Cogging Torque Minimization of PMBLDC Motor Using Magnet Shifting and Magnet Shaping

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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 Magnet Shifting and Magnet Shaping. 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).

1. INTRODUCTION

Permanent Magnet Brushless DC (PMBLDC) Motor becoming popular in industrial applications such as fans, washing machines, air conditioners because of its superior performance compared to conventional electric motors. 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 various techniques 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 the 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".

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

Cogging torque is affected by a lot of factors as form of the magnetic field, number of slots per pole and phase, slot opening and filling factor, pole pitch and distribution of magnetic flux density.

It is Important to point out that minimizing cogging torque does not necessarily minimize torque ripple.

4. COGGING TORQUE REDUCTION TECHNIQUES

4.1 Magnet Shifting (200 W Model)

4.1. (A) 1^0 , 2^0 , 3^0 Magnet shift

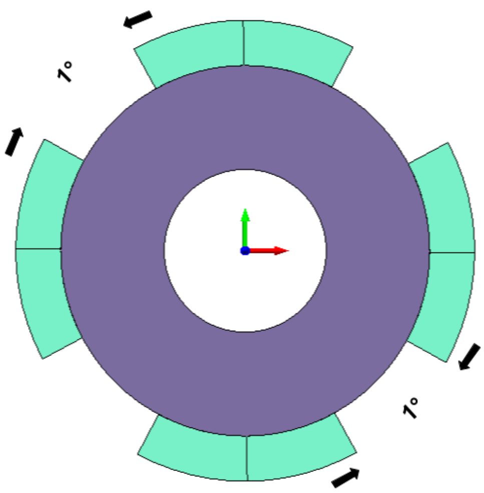

Figure 1 1^0 magnet shift of 200 W model.

In magnet shifting techniques magnet shift 1^0 , 2^0 , and 3^0 respectively. Cogging torque reduction is achieved by these techniques.

200 W initial model cogging torque is 6 Nm. 3^0 magnet shift technique 45.46 % 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	1^0	1	46.03	10
3	2^0	0.8	38.62	27.27
4	3^0	0.6	30.68	45.46

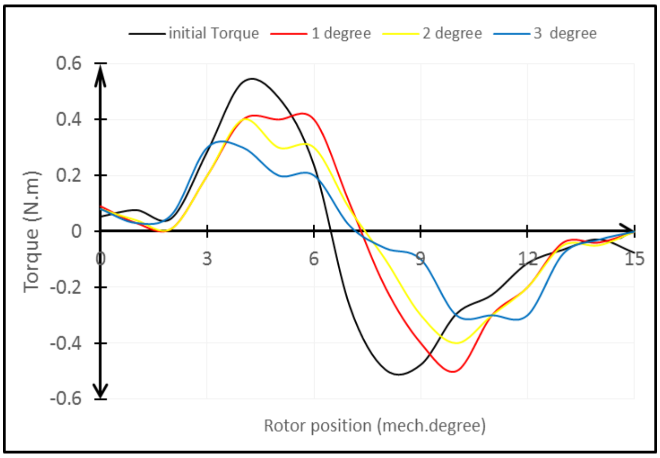

Figure 2 Comparison between different angles of magnet shifting. (200 W)

In 1^0 magnet shift technique Peak to peak cogging torque is about 1.1 N.m. and while the initial model cogging toque is 1 N.m. so the cogging torque is reduce by 10% that of initial model.

In 2^0 magnet shift technique Peak to peak cogging torque is about 1.1 N.m. and while the initial model cogging toque is 0.6 N.m. so the cogging torque is reduce by 27.27% that of initial model.

4.2 Magnet Shifting (2.2 kW Model)

4.2. (A) *1^0 , 2^0 , 3^0* Magnet shift

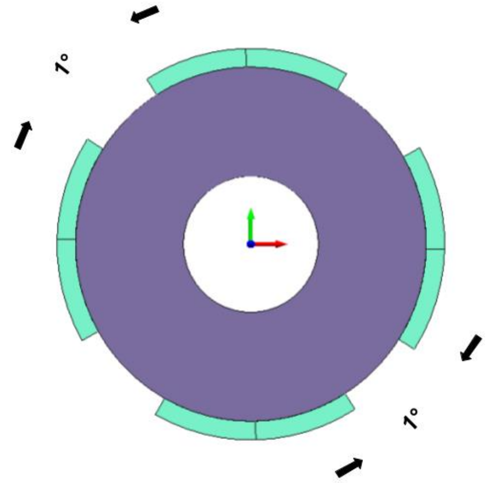

Figure 3 1^0 magnet shift of 2.2 kW model.

