A Study on Design of IPMSM for Reliability of Demagnetization Characteristics-based Rotor
Geochul Jeong¹, Hyungkwan Jang¹, Hyunwoo Kim¹, Ju Lee¹

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Background

- The IPMSM used in this study is a traction motor for railway vehicles, and it is located at a low part of a railway vehicle and has a totally enclosed type structure to block the inflow of dust and foreign substances during operation.
- Since the traction motor for railway vehicles desperately should have high power density, the rare earth neodymium permanent magnet with high residual magnetic flux density was used to increase power density.

Objectives

- The totally enclosed type structure of the IPMSM is vulnerable to temperature because heat does not circulate within it, and the neodymium permanent magnet has a property of being demagnetized at high temperature.
- If a power converter breaks down, high current may flow. This high current creates a large reverse magnetic field, and this reverse magnetic field also may generate demagnetization.
- Therefore, this paper proposes a analysis method of demagnetization characteristics that considers the recoil line based on FEM.
- Development of next-generation railway vehicles recently aims at energy saving and weight-lightening so that a rare-earth permanent magnet with high energy density is applied to a synchronous motor, and a considerable number of interior permanent magnet synchronous motors which have power density than those of an induction motor have been developed.

IPMSM for Traction of Railway Vehicles

![Fig. 2 Torque-speed curve and IPMSM model (a) Required traction force curve per railway vehicle motor (b) IPMSM model for traction of railway vehicles](image1)

![Fig. 3 IPMSM torque waveform for traction of railway vehicles](image2)

Analysis Method for FEM-based Demagnetization Characteristics

**A. Analysis Method for FEM-based Demagnetization Characteristics**

- The demagnetization analysis is definitely necessary, and the analysis result shows that the phenomenon of being permanently demagnetized by the new recoil line occurs. Therefore, this paper proposes an analysis method of demagnetization characterization that considers the recoil line.
- The analysis of demagnetization characterization that considers the recoil line shows that as the temperature rises during operation of the motor in Fig. 4, the B-H curve changes and the permeance coefficient changes by the reverse magnetic field during the load.
- We have constructed the scenario in this paper that the motor is actually operated, and have studied the analysis method of the demagnetization characteristics by considering the recoil line.
- Scenario T1 is the driving section under the no-load condition.
- T2 is the driving section under the 100% and 200% load condition.
- T3 is the section that the demagnetized counter electromotive force is identified after driving (reverse magnetic field) under load.

Conclusion

- This paper describes a study on an analysis method of demagnetization characteristics of a permanent magnet synchronous motor based on the FEM (finite element method).
- The totally enclosed type structure of the IPMSM is vulnerable to temperature, and if a power converter breaks down, high current may flow so that it is definitely necessary to consider analysis of the demagnetization characteristic in the design and analysis stage.
- This paper proposed an analysis method of demagnetization characteristics by considering the recoil line based on FEM.
- This proposed method quantitatively predicted effects of the demagnetization through the Back electromotive force and magnetic flux distribution, and its reliability was improved by reanalysis after changing material.
- Validity of the analysis method proposed by the temperature saturation test and the performance test of the prototype was proven, and in conclusion, an analysis method process of the FEM-based demagnetization characteristics was also established.

![Fig. 1 Demagnetization analysis results](image3)

Prototyping and Performance Test

- As the permanent coefficient \( C_m \) becomes \( C_m \) during load, and the permanent demagnetization of the IPMSM caused by high temperature and by the reverse magnetic field occurs at constant force of \( 350 \text{ A/m} \) and a magnetic flux density of \( 1.3 \text{ T} \).
- As this line, a curve was drawn from point a to point b, and the demagnetization process is completed.

![Fig. 10 IPMSM prototype](image4)

![Fig. 11 Torque property comparison of IPMSM at 2400rpm](image5)

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