A study on Double Layer V-Shape Magnet Type IPMSM design in view of demagnetization

Ji-Han Lee[1], Jin-Seok Kim[1], Yong-Jae Kim[2], Sang-Yong Jung[1]

1. School of Electrical Engineering, Sungkyunkwan University, Suwon, 440-746, Korea
2. Department of Electrical Engineering, Chosun University, Gwngju, 61452, Republic of Korea

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Background

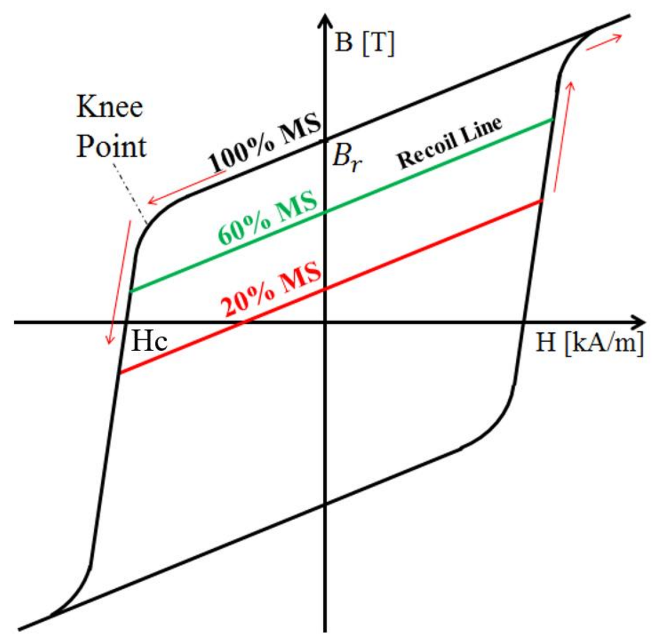
Among the various industries, the use of IPMSM in electric vehicle is increasing.In particular, in the case of an electric vehicle drive motor, the mechanical strength of the rotor is important because it operates in a high-speed operation region.Therefore, the double layer V-shaped magnet type IPMSM is more widely used in electric vehicles currently selling, because the double layer V-shaped magnet has better mechanical strength than other shapes.
However, in the case of a double layer V-shaped magnet, the total magnet amount is similar to other magnet shapes, but it is thinner than the thickness of one layer magnet type because it is composed of two layers. Since the thickness of the magnet has a great influence on the demagnetization, the double layer V-shaped magnet made of two layers is vulnerable to demagnetization.
Therefore, in this paper, we study the design method of the double layer V-shaped IPMSM

Conclusion

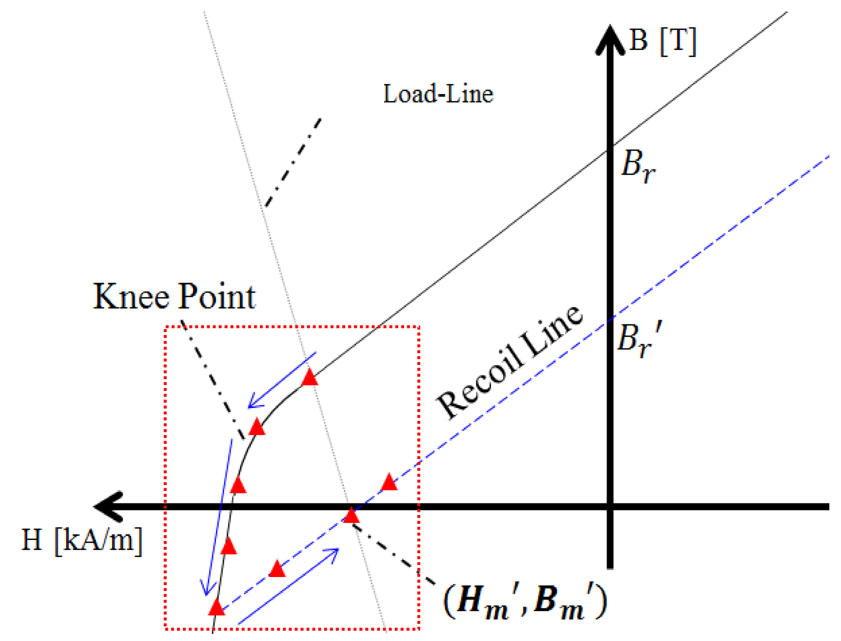
- In the case of double layer v-shape magnet type PMSM, High demagnetization ratio at both ends of magnet
- In the case of demagnetization generated at both ends of the magnet, demagnetization ratio tends to decrease when using flux barrier
- However, in the case of demagnetization generated inside the magnet, after the specific flux barrier size, the demagnetization ratio tends to be rapidly increased due to the concentration of the flux by the barrier
- Therefore, in the case of demagnetization inside the magnet, it is necessary to other design parameters for anti-demagnetization
- Because the performance of the motor varies depending on the size of the flux barrier, it is important to calculate the flux barrier size considering the design spec.

