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品質工學(TAGUCHI METHOD)에 의한 COMPRESSOR의 性能과 騷音에 관한 研究

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(Application of Quality Engineering for EER and Noise of Compressor)

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1. INTRODUCTION

The past 10 years have seen an international consensus reached that steps should be taken to reduce the emissions of both ozone layer depleters and "green house" gases that are implicated in global warming. All these CFC and HCFC compounds possess an ozone depletion potential(ODP) and a global warming potential (GWP).

This paper is concerned with the challenge presented to the refrigeration industry by the need to reduce or even eleminate the emissions of all compounds with a significant ODP and/or GWP. In this standpoint, we must develop higher efficency compressor for refrigeration industry in order to satisfy a growing world-wide demand.The study presented in this paper was to utilize Taguchi method to optimize design process of valve system of compressor that would affect the energy efficiency ratio (EER). Several parameters that influenced refrigeration capacity were investigated in order to determine the optimization of design process of valve system.

The Signal-to-Noise (SN) ratio was used as a performance index for each experimental combination to analyze the data to determine significant factor and the level at which the improvement could be achieved when design parameters were changed or adjusted.

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2. THE ENGINEERED SYSTEM

2-1. BASIC Function

The most effective basic function for the compressor system is defined as :

Input Signal (M), Out Response (y)

$$\sqrt{y} = \beta \sqrt{M} \quad ---(1)$$

Above definition of the basicl function is considered by the engineer to be the most correct interpretation of the system input/output energy transfer. The direct measurement of the planetary input/output energy by the experimental apparatus in this test is shown in Fig.1 and the various type of valve system (Fig.1, including suction and discharge valve, head seat) are assembled into the whole system of compressor.

2-2. CONTROL AND NOISE FACTORS

There are a number of factors as illustrated in Fig.2 which can affect the EER.

In Table 1, most important 8 factors based on engineer 's experience have been chosen as control factors for the experiment design. The inner array contains all control factors, i.e. those factors whose level can be set and maintained in the experiment. The L18 orthogonal array arrangement which adopted in this study is shown as belows. For the outer orthogonal array, voltages are used as the signal factors and N1,N2 are used as compounded noise factors which were chosen to anticipate the effect of manufacturing variability and application conditions.

Inner Array

Factors	Level 1	Level 2	Level 3
1. A	2.0	4.0	-
2. B	4.0	5.0	6.0
3. C	1.5	2.0	2.5
4. D	3.0	5.0	7.0
5. E	1.5	1.8	2.1
6. F	0.15	0.20	0.25
7. G	0.20	0.25	0.30
8. H	2.00	2.05	2.10

Outer array

Factors	Level 1	Level 2	Level 3
1.Signal Factor	210 V	220 V	230 V
2.Noise Factor	Little	Much	

3. EXPERIMENTAL APPARATUS AND MEASUREMENT

The experimental apparatus used in this test is shown in Fig1. Various type of valve systems are assembled into test compressor and input/output electric energies (EER) are measured by calorimeter. As well as we measured temperature and pressure of many interesting parts, we recorded those data in recoder and oscilloscope. Also we measured discharge valve displacement by using eddy-current type gap sensor and then knew cylinder volume in result. Our experiment raw data is shown in Table 2.

4. RESULTS AND DATA ANALYSIS

The dynamic analysis of signal-to-noise ratio (SN) is based on the following equation :

$$\eta = 10 \log \frac{(S\beta - Ve)}{2 \gamma V_N} \quad \text{---(2)}$$

The experimental and calculated datas are listed in Table 3. Also the results of SN calculation are listed in Table 3, Table 4 and shown in Fig.2. As shown in Fig.2, the optimum condition which can provide higher S was determined as following :

A2B3C1D1E3F1G1H2 for S ---(3)

Sensitivity S is also shown in Fig.2. The method of two step optimization is used effectively in Taguchi method with SN and S.

5. CONFIRMATION

The Table 5 shows results of confirmation study based on the optimum condition discussed previously. The process average estimates are calculated by using general form of equation as indicated below :

$$\mu = A_i + B_i + \text{---} + H_i - (K-1)\bar{T} \quad \text{---(4)}$$

where, A_i , etc = the factor level average response for level i

K = the number of main factor

$\bar{T}$ = grand average

As shown in Table 5, an improvement in SN about 3.6dB and in S about 0.28dB compared with non-optimum current condition. Then it suggested that L18 array experiment for signal-to-noise (SN) ratio and sensitivity S in this study is based on a good approximationofthe validity and small difference of SN is based on the mistaken determination of the combined noise condition. The slope of input to output energy for the optimum condition is quite linear.

