Study on Pole Arrangement of the CEDM Coils

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1. Introduction

The Control Element Drive Mechanism (CEDM) is an electro-mechanical device that provides a controlled linear motion for the control element assembly. Each CEDM has a coil stack assembly to produce magnetic force needed for operations. The coil stack assembly consists of two sets of lift and latch coils. Since the coil stack assembly is important for reliable operation of the CEDM, there have been efforts to improve the design by optimizing the design parameters such as dimensions and winding turns [1].

However, magnetic forces of the CEDM can also change by different pole arrangement even if their design parameters are the same. Since the latch coil and lift coil are installed connected to each other, they produce magnetically coupled field when they are energized at the same time. This coupling field can affect the magnetic force of the CEDM significantly.

In this paper, coil pole arrangement effects are studied. Electro-magnetic analysis is performed for the different pole arrangements of the CEDM coils to calculate the magnetic forces.

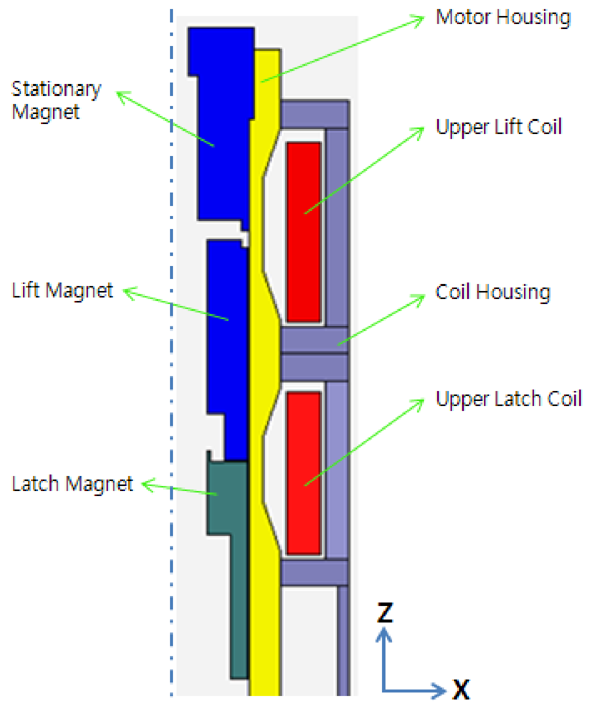

Fig. 1. Analysis Model (upper part only)

2. Modeling and Analysis

A 2D axisymmetric model of the CEDM has been developed using Maxwell [2]. Fig. 1 shows the upper part of the model. The gap between the upper lift magnet and upper latch magnet is modeled to be closed and the other gaps are modeled to be open to describe the hold mode condition.

Non-linear characteristic of magnetic material is considered by applying the B-H curve of the CEDM components as shown in Fig. 2.

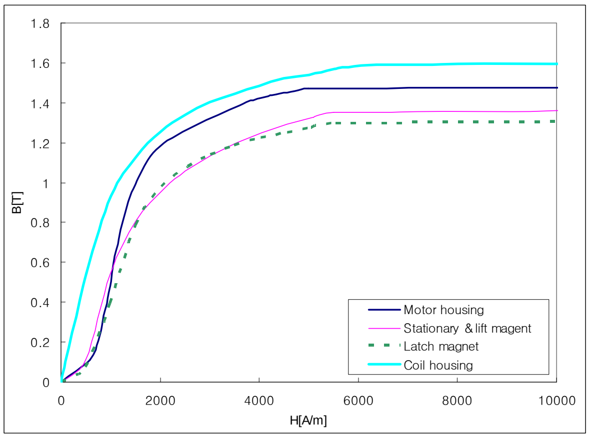

Fig. 2. B-H curves

Analyses for the two cases in Table I are performed. Magnetic pole of the CEDM coil can be arranged by the direction of the current to energize the coils. Case I energizes the lift coil with the opposite direction to the latch coil and Case II energizes the two coils with the same direction.

Magnetic forces for the hold mode and lift mode are calculated. For the hold mode analysis, the latch coil is energized with input current of 5.2A while the lift coil remains de-energized. For the lift mode analysis, the lift coil is energized with input current of 16.5A while the other condition is the same condition with the hold mode analysis.