Sr.no	Magnet Shift	Cogging Torque(Nm)	% Torque Ripple	% Reduction in Cogging Torque
1	Initial	6	47.96	-
2	1^0	4	46.03	33.34
3	2^0	2	47.48	66.67
4	3^0	2	40.28	66.67

In 1^0 magnet shift technique Peak to peak cogging torque is about 4 N.m. and while the initial model cogging toque is 6 N.m. so the cogging torque is reduce by 33.34% that of initial model.

In 2^0 magnet Shift technique Peak to peak cogging torque is about 2 N.m. and while the initial model cogging toque is 6 N.m. so the cogging torque is reduce by 66.67% that of initial model.

In 3^0 magnet shift technique Peak to peak cogging torque is about 2 N.m. and while the initial model cogging toque is 6 N.m. so the cogging torque is reduce by 66.67% that of initial model.

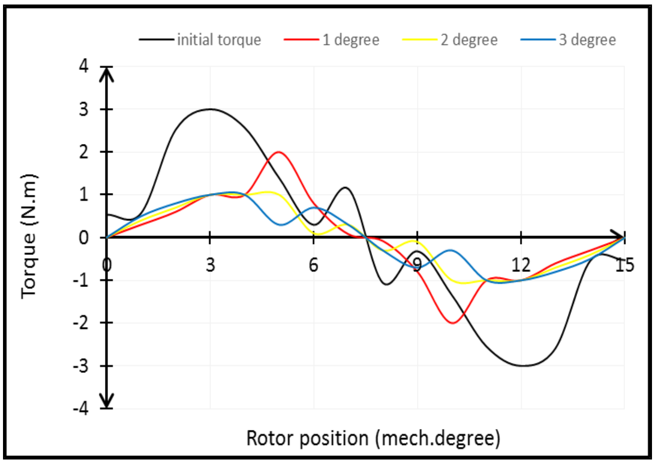

Figure 4 Comparison between different angles of magnet shifting. (2.2 kW)

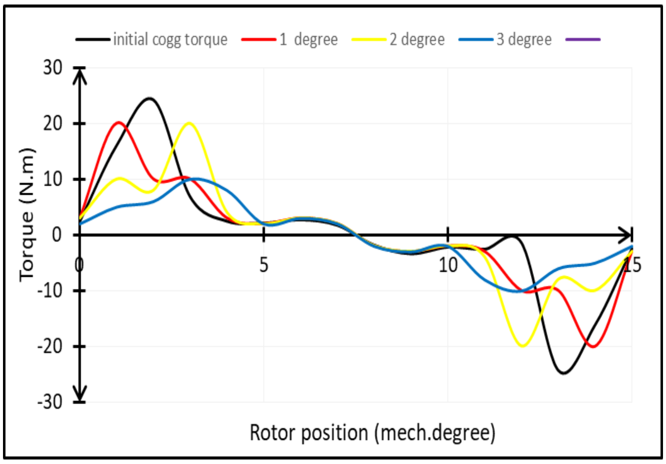

Figure 6 Comparison between different angles of magnet shifting. (20 kW)

4.3 Magnet Shifting (20 kW Model)

4.3. (A) 1^0 , 2^0 , 3^0 Magnet shift

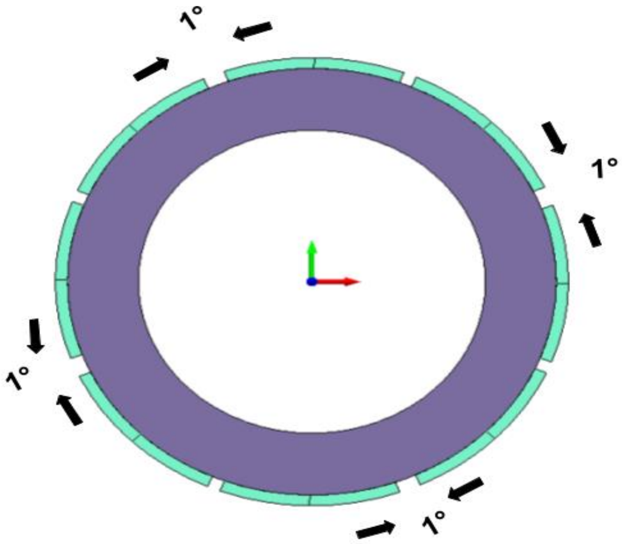

Figure 5 1^0 magnet shift of 20 kW model.

