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Effect of Magnetic Drive Shaft on Magnetic Forces of the IV-CEDM

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1. Introduction

A magnetic jack type IV-CEDM (In-vessel Control Element Drive Mechanism) was proposed as shown in Fig. 1 to fundamentally eliminate the rod ejection accident [1], and its development program is in progress. The proposed IV-CEDM is based on the proven design of the external type CEDM. However, there are some significant differences between the conventional CEDM and the proposed IV-CEDM. For example, the IV-CEDM does not have any pressure boundary component unlike the conventional CEDM. There are also some important changes on coil material in order to be operable inside nuclear reactors.

Another important change has made to the drive shaft because of the IV-CEAPI (In-vessel Control Element Assembly Position Indicator). Through a technical survey and evaluation, the IV-CEAPI was determined to be a solenoid type [2] which requires a magnetic drive shaft unlike the conventional CEDM. Since the magnetic drive shaft is located inside the magnets of the latch assembly, it induces leakage flux to reduce magnetic force of the IV-CEDM.

In this paper, electromagnetic analyses are presented to evaluate effect of magnetic drive shaft on magnetic forces of the IV-CEDM.

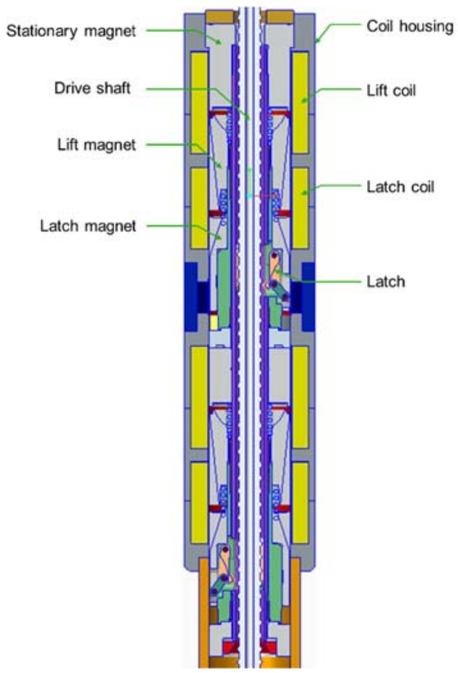


Fig. 1. Magnetic Jack Type IV-CEDM

2. Analysis

Analyses were performed for two cases to represent the IV-CEDMs with a magnetic drive shaft and a non-magnetic drive shaft using a commercial FEM software, Maxwell2D.

Fig. 2 shows the basic axisymmetric model to represent the IV-CEDM with a magnetic drive shaft. Since the design parameters of the upper assembly are almost the same as the ones of the lower assembly, only the upper assembly was modeled. The model includes coils, coil housing, drive shaft and magnets. The other components excluded in the model are non-magnetic. The gap between the stationary magnet and the lift magnet is modeled to be open, whereas the gap between the lift magnet and latch magnet is modeled to be closed to describe the moment when the lifting action is just about to occur. BH curves of corresponding materials were applied to the coil housing, drive shaft and magnets.

For the case of non-magnetic drive shaft, the drive shaft in Fig. 2 was simply deleted.

Magnetic forces were calculated for both hold mode and lift mode. Table 1 shows analysis inputs which have been determined by design parameters and expected operation points.

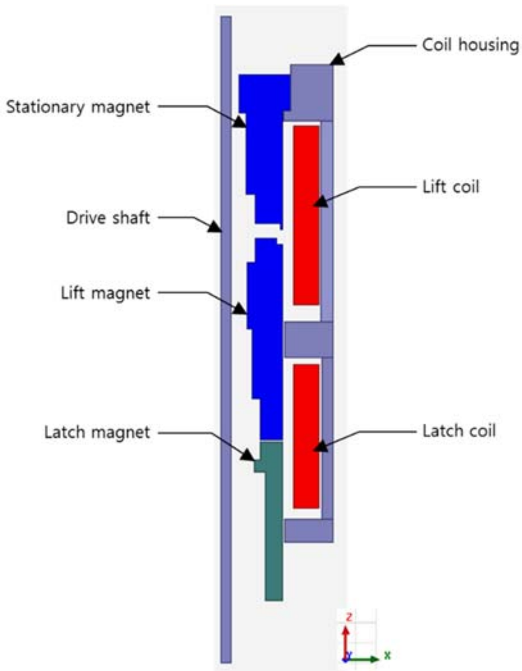


Fig. 2. Electromagnetic Analysis Model of the IV-CEDM

Table 1 Analysis Inputs

Mode	Coil	Magneto-motive Force [Ampere-turns]
Hold	Latch	2,460
Lift	Latch	2,460
	Lift	6,240

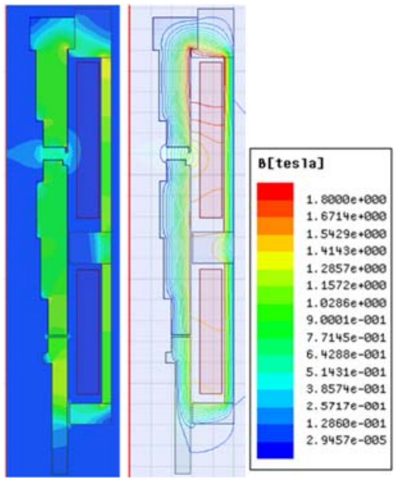
3. Results and Discussion

Magnetic flux distribution was calculated as shown in Fig. 3. As expected, case (b) with magnetic drive shaft shows more leakage flux than case (a) with non-magnetic drive shaft. Because of the leakage flux caused by magnetic drive shaft, the magnetic force reduced about 3 ~ 9 % comparing to the case (a) with non-magnetic force as indicated in Table 2. Therefore, in case of using magnetic drive shaft, additional considerations should be given to establishing electrical power source set-points of the IV-CEDM control system.

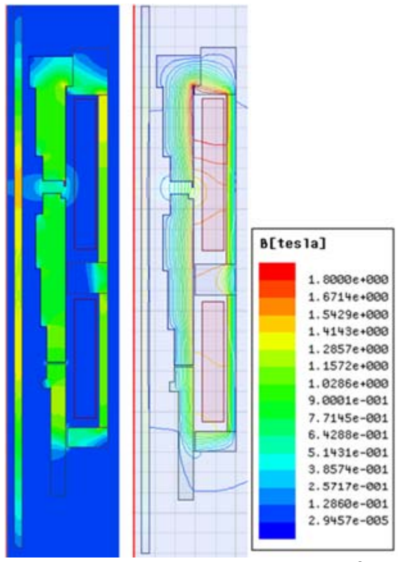
Table 2 Analysis Result of Magnetic Force [N]

Mode	Force	(a)	(b)	(b)/(a)
Hold	Holding	1,200	1,094	0.91
Lift	Holding	1,810	1,686	0.93
	Lifting	1,076	1,048	0.97

(a) Non-magnetic drive shaft
(b) Magnetic drive shaft



(a) IV-CEDM with non-magnetic drive shaft



(b) IV-CEDM with magnetic drive shaft

Fig. 3. Magnetic Flux distribution

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[2] Jang Yongtae, Park Jinseok, Lee Myounggoo, Cho Yeonho, Kim Hyunmin. Technical Survey and Feasibility Review for Development of IV-CEAPI, Proc. of the Korean Nuclear Society '16 Spring Conference, 2016