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Cogging Torque Minimization Of PMBLDC Motor Using 5 Parts Alternate PM And Stator Slot Design

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Abstract – This paper proposes a method to reduce the cogging torque of PMBLDC motor. This paper presents some effective methods of minimizing cogging torque, which have minimum effects on the performance of the motor. In this paper we are applied two techniques 5- Parts Alternate PM and Stator Slot design. In this paper using Magnet Software a cogging torque reduction can be achieved.

Key Words: **Cogging Torque, Permanent Magnet Brushless DC Motor (PMBLDC), Torque Ripple, Finite Element Analysis (FEA).**

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1. INTRODUCTION

Permanent Magnet Brushless DC (PMBLDC) Motor are becoming increasingly popular in industrial applications. They offer a high-power density, high efficiency and low size and cost continues to decrease. They have the opportunity to become a dominant force in the industrial market. Cogging torque is inherent in PMBLDC motor. Cogging torque deteriorates torque quality of PMBLDC motor. It generated noise and vibrations during operating conditions. Various techniques have been implemented for the reduction in the cogging torque. Cogging torque can be minimized by several techniques adopted on stator side, rotor side and air gap likewise Magnet shaping, Magnet shifting techniques are studied. Performance of the PMBLDC motor is improved by applying these techniques to the motor to minimize the cogging torque. In this paper two techniques 5- Parts alternate PM and Stator slot design to reduce cogging torque are implemented for 3 Model i.e. (1) 200 W, 1000 RPM (2) 2.2 kW, 1450 RPM and (3) 20 kW, 1500 RPM radial flux PMBLDC motor. The cogging torque is reduced considerably using these techniques. Performance of the motor is improved as cogging torque is reduced.

2. MOTOR INTIAL DESIGN

Initial model is design for 200 W, 2.2 kW , 20 kW in MagNet software.

Table -1: Motor Initial Data

Sr.no	Motor Initial Ratings	Cogging Torque (Nm)	% Torque Ripple
1	200 W	1.1	48.05
2	2.2 kW	6	47.96
3	20 kW	48.6	44.91

3. COGGING TORQUE

Permanent Magnet Brushless DC (PMBLDC) Motor becoming popular in industrial applications because of its superior performance. But one major drawback to cogging torque is the inherent element of the design which leads to the undesired output of the motor. It creates jerkiness and vibration in the motor.
Cogging torque is produced due to interaction between the magnet pole on rotor and the stator slot. It is also known as “detent torque” or “no current torque”.

$$T_{cog} = -\frac{1}{2}\phi_g^2 \frac{dR}{d\theta}$$

One of the main contributors to this torque ripple is cogging torque, which is the interaction between rotor magnet and stator slot. It is caused uneven air gap in the magnets.
It is Important to point out that minimizing cogging torque does not necessarily minimize torque ripple.

4. COGGING TORQUE REDUCTION TECHNIQUES

4.1 5- Parts Alternate PM (200 W Model)

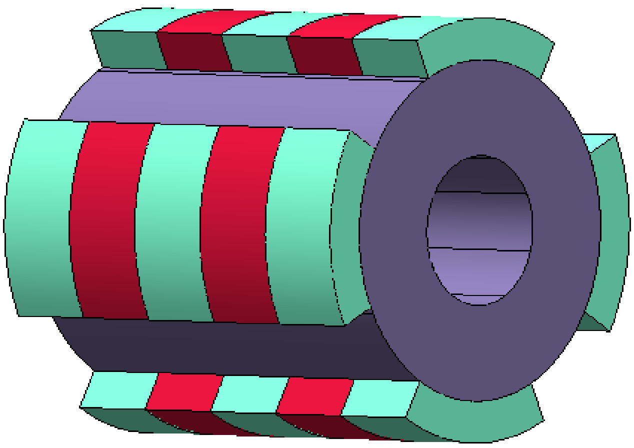

Figure 1 5- Parts Alternate PM of 200 W model.

In 5- parts alternate PM techniques material assign in the five parts of the magnet is different it is like alternate PM it means material assign in the first part of the magnet is NdFeB and then the material assign in the second part of the magnet is Alnico and likewise.
200 W initial model cogging torque is 1.1 Nm. 5- Parts Alternate PM technique 23.63 % cogging torque reduce compared to initial model.

