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Partial Irreversible Demagnetization Reduction of Permanent Magnet Synchronous Motor

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Abstract: Synchronous motors are widely used nowadays in both high and low-speed applications. There are many types of the synchronous motor such as hysteresis synchronous motor (HSM), reluctance synchronous motor (RSM), permanent magnets synchronous motor (PMSM) and direct current (DC) excited synchronous motor. In this study, PMSM has been chosen since the life span of the chosen motor decreased due to the presence of demagnetization. This may be caused by the high temperature of the motor and the high magnitude of the current. Thus, this study aims to minimise the demagnetization value of PMSM using JMAG software. The partial irreversible demagnetization was applied to the permanent magnet. It is partial demagnetization since only some part of the permanent magnet has demagnetised. So, two designs have been proposed by adjusting the configuration of the permanent magnet. The comparison between the original design and two proposed designs had been explained clearly in this report. As the result, the proposed designs are able to minimise the value of demagnetization but the performance of PMSM decreased as well.

Keywords: Demagnetization, Permanent Magnet, PMSM, Synchronous Motor

1. Introduction

Currently, permanent magnet synchronous motor (PMSM) is widely used due to its advantages which are high density, high power factor, high efficiency, lower life cycle and able to adapt numerous voltage supplies and frequencies [1]-[3] However, demagnetization is a natural phenomenon that occurs to a motor but whether sooner or later depends on the root [4]. There are some common causes of demagnetization. First is thermal and pressure demagnetization [4], [5]. For thermal demagnetization, magnetic material will loss of energy once it is exposed to a high temperature. If the temperature is too high, it will pass the Curie point. In [5] mentioned, each permanent magnet has a different Curie temperature or known as the Curie point. Then, the magnet will damage as well as the losses its magnetization properties. In contrast to pressure demagnetised, the magnet becomes demagnetization due to extremely high pressure or dropping on a hard surface.

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In addition, self-demagnetization also contributes to the occurrence of demagnetization of the magnet [4]. It is an abundantly slow natural phenomenon. If there are too many magnets in a system, it caused the orientation of magnetic material to change and the magnetic strength becomes decreased. Other than that, if there are too many magnetic loads, it can lead to magnetic field effects [5].

Besides all these stated causes of demagnetization, it also may happen because of alternating current by giving a higher starting current and then lessening the magnitude of current until zero of a sudden [5]. This process affects the electromagnetic field of the magnet and causes hysteresis.

In this study, the irreversible demagnetization and neodymium iron boron permanent magnet have been chosen. Therefore, this study will focus on the partial irreversible demagnetization reduction of PMSM.

2. Methodology

This section consists of the flowchart of the study process of designing PMSM. It also includes specifications, materials and conditions of PMSM.

2.1 Design and Simulation Framework

Figure 1 shows the flowchart of the overall process.

