STUDY OF INDUCTANCE CALCULATION IN PERMANENT MAGNET TYPE TRANSVERSE FLUX LINEAR MOTOR

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INTRODUCTION

In the design and analysis of electrical machines, mathematical models are often required for performance assessment and system simulation. Inductance is an important parameter of the models.

Inductance can be classified into three kinds such as apparent, L_{app}, effective, L_{eff}, and incremental, L_{inc}, inductances [4]. While the apparent inductance is the parameter that can be compared to the value of measurement, the incremental inductance can be the essential parameter for system simulation.

Generally, there are several application examples of inductance calculation method for transformers or longitudinal flux motors [1-4]. However it is difficult to find an inductance calculation method for transverse flux machines. Moreover the methods used for longitudinal flux machines need to be changed and supplemented for transverse flux machines because winding shapes and flux paths are quite different.

Therefore, this paper deals with simple and effective calculation methods of both apparent and incremental inductances for a permanent magnet (PM) type transverse flux linear motor (TFLM) that is fabricated as a vibrator. Firstly the analysis model is divided into three parts according to coil shapes and flux paths because the coil is too long to model the whole shape. The inductance calculation methods then are explained for each part. The flux or energy used to calculate the inductance of the TFLM is obtained by three-dimensional equivalent magnetic circuit network (3D EMCN)[5]. The calculation method is verified by comparison of the calculated inductances and test data of the machine.

ANALYSIS MODEL

Figure 1 shows the part of 3D configuration of TFLM. The mover consists of 7 iron poles and 8 permanent magnets, and 2 coils are wound on the stator, which comprises 20 pairs of poles. Table 1 presents the specification of the machine.

Figure 2 shows the configuration of one phase coil that is divided into three parts, and the three analysis model shapes are different from each other. Pt_M is the coil part where the main flux exists and thrust occurs. Pt_L is the part where leakage flux exists, and Pt_E is the end coil part.

To consider the inductance of the actual model, the obtained inductance from analysis model is multiplied by the multiple-ratio in Table II. The multiple-ratio of Pt_M is decided by the ratio of the number of mover pole. The number of mover pole is 2 in analysis model and 7 in actual model, and the ratio can be 3.5. For Pt_L, the round number of the length ratio is taken.

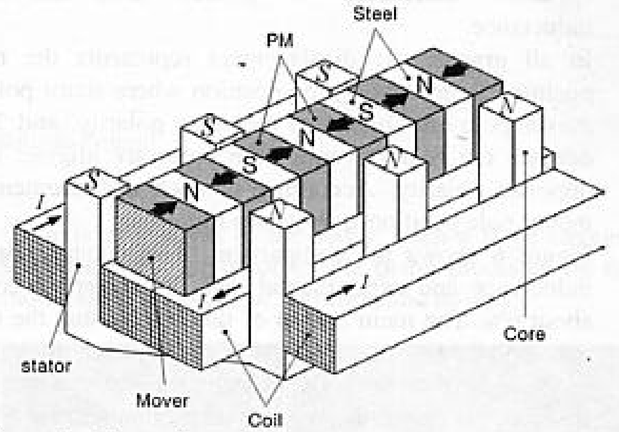

Figure 1: Three-dimension partial configuration of TFLM

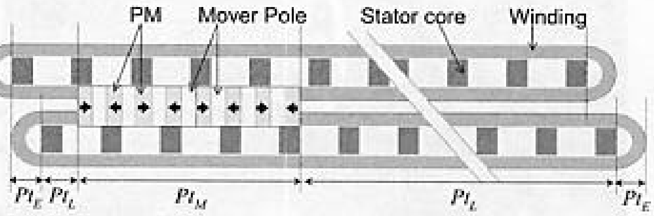

Figure 2:Whole coil configuration of one phase(top view)

TABLE 1- Specifications of TFLM

Stator	No. of Pole	20 pair
	No. of turn	140 turn
	Rated Current	20 A
	Material	S12
Mover	No. of Pole	7
	Permanent Magnet	Br=1.7 T, μ=1.05
	Material	S20C

TABLE 2- Length and Multiple ratio of TFLM

	Analysis Model	Actual Model	Length-ratio	Multiple-ratio
Pt_M	40 mm	150 mm	3.75	3.5
Pt_L	40 mm	714 mm	17.85	18

INDUCTANCE CALCULATION METHODS

Figure 3 shows each inductance calculation method for TFLM. The analytical method is needed to calculate the inductances of Pt_M and Pt_L, however the end coil inductance, L_{end} can be obtained by the experimental inductance [7]. By summing these inductances of three parts, apparent and incremental inductances can be obtained for current change.

