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Analysis on Electromagnetic Characteristics of Research Reactor Control Rod Drive Mechanism for Thrust Force Improvement

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1. Introduction

The control rod drive mechanism (CRDM) is the part of reactor regulating system (RRS), which is located in the reactor pool top or the room below the reactor pool. The function of the CRDM is to insert, withdraw or maintain neutron absorbing material (control rod) at any required position within the reactor core, in order to the reactivity of the core. There are so many kinds of CRDM, such as magnetic-jack type, hydraulic type, rack and pinion type, chain type and linear or rotary step motor and so on. As a part of a new project, we are investigating the movable coil electromagnetic drive mechanism (MCEDM) which is new scheme for the reactor control rod adopted by China Advanced Research Reactor (CARR) as shown in Figure 1[1]. To have a better knowledge of the electromagnetic and magnetic characteristics, numerical models of MCEDM are proposed. Especially in order to achieve improved thrust force, numerical magnetic field calculations for various kinds of magnetic and electromagnetic configuration have been performed. As a result, we present the improved design of MCEDM for research reactor[2].

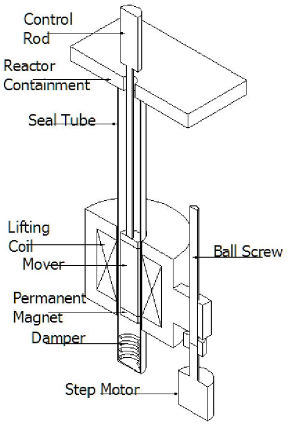


Figure 1. Schematic drawing of MCEDM

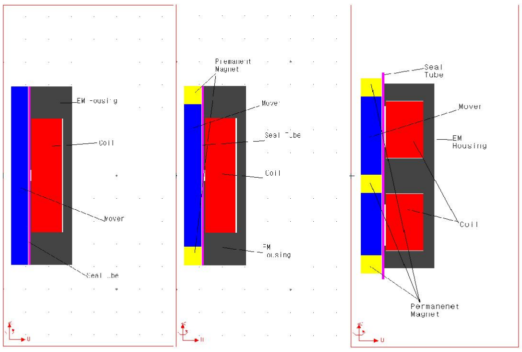
2. Methods and Results

In this section some of the numerical magnetic field calculations with finite element method are described as well as the details of MCEDM configurations for the new CRDM which is operated in the room below the reactor pool.

2.1 Proposed Three Models

The choice of the magnetic circuit (window) shape of electromagnet will mainly depend on the designer's experience in magnetism, since the mathematical treatment of the magnetic circuit is inaccurate in most cases. As many parameters are unknown or can be predicted only with difficulty, such as the operating points of the electromagnet yoke on the hysteresis loop, the influence of small air gaps following mechanical mounting and the magnetic and mechanical tolerances of the mover, calculations of the circuit with the reluctance model, for example, will lead to only rough approximation. In order to achieve improved thrust force, the use of numerical field calculations with finite-element method with the aid of a computer is necessary.

Three different configurations of electromagnet and permanent magnet of MCEDM type CRDM are shown in Figure 2. Figure 2 (a) shows the one-coil type electromagnet. Figure 2 (b) shows the 2PM-1coil type electromagnet which is composed of two permanent magnets and one coil electromagnet, which plays an important role in concentrating magnetic flux inside the electromagnet yoke. Figure 2 (c) shows the 3PM-2coil type electromagnet, which plays an important role in decreasing the magnetic saturation around the electromagnet.



(a) (b) (c)

Figure 2. 2D Electromagnet FE models : (a) one-coil type (b) 2PM-1coil type (c) 3PM-2coil type.

2.2 Electromagnetic 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. Table 1 shows the input data for electromagnet FEM analysis corresponding Figure 3 designated numbers.

