Study on Optimization of IV-CEDM Coil Assembly

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1. Introduction

The In-Vessel Control Element Drive Mechanism (IV-CEDM) developed for Small Modular Reactors has a coil stack assembly which produces magnetic force to lift and hold the control element assembly. The magnetic force produced by lift and latch coils can be changed by the design parameters of the coil housing.

Fig. 1 shows the upper part of coil stack assembly of IV-CEDM [1]. Generally, the top plate and bottom plate of coil housing have the same thickness (T1, T3) and T2 is twice as thick as the top or bottom plate. As shown in Fig. 2, flux distribution in lifting mode is different depending on the magnetic pole arrangement [2]. With opposite pole, there are lots of flux lines passing through T2. It means that it is important to design T2 thick enough to prevent too much magnetic resistance. However, in case the magnetic pole is arranged with the same direction, T2 has much less flux lines, which means more efficient design may be achievable by reducing T2 and assigning the additional space for winding. In this paper, optimization of the thickness (T2) is performed to increase magnetic forces.

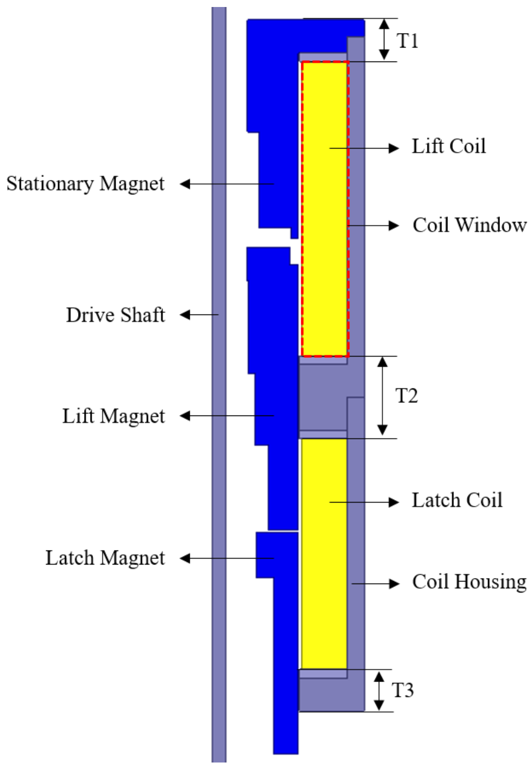

Fig. 1. Analysis Model (Upper Part Only)

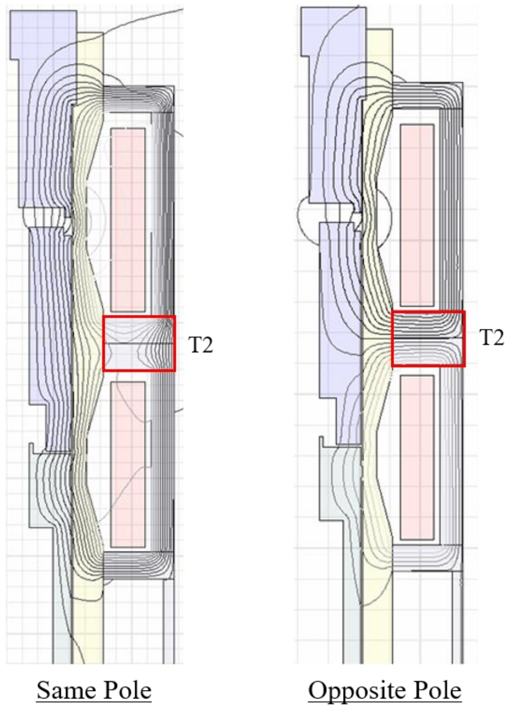

Fig. 2. Typical Flux Distribution

2. Modeling & Analysis

As the structure of the IV-CEDM is symmetric, 2D axisymmetric model is generated using Maxwell [3]. The gap between the lift magnet and latch magnet shown in Fig.1 is modeled to be closed and the other is modeled to be open to describe the holding mode. The magnetic poles of the lift coil and latch coil is modeled to have the same direction. Only the magnetic material is considered in electro-magnetic analysis. B-H curve which is material property of the magnetic components is shown in Fig. 3.

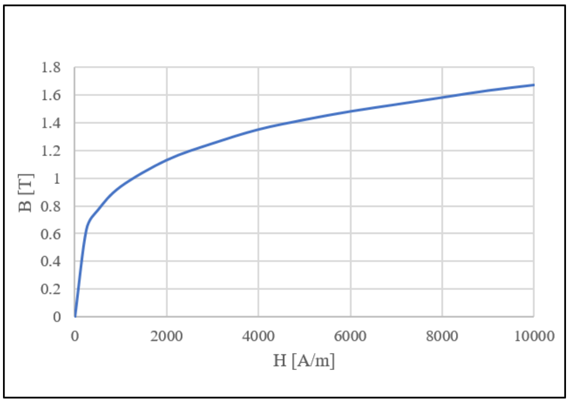

Fig. 3. B-H Curve

There are two modes to calculate the magnetic force; the holding mode and the lifting mode. For the holding mode, the input current of 6A is assumed for the latch coil. For the lifting mode, the latch coil is also energized with 6A and the lift coil is assumed to have 12A. Magnetic forces under the two modes are calculated.

Table 1 shows the analysis cases. As shown in Fig. 4, the size of coil window increases as much as T2 decreases so that winding turns of lift coil and latch coil also increase. In this paper, the winding turns increase by 9 turns every cases, equal to adding the 1 layer of coil. Other design parameters are fixed to simplify the study.

