Design Study on Maximizing the Electromagnetic Lifting Force of an In-Vessel CRDM

Lee Jae-Han*, Lee JaeSeon

KAERI (Korea Atomic Energy Research Institute), *jhlee@kaeri.re.kr

KAERI 한국원자력연구원 Korea Atomic Energy Research Institute

1. Introduction

The CRDM in SMART reactor is a magnetic jack type and it is immersed in cooling water inside a reactor vessel. It consists of a motor assembly (including the latch assemblies), a motor housing, an extension shaft assembly (ESA), and an electromagnetic coil assembly (including one lift and two latch coils) as shown in Fig. 1. The electromagnetic coils of the CRDM must be designed to produce sufficient electromagnetic attraction force to handle the weight of the ESA so that the lifting clearance gap of 12 mm could be closed. The coil assembly designs are performed to generate an electromagnetic traction 1800 N or more for lifting the ESA under the constraint of minimizing the outer diameter of the In-Vessel CRDM within 200 mm. The motor assembly is the same as previously designed and is used as it is.

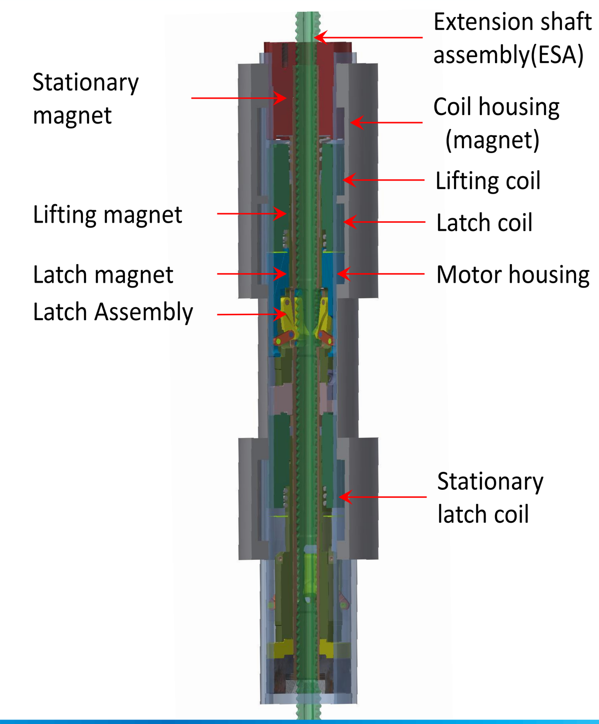

Figure 1 Components of the In-Vessel CRDM

2. Electromagnetic flux flow resistances

- The motor magnets and the coil housing are made of AISI 410T and S420 stainless steels, respectively. The motor housing is initially assigned with a SS304 of non-magnetic.
- The electromagnetic flux mainly passes through the lift coil housing(⑤, ⑥) and the motor magnets(①, ③) crossing the two regions(④, ⑦) of the motor housing. The electromagnetic attraction to handle an extension shaft assembly (ESA) is created at the gap (②) between the stationary and lift magnets (Fig.2).
- The motor housing parts(④, ⑦) increase the magnetic flux flow resistance because of the non-magnetic material.

- The two parts of the motor housing are locally replaced with the electromagnetic material to reduce the flux flow resistance as represented in model A to model B in Fig.3.
- The flux flow resistances from model A to model B are greatly reduced from 24.9 to 4.6 at ⑦, and from 11.1 to 1.0 at ④ as represented in Fig.4.
- The model C is designed to get an additional reduction of flux resistance at region ⑦.
- The model D and E are designed to increase the magnetic flux amount at the gap ②.
- The motor housing has three bi-metal welded parts by the local material changes.