6. CONCLUSION

The dynamic analysis of S/N ratio in this study to improve EER has proven to be very effective. The optimized condition can improve EER during the developing process without increasing noise and any other investment.

If this method is used widely to design valve systems of compressor for refrigeration and air-conditioning, output capacity will be greatly increased for industry.

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REFERENCE

1. Taguchi.G. 1991, TAGUCHI ON ROBUST TECHNOLOGY DEVELOPMENT Bringing Quality Engineering (QE) Upstream, ASME Press, New York.
2. Taguchi.G. 1987, Introduction to QE, American Supplier Institute, Inc., Michigan.
3. 田口玄一, 1991, "품질설계를 위한 실험계획법", 한국공업표준협회(KSA)
4. 田口玄一, 1991, "품질평가를 위한 SN비", 한국공업표준협회(KSA)
5. 田口玄一, 1991, "개발/설계단위의 품질공학", 한국공업표준협회(KSA)
6. 田口玄一, 1991, "제2차 품질공학사례 발표 SYMPOSIUM", 일본규격협회(JSA)
7. 이종원,김추호, 1994, "다구찌방법을 이용한 컴퓨터원용 강건설계기법의 개발", 대한기계학회논문집, 제18권 제2호, PP. 278-291.

Table1 Factor Select by Experience

FACTOR / LEVEL	A	B	C	D	E	F	G	H
1	2.0	4.0	1.5	3.0	1.5	0.15	0.20	2.00
2	4.0	5.0	2.0	5.0	1.8	0.20	0.25	2.05
3		6.0	2.5	7.0	2.1	0.25	0.30	2.10

Table. 2 Experiment Raw Data

NO		N 1			N 2		
		M1	M2	M3	M1	M2	M3
1	I	9.84	9.93	10.06	9.91	10.00	10.12
	0	9.53	9.53	9.52	9.41	9.40	9.45
2	I	9.24	9.36	9.50	9.32	9.41	9.55
	0	8.54	8.55	8.58	8.67	8.60	8.57
3	I	8.50	8.65	8.81	8.68	8.81	8.95
	0	6.81	6.91	6.84	7.23	7.22	7.20
4	I	9.84	9.94	10.07	9.85	9.94	10.06
	0	9.39	9.39	9.39	9.44	9.47	9.38
5	I	9.63	9.73	9.86	9.67	9.78	9.91
	0	9.23	9.24	9.27	9.34	9.36	9.31
6	I	8.92	9.06	9.21	9.05	9.09	9.28
	0	7.91	8.04	7.99	8.21	8.23	8.22
7	I	9.11	9.22	9.35	9.20	9.31	9.46
	0	8.26	8.22	8.19	8.47	8.45	8.45
8	I	8.93	9.01	9.19	9.01	9.09	9.27
	0	7.92	7.92	7.94	7.86	8.14	7.91
9	I	9.93	10.03	10.15	10.09	10.18	10.29
	0	9.67	9.73	9.70	9.77	9.83	9.83

NO		N 1			N 2		
		M1	M2	M3	M1	M2	M3
10	I	9.10	9.21	9.36	9.16	9.26	9.40
	0	8.13	8.14	8.12	8.19	8.22	8.24
11	I	9.34	9.46	9.07	9.57	9.67	9.79
	0	8.43	8.39	8.43	8.58	8.60	8.56
12	I	9.36	9.53	9.66	9.45	9.55	9.68
	0	8.85	8.88	8.89	8.96	8.97	9.02
13	I	9.51	9.67	9.75	9.54	9.70	9.75
	0	8.81	9.39	8.93	8.99	9.39	9.27
14	I	9.04	9.15	9.28	9.08	9.20	9.34
	0	8.23	8.25	8.25	8.39	8.40	8.37
15	I	9.50	9.61	9.75	9.59	9.69	9.82
	0	8.82	8.80	8.80	8.65	8.76	8.74
16	I	9.11	9.25	9.38	9.17	9.27	9.41
	0	8.48	8.48	8.46	8.51	8.43	8.48
17	I	10.08	10.15	10.27	10.12	10.20	10.31
	0	9.93	9.78	9.80	9.89	9.90	9.90
18	I	9.29	9.41	9.55	9.36	9.47	9.61
	0	8.59	8.66	8.70	8.87	8.87	8.81
op	I	9.90	9.99	10.11	9.92	10.01	10.13
	0	9.78	9.80	9.78	9.83	9.83	9.86

