A Study on Improvement of Initial Drop Time for Bottom-mounted Control Rod Drive Mechanism with a Hybrid Type Electromagnet in a Upward Flow Research Reactor

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1. Introduction

Compared to the Top-mounted CRDM (TMCRDM) such as HANARO and Jordan Research and Training Reactor (JRTR), the Bottom-mounted CRDM (BMCRDM) for KIJANG research reactor (KJRR) is quite a different design concept.

The main drive mechanism of the BMCRDM is located in a Reactivity Control Room (RCM) room under the reactor pool bottom, which can reduce interference with the equipment in the reactor pool.

Furthermore, in the downward core flow reactor such as KJRR, the thrust force of the electromagnet (EM) is much more needed due to the fluid friction resistance.

BMCRDM with a hybrid type EM is a newly proposed device, in which a permanent magnet (PM) and an EM are connected in series to increase the thrust force at a relatively low supply current as shown in Fig. 1(a) [1,2].

As a part of a new project, BMCRDM with a hybrid type EM in a downward flow was fabricated and performance verification tests were conducted. As a result, it was proven to be far better than the target expectations [3].

In the case of downward core flow research reactor unlike the above, the main concern is how to reduce the CAR drop time rather than increase the thrust force of the EM.

In order to make the CAR drop time faster, the electromagnetic field FEM analysis was carried out to see what effect is produced when the PM connected with the EM is moved and coupled with the mover as shown in Fig. 1(b).

First, through the electromagnetic FEM analysis, the size of the PM located inside the mover, which can generate the thrust force as in the conventional method of installing the PM to the external EM, is obtained as shown in Fig. 1.

Based on these results, a study was made to reduce CAR drop time.

And by changing the polarity of the EM instantaneously, it is possible to remove the residual magnetism of the EM and to obtain the repulsive force of the PM, so that the initial CAR drop time can be reduced.

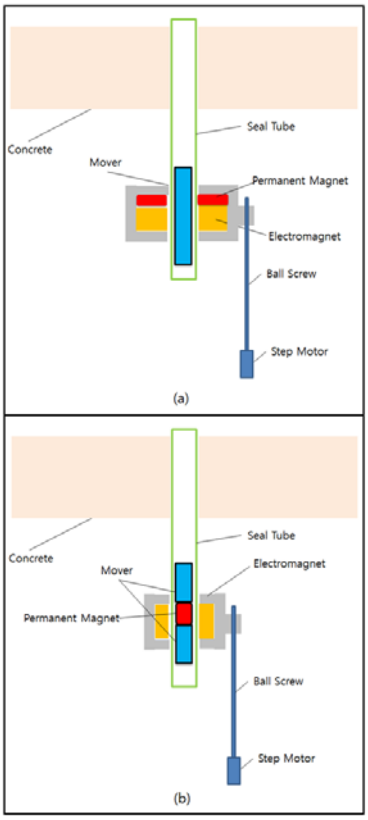

Fig. 1. Schematic diagram of hybrid type BMCRDMs which are (a) PM coupled with EM and (b) PM coupled with mover.

2. Methods and Results

In this section the FEM analysis on the numerical magnetic field with ANSYS code is described.

2.1 Proposed FEM Analysis Model

The choice of the magnetic circuit (window) shape of an 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 a rough approximation.

Fig. 2 shows an axisymmetric 2D/3D BMCRDM model, which is composed of PM coupled with mover, housing, and an EM.

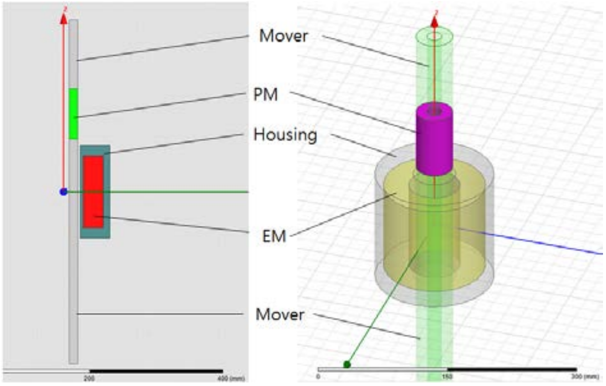

Fig.2. FEM 2/3-D model of hybrid type BMCRDM.