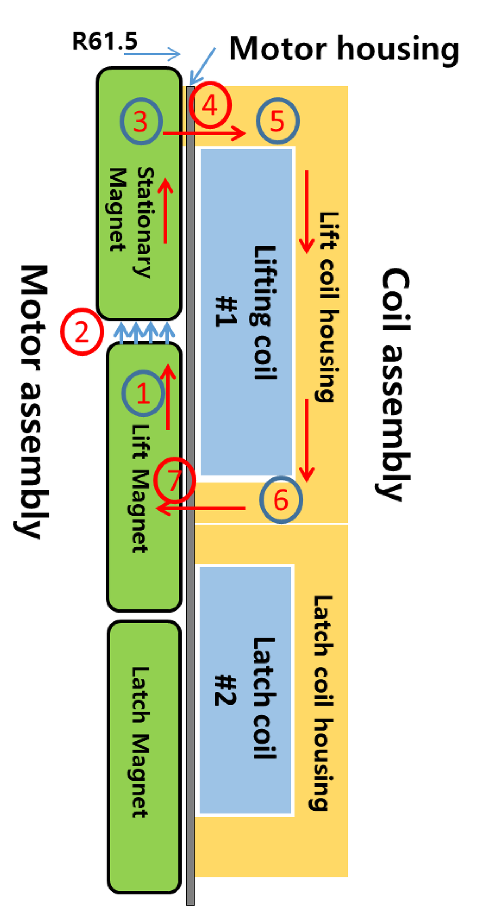

Figure 2 Axisymmetric coils & magnets

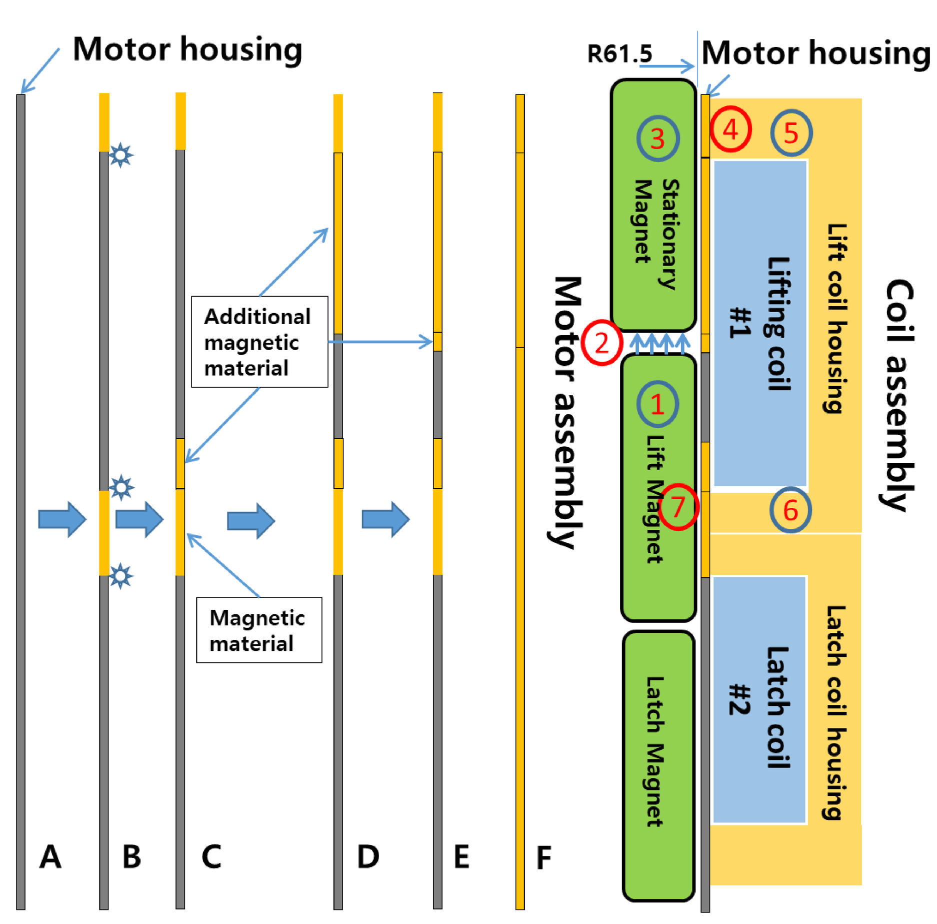

Figure 3 Magnetic-materialized parts of motor housing

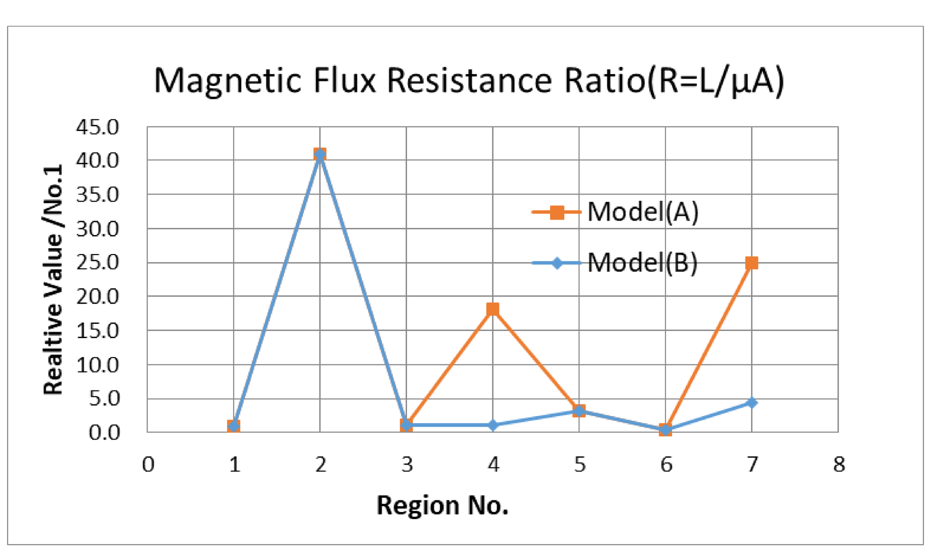

Figure 4 Electromagnetic flux flow resistance ratios (region No. 1~7 / region No.1)

3. Electromagnetic field analysis model

- Non-magnetic material and filled water are considered as air permeability property in the analysis.
- The magnetic materials use the permeability characteristics of 400°C.
- The coil spaces (width x length) are allocated by 20 mm x 157 mm for the lift coil and 20 mm x 117 mm for two latch coils.
- The coil spaces can accommodate the required 331 and 245 coil turns respectively, which are achieved by winding a mineral insulated(MI) coil with a diameter of 3 mm.
- 19 A is on the lift coil, while the latch coil current of 10 A is supplied.
- Fig. 5 shows the meshed shape of the electro-magnetic field analysis model with ANSYS Emag.

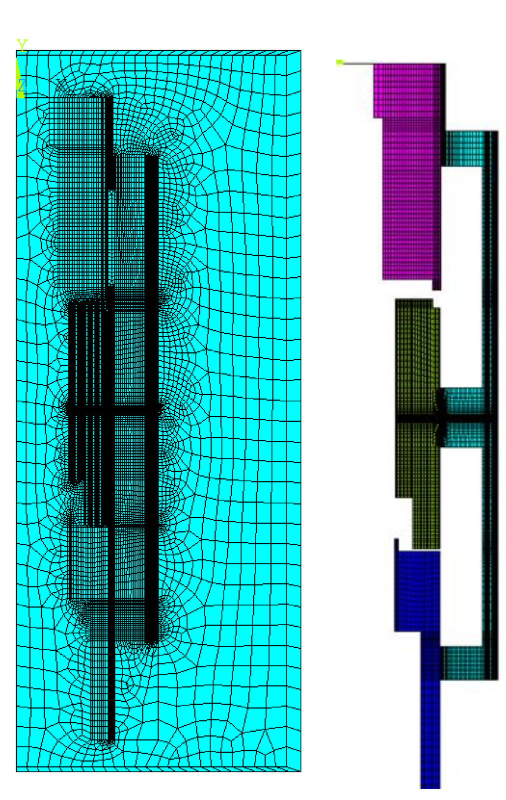

Figure 5 Mesh configuration

4. Electromagnetic Force Analysis Results

- Design studies are carried out to partially change the motor housing material while all other variables are constant so that the outer diameter of CRDM is fixed by 194 mm.
- 6 electromagnetic traction force calculations are performed with the models (from A to F) of the motor housing in Fig.3.
- The motor housing thickness (T2) of 5 mm is fixed so that it could withstand the operation loads and support the weight of both the motor assembly and coil assembly. And the coil housing thickness(9.45 mm) is set so that the outer diameter of CRDM is by 194 mm.
- Fig. 6 shows the analysis results. As the electromagnetic materialization area changes in the order of A→B→ C→D→E.
- Fig. 7 presents the electromagnetic flux contour of the model C and D of the motor housing.
- The resulting force of the motor housing model E satisfies the electromagnetic traction force requirement of 1,800 N or more.
- Fig.8 and Fig.9 represent the electromagnetic flux concentrated in region ② for the model E.
- The model F is the whole electromagnetic materialization condition of the motor housing. A quite low attraction force is generated in the gap of region ② compared to other models(A to E) because a part of electromagnetic flux is directly transmitted to the motor housing without passing through the gap ②.