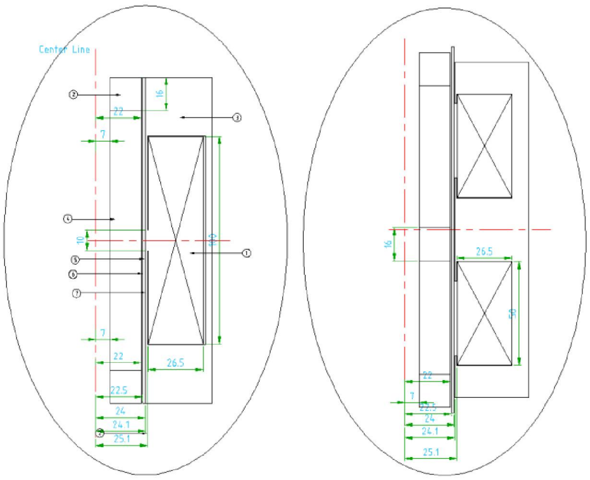


Figure 3. A dimension of proposed electromagnets.

Table 1. A design specification of electromagnet model.

No.	Component	Material	Remark
①	Lifting coil	Copper	26.5x100
			26.5x50
②	Permanent magnet	SmCo28	Hc:820kA/m Br:1.07T
③	Coil housing	S20	
④	Mover	STS430	
⑤	Seal tube	STS316	
⑥	Air-gap 1	Air	0.5mm
⑦	Air-gap 2	Air	0.1mm
	Current	2A	
	Coil Diameter	ф0.75	
	Coil Turn	4,200	
	Space factor	0.7	

A proposed three models for such a computation is given in Figure 4, where the exact course of the magnetic equi-flux of a electromagnet is shown.

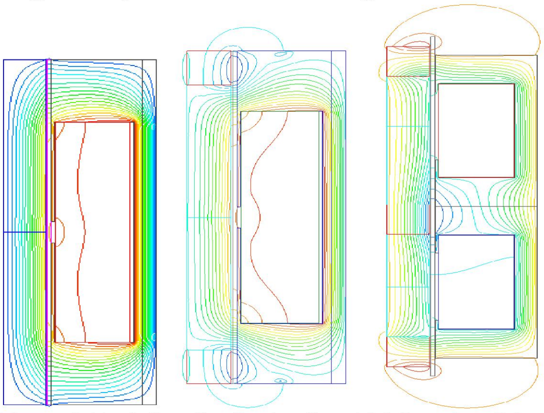


Figure 4. Equi-flux distribution lines FEM results of three electromagnets : (a) one-coil type (b) 2PM-1coil type (c) 3PM-2coil type.

Figure 5 is the results of the FEM analysis. As a result, the thrust force of 2PM-1coil type electromagnet is superior to 3PM-2coil type and one-coil type.

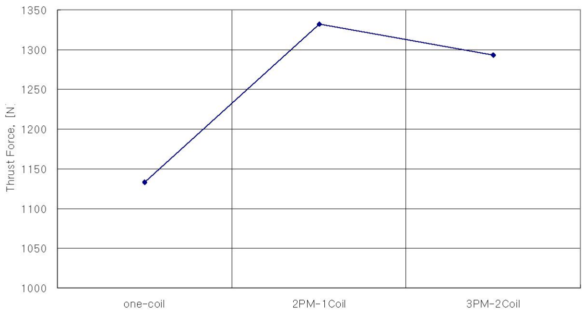


Figure 4. Comparison of thrust force calculation using FEM for proposed three electromagnet models.

3. Conclusion

The main FEM results from the three proposed electromagnet of MCEDM type CRDM are as follows:

(1) The thrust force of 2PM-1Coil type electromagnet is 1,332[Newton] superior to one-coil type and 3PM-2Coil type, and shows the improvement of thrust force about 20% increase than that of one-coil type under the same conditions.

(2) PM helps improve a thrust force of electromagnet slightly.

(3) The developed FE model and analysis procedure could be useful tools for predicting the thrust force of MCEDM type CRDM.

REFERENCES

[1] Ji-Ge Zhang, Hui-jie Yian et al., "Research on the Electromagneic Structure of Movable Coil Electromagnet Drive Mechanism for Reactor Control Rod," J. of Nucl. Sci. and Tech., 44[2] 163, 2007

[2] Hyung Huh et al., "Electromagnetic Analysis of Magnetic-Jack type CRDM for Thrust Force Improvement," Transaction of the KNS Spring Meeting, 2007