Sr.no	Magnet Shift	Cogging Torque (Nm)	% Torque Ripple	% Reduction in Cogging Torque
1	Initial	1.1	48.05	-
2	5- Parts Alternate PM	0.84	38.42	23.63

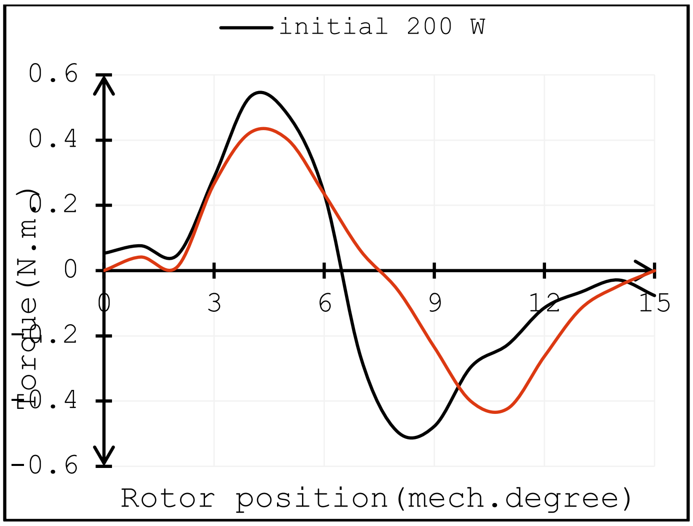

Figure 2 Comparison between initial and 5- Parts Alternate PM (200 W)

In 5- Parts Alternate PM technique Peak to peak cogging torque is about 0.84 N.m. and while the initial model cogging toque is 1.1 N.m. so the cogging torque is reduced by 23.63% that of initial model.

4.2 5- Parts Alternate PM (2.2 kW Model)

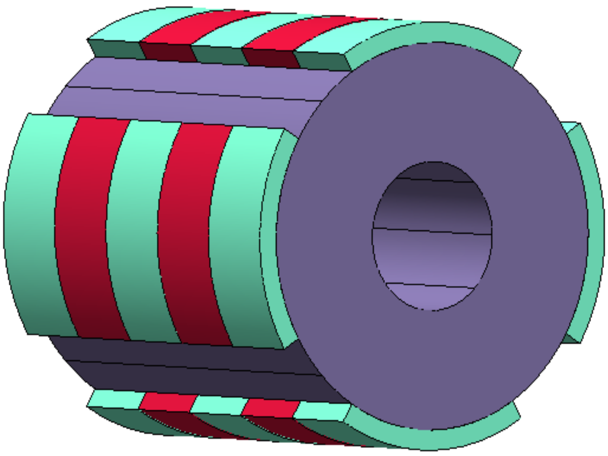

Figure 3 5- Parts Alternate PM of 2.2 kW model.

Sr.no	Magnet Shift	Cogging Torque (Nm)	% Torque Ripple	% Reduction in Cogging Torque
1	Initial	6	47.96	-
v2	5- Parts Alternate PM	4.98	54.76	17

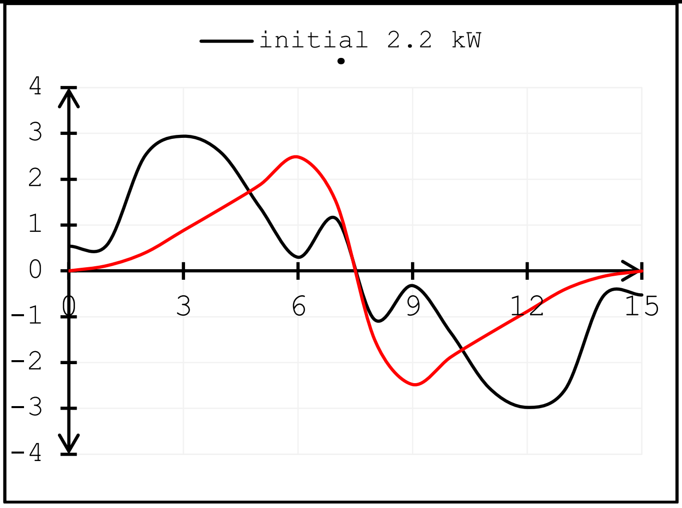

Figure 4 Comparison between initial and 5- Parts Alternate PM (2.2 kW)

