5 mm magnet edge inset

Magnet edge inset is introduced in improved design and varied from 0 mm to 1.5 mm maintaining other design parameters same. Finite Element Analysis (FEA) is performed to obtain cogging torque profile. Cogging torque profile is influenced and reduced as shown in fig 3.

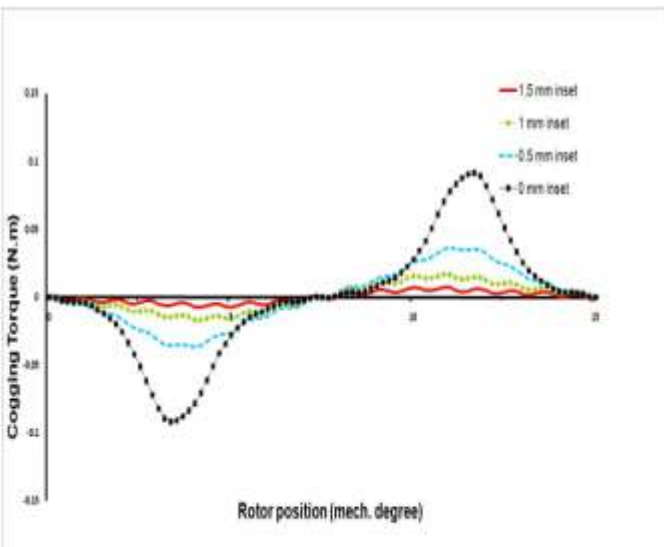

Fig.3 Cogging torque profile of 70 W radial flux PMBLDC motor

It is observed that peak to peak cogging torque is reduced from 0.0476 N.m. to 0.0159 N.m. without affecting other performance parameters.

A magnet edge inset of 1.5 mm gives the desirable result in term of cogging toque. It is observed that flux density in different section of magnetic circuit is as per the assumption.

B. 2.2 kW / 230 V Radial Flux PMBLDC Motor

2.2 kW, 230 V radial flux PMBLDC motor is designed based on sizing equations. Computer Aided Design (CAD) algorithm is developed for whole design. Model based on design information is prepared as shown in fig.4 to carry out Finite Element Analysis (FEA).

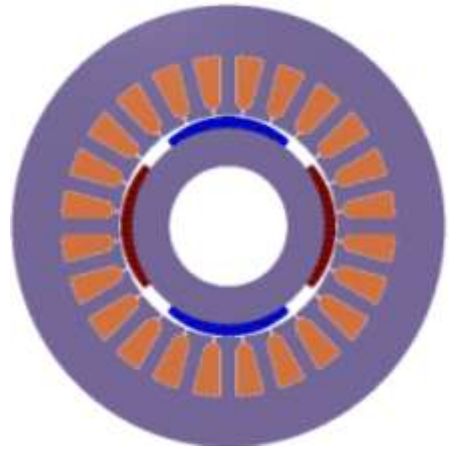

Fig.4 Model of 2.2 kW motor with 1.5 mm magnet edge inset

Magnet edge inset is introduced in improved design and varied from 0 mm to 1.5 mm maintaining other design parameters same. Finite Element Analysis (FEA) is performed to obtain cogging torque profile. Cogging torque profile is influenced and reduced as shown in fig 5.

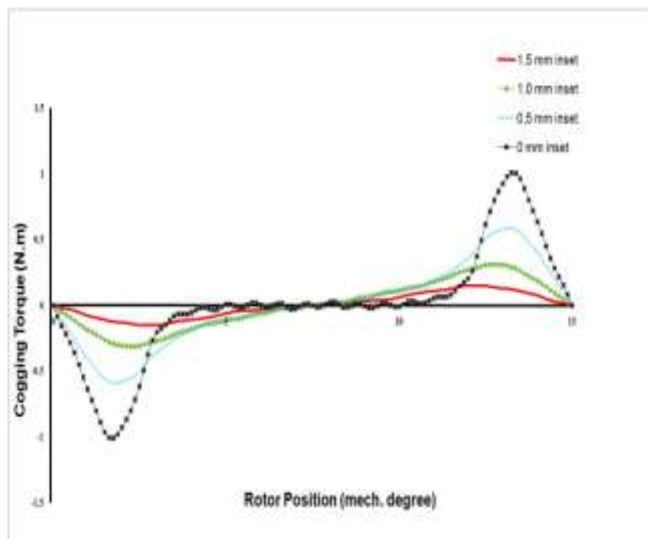

Fig.5 Cogging torque profile of 2.2 kW radial flux PMBLDC motor

It is observed that peak to peak cogging torque is reduced from 1.01 N.m. to 0.151 N.m. without affecting other performance parameters.