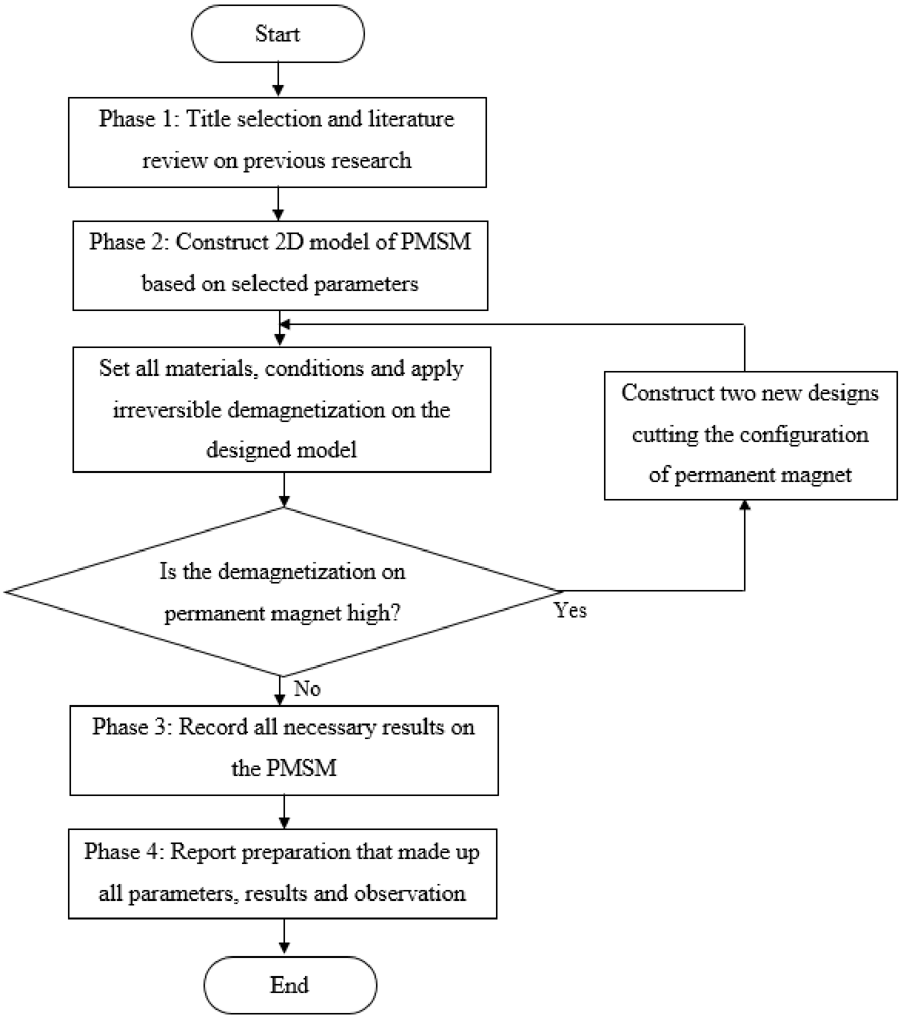

Figure 1: Flowchart of overall process

2.2 Design Configuration Specifications

Table 1 consists of selected parameters of PMSM configuration while Table 2 consists of materials and applied conditions that were used to construct the 2D model.

Table 1: Permanent Magnet Synchronous Motor Specifications

Specification	Description
Stator slot	6
Rotor pole	4
Shaft radius	5mm
Outer rotor radius	24mm
Permanent magnet width	10mm
Permanent magnet length	3.5mm
Rotor pole width	10mm
Rotor pole length	10mm
Inner stator radius	24.5mm
Outer stator radius	45mm
Stator outer pitch	5mm
Air gap	0.5mm
Rated voltage	415V
No of turn per phase	10
Rated speed	1200rpm

Table 2: Materials and conditions of PMSM

Parts	Materials	Conditions
Rotor	Nippon Steel 35H210	Motion: Rotation Torque: Nodal Force
Stator	Nippon Steel 35H210	-
Armature Coil	Conductor Copper	FEM Coil
Permanent Magnet	Neomax-35AH (irreversible) (Magnetization pattern: radial direction)	Motion: Rotation Torque: Nodal Force

2.3 Software Development

Figure 2 illustrates the complete design of PMSM. The configuration consists of a shaft, rotor, stator, armature coil and permanent magnet. The air gap between the permanent magnet and static compartment was 0.5mm.

For the proposed design, only the permanent magnet had been adjusted. All the specifications, materials, conditions as well as FEM Coils were the same as the original design.

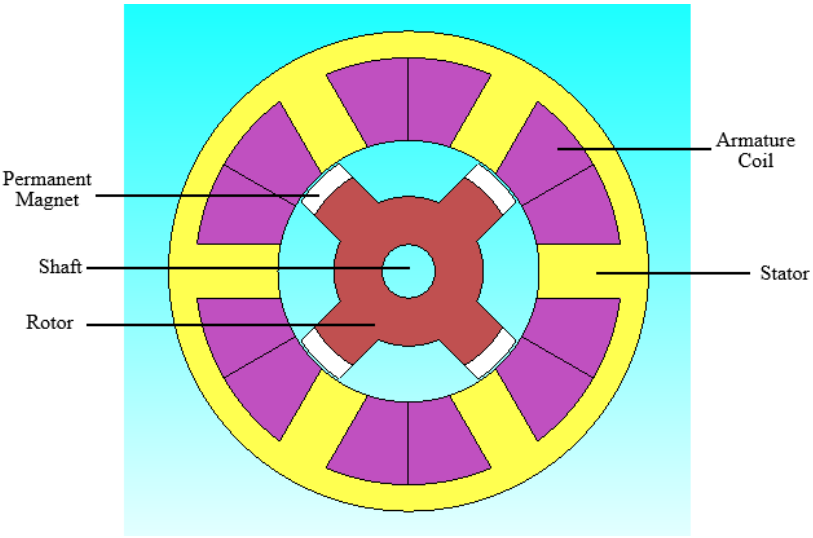

Figure 2: Complete original design of PMSM

2.4 Permanent Magnet Configurations

In this study, there are three configurations of the permanent magnet. All those designs were illustrated in Figure 3,

Figure 4 and Figure 5. The rotor configuration of the proposed design was an implementation from [6].