In 1^0 magnet shift technique Peak to peak cogging torque is about 40 N.m. and while the initial model cogging toque is 48.6 N.m. so the cogging torque is reduce by 17.70% that of initial model.

Sr.no	Magnet Shift	Cogging Torque(Nm)	% Torque Ripple	% Reduction in Cogging Torque
1	Initial	48.6	44.91	-
2	1^0	40	46	17.70
3	2^0	40	47	17.70
4	3^0	20	47.77	58.84

In 2^0 magnet shift technique Peak to peak cogging torque is about 40 N.m. and while the initial model cogging toque is 48.6 N.m. so the cogging torque is reduce by 17.70% that of initial model.

In 3^0 magnet shift technique Peak to peak cogging torque is about 20 N.m. and while the initial model cogging toque is 48.6 N.m. so the cogging torque is reduce by 47.77% that of initial model.

5. COGGING TORQUE REDUCTION TECHNIQUES

5.1 Rounded inside shape (200 W)

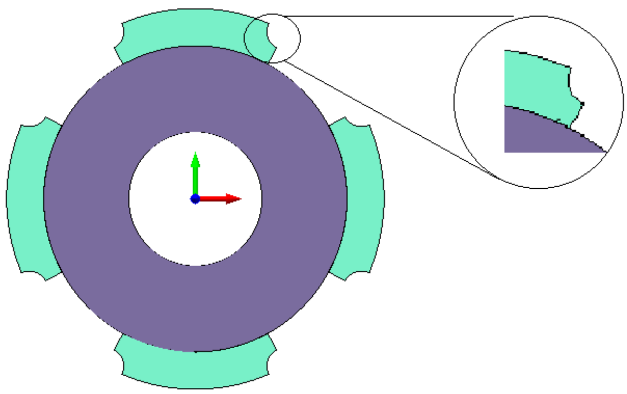

Figure 7 Rounded inside shape for magnet of 200 W.

In the rounded inside magnet shape the shape of magnet is design such rounded inside type for both sides of each magnet.

Sr.no	Magnet Shift	Cogging Torque(Nm)	% Torque Ripple	% Reduction in Cogging Torque
1	Initial	1.1	48.05	-
2	Rounded	0.514	22.72	53.28

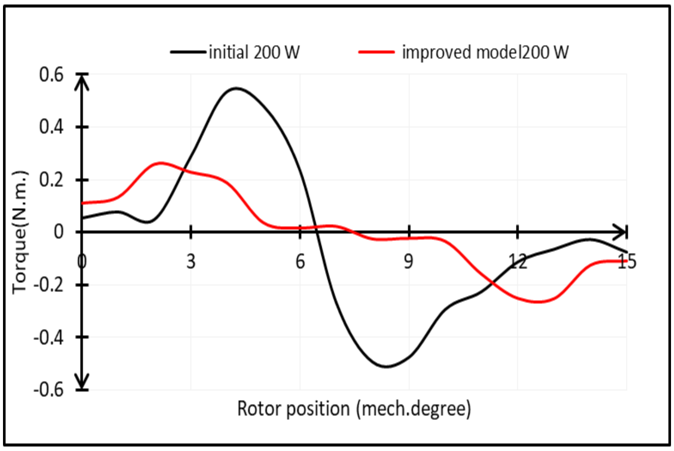

Figure 8 Comparison between initial model and improved model (200 W).

