Pre-Processing for Deep Learning of Motor Characteristics Using Empirical Mode Decomposition

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Abstract

The novel preprocessing method to improve the prediction accuracy of deep learning (DL) has been proposed. In the proposed method, the Empirical Mode Decomposition (EMD), one of the frequency decomposition methods, is applied to the gap magnetic flux density distribution, the input data of DL. The method is applied to DL to predict motor characteristics.

1 Introduction

Numerical analysis techniques such as the Finite Element Method (FEM) are widely used to improve the efficiency of the electrical equipment design process. This method provides a detailed understanding of physical phenomena. However, the analysis time increases depending on the calculated characteristics, especially motor characteristics. Therefore, Deep Learning (DL) methods have been proposed for the fast prediction of motor characteristics [1][2]. In order to predict the characteristics of various rotor magnetic structures, the motor characteristics are predicted from the gap magnetic flux density distribution between the rotor and stator of the motor [2]. However, the prediction accuracy of the method is poor and effective improvement is expected from data pre-processing. For this reason, the novel data pre-processing method using Empirical Mode Decomposition (EMD) [3] is proposed to improve the prediction accuracy of DL. EMD generates multiple Intrinsic Mode Functions (IMFs) from the input data to extract characteristics and then improve DL training accuracy.

In this paper, the method is applied to DL model to predict the average torque and torque amplitude of Permanent Magnet Synchronous Motors (PMSMs).

2 Proposed method

2.1 Convolutional Neural Network for Torque Characteristics

The overview of the proposed method is shown in Fig. 1. In this paper, the 1D-Convolutional Neural Network (1D-CNN) is applied to the prediction model of average torque and torque amplitude. In order to obtain data with various magnetic structures, the NGnet-On/Off method, one of the topology optimization methods is employed [4]. The 10,000 data are calculated by FEM during topology optimization and are split 8:2 into training and test data.

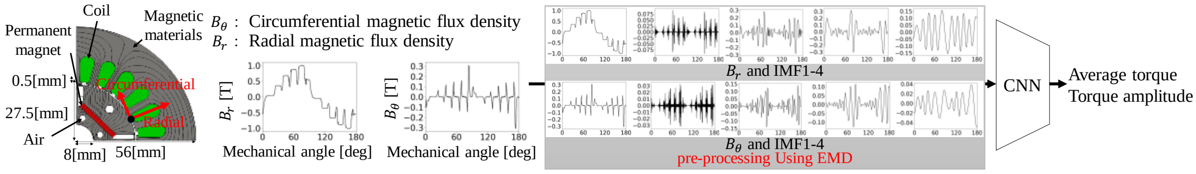

Figure 1: Overview of the proposed method

2.2 Preprocessing method using Empirical Mode Decomposition

EMD is a method for decomposing a nonlinear waveform $x(t)$ into multiple IMFs [3] defined by

$$x(t) = \sum_{i=1}^{n} \mathrm{IMF}_i(t) + r(t) \qquad ,(1)$$

where, $r(t)$ is a residual of $x(t)$. IMF is a function that satisfies the following two conditions: First, the difference between the number of extreme values and the number of zeros of the signal is 0 or 1. Second, the mean value of the envelope connecting the maxima and minima at any given time is zero.

In the proposed method, EMD is performed on the gap flux density distribution, and IMFs of IMF_1 to IMF_4 are used for input of the 1D-CNN. The input data consists of 720 points, and the output of 1D-CNN is the average torque and torque amplitude. Each IMF is broken down into narrow bands, and using their characteristics as inputs are thought to improve the accuracy of the prediction.

3 Results and Conclusion

The losses calculated on the training data is shown in Fig. 2. It is confirmed that the loss of training data is improved by preprocessing using EMD. In the full paper, the generalization performance of the proposed method will be discussed in detail.

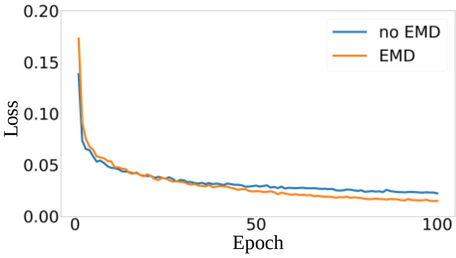

Figure 2: Training curve for training data

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