# Evaluation of Electromagnetic Characteristic for APR1400 CEDM

Seung Hee Jang*, Jin Seon Kim, Min Su Kim, Il Jung Jun, Yong Kyu Kim
*Doosan Heavy Industries & Construction, 555 Gwigok-Dong, Changwon, Gyeongnam, Korea*
**Corresponding author: Seunghee.jang@doosan.com*

## 1. Introduction

Control Element Drive Mechanism (CEDM) is the device that controls the reactor power by driving and holding of Extension Shaft Assembly (ESA) and Control Element Assembly (CEA). CEDM is operated by applying localized magnetic flux fields which activate parts made of magnetic material which are internal to the pressure boundary. Driving and holding of the ESA and CEA occur when power is sequentially applied to the series of the CEDM electrical coils external to the pressure housing.

Because CEDM is operated by electromagnetic force, it is important to evaluate an electromagnetic characteristic of the CEDM. In this study, the electromagnetic analysis of the APR1400 CEDM was performed to evaluate the electromagnetic characteristic of CEDM in holding and withdrawal condition.

## 2. Methods and Results

The electromagnetic analysis for APR 1400 CEDM was performed in this study. CEDM model for electromagnetic analysis was developed and B-H curve data of CEDM materials and coil voltages are applied to FEM model.

### *2.1 Electromagnetic Finite Element Model for CEDM*

The FEM model for CEDM electromagnetic analysis was developed using computer code ANSYS [1]. The model is composed of latch and lift magnets, housing, coils and etc. Gap conditions including air region were also modeled for analysis. The detailed FEM model was shown in Figure 1. Because this study was only concerned with the electromagnetic analysis, upper pressure housing and lower part of nozzle were not modeled. Materials for each part were also shown in Figure 1.

### *2.2 B-H Curve Data*

B-H curve or magnetization curve shows how much flux density (B) results from increasing the flux intensity (H). B-H curve data for coil housing (CS1010) was obtained from ANSYS reference database. B-H curve data for the rest of magnet materials were obtained from the material test results. Nonmagnetic materials including air and coil have a constant relative permeability, 1(one). Various cases for the application of these B-H curve data were considered for CEDM analysis.