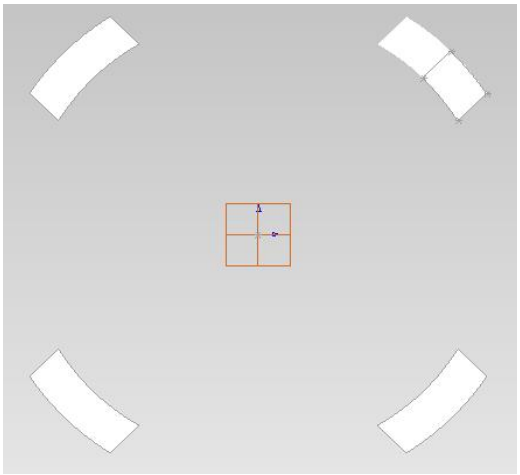

Figure 3: Permanent magnet of the original design

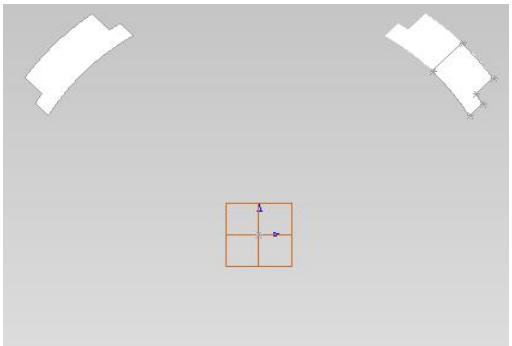

Figure 4: Permanent magnet of Design 1

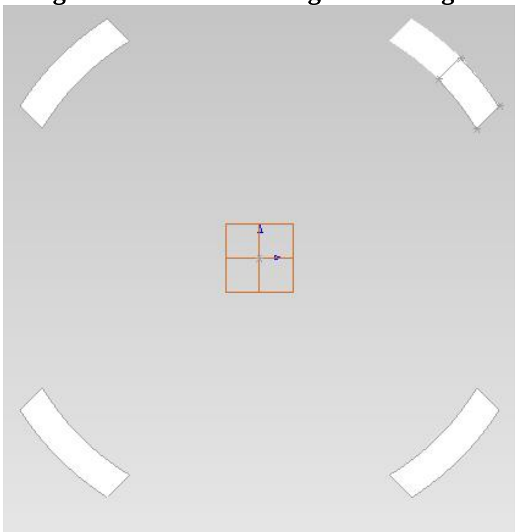

Figure 5: Permanent magnet of Design 2

The permanent magnet of original design and Design 2 configurations as shown in Figure 3 and Figure 5 were looked alike but with different width of permanent magnet. It was different from Design 1 by referring to

Figure 4. The configurations were completely different from the original design and Design 2. This section could be summarised as it focused on the method of the study. Thus, the outcome of the methods taken will be discussed in the next section.

3. Results and Discussion

This section explained in detail the comparison of irreversible demagnetization value between all designs of PMSM. It also discussed the performance of the PMSM

Irreversible demagnetization has been applied in this study on the permanent magnet of PMSM. Demagnetization could be determined during no load condition. The outcome of demagnetization was illustrated in detail in Figure 6. Figure 6 shows the maximum value of flux density was at the permanent magnet of PMSM while the minimum value of flux density was at the stator. The maximum value of flux density was 0.9432T while the minimum value was 0.0004T. In order to justify the presence of

demagnetization, the B-H curve needs to be referred to as it was describing the magnetization properties [7]. According to the B-H curve of the NdFeB permanent magnet in Figure 7, the magnet becomes demagnetized once it reaches 0.9T at 150°C since it was the highest withstand temperature for this permanent magnet.