Demagnetization

Permanent Magnet Charateristic



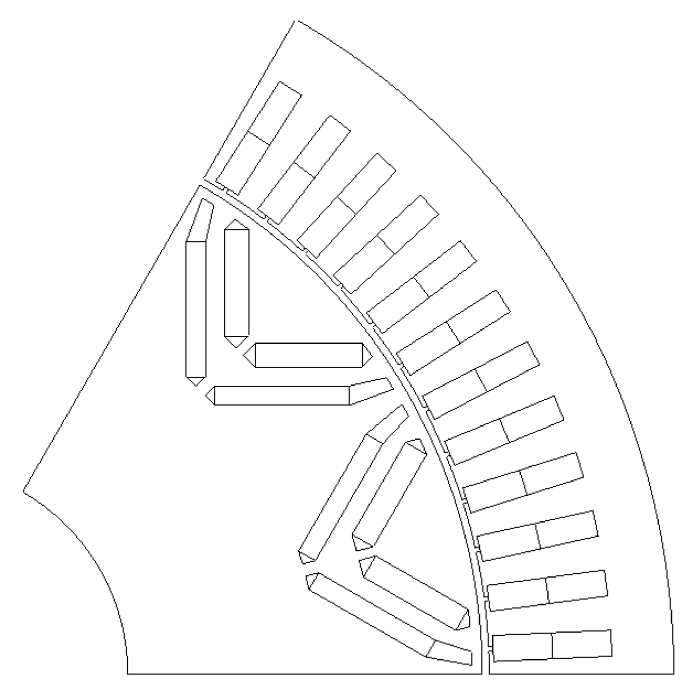
- The larger the residual magnetic flux density (Br), the stronger the magnetic force
- The larger the coercive force (Hc), does not easily lose magnetic force
- The lower the Knee Point, does not easily lose magnetic force
- Losing magnetic force is called as demagnetization



- When the operating point of the permanent magnet is formed below the knee point, it becomes demagnetization
- Because the permanent magnets is demagnetization, the operating point is formed along the recoil line.