2.2 Hybrid Type BMCRDM FEM Analysis Results

The improvement of CAR drop time tries to use the repulsive force of the PM through polarity changes at the same time while eliminating the residual magnetism of the EM which is relatively easily accessible among various factors that have a great influence on the CAR drop time.

Table 1 shows the input data for a hybrid electromagnet magneto-static FEM analysis.

Fig 3 shows the electromagnetic equi-flux distribution when the EM input current is applied.

The calculated thrust force is shown in Fig. 4.

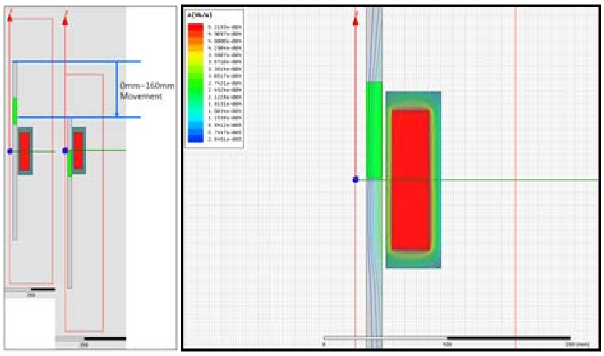

Fig.3. Electromagnetic qui-flux distribution of hybrid type BMCRDM.

Table 1: Design specification of hybrid BMCRDM model.

No	Component	Material	Remark
1	Permanent Magnet	NdFe35	Hc:890kA/m Br:1.05T H:76mm
2	Electromagnet Coil, mm	Copper	33x110, ϕ1.1 2[A]x2,800[Turn]
3	Housing	STS410	Ferromagnetic
4	Mover	STS410	Ferromagnetic
5	FEM solver	ANSYS-Maxwell, Axisymmetric, Transient	

As shown in the left figure of Fig 3, the thrust force was calculated by moving the mover from 0[mm] to 160[mm].

For example, instantly changing the input current polarity of the EM in the yellow region of Fig. 4, momentary repulsive force like red graph will occur.

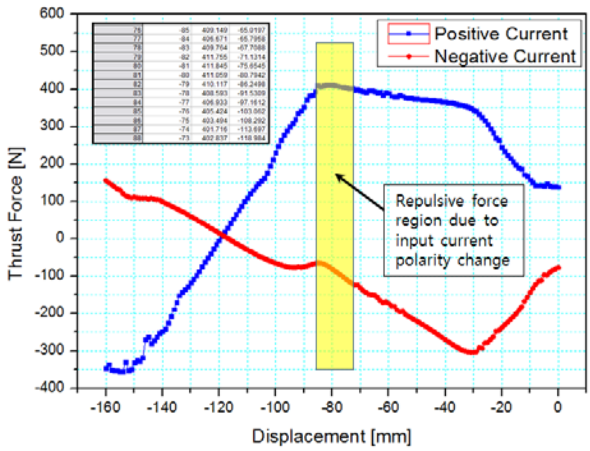

Fig. 4. Comparison of thrust force calculated according to change of EM input current polarity.

4. Conclusion

The following conclusions were obtained through this study:

(1) The size of the PM located inside the mover was calculated to obtain the same thrust force as the existing PM installed in the external EM.

(2) The polarity of the input current of the EM was instantaneously changed to obtain the maximum repulsive force of about 12[kgf] with the PM located inside the mover as well as the residual magnetism of the EM/PM. These can reduce the initial CAR drop time.

Acknowledgement

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