5.2 Rounded inside shape (2.2 kW)

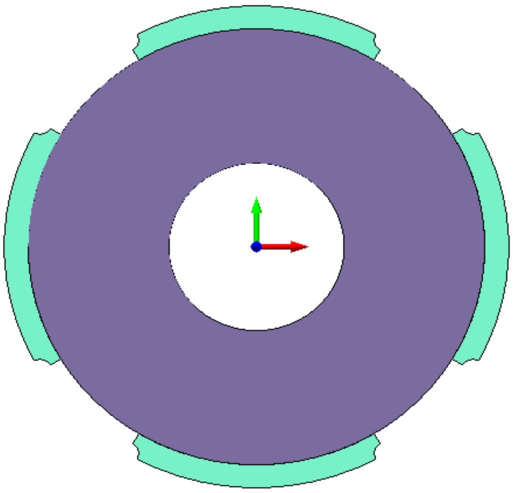

Figure 9 Rounded inside shape for magnet of 2.2 kW.

In the rounded inside magnet shape the shape of magnet is design such rounded inside type for both sides of each magnet.

Sr.no	Magnet Shift	Cogging Torque(Nm)	% Torque Ripple	% Reduction in Cogging Torque
1	Initial	6	47.96	-
2	Rounded	4.56	48.22	24

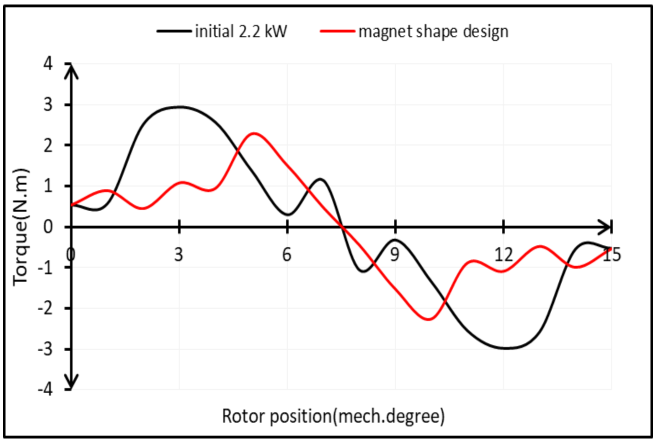

Figure 10 Comparison between initial model and improved model (2.2 kW).

5.3 Rounded inside shape (20 kW)

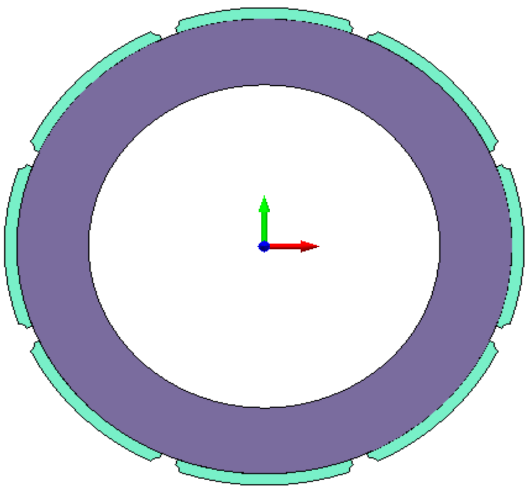

Figure 11 Rounded inside shape for magnet of 20 kW.

In the rounded inside magnet shape the shape of magnet is design such rounded inside type for both sides of each magnet.

Sr.no	Magnet Shift	Cogging Torque (Nm)	% Torque Ripple	% Reduction in Cogging Torque
1	Initial	48.6	45	-
2	Rounded	39.8	43.63	18.11

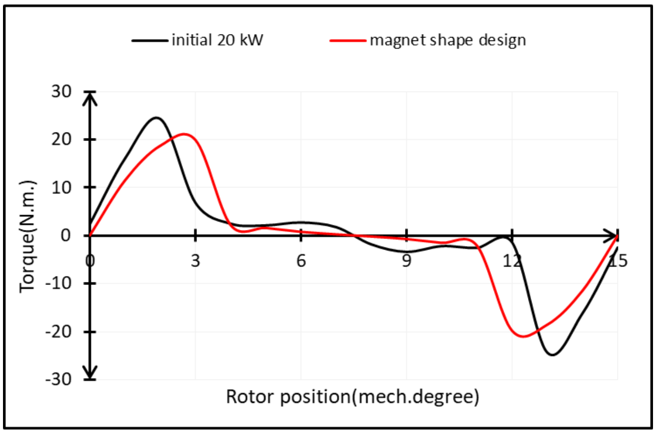

Figure 12 Comparison between initial model and improved model (20 kW).