4.3 5- Parts Alternate PM (20 kW Model)

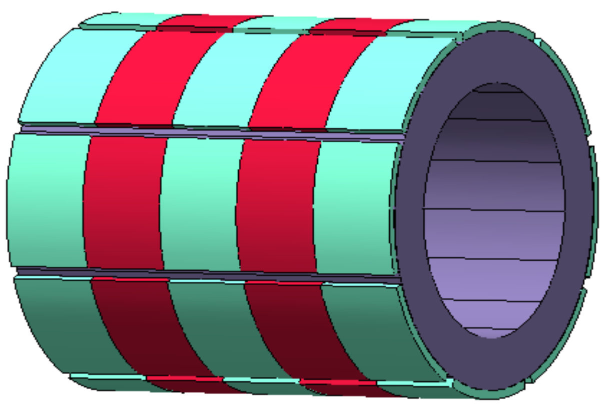

Figure 5 5- Parts Alternate PM of 20 kW model.

Sr.no	Magnet Shift	Cogging Torque (Nm)	% Torque Ripple	% Reduction in Cogging Torque
1	Initial	48.6	45	-
2	5- Parts Alternate PM	37	47	23.86

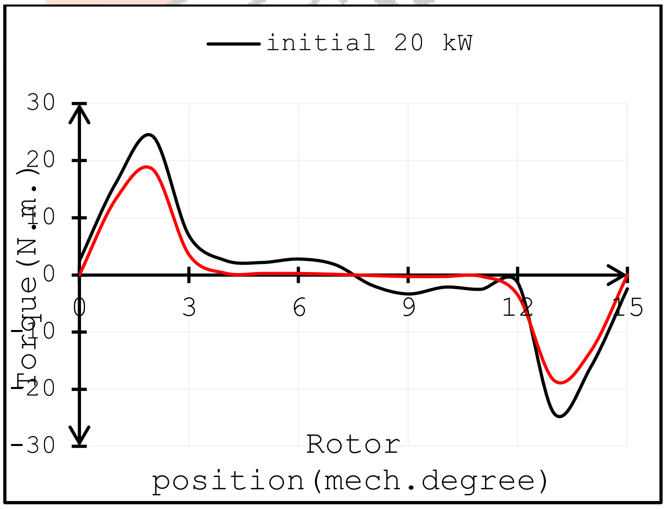

Figure 6 Comparison between initial and 5- Parts Alternate PM (20 kW)

Cogging torque produce by this model is about 37 Nm. Whereas the Cogging torque of the initial model is 48.6 N.m.
So, the reduction in the Cogging torque is 23.86% that of Cogging torque of initial Model.

5– Parts Alternate PM technique applied to all three different ratings model. And reduced Cogging torque about 23.86 % that of initial model.

Thus, we can conclude here that 5- Parts Alternate PM techniques can be helpful in reducing the Cogging torque and torque ripple also but there will be compromise with the average torque.

5. COGGING TORQUE REDUCTION TECHNIQUES

5.1 Stator Slot Design (200 W)

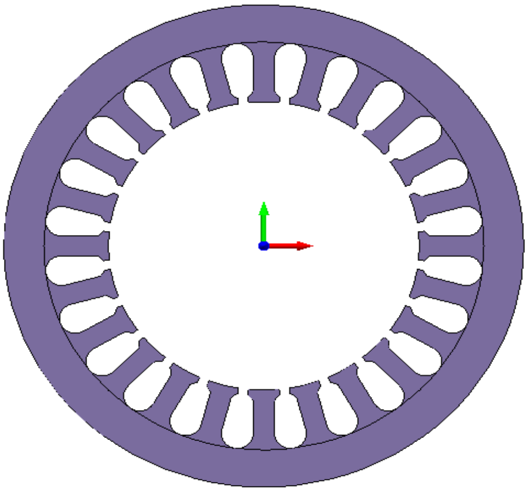

Figure 7 Stator cross section of 200 W.

Stator cross section of initial model of 200 W PMBLDC motor is shown in the above figure. Here in this model, there are 24 teeth and in these teeth the teeth edge is similar in both sides from Centre of the tooth but in the stator slot design it is one side as shown in figure below.