Figure 6: Permanent magnet demagnetization of original design

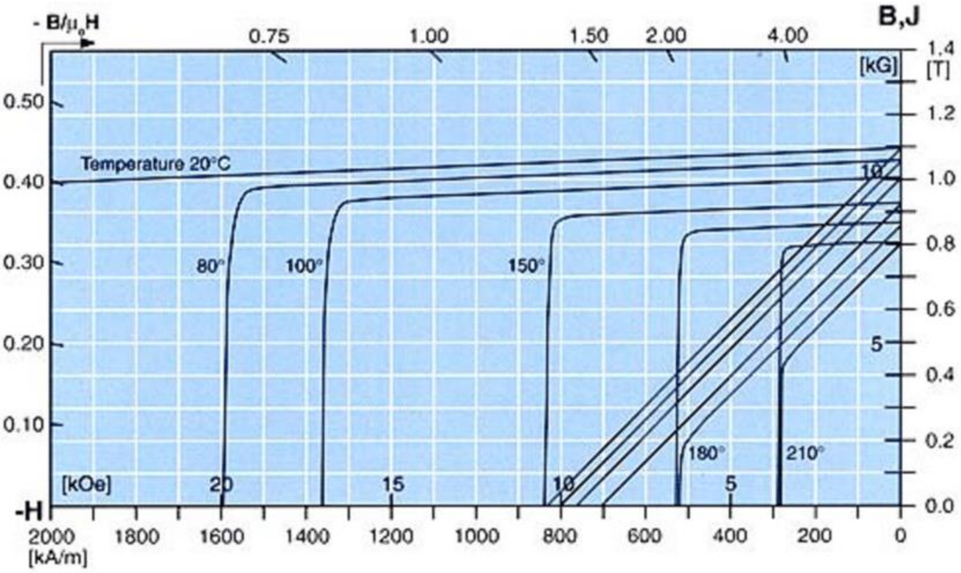

Figure 7: B-H curve of NdFeB permanent magnet [7]

Design 1 was simulated with the same frequency value which was 40Hz. In Figure 8, the maximum value of flux density was no longer at the permanent magnet as the maximum value was changed at the rotor of PMSM. The maximum value of flux density was 0.9535T while the minimum value remained at the stator with 0.0002T.

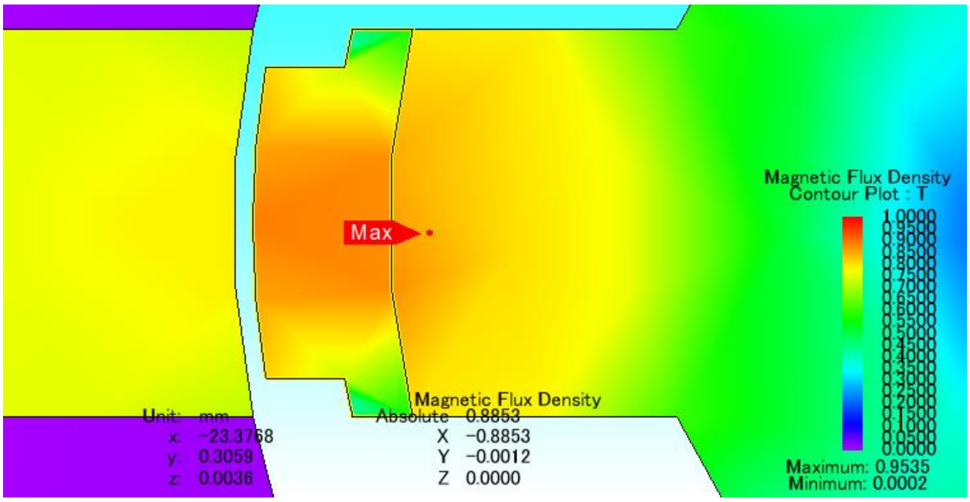

Figure 8: Permanent magnet demagnetization of Design 1

According to Figure 8, the value of flux density for permanent magnet Design 1 was 0.8853T. By referring to the B-H curve of the NdFeB permanent magnet in Figure 7, the permanent magnet of Design 1 would be demagnetized if the flux density reaches 0.9T and above. In this case, the permanent magnet was safe from being demagnetized since the flux density was lower than 0.9T. The flux density value of permanent magnet Design 2 was 0.6409T. By referring to the B-H curve of the NdFeB permanent magnet in Figure 9, the permanent magnet of Design 2 would be demagnetized if the flux density achieves more than 0.9T. In this case, the permanent magnet was safe from being demagnetized since the flux density was lower than 0.

