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Design, Fabrication, and Characteristics Experiment of a Large LVDT Sensor for of Bottom Mounted CRDM

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1. Introduction

A bottom mounted control rod drive mechanism (BMCRDM) in a research reactor is composed of an electromagnet, stepping motor, ball screw, guide tube, armature and extension shaft assembly, damping mechanism and Linear Variable Differential Transformer (LVDT) as shown in Fig. 1. The stepping motor directly drives the ball screw, and the nut of the ball screw makes the electromagnet move up and down along the guide tube. At this time the higher force of an electromagnet will greatly result in less position fluctuation of the armature for a given variation of loadings. The magnetic rigidity represents one of the most important characteristics of the electromagnet. For this reason, it is necessary to measure control rod position including sagging rate due to loadings exactly. Therefore, KAERI has developed electromagnet rigidity measuring sensor using LVDT. This paper presents the case numerical and experimental research of prototyping a large LVDT sensor for BMCRDM. [1][2][3]

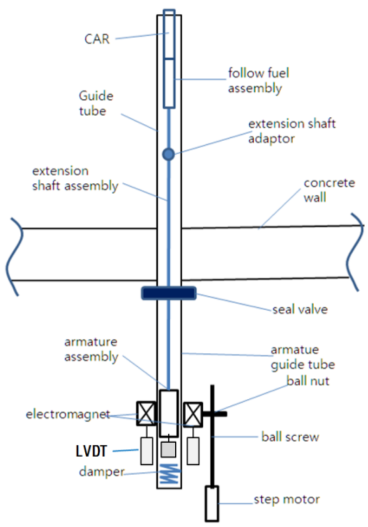

Fig. 1. Schematic of BMCRDM.

2. LVDT Sensor for Electromagnet Rigidity Measurement

A large LVDT Sensor for electromagnet rigidity measurement consists of core, winding housing, primary coil, and secondary coils. Fig. 2 shows a newly proposed LVDT for measuring control rod sagging displacement.

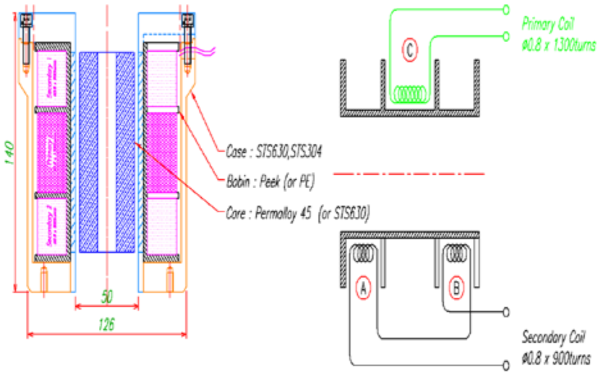

Fig. 2. A detailed view of proposed large LVDT for control rod sagging measurement system.

3. Methods and Results

In this section the numerical magnetic field calculation with FEM for the optimal design of a large LVDT is described and compared with control rod sagging displacement measurement characteristics of fabricated proto-type large LVDT.

3.1 LVDT FEM Analysis Results

In recent year, the FEM has become widely accepted by the engineering professions as an extremely valuable method of analysis. Its application has enabled satisfactory solutions to be obtained for many problems which had been regarded as insoluble, and the amount of research effort currently being devoted to the FEM ensures a rapidly widening field of application. A newly developed technique of the LVDT for such a computation is given in Fig. 3. Fig 4 shows FEM results as induced voltage from secondary coils of LVDT 2D-model. Table 1 shows the input data for electromagnet FEM analysis corresponding Fig. 3 designated names.

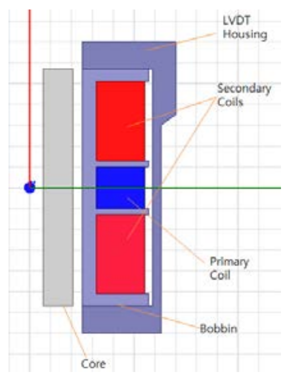

Fig. 3. FEM model of LVDT.