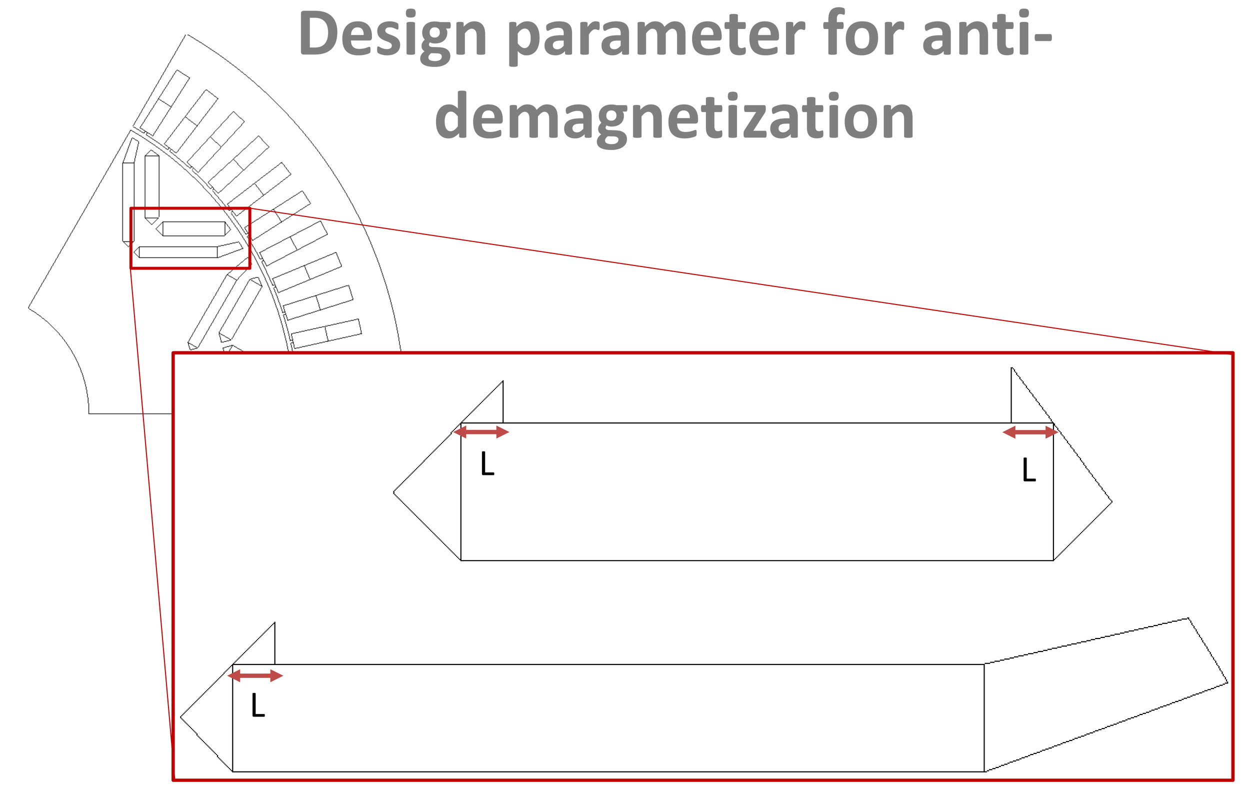
Analysis Model

Spec & Model design



Classification	Spec
# pole / # slot	12 / 72
Mag spec	N48(100℃)
Core spec	50JN270
Outside diameter	150 mm
Air gap length	0.7mm
Stack length	80 mm
RPM	3000
Input Current	440 A

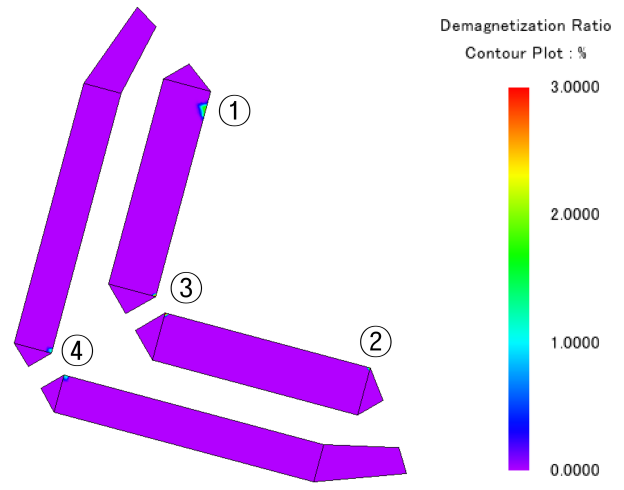
Design parameter for anti-demagnetization

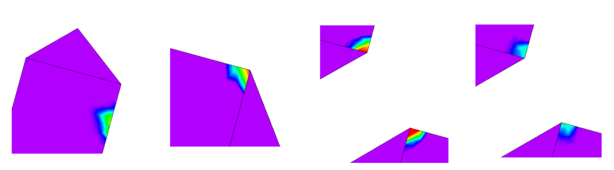


- The rotor flux barriers are set as design parameters. Rotor flux barriers can prevent irreversible demagnetization at both ends of the permanent magnets while maintaining the thickness of the permanent magnets

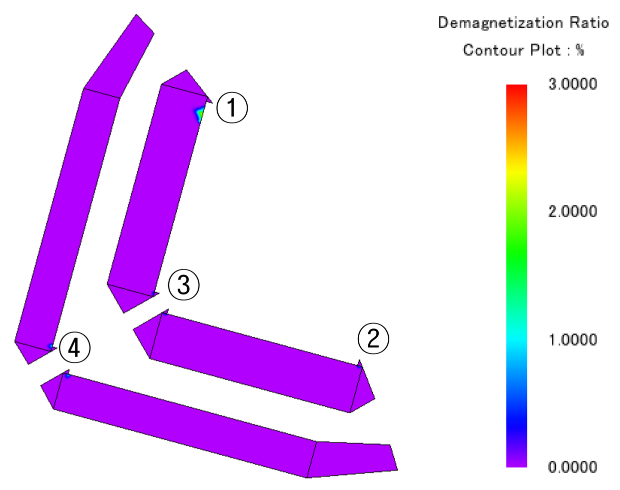
Demagnetization Analysis

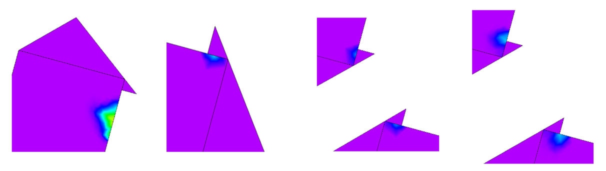
Model 1 (L=0)



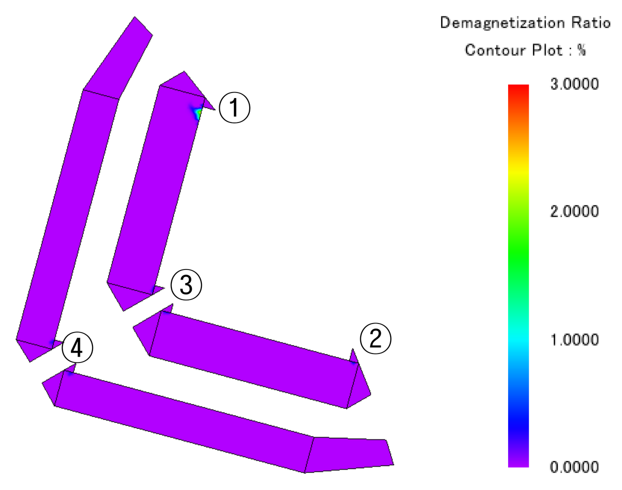
Detail	①	②	③	④
Demag Ratio Contour				
Max Ratio	2.39%	6.24%	9.3%	1.48%

