Hysteresis Torque Analysis of Permanent Magnet Motors Using Preisach Model

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Abstract — In the paper, the method of computing hysteresis torque of permanent magnet motor using Preisach model is studied. Generally, finite element method (FEM) with Preisach model is very complicate because of nonlinear characteristic of materials. Preisach hysteresis model is not combined with solver but post-processor of FEM. This process is easy to find hysteresis loop of soft magnetic material.

I. Introduction

Hysteresis phenomena of metals such as iron are applied to various area from industrial applications using magnetic energy to magnetic storage devices in data storage area. Hysteresis loss is generating the braking torque in permanent magnet motors. Such as electric power steering(EPS) motor, the braking torque occur serious problems in restoring operating. The performance of restoring force in vehicle steering wheel is determined by hysteresis torque in special control required system or EPS.

In the recent trend of analysis hysteresis loss, the FEA which combined with hysteresis model is used. However, complex processes such as realization of analysis method and formulation of finite element are gone through to apply hysteresis phenomena to finite element analysis [1-2]. In this study, the result of FEM is applied to Preisach model and computed the loss and torque of permanent magnet motors. The method in consideration of complicated hysteresis phenomena using FEM is considered easier and defined as post-Preisach analysis. In the result, hysteresis torque is compared simulation and measurement of permanent magnet motor to verify the validity of analyzing method.

II. Hysteresis Torque

A. *Hysteresis torque in Permanent magnet motor*

Generally, in motors that permanent magnet is applied, the phenomenon of cogging torque takes place by slots and poles. There have been many researches conducted on the cogging torque, suggesting design methods to reduce it. However, as suggested by some researches, the cogging torque can be evaluated with its amount suggested, except the friction torque, in the domain of zero torque. When the cogging torque is measured, the friction torque of a motor is measured by adjusting the offset to 0 point in the device. Nevertheless, in some cases of actual measures, the cogging torque alters to neither positive (+) nor negative (-) directions, showing offset measures. The reason seems to be because of the bearing friction and the hysteresis torque.

When field intensity is sustained as 0, flux intensity takes place due to the magnetic domain. When PM of fig.1 moves to the direction of *F*, force does not act on the premise that the iron core on the low side is flat and the friction of mover does not exist. However, since flux density is sustained onto the iron core on the low side due to the hysteresis phenomenon, braking force occurs into the reverse direction of *F*. Force taking place due to the hysteresis phenomenon is called hysteresis force.

This hysteresis torque creates the offset phenomenon of cogging torque as shown in fig. 2. Such a phenomenon makes it difficult to secure the linearity when controlled in the range of hysteresis torque, and it also acts as a large exterior braking torque in a precise system with gear ratio. Small friction is translated to geared output torque as large friction torque in the geared motor.

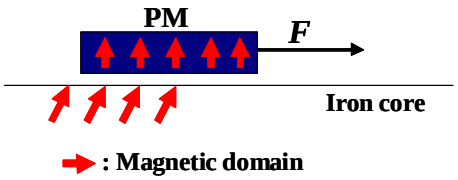

Fig. 1. Hysteresis force in linear motion

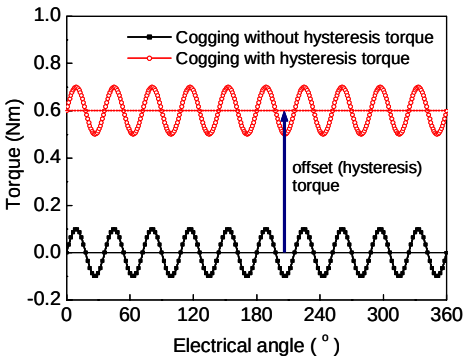

Fig. 2. Hysteresis torque of rotational electric motor

B. *Analysis Model*

The model used in experiment and analysis is composed of 6pole and 9slot as shown in fig. 3 and has shape of IPM. Stator outer diameter is 86mm and stack length is 50mm.