Table 1. Analysis Cases

Case	Winding Turns		T2 / T1*
	Lift Coil	Latch Coil	
1	Original		2
2	+ 9 turns		1.76
3	+ 18 turns		1.52
4	+ 27 turns		1.27
5	+ 36 turns		1.03
6	+ 45 turns		0.79
7	+ 54 turns		0.55

* Thickness ratio of T1 and T2

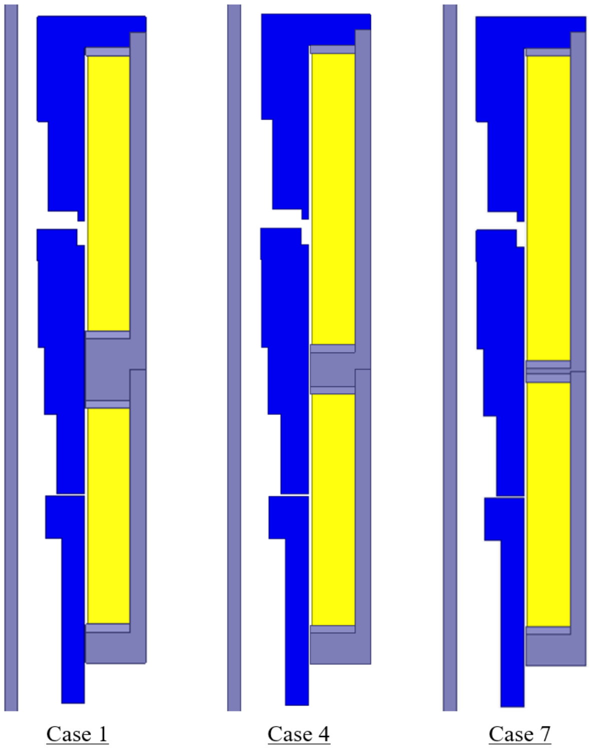

Fig. 4. Analysis Model of Case 1, 4 and 7

3. Results & Review

Fig. 5 shows the analysis results. The calculated magnetic forces are compared with the required forces of the lifting and holding modes.

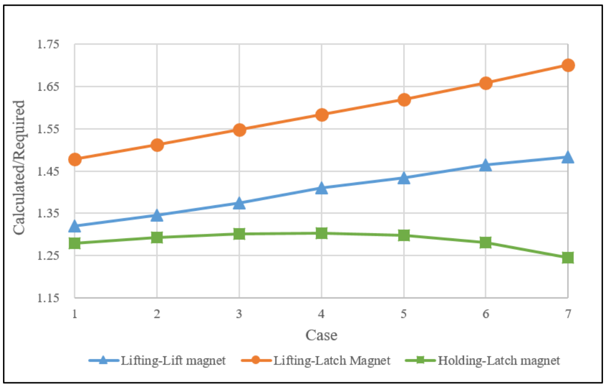

Fig. 5. Analysis Results

In lifting mode, as T2 decreases, both lifting and holding forces increase. Since magnetic flux does not pass through T2, decrease of T2 has almost no effect on magnetic forces. Therefore, the magnetic forces increase due to the increment of the winding turns.

In holding mode, on the other hand, T2 is a part of the major path for magnetic flux as shown in Fig. 6. So magnetic force decreases from certain point (Case 4) where the effect of magnetic saturation overwhelms the effect of winding turns increase.

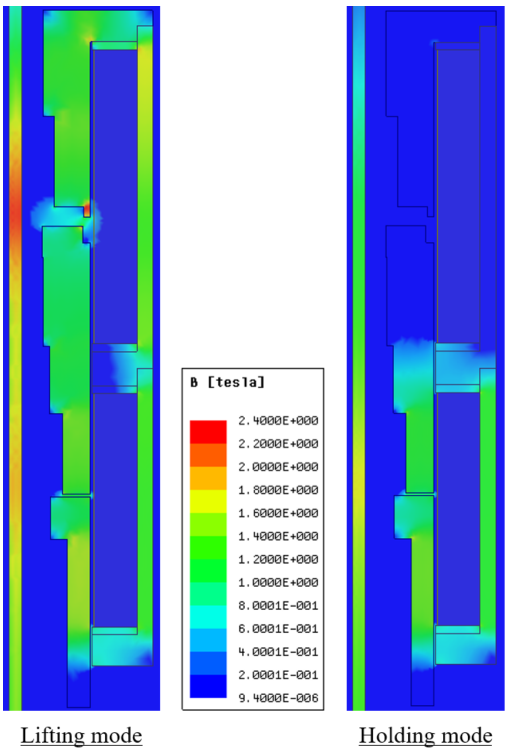

Fig. 6. Flux Density of Case 4

4. Conclusion

In this paper, electro-magnetic analyses were carried out to optimize the design parameter of IV-CEDM for maximum magnetic force. The results show that in the lifting mode, higher magnetic force is produced by the increment of the winding turns. On the other hand, in the holding mode, as the reduced thickness between the lift coil and latch coil affects the magnetic flux lines, the magnetic force decreases from certain point in spite of the considerable winding turns. In this paper, the lifting force increases by approximately 6.7% compared to the original case by optimizing the IV-CEDM coil assembly.

5. Future Works

In this paper, the optimization of the coil assembly was studied. The latch assembly, the size of each magnets or the other thickness of coil housing (T1, T3) also need to be optimized in the next research. In doing so, the correlation between components can be identified and the optimum design can be achieved.

REFERENCES

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