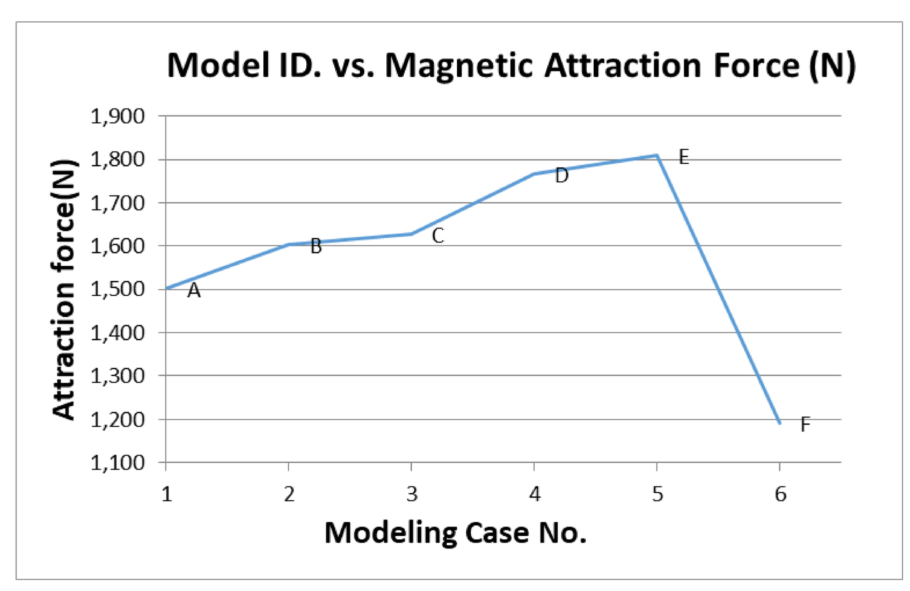

Figure 6 Attraction forces vs. modeling cases (A to F) of the motor housing

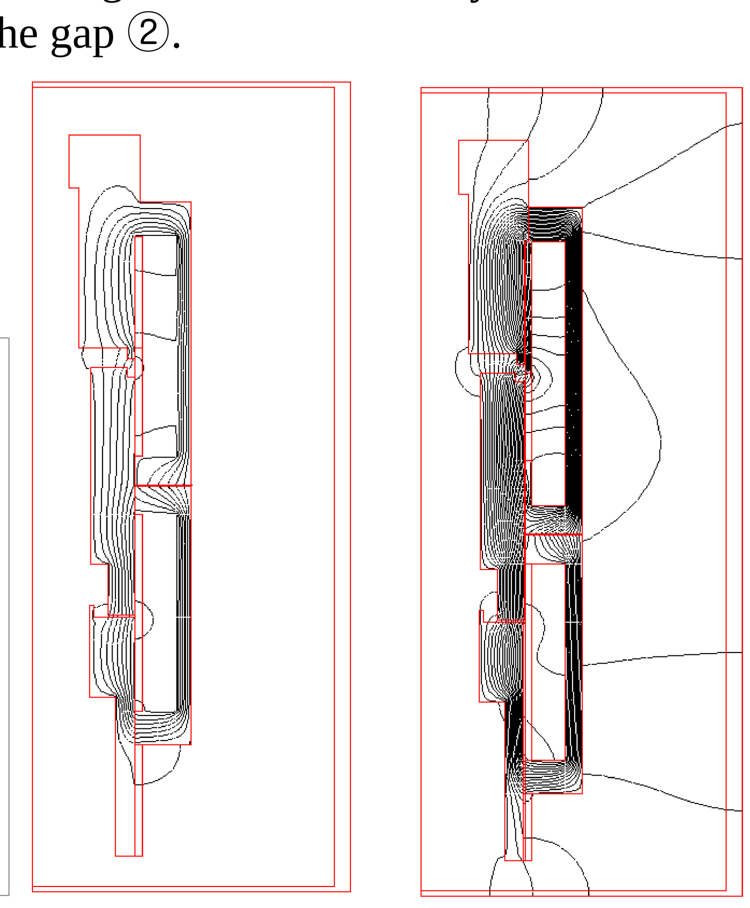

Figure 7 Electromagnetic flux distributions for the motor housing model C and D

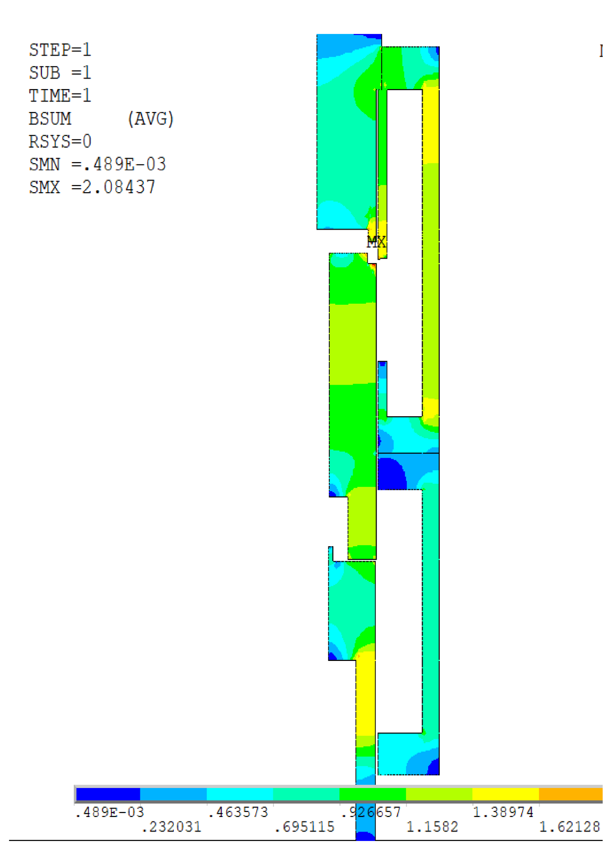

Figure 8 Electromagnetic flux contour of ID 9 of model E

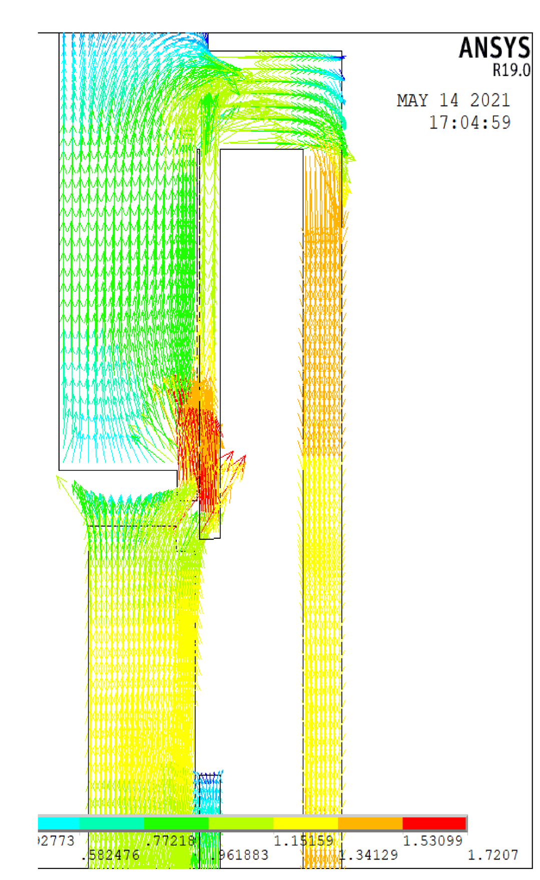

Figure 9 Electromagnetic flux concentration of the motor housing model E

5. Conclusions

- The local electromagnetic material adoption for the motor housing could reduce the electromagnetic flux resistance in the magnetic flow path, then the electromagnetic traction force of CRDM is increased above design requirement of 1,800N and the design margin is secured.
- Based on the design studies for the magnetic materialization models of the motor housing, further minimization of the outer diameter of the CRDM even in the new design environments could be feasible by various combinations of design parameters such as the motor housing thickness, the coil housing thickness, and enforced coil current.