Table I: Magnetic pole directions

	Latch Coil	Lift Coil
Case I	North Up (↑)	North Down (↓)
Case II	North Up (↑)	North Up (↑)

3. Results and Review

Fig. 3 and 4 show the magnetic flux distribution of Case I and Case II, respectively. There is significant difference in magnetic flux path and distribution between the two cases.

In Case I, the latch coil and lift coil produce magnetic flux curling around their own coils independently since the direction of the magneto-motive force of the lift coil and latch coil is opposite to each other. When the lift coil is energized in Case I, magnetic field is generated in the opposite direction to the one induced by the latch coil. Therefore, it weakens the magnetic field.

In Case II, on the other hand, most of the flux induced by the two coils produces magnetic flux curling around both of the two coils together. Since the magnetic filed in Case II is in the same direction, they magnifies each other's field.

As the results shown in Table II, holding force (between the latch magnet and lift magnet) of Case I decreases as the lift coil is energized from the hold mode condition while the holding force of Case II increases because of the magnifying effect. Lift forces also show difference between the two cases. Case II produces magnetic force about 10% greater.

Table II: Magnetic force [lbs]

Mode	Force	Case I	Case II
Hold	Holding	756	
Lift	Holding	609	769
	Lifting	779	853

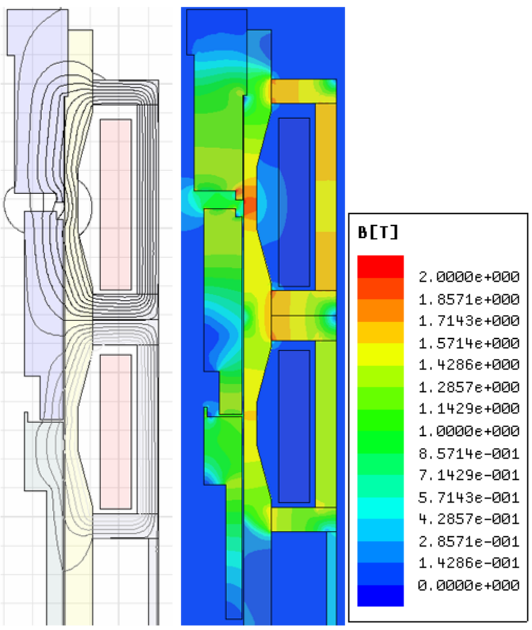

Fig. 3. Magnetic flux distribution - Case I

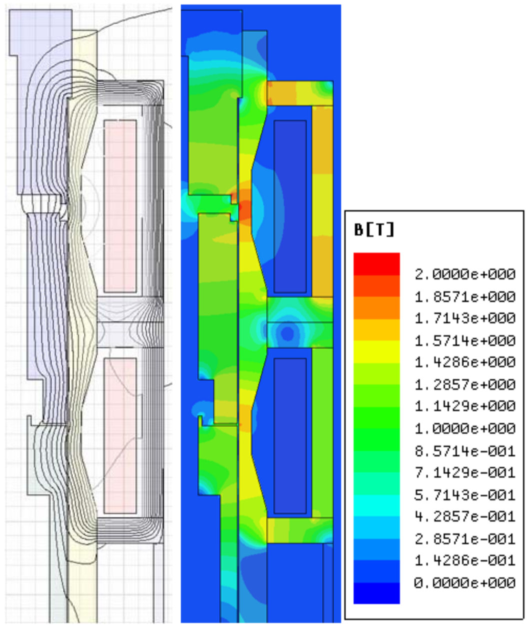

Fig. 4. Magnetic flux distribution - Case II

4. Conclusions

Pole arrangement effects on magnetic forces were studied by static analysis of the CEDM magnetic field. Magnetic forces were calculated and compared for the two different pole arrangements of the coils. The results show that the magnetic poles of the lift coil and latch coil shall be arranged to have the same magnetic pole direction to achieve higher magnetic force. Both of lifting and holding forces are turned to increase when the coils are arranged to have the same pole direction.

5. Future Works

In this paper, pole arrangement effects were studied only from the static analysis point of view. This issue should also be reviewed from the transient analyses point of view in the future because the coupled magnetic field can affect the current of the coils, which is assumed to be steady in the static analyses. Since the magnetic force changes due to the current variation, transient effects should be reviewed in the next research.

Acknowledgement

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REFERENCES

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[2] ANSOFT Inc., MAXWELL 2D V.12 User's Manual, 2008