5.1.1 Case 1 (200 W)

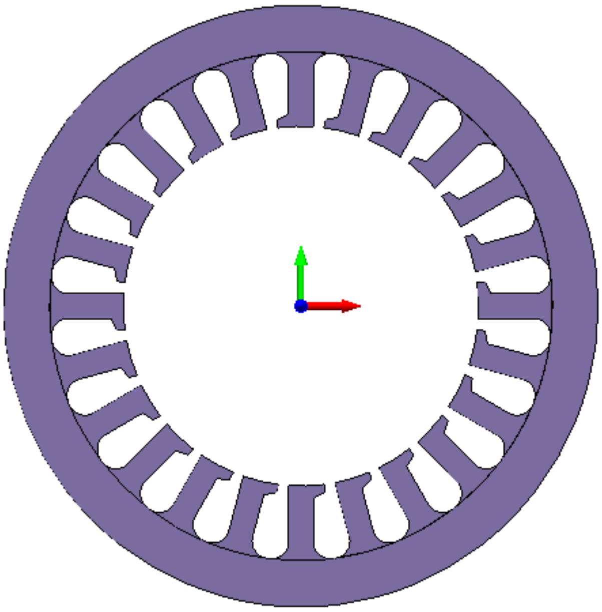

Figure 8 Stator cross section of new slot design for Case 1.

5.1.2 Case 2 (200 W)

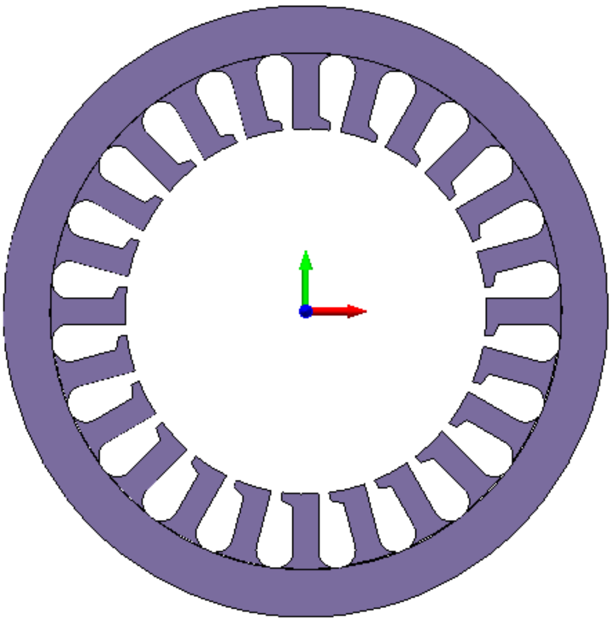

Figure 9 Stator cross section of new slot design for Case 2.

Sr.no	Magnet Shift	Cogging Torque (Nm)	% Torque Ripple	% Reduction in Cogging Torque
1	Initial 200 W	1.1	48.05	-
2	Slot design case 1	0.66	39.45	40
3	Slot design case 2	0.6	28.96	45

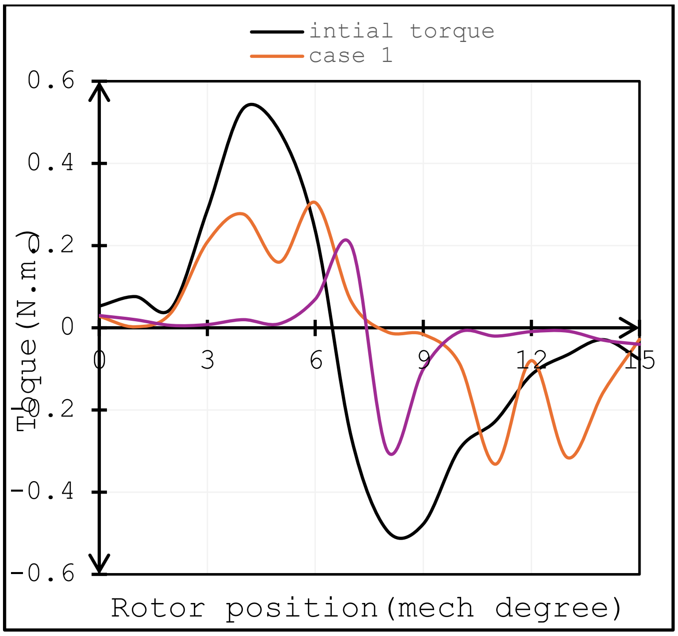

Figure 10 Comparison between different cases of slot design model. (200 W).