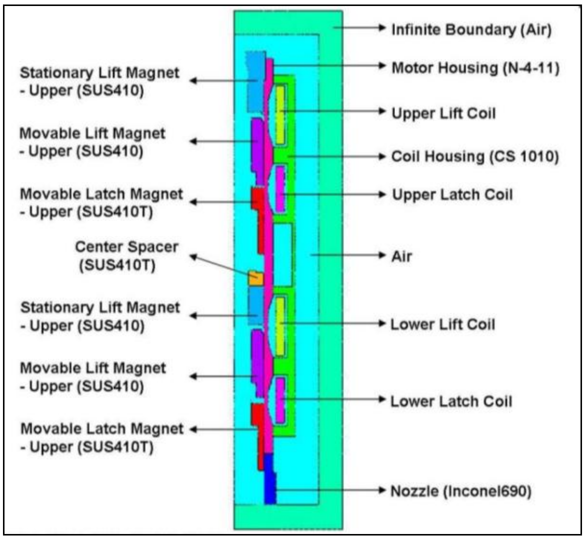


Fig. 1. CEDM Electromagnetic FEM model

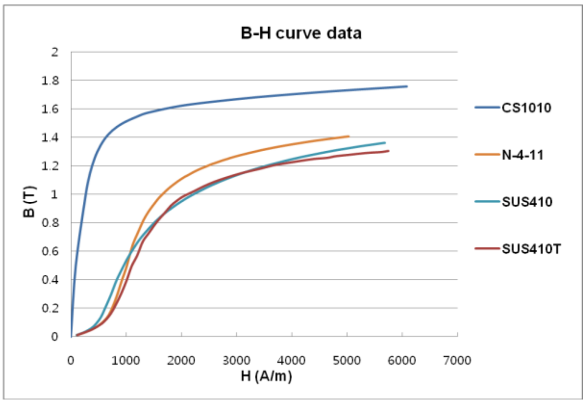


Fig. 2. B-H curve data from test results

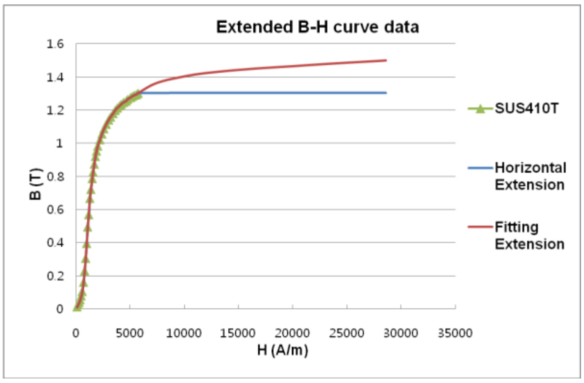


Fig. 3. Extended B-H curve data

Case 1 : Each B-H curve data from the test results were used for each material. B-H curve data of each material were shown in Figure 2.

Case 2: B-H curve of SUS410T, which have the lowest flux density (B) at the same flux intensity (H) as shown in Figure 2, was used to all materials for evaluation of the severe condition which means that CEDM has the minimum electromagnetic forces.

Case 3: Two types of extended SUS410T B-H curves, which are extended from an end point of the SUS410T B-H curve to a horizontal direction and extended from an end point to a curvature direction, were used to all materials to evaluate the effect of B-H curve ranges in CEDM analysis. These curves were shown in Figure 3.

### *2.3 Coil Voltage*

Coil voltages applied for CEDM analysis were shown in Table I. The negative sign means the reverse direction of the current. In this study, the operation of upper magnets was considered and it was assumed that no currents or voltages were applied to lower coils.

Table I: Coil voltage

| | Holding Mode | Withdraw Mode |
|---|---|---|
| | Voltage (V) | Voltage (V) |
| Upper Lift Coil | 0 | 145 |
| Upper Latch Coil | -45 | -45 |
| Lower Lift Coil | 0 | 0 |
| Lower Latch Coil | 0 | 0 |

### *2.4 Analysis Results*

The analysis results in case 1 and 2 were shown in Table II. It was found that CEDM had the minimum magnet forces when the lowest B-H curve was used to all materials (Case 2). All calculated values per each case were shown to meet the requirement of CEDM design specification [2].

Table II: Calculated Magnet forces

| Operating Mode | Case1 | Case2 | Requirement |
|---|---|---|---|
| | Latch Magnet Force (lbf) | | |
| Holding | 829.2 | 789.9 | 500 |
| Withdraw | 737.2 | 695.2 | |
| | Lift Magnet Force (lbf) | | |
| Holding | 0 | 0 | 700 |
| Withdraw | 1060.8 | 998.7 | |

The analysis results in case 3 were shown in Table III.
Because the magnet forces resulting from applying the horizontal extension of B-H curve were almost the same with the magnet forces resulting from case 2, it was found that the end point of B-H curve data was the saturation point of B-H curve.
Because the magnet forces of fitting extension of B-H curve were greater than the result of horizontal extension of B-H curve, it was found that the extension of B-H curve above the horizontal direction was affected to magnet forces.
All calculated values in case 3 were also shown to meet the requirement of CEDM design specification.

Table III: Magnet force due to extended B-H curve

| Operating Mode | Horizontal Extension | Fitting Extension | Requirement |
|---|---|---|---|
| | Latch Magnet Force (lbf) | | |
| Holding | 772.6 | 962.6 | 500 |
| Withdraw | 693.8 | 825.2 | |
| | Lift Magnet Force (lbf) | | |
| Holding | 0 | 0 | 700 |
| Withdraw | 986.7 | 1175.7 | |

## 3. Conclusions

In this study, electromagnetic analysis based on APR1400 CEDM dimensions was performed. FEM model for electromagnetic analysis was developed and B-H curve from the test results were applied to the model. Case studies were performed to evaluate the effect of B-H curve data in condition of holding and withdraw. The results can be concluded as follows.

1. The magnet forces resulting from applying the lowest B-H curve to all materials were shown to meet the requirement of magnet forces in design specification.

2. It was found that the end point of B-H curve was the saturation point in ANSYS application method. And it was also found that the extension of B-H curve above the horizontal direction was affected to magnet forces. Regardless of B-H curve extension, the results from various cases were shown to meet the requirement of magnet forces in design specification.

## REFERENCES

[1] Computer Code ANSYS, Release 10.0
[2] Specification No. 3L186-ME-DS250-00, Revision 04, Design Specification for Control Element Drive Mechanism and CEA Extension Shaft Assemblies for Shin-Kori Units 3 and 4.