C. *Analysis Methods*

In the paper, conventional FEM code is used for calculating the field strength of magnetic cores. Preisach model is applied to post-processor in FEA. Post-Preisach analysis is conducted after H, B field is saved in solving processor. Post-Preisach analysis is plotted in fig. 4.

III. RESULT AND EXPERIMENT

Torque detector (AMT-2) of Sugawara Corporation is used for hysteresis torque test. Test equipment and motor is shown in fig. 5. Test equipment is composed of analysis model, which is the EPS(Electric Power Steering) motor. Bearing friction torque and cogging torque are removed after cogging torque is measured which includes offset due to the difficulty in direct measurement of hysteresis torque.

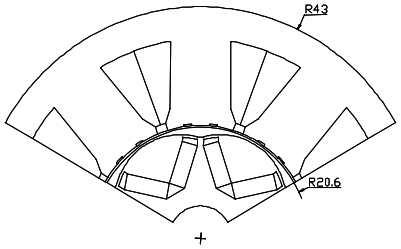

Fig. 3. The cross-section view of analysis model

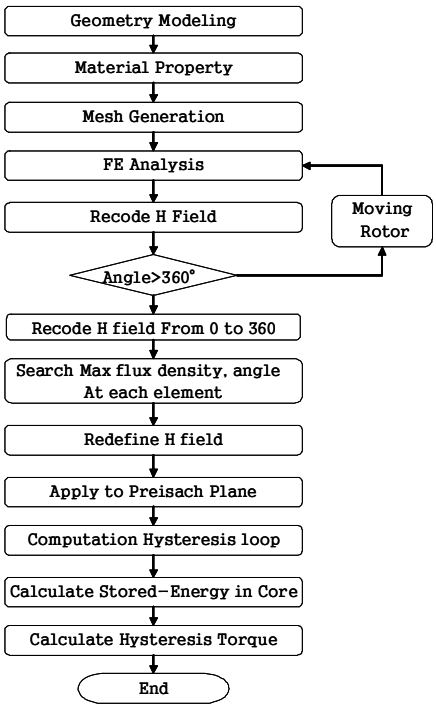

Fig. 4. Post Preisach analysis for hysteresis analysis

The simulation result of hysteresis torque is plotted in fig. 6. Movement of initial ascending section follows initial magnetizing curve by the analysis. Initial ascending section is removed due to no meaning by analysis. Hysteresis torque is considered in the section of over 60° where half of period is passed. Average value is 22.7mNm in the section of over 60°. Especially hysteresis torque is shown by not only effect of offset but also value of periodic change by combination of hysteresis teeth and slot.

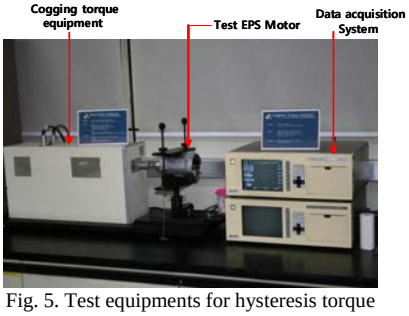

Fig. 5. Test equipments for hysteresis torque

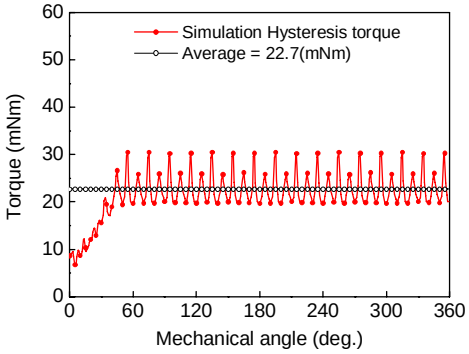

Fig. 6. Simulated hysteresis torque

IV. CONCLUSION

In the paper, the method of considering hysteresis phenomenon using FEM is suggested. Preisach model is applied to post processing for realization of hysteresis model. Other interesting result and detailed descriptions on experiments and analysis will be included in the full paper. This method is useful for considering hysteresis phenomenon in FEA.

ACKNOWLEDGMENT

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V. REFERENCES

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