Cogging torque produced by case 1 model is about 0.66 N.m. whereas the cogging torque of the initial model is 1.1 N.m. So, the reduction in the cogging torque is 40% that of cogging torque of initial model.

Cogging torque produced by case 2 model is about 0.6 N.m. whereas the cogging torque of the initial model is 1.1 N.m. So, the reduction in the cogging torque is 45 % that of cogging torque of initial model.

5.2 Stator Slot Design (2.2 kW)

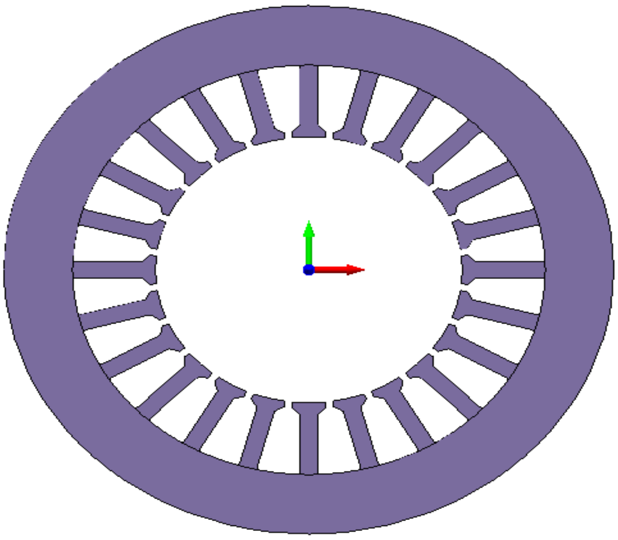

Figure 11 Stator cross section of 2.2 kW.

Cogging torque produced by case 1 model is about 3.68 N.m. whereas the cogging torque of the initial model is 6 N.m. So, the reduction in the cogging torque is 38.7% that of cogging torque of initial model.

Cogging torque produced by case 2 model is about 3.68 N.m. whereas the cogging torque of the initial model is 6 N.m. So, the reduction in the cogging torque is 38.7% that of cogging torque of initial model.

5.2.1 Case 1 (2.2 kW)

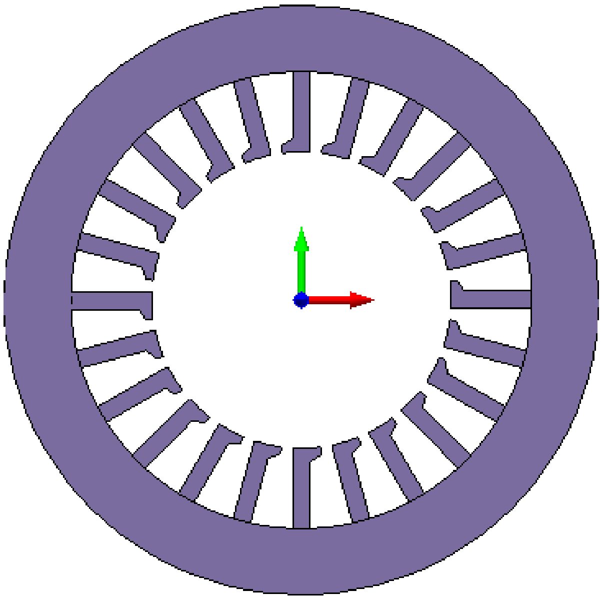

Figure 12 Stator cross section of new slot design for Case 1.

