THE SUMMARY OF Ph. D. DISSERTATION

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Title

A Study on Analysis of Iron Loss and Temperature of Switched Reluctance Motor by Finite Element Method

Abstract

This thesis describes the analysis of iron loss and temperature of Switched Reluctance Motor(SRM) by Finite Element Method(FEM). For the design of SRM, many researchers have studied the characteristics of performance, drive circuit, vibration, efficiency, control, etc. Especially, the efficiency is one of the most important factors for saving energy. The efficiency in SRM is greatly affected by the iron loss generated due to the variation of flux density, the iron loss is needed to be estimated correctly. Since last ten years, however, few papers about the estimation of iron loss of SRM have been reported by the numerical approach.

In this thesis, a simple estimation method of iron loss is proposed. In addition, temperature analysis that is taken into account the temperature rise in the inside air of SRM has been implemented in terms of the estimated iron and copper loss. In conclusion, the validity of these analyses can be shown.

The thesis consists mainly of six chapters and its contents are as follows.

In Chapter 1, 2, the introduction and basic theory of FEM and SRM are described. The governing equation of electromagnetic field and heat transfer for the FE analysis, and the operation principle, and the fundamental characteristics of SRM are summarized.

In Chapter 3, the effects of iron loss on the fundamental characteristics were examined from the results of experiments. For verifications, the experiments were implemented using by the same size and shape of prototype SRMs made from the steel sheets with the different characteristics of iron loss. From these experiments, iron loss can be found to be much bigger than the others and reach about 50% of input power. Therefore, it is clearly verified that iron loss is the important factor for efficiency of SRM. For the high efficiency, it is desirable to apply the steel sheets with low iron loss, and the numerical estimation of iron loss is needed.

In Chapter 4 a simple estimation method of iron loss is proposed. This method is based on 2D analysis by FEM. In this method the iron loss is evaluated by Fourier transform and the classification of shape of flux density inside the iron core, which is simpler and has lower cost than the conventional method. Compared between the estimated results and experimental ones in two types of SRM, the validity of this method can be shown. On the other hand, the laminated iron steel has the less property in iron loss, that is, the eddy current loss rises 5-6 times as much as catalog data. And this causes the large error for loss estimation. In order to investigate this error, the eddy current was analyzed numerically in two-layer lamination model, and it is found that the effect of lamination does not work well even if the lamination is broken slightly at both ends. Thus iron loss can be calculated with accuracy, using the parameters obtained by combination of experimental and FE analysis results.

In Chapter 5 the temperature rise in SRM was analyzed. The heat source for the analysis is iron loss and copper loss obtained in former chapter. The analysis is carried out by both 2D and 3D, and compared with the experimental results. From 2D analysis results, the large error is shown because of the lack of the modeling of the frame of SRM. Therefore, it is clear that the 2D analysis is not valid for the temperature rise analysis of SRM. In addition, the convection between iron and inside air of SRM was discussed because the temperature in the inside air rises. For this reason, a model of the temperature rise in the inside air was introduced. This equation is separately defined from the FE analysis and solved simultaneously by the iteration method. From the comparison with experimental results, the distribution of steady temperature can be obtained with accuracy. And it is shown that the temperature in the rotor is higher than that in the stator. Consequently, the temperature rise estimation in the points where it is difficult to measure temperature can be obtained such as temperature in the rotor and the coil. On the contrary, time constant is different from the experiment results. From these results, it can be mentioned that the more detailed modeling of temperature rise in the inside air is need for more accurate analysis.

In Chapter 6, the proposed methods in the thesis and their results are summarized. FEM is concluded to be useful approach for the research and development of SRM.