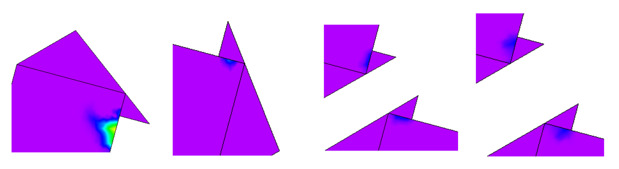
Model 2 (L=0.25)



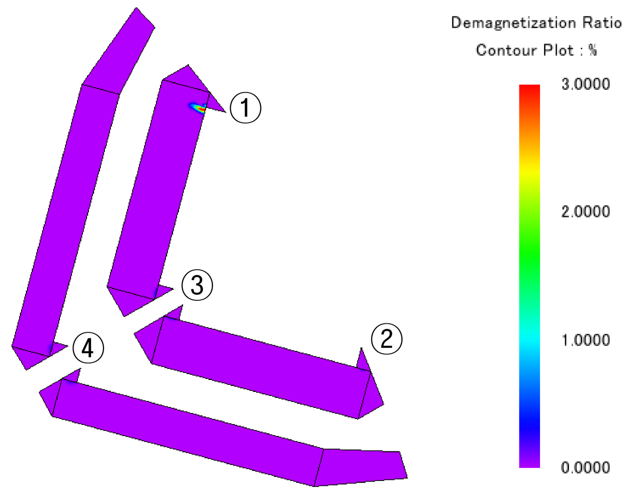
detail	①	②	③	④
Contour				
Max Ratio	3.29%	1.63%	1.29%	1.57%

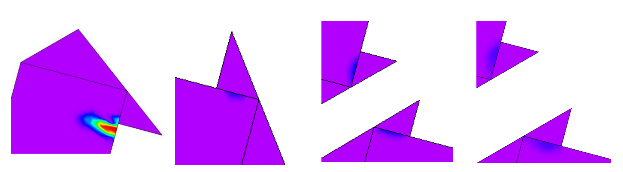
Model 3 (L=0.5)



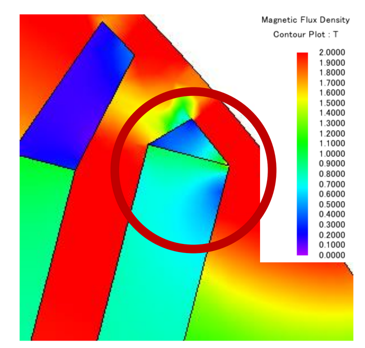
detail	①	②	③	④
Contour				
Max Ratio	2.79%	1.17%	0.69%	0.40%

Model 4 (L=0.75)

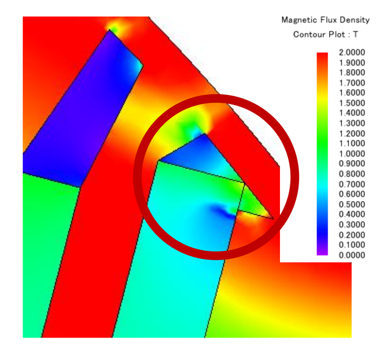


detail	①	②	③	④
Contour				
Ratio Max	37.25%	0.52%	0.43%	0.2%

Anaysis



<Model 1 Flux Density>



<Model 4 Flux Density>

- For demagnetization from both ends of the magnet, we can identify reduction of the rate of demagnetization when using the flux barrier. (②~④)
- However, in the case of demagnetization not at both ends, the flux barrier tends to increase the demagnetization ratio by concentrating the flux as shown above. (①)

Moter Performance Analysis

Performance	Model 1	Model 2	Model 3	Model 4
Average torque	140.28 Nm	140.41 Nm	140.31 Nm	139.91 Nm
Torque ripple	7.15 %	7.053 %	6.87 %	7.50 %
Cogging Torque	1.32 Nm	0.68 Nm	0.49 Nm	1.58 Nm
Back EMF THD	4.53 %	4.90 %	5.33 %	5.10 %

- From Model 1 to Model 3, as the flux barrier increases, the average torque is maintained, the torque ripple and cogging torque tend to decrease, and THD tends to increase..
- In the case of Model 4, the demagnetization ratio inside the magnet rapidly increases due to the flux barrier, so that it shows the different trend.