5.2.2 Case 2 (2.2 kW)

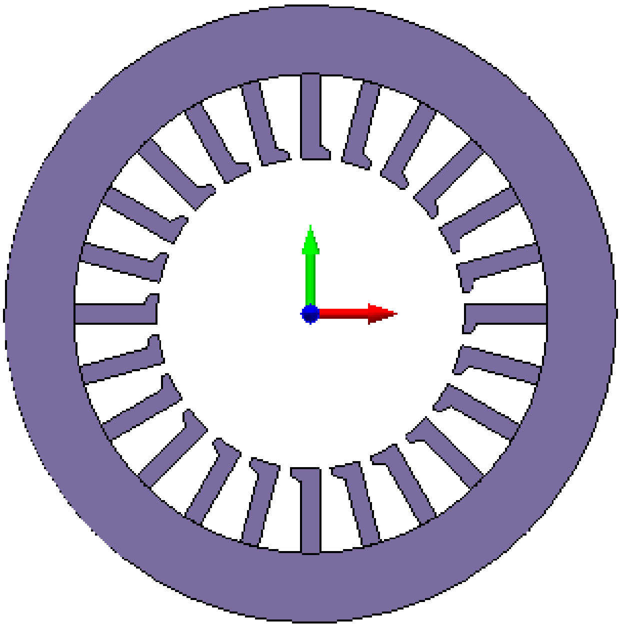

Figure 13 Stator cross section of new slot design for Case 2.

Sr.no	Magnet Shift	Cogging Torque (Nm)	% Torque Ripple	% Reduction in Cogging Torque
1	Initial 2.2 kW	6	47.96	-
2	Slot design case 1	3.68	39.75	38.67
3	Slot design case 2	3.68	39.05	38.67

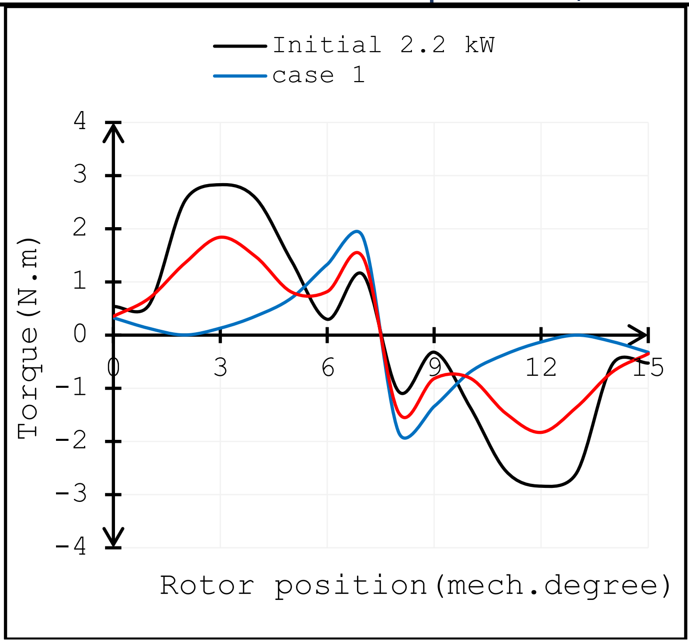

Figure 14 Comparison between different cases of slot design model. (2.2 kW).

5.3 Stator Slot Design (20kW)

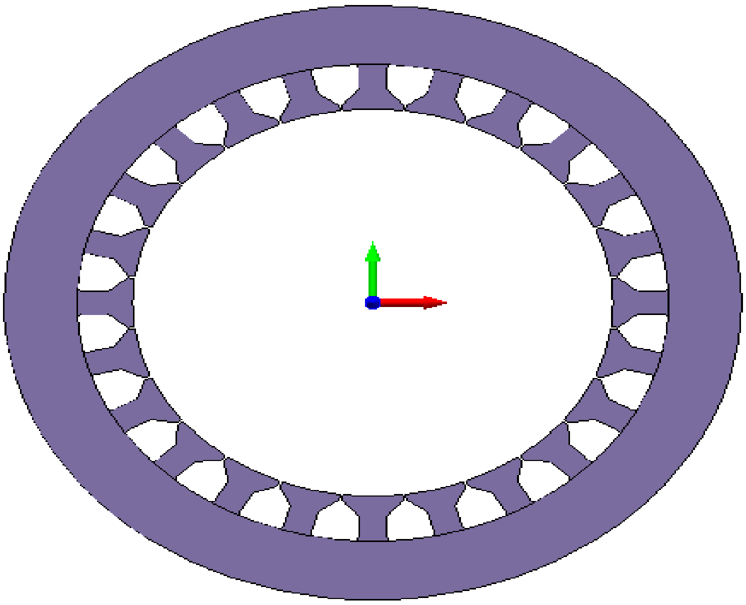

Figure 15 Stator cross section of 20 kW.