CALCULATION AND EXPERIMENT RESULTS

Figure 4 shows the incremental inductances for current variation. These are the sum of each incremental inductance of Pt_M and Pt_L, and the leakage inductance of Pt_E. The apparent inductances are also calculated for current variation as shown in Figure 5. Since this TFLM is saturated partially even in the case of zero current, the apparent inductance is greater than incremental inductance.

In all graphs, the displacement represents the mover position. 0mm denotes the position where stator pole and mover pole are aligned in the same polarity, and 20mm denotes the position where the poles are aligned in the opposite polarity. According to each displacement, the mover pole position is shown in Figure 5.

Figure 6 shows the comparison of calculated apparent inductance and experimental data. The average error is about 6%. The main reason of the error is that the test is accomplished with 60Hz AC current even though the analysis is done with DC current for static state. If the frequency is lower, the error could be smaller than 5%.

CONCLUSION

In this paper the efficient calculation methods of apparent and incremental inductances are proposed for PM type TFLM. Considering the coil shape of the machine, the analysis model is divided into three parts, and the calculation methods are explained for each part. The apparent and incremental inductances are computed by the sum of each part inductance, which is calculated with the parameter obtained from 3D EMCN. The calculation results are compared with the test values, and the comparison show the validity of the calculation methods. It is expected that those inductances, calculated in this research, can be used practically as reliable parameters in dynamic simulation preceding controlling TFLM as a vibrator.