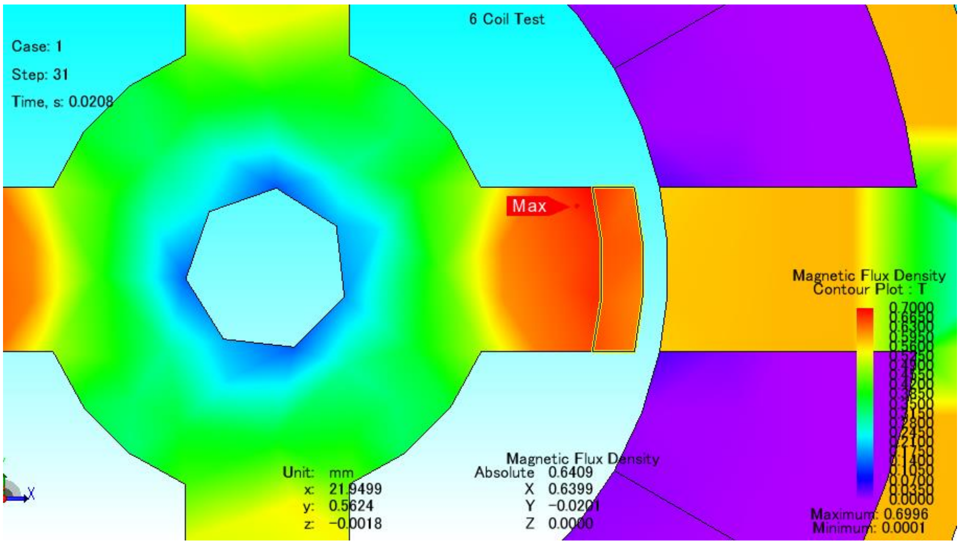

Figure 9: Permanent magnet demagnetization of Design 2

In full load condition, the output torque versus armature current density and output torque, power versus speed of PMSM could be determined in Figure 10.

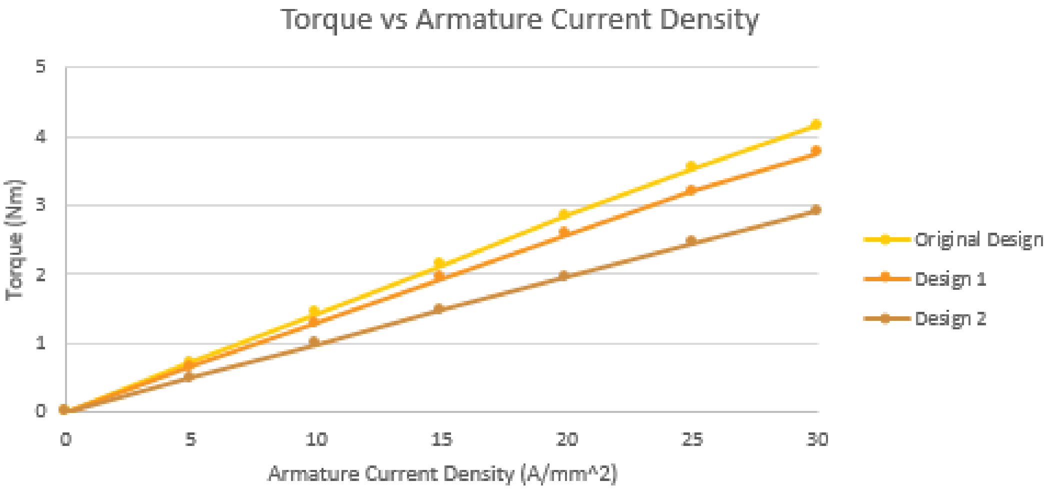

Figure 10: Output torque vs armature current density of PMSM

The highest injected armature current density was 30A/mm2 with a decrement of 5A/mm2. The output torque was directly proportional to the armature current density. If the armature current density increased, the output torque of PMSM was increased as well. The output torque of the PMSM for original design was 4.16Nm with the highest value of armature current density which was 30A/mm2. The lowest value of armature current density was 0.0001A/mm2. Meanwhile, the highest value of output torque for Design 1 at 30A/mm2 was 3.77Nm with 30A/mm2 while the lowest value of output torque was 0Nm at 0 A/mm2. In addition, the highest value of output torque for Design 2 at 30A/mm2 was 2.91Nm. The lowest value of the output torque at 0 A/mm2 was 0.00004Nm which was a very small value of output torque. The demagnetization value of Design 1 was lower than the original design about 6.14%. However, the output torque of the Design 1 decreased as well. The output torque drops about 9.38% with the same injected value of armature current density which was 30A/mm2 at the 729.23rpm. Furthermore, the demagnetization value of the original design and Design 2 also could be compared. The demagnetization value of Design 2 dropped about 32.05% compared to the original design. The output torque of Design 2 was lower than the original design by about 30.05%. According to the observation, Design 1 had better output torque than Design 2 even though the demagnetization reduction of Design 2 higher was than Design 1. Since the output torque reduction of Design 2 dropped too much, so Design 1 had better performance compared to Design 2.

4. Conclusion

In conclusion, the three phase 6 slots 4 poles of PMSM have been constructed. The partial irreversible demagnetization was successfully applied in all designs and simulated using JMAG software. So, the first and second objectives of this study were achieved. Based on the observation, the demagnetization value of the original design, Design 1 and Design 2 can be compared. Other than that, Design 1 and Design 2 was able to minimise the demagnetization value on NdFeB permanent magnets. It helps to increase the lifespan of a PMSM permanent magnet. Therefore, the third objective of this study was achieved by proposing Design 1 and Design 2.

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