Cogging torque produced by case 1 model is about 22.4 N.m. whereas the cogging torque of the initial model is 48.6 N.m. So, the reduction in the cogging torque is 54% that of cogging torque of initial model. So, it is half of the cogging torque of initial model.

Cogging torque produced by case 2 model is about 22 N.m. whereas the cogging torque of the initial model is 48.6 N.m. So, the reduction in the cogging torque is 54.74% that of cogging torque of initial model. So, it is half of the cogging torque of initial model. There is quite less difference between the case 1 and case 2 as far as the reduction in the cogging torque.
Thus, we can conclude here that Slot design can be helpful in reducing the cogging torque and torque ripple also but there will be compromise with the average torque.

5.3.1 Case 1 (20 kW)

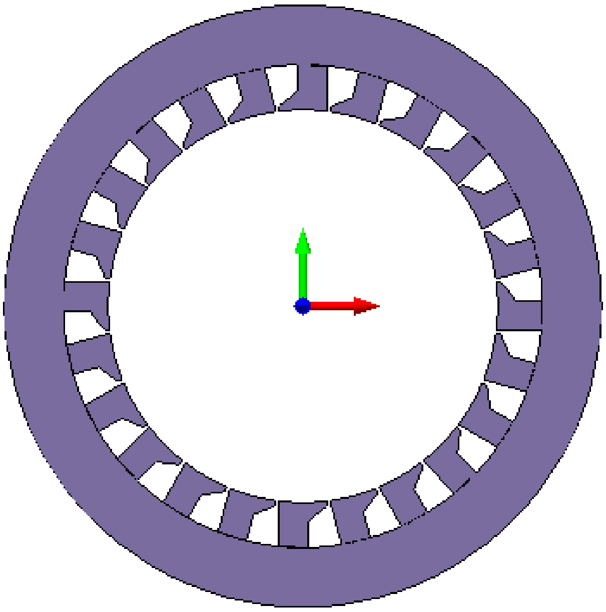

Figure 16 Stator cross section of new slot design for Case 1.

5.3.2 Case 2 (20 kW)

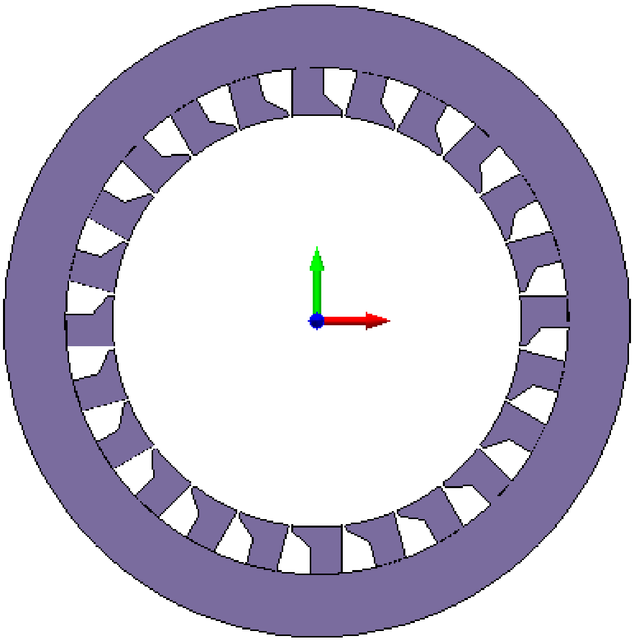

Figure 17 Stator cross section of new slot design for Case 2.

Sr.no	Magnet Shift	Cogging Torque (Nm)	% Torque Ripple	% Reduction in Cogging Torque
1	Initial 20 kW	48.6	44.91	-
2	Slot design case 1	22.4	25.97	54
3	Slot design case 2	22	25.91	54.74