A magnet edge inset of 1.5 mm gives the desirable result in term of cogging toque. It is observed that flux density in different section of magnetic circuit is as per the assumption.

C. 20 kW / 230 V Radial Flux PMBLDC Motor

20 kW, 230 V radial flux PMBLDC motor is designed based on sizing equations. Computer Aided Design (CAD) algorithm is developed for whole design. Model based on design information is prepared as shown in fig.3 to carry out Finite Element Analysis (FEA).

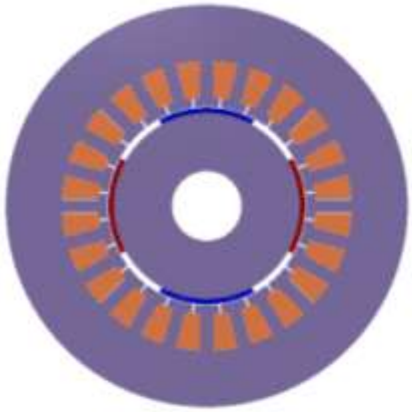

Fig.6 Model of 20 kW motor with 1.5 mm magnet edge inset

Magnet edge inset is introduced in improved design and varied from 0 mm to 1.5 mm maintaining other design parameters same. Finite Element Analysis (FEA) is performed to obtain cogging torque profile. Cogging torque profile is influenced and reduced as shown in fig 7.

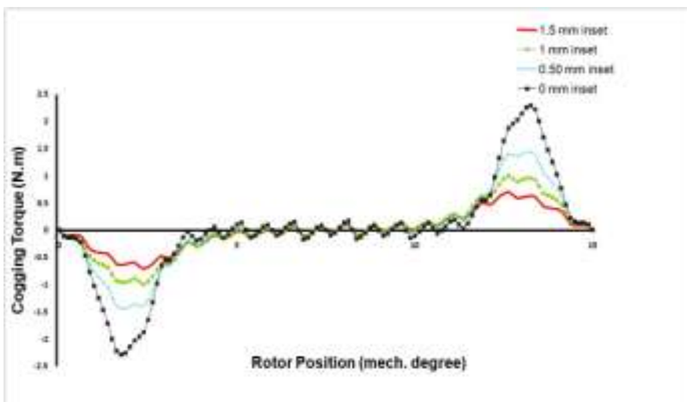

Fig.7 Cogging torque profile of 20 kW radial flux PMBLDC motor

It is observed that peak to peak cogging torque is reduced from 2.39 N.m. to 0.646 N.m. without affecting other performance parameters.

A magnet edge inset of 1.5 mm gives the desirable result in term of cogging toque. It is observed that flux density in different section of magnetic circuit is as per the assumption.

III. CONCLUSION

Magnet edge inset technique is required to minimize cogging torque effect on performance. Magnet edge inset is varied keeping other parameters same in three different standard rating motors and effect on cogging torque is analysed with FEA. Peak to peak cogging torque is reduced from 0.0476 N.m. to 0.0159 N.m. (i.e. 66.5 %) in 70 W / 24 V motor, 1.01 N.m to 0.151 N.m (i.e. 85 %) in 2.2 kW / 230 V motor and respectively from 2.39 N.m to 0.646 N.m (72.9 %) in 20 kW / 230 V. magnet edge inset of 1.5 mm is appropriate as cogging torque reduction is considerable without affecting other performance parameters. The results confirm that variation in magnet edge inset is quite worthwhile in cogging torque reduction and results improved torque quality.

REFERENCES

[1] D. C. Hanselman, “Brushless Permanent Magnet Motor Design” New York McGrow-Hill 1994.

[2] I. R. Handershot and T. J. E. Miller, Design of Brushless PermanentMagnet Motors. Oxford, U.K.: Oxford, 1994.

[3] Oleg Kudrjavtsev, Aleksander Kilk, “Cogging torque reduction methods” unpublished

[4] L. Dosiek and J. Pillay : "Cogging torque reduction in permanent magnet machines", IEEE Trans Industry and Application, Vol. 43, no.6 pp. 1656-1571, 2007.