Design of Air compressor Driving Linear Actuator for the High Performance of Fuel Cell BOP System using Taguchi Method

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Abstract — Reciprocating and rotary types are established driving system for air blower compressor. Compared to rotary type compressor, reciprocating compressor is particularly effective to improve compressor efficiency as it does now require additional mechanic convergence. Linear compressor can reduce the noise and minimize the power consumption by controlling piston compressor distance from rectilinear motion inside the compressor. Linear compressor can quickly provide cold air as its operating section is narrower than an inverter compressor. The study aims to improve fuel cell system performance by designing the linear compressor for air blower with Taguchi Method.

I. INTRODUCTION

As a new energy source, hydrogen energy is getting the global spotlight due to the increasing concerns for depletion of fossil fuels and emission of green house gas. Pump, fan, compressor, and blower are the major fuel supply module in hydrogen fuel battery. Among these, air blower affects 20 to 30 percent. Linear motion creates minimum power consumption compared to rotary type motion. Electromagnetic actuator for linear compressor was operated by a Lorentz force which is the relationship between flux of the permanent magnet and the applied current to the coil. The Lorentz force is given by equation (1).

$$F_{Lorentz} = n \cdot B_g \cdot i \cdot l_{eff} \qquad (1)$$

There are some methods to improve the performance of the electromagnetic actuator. One method is to increase a number of coil turns or an effective coil length. However, this method also makes the actuator size larger. Another method is to apply high current to the coil. But, this has a drawback of power consumption. So, this paper considers making flux density of the air gap stronger. One way is using rectangular shaped permanent magnet instead of round-shaped permanent magnet or ring-shaped permanent magnet. Especially, the actuator that is use rectangular shaped permanent magnet called quadratic actuator. [1]. In this paper, we used rectangular shaped magnet for strong flux density and proposed quadratic actuator and focused on design of a linear compressor for air blower with Taguchi Method.

II. PLAN FACTOR DECISION FOR TAGUCHI METHOD

Fig. 1 shows the schematic diagram of cross-sectional quadratic electromagnetic linear actuator. Fig. 2 shows the operation principle of linear compressor.

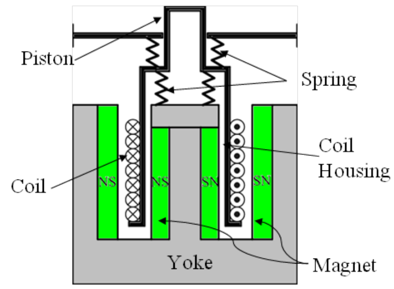
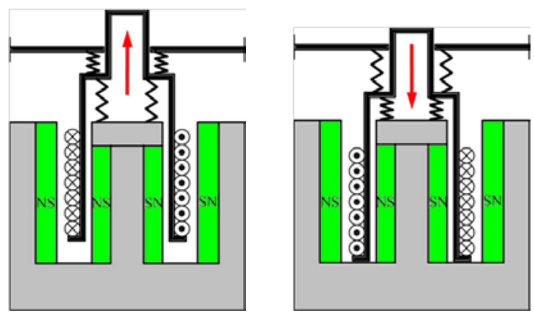


Fig. 1. Schematic diagram of cross- sectional quadratic electromagnetic linear compressor.



(a) (b)
Fig. 2. Principle of operation (a) at the upper position (b) at lower position.

Taguchi Method used control factor and noise factor for static characteristics control. Control factors are inner magnet (A), height of upper yoke (B), thickness of outer magnet (C) and thickness of lower yoke (D). Fig. 3 shows the control factors for Taguchi Method. Control factors and noise factors are shown in table 1.

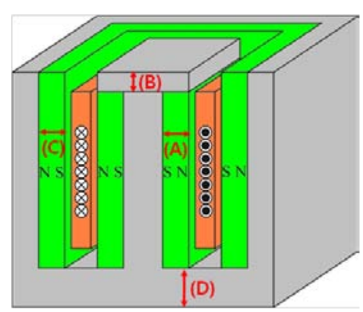


Fig. 3. Control factors for Taguchi Method.