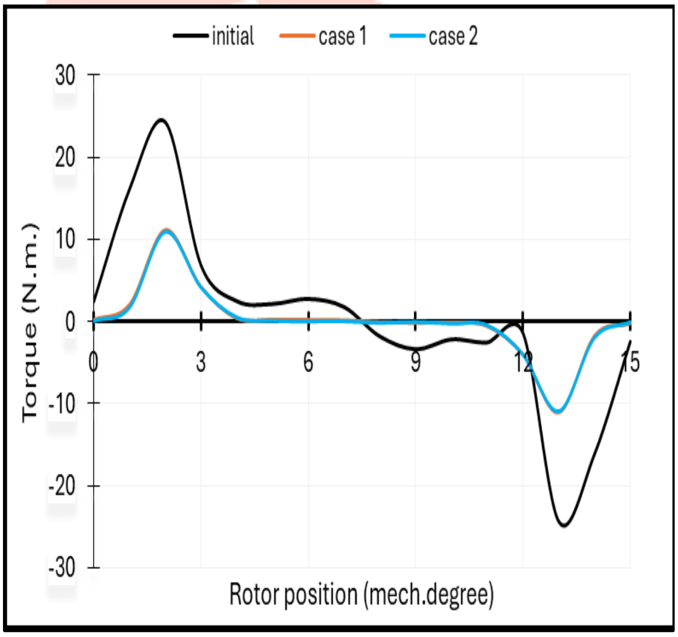

Figure 18 Comparison between different cases of slot design model. (20 kW).

7. CONCLUSION

This paper presented the different topologies for minimization of the cogging torque and the suppression of the torque ripple in surface mounted PMBLDC motor. In which 5- Parts alternate PM and Stator slot techniques are included. Proper design of the motor by shaping the rotor pole or rotor magnet cogging torque of the motor is reduce and torque ripple can be reduced. In the 5- Parts alternate PM technique was studied, and the comparison result prove that reduces the cogging torque almost 23.86% that of initial model (20 kW). In the Stator slot design techniques where two combinations of stator were studied like case 1 is right sided stator slot shifted and case 2 is left sided stator slot shifted. Comparison result from the FEA proves that case 2 left side stator slot shifted technique reduces the cogging torque about 54.74% that of cogging torque of initial model (20 kW).

8. REFERENCES

[1] T.A. Anuja, Arun Noyal Doss M, R. Senthilkumar, Rajesh K. S and R. Brindha "Modification of pole pitch and pole arc in rotor magnet of cogging torque reduction in BLDC motor" Nov 2022.

[2] Chengcheng Liu, Jianguo Zhu, Youhua Wang, Gang Lei and Youguang Guo "Cogging Torque Minimization of SMC PM Transverse Flux Machines Using shifted and Unequal Width Stator Teeth" IEEE Transactions on applied Superconductivity, Vol.26, No.4, June 2016.

[3] G. J. Li and Z. Q. Zhu "Analytical Modeling of Modular and Unequal Tooth Width Surface Mounted Permanent Magnet Machines" IEEE Transactions on Magnetics, Vol.51, No.9, September 2015.

[4] Li Hao, Mingyao Lin, Da Xu, Nian Li and Wei Zhang "Cogging Torque Reduction of Axial Field Flux switching Permanent Magnet Machine by Rotor Tooth Notching" IEEE Transactions on Magnetics, Vol.51, No. 11, November 2015.

[5] Jian Yuan, Cen Wei Shi, Jian Xin Shen "Analysis of Cogging Torque in Surface Mounted Permanent Magnet Machines with Segmented Stators" 17th International Conference on Electrical Machines and Systems, Oct 22-25, 2014, Hangzhou, China.

[6] Mourad Chabchoub, Ibrahim Ben Salah, Guillaume Krebs, Rafik Neji and Claude Marchand "PMSM Cogging Torque Reduction: Comparison between different shapes of magnet" 2012 First international Conference on Renewable Energies and Vehicular Technology.

[7] J. G. Wanjiku, Student Member, IEEE, H. Jagau, Student Member, IEEE, M. A. Khan and P. S. Barendse, IEEE, Member "Minimization of Cogging Torque in a Small Axial Flux PMSG with a Parallel teeth Stator" Department of Electrical Engineering, University of Cape Town, Rondebosch 7701 Cape Town, South Africa, 2011.

[8] Boussad Boukais and Houcine Zeroug "Magnet Segmentation for Commutation Torque Ripple Reduction in a Brushless DC Motor Drive" IEEE Transactions on Magnetics, Vol.46, No.11, November 2010.

[9] Luke Dosiek, Student Member, IEEE, and Pragasen Pillay, Fellow, IEEE "Cogging Torque Reduction in Permanent Magnet Machines" IEEE Transactions on Industry Applications, Vol.43, No.6, December 2007.