Table 1. Design specification of LVDT model.

No	Component	Material	Remark
1	Primary coil, mm	Copper	24x40, 1300turns
2	Two Secondary coils, mm	Copper	25x28, 900turns
3	Housing	STS630	Ferromagnetic
4	Core	Permalloy 45	L:140[mm] High permeability
5	Input	30*SQRT(2)*Cos(2*pi*70*time), 70Hz, 30Vrms	
6	Initial output	0[V]	
7	FEM solver	ANSYS-Maxwell, Axis-symmetric-Transient	

Fig. 4. FEM result of induced voltage from secondary coils.

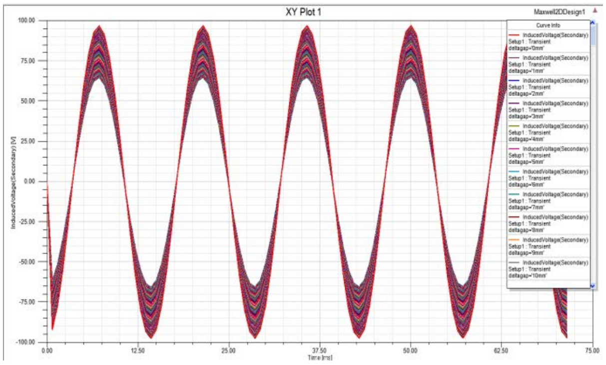

Fig 5 shows summarized induced voltages from secondary coils when the core moves up and down from the center of LVDT. As a result, it is shown that the linearity of the LVDT have a good agreement between 0[mm] and ±70[mm].

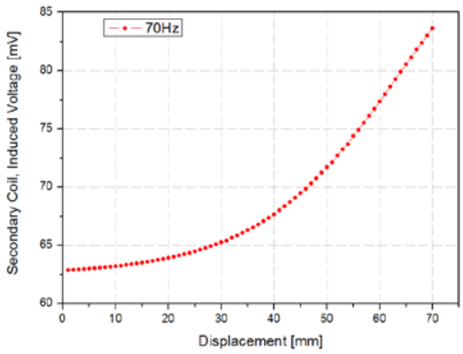

Fig. 5. FEM result of induced voltages

3.2 Experimental Results of Proto-type Large LVDT

Fig. 6 shows the experimental setup for control rod sagging displacement measurement of fabricated proto-type large LVDT which is designed by FEM analysis result. Fig. 7 is the output of the measured result (induced current) of proto-type large LVDT. As a result, the measured result has good linearity agreement of displacement vs. induced currents between 0[mm] and ±22[mm] intervals.

Fig. 6. Experimental setup of proto-type large LVDT.

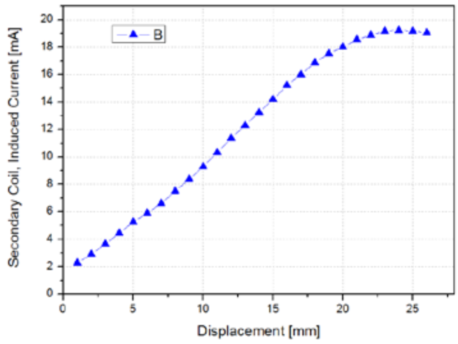

Fig. 7. Experimental result of induced currents

4. Conclusion

The results of FEM and the experiment in this work lead to the following conclusions:

(1) The FEM and experimental results for optimized large LVDT shows good linearity agreement of displacement vs. induced currents between 0[mm] and ±22[mm] intervals. The experimental result has shorter linearity interval than that of FEM result due to 100[mm] core length using experimental test.

(2) The developed FE model and analysis procedure could be useful tools for predicting the linearity of displacement of a large LVDT.

REFERENCES

[1]Hyung Huh et al., “Numerical Research on LVDT Sensor for Electromagnet Rigidity Measurement of Bottom Mounted CRDM,” Transaction of the KNS Spring Meeting, 2014.

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