6. COGGING TORQUE REDUCTION TECHNIQUES

6.1 Chamfered Magnet Shape (200 W)

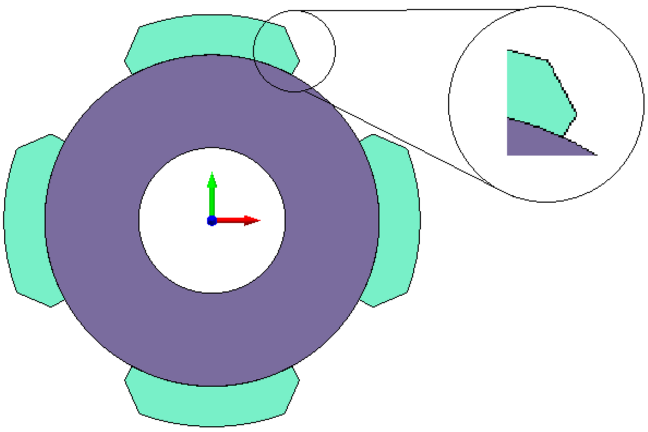

Figure 13 Chamfered Magnet shape for magnet of 200 W.

In the Chamfered magnet shape the shape of magnet is design such Chamfered type for both sides of each magnet.

Sr.no	Magnet Shift	Cogging Torque (Nm)	% Torque Ripple	% Reduction in Cogging Torque
1	Initial	1.1	48.05	-
2	Chamfered	0.806	19.65	26.72

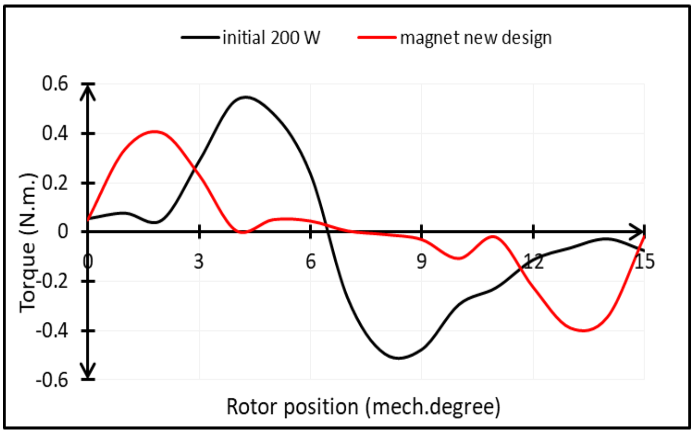

Figure 14 Comparison between initial model and improved model (200 W).

6.2 Chamfered Magnet Shape (2.2 kW)

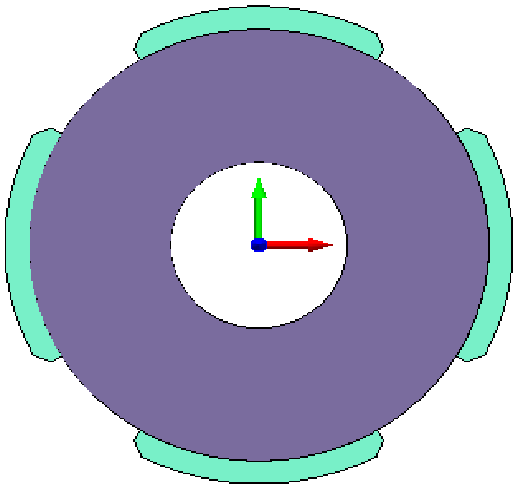

Figure 15 Chamfered Magnet shape for magnet of 2.2 kW.

In the Chamfered magnet shape the shape of magnet is design such Chamfered type for both sides of each magnet.

