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# Electromagnetic Analysis of Magnetic-Jack type CRDM for Thrust Force Improvement

Hyung Huh, Jae Sun Lee, Ji Ho Kim, Suhn Choi, Keun Bae Park
*Korea Atomic Energy Research Institute, Mechanical Engineering Div. , 150 Deokjin-dong, Yuseong-gu, Daejeon, 305-353, Korea, hhuh@kaeri.re.kr*

## 1. Introduction

The magnetic-jack (magjack) type is used for control rod drive mechanism (CRDM) of the System-integrated Modular Advanced Reactor (SMART). An arrangement of three flat-face plunger electromagnets, when energized in a controlled sequence, will lift, hold, or insert a rod cluster in the reactor core. Especially the thrust force of magjack type electromagnet for the SMART needs more than that of KSNP (Korean Standard Nuclear Power Plant) under the same spatial constraints. In order to achieve improved thrust force, numerical magnetic field calculations for various kinds of magnetic yoke configuration of electromagnet have been performed. As a result, we present the improved design of electromagnet of magjack type CRDM for the SMART.

## 2. Methods and Results

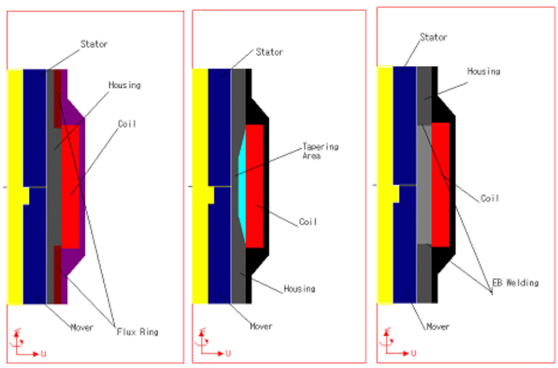
In this section some of the numerical field calculations with finite element are described as well as the details of magnetic yoke configurations of electromagnet for the SMART magjack type CRDM.

### *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 approximations. 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 of magjack type CRDM are shown in Figure 1. Figure 1 (a) shows the flux-ring type electromagnet which is composed of magnetic soft steel along the magnetic circuit called flux ring, which plays an important role in concentrating magnetic flux around inside the electromagnet yoke. Figure 1 (b) shows the tapering type electromagnet which is composed of tapering area, which plays an important role in checking the rush of magnetic flux as a bottleneck.

Figure 1 (c) shows the electron beam welding (EBW) type which is composed of nonmagnetic material, which plays an important role in increasing the reluctance inside the electromagnet yoke.




(a) (b) (c)

Figure 1. 2D Electromagnet FE models : (a) flux ring type (b) tapering type (c) EBW 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 2 designated numbers.

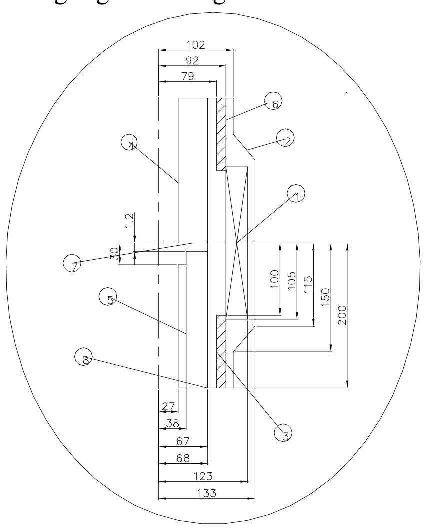



Figure 2. A dimension of electromagnet.

Table 1. A design specification of electromagnet model.

| No. | Component | Material | Remark |
|---|---|---|---|
| ① | Lifting coil | Copper | 31x100 |
| ② | yoke | S20 | |
| ③ | housing | STS410 | |
| ④ | Lifting pole (stator) | STS410 | |
| ⑤ | Lifting armature(mover) | STS410 | |
| ⑥ | Flux ring | S20 | T : 13 mm |
| ⑦ | Air-gap 1 | Air | |
| ⑧ | Air-gap 2 | air | |
| | Current density | 4.0 A/mm$^2$ | |

A proposed three models for such a computation is given in Figure 3, where the exact course of the magnetic equi-flux of a electromagnet is shown.

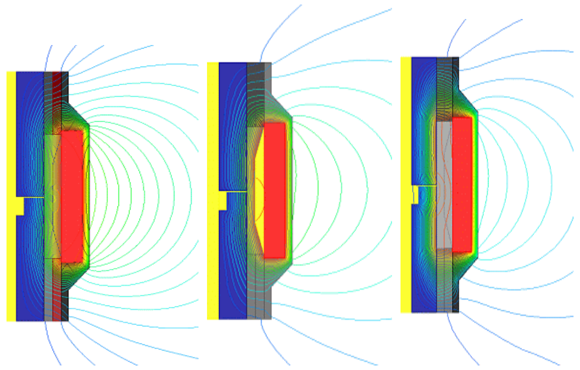


Figure 3. Equi-flux distribution lines FEM results of three electromagnets : (a) flux ring type (b) tapering type (c) EBW type.

Figure 4 is the results of the FEM analysis. As a results, the thrust force of EBW type electromagnet is superior to flux ring type and tapering type.

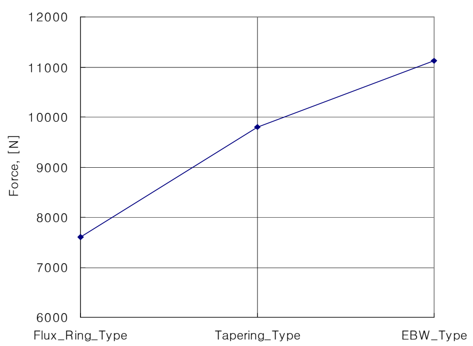



Figure 4. Comparison of thrust force calculation using FEM for three electromagnet models.

The case study results of flux ring type electromagnet are presented in Figure 5 and Figure 6. As a result, the position and thickness of flux ring help improve a thrust force of electromagnet.

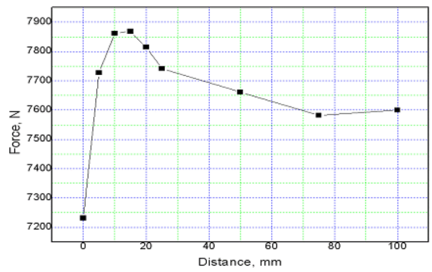



Figure 5. Thrust force variation of flux ring moving from yoke's center line to upper and lower direction with 5 mm simultaneously.

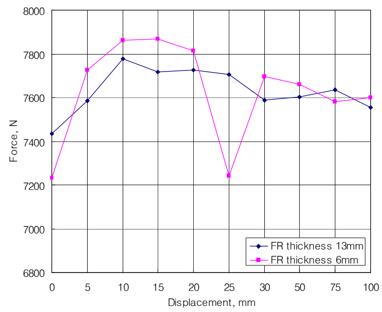



Figure 6. Thrust force variation of flux ring of 6 mm and 13 mm thick, moving from yoke's center line to upper and lower direction with 5 mm at the same time, respectively.

## 3. Conclusion

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

(1) The thrust force of EBW type electromagnet is 11,128[Newton] superior to flux ring type and tapering type, and shows the improvement of thrust force about 50% increase than that of flux ring type under the same conditions.

(2) The position and thickness of flux ring help 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 a electromagnet.

## Acknowledgement

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## REFERENCES

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