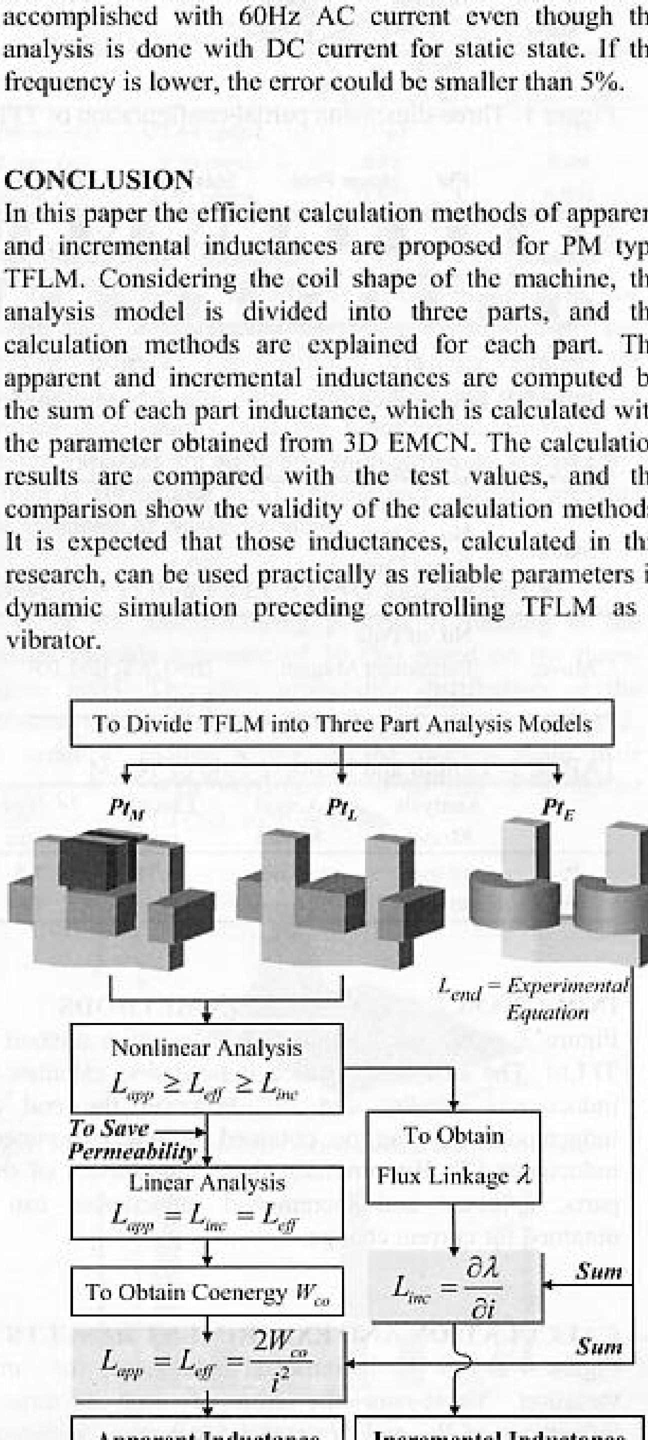

Figure 3: Inductance Calculation Method of TFLM

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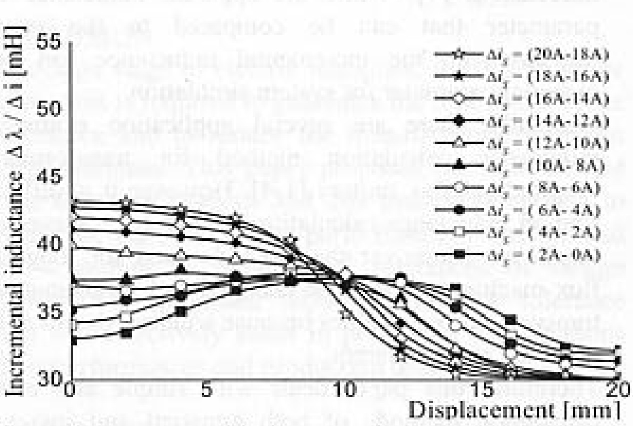

Figure 4: Incremental inductance for current variation

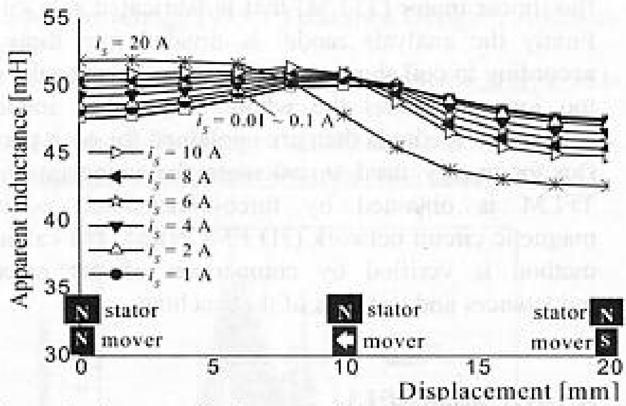

Figure 5: Apparent inductance for current variation

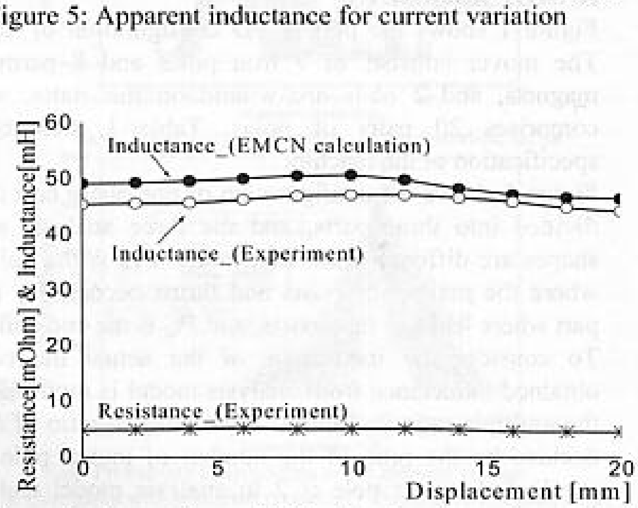

Figure 6: Comparison of Calculated and experimental inductances for stator current i_s 4A

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