Sr.no	Magnet Shift	Cogging Torque(Nm)	% Torque Ripple	% Reduction in Cogging Torque
1	Initial	6	47.96	-
2	Chamfered	4	44.77	33.33

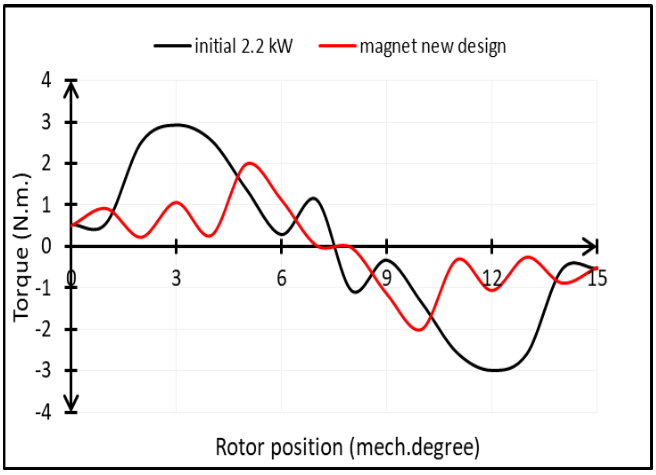

Figure 16 Comparison between initial model and improved model (2.2 kW).

6.3 Chamfered Magnet Shape (20 kW)

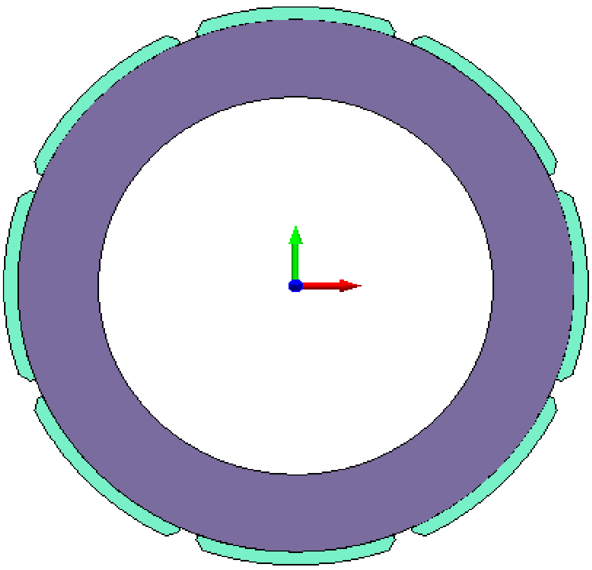

Figure 17 Chamfered Magnet shape for magnet of 20 kW.

In the Chamfered magnet shape the shape of magnet is design such Chamfered type for both sides of each magnet.

Sr.no	Magnet Shift	Cogging Torque(Nm)	% Torque Ripple	% Reduction in Cogging Torque
1	Initial	48.6	45	-
2	Chamfered	36.6	32.96	24.69

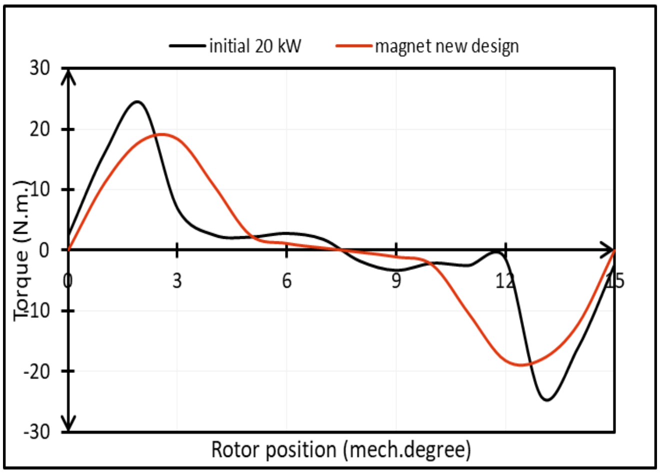

Figure 18 Comparison between initial model and improved model (20kW).

7. CONCLUSIONS

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 magnet shaping, magnet shifting techniques are included. Proper design of the motor by shaping the rotor pole or rotor magnet cogging torque of the motor is reduce and also torque ripple can be reduced. In magnet shaping two different shapes were studied and the comparison result prove that the rounded inside type magnet shape reduces the cogging torque almost 53.28% that of initial model (200 W). In the magnet shifting the combination of degrees for magnet shifted were studied like 1^0, 2^0 and 3^0 degree magnet shifted. Comparison result from the FEA proves that 3^0 shifted magnet reduces the cogging torque about 66.67% that of Cogging torque of initial model (2.2 kW).

8. REFERENCES

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