A Study on the Electromagnet Thrust force Characteristics of Newly Proposed Hybrid Bottom-mounted Control Rod Drive Mechanism for Research Reactor

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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 (Top-mounted) or the room below the reactor pool (Bottom-mounted). The function of the CRDM is to insert, withdraw or maintain neutron absorbing material at any required position within the reactor core, in order to the reactivity control 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 have investigated 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 Fig.1 [1]. To improve a better function of the electromagnetic and magnetic characteristics, new model CRDM, which is named a hybrid bottom-mounted CRDM (HBCRDM), is proposed. Especially in order to achieve improved thrust force, numerical magnetic field calculations between MCEDM and HBCRDM have been carried out and the HBCRDM FEM results have been compared with the MCEDM FEM results, and FEM results are summarized in the following sections.

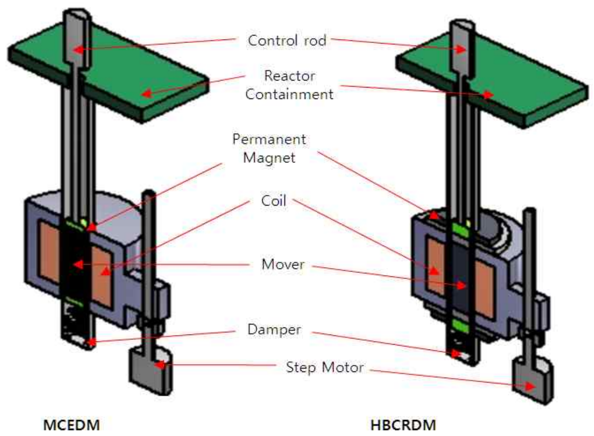


Fig. 1. Schematic of HBCRDM and MCEDM .

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 HBCRDM and MCEDM configurations [2].

2.1 Newly Proposed Model

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.

Two different configurations of electromagnet and permanent magnets of HBCRDM and MCEDM are shown in Fig. 2. Fig. 2(a)-MCEDM shows 2PM-internal mover type electromagnet which is composed of two permanent magnets mover and a coil. Fig. 2(b)-HBCRDM shows the 2PM-external yoke type electromagnet which is composed of two permanent magnets on the yoke and a coil. Here the function of permanent magnet plays an important role in sharing the work with a coil so that the coil temperature due to magnetic saturation around the yoke is decreased.

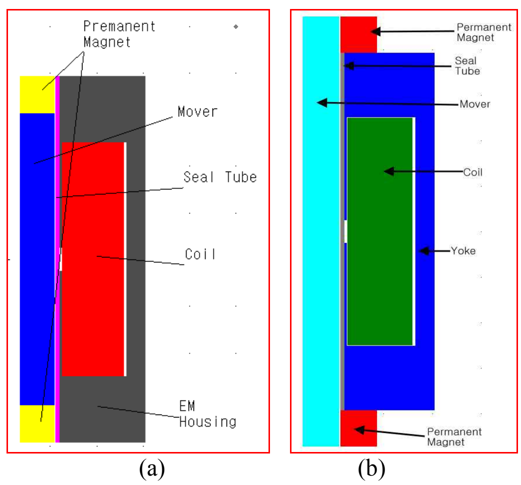
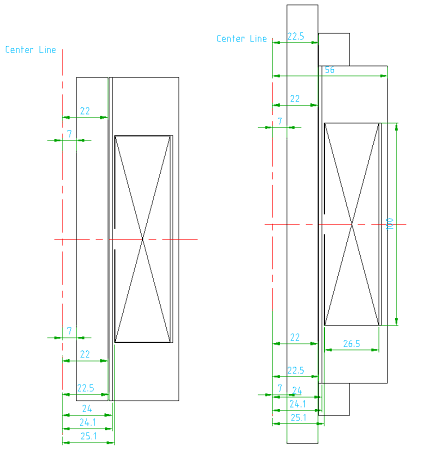


Fig. 2. 2D electromagnet FE models : (a) MCEDM (b) HBCRDM.

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 Fig. 3.



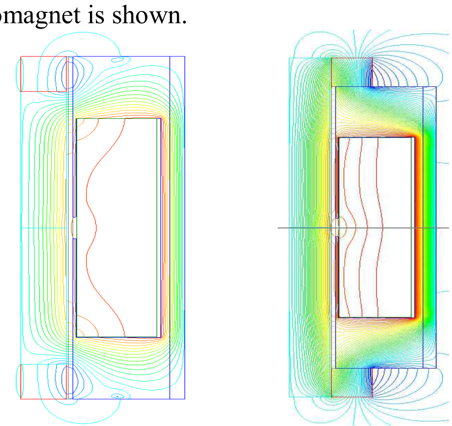
(a) (b)

Fig. 3. A dimension of Electromagnets : (a) MCEDM (b) HBCRDM.

Table 1. A design specification of electromagnet model.

Component	Material	Remark
Lifting coil, mm	Copper	26.5x100
Permanent magnet	SmCo28	Hc:820kA/m Br:1.07T
Coil housing	S20	
Mover	STS430	
Seal tube	STS316	
Air-gap 1, mm	Air	0.5
Air-gap 2, mm	Air	0.1
Current, A		2
Coil diameter, mm		ϕ0.75
Coil turn		4,200
Space factor		0.7

Two models for such a computation is given in Fig. 4, where the exact course of the magnetic equi-flux of electromagnet is shown.



(a) (b)

Figure 4. Equi-flux distribution lines FEM results of electromagnets : (a) MCEDM (b) HBCRDM.

Fig. 5 is the results of the FEM analysis. As a result, the thrust force of HBCRDM electromagnet is superior to MCEDM.

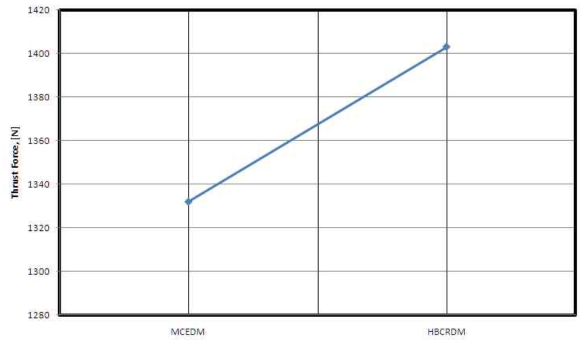


Fig. 5. Comparison of thrust force calculation using FEM for MCEDM and HBCRDM.

3. Conclusion

The main FEM results from the newly proposed electromagnet of HBCRDM are as follows:

(1) The thrust force of HBCRDM electromagnet is 1,403[Newton] and superior to MCEDM electromagnet, and shows the improvement of thrust force about 5% increase than that of MCEDM under the same conditions.

(2) Permanent magnet plays a role in sharing the work with a coil so that the coil temperature due to magnetic saturation around the yoke is decreased.

(3) The PM of HBCRDM electromagnet located external housing region is not breakable easily due to shutdown and the accessibility and maintenance of PM are easier than that of MCEDM electromagnet.

(4) The developed FE model and analysis procedure could be useful tools for predicting the thrust force of HBCRDM electromagnet.

REFERENCES

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

[2] Hyung Huh et al., "Analysis on Electromagnetic Characteristics of Research Reactor Control Rod Drive Mechanism for Thrust Force Improvement," Transaction of the KNS Autumn Meeting, 2010