Separating	Indication	Name	1Level	2Level
Control factor	A	Thickness of inner magnet	20mm	22mm
	B	Height of upper yoke	5mm	7mm
	C	Thickness of outer magnet	12.5mm	14.5mm
	D	Thickness of lower yoke	20mm	22mm
Noise factor	R	Repetition	Repetition1	Repetition2
Signal factor	M	Current	40A	35A

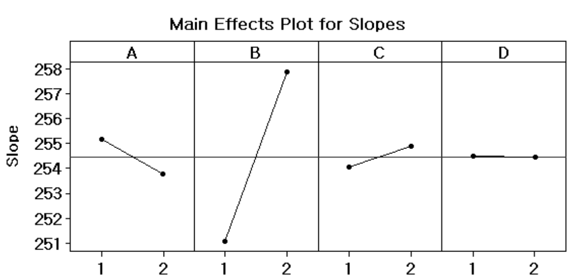
Table. 1. Control factors and noise factors

III. Optimal design using orthogonal arrays

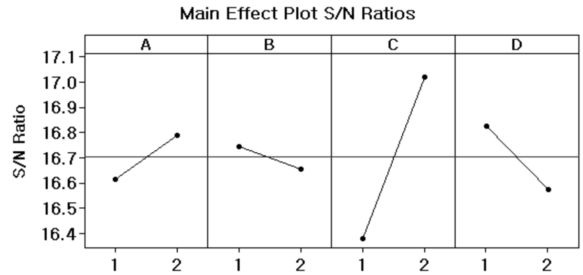
The orthogonal array matrix consist of four factors with 2 Levels as shown in table2, so it comes to the $L_8(2^7)$. And Fig.2 shows main effects plot of S/N ratio and main effects plot of slopes. The factor C was chosen Level2 by main effects plot of S/N ratio. In addition, the factor B was chosen Level2 by main effects plot of slopes. The factor A and factor D were chosen because there is no significant difference between Level factor A and factor D. Therefore, the final optimal design is $A_1B_2C_2D_1$.

	Inner array							Outer array			
								M1		M2	
	A	B	e	C	D	e	e	N1	N2	N1	N2
1	1	1	1	1	1	1	1	9879.5	9872.8	8706.4	8700.4
2	1	1	1	2	2	2	2	10219	10213	8997.8	8992.6
3	1	2	2	1	1	2	2	10150	10127	8946.6	8926
4	1	2	2	2	2	1	1	10482	10470	9230.5	9219.9
5	2	1	2	1	2	1	2	10115	10109	8913	8906.2
6	2	1	2	2	1	2	1	9853.1	9844.1	8678.4	8670.5
7	2	2	1	1	2	2	1	10400	10401	9164.7	9154.4
8	2	2	1	2	1	1	2	10130	10117	8923	8911.3

Table. 2. Configuration of orthogonal array matrix



(a)



(b)

Fig. 2. (a) Main effect plot for slopes (b) Main effect plot S/N ratios.

The signal, noise ratio and slope, called "Predict Taguchi result" are derived by the final optimal design $A_1B_2C_2D_1$. Table. 3 shows S/N ratio and Slopes both at initial condition and optimal condition. The expected performance from the optimal design is expected to be S/N = 17.0143. Based on an evaluation of samples from initial design, the initial status is found to be S/N = 16.4647. The S/N ratio at the optimal condition was improved 0.5496 compared with initial condition. Loss/unit of product at optimal design is 1.13 from equation $10^{0.05496}=1.13$. The optimal design becomes 1.13 times cost saving. Future study will make high efficiency linear compressor using by the more factors and levels.

	Initial condition	Optimal condition
S/N ratio	16.4647	17.0143
Slopes	251.387	258.994

Table. 3. S/N ratio and Slopes at initial condition and optimal condition.

IV. Reference

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