Table 3 Experiment Calculation Data

NO	ST	L1	L2	S(β)	S(Nxβ)	Se	V(N)	Ve
1	538.60	284.2383	283.0117	538.5133	0.0468	0.0399	0.0173	0.0100
2	442.36	240.4152	243.6491	442.2934	0.0000	0.0666	0.0133	0.0167
3	297.06	177.9509	190.7844	296.9202	0.0831	0.0567	0.0280	0.0142
4	531.26	280.3670	281.4124	531.1992	0.0023	0.0585	0.0122	0.0146
5	518.16	270.3090	274.0774	518.1059	0.0028	0.0514	0.0108	0.0128
6	393.72	216.9660	225.3770	393.6335	0.0413	0.0452	0.0173	0.0113
7	417.38	227.6526	236.4717	417.2778	0.0314	0.0707	0.0204	0.0177
8	379.16	215.0272	218.1101	379.0596	0.0013	0.0991	0.0201	0.0248
9	570.95	292.0039	299.8127	570.9182	0.0016	0.0302	0.0064	0.0075
10	400.82	224.8585	228.5641	400.7720	0.0025	0.0455	0.0096	0.0114
11	433.44	234.5832	249.1428	433.2843	0.0512	0.1045	0.0311	0.0261
12	478.32	253.3647	257.6040	478.2727	0.0071	0.0402	0.0095	0.0100
13	500.58	261.7762	267.2944	500.3497	0.0368	0.1935	0.0461	0.0484
14	414.92	226.4191	231.6757	414.8480	0.0151	0.0569	0.0144	0.0142
15	460.66	254.1893	253.7735	460.5802	0.0403	0.0395	0.0160	0.0099
16	430.69	235.1103	235.9968	430.6206	0.0022	0.0672	0.0139	0.0168
17	584.20	300.0612	303.0571	584.1336	0.0006	0.0658	0.0133	0.0164
18	459.37	244.4362	251.6231	459.2835	0.0307	0.0558	0.0173	0.0139
opt.	577.70	293.5794	295.7429	577.6600	0.0018	0.0382	0.0080	0.0095

NO	1 A	2 B	3 C	4 D	5 E	6 F	7 G	8 H	SN	S	beta
1	1	1	1	1	1	1	1	1	17.16	-0.4516	0.94934
2	1	1	2	2	2	2	2	2	17.97	-0.7840	0.91371
3	1	1	3	3	3	3	3	3	13.65	-1.8817	0.80524
4	1	2	1	1	2	2	3	3	18.66	-0.4863	0.94557
5	1	2	2	2	3	3	1	1	19.23	-0.4299	0.95172
6	1	2	3	3	1	1	2	2	16.61	-1.0135	0.88988
7	1	3	1	2	1	3	2	3	15.97	-0.9244	0.89906
8	1	3	2	3	2	1	3	1	15.81	-1.1586	0.87515
9	1	3	3	1	3	2	1	2	21.66	-0.3123	0.96469
10	2	1	1	3	3	2	2	1	19.11	-1.0722	0.88388
11	2	1	2	1	1	3	3	2	14.11	-0.9568	0.89572
12	2	1	3	2	2	1	1	3	19.66	-0.5745	0.93601
13	2	2	1	2	3	1	3	2	12.88	-0.4852	0.94571
14	2	2	2	3	1	2	1	3	17.56	-0.8615	0.90559
15	2	2	3	1	2	3	2	1	17.12	-0.8506	0.90672
16	2	3	1	3	2	3	1	2	17.80	-0.7807	0.91406
17	2	3	2	1	3	1	2	3	18.49	-0.2779	0.96852
18	2	3	3	2	1	2	3	1	16.95	-0.6692	0.92586
optimum condition									20.79	-0.1737	0.98021

Table 4 RESPONSE TABLE

SN RATIO

LEVEL	A	B	C	D	E	F	G	H
1	17.41	16.94	16.93	17.87	16.39	16.77	18.84	17.56
2	17.07	17.01	17.19	17.11	17.84	18.65	17.54	16.84
3	-	17.78	17.61	16.76	17.50	16.31	15.35	17.33

Sensitivity

LEVEL	A	B	C	D	E	F	G	H
1	-0.8269	-0.9535	-0.7001	-0.5559	-0.8128	-0.6602	-0.5684	-0.7720
2	-0.7254	-0.6878	-0.7448	-0.6445	-0.7725	-0.6976	-0.8204	-0.7221
3	-	-0.6872	-0.8836	-1.1280	-0.7432	-0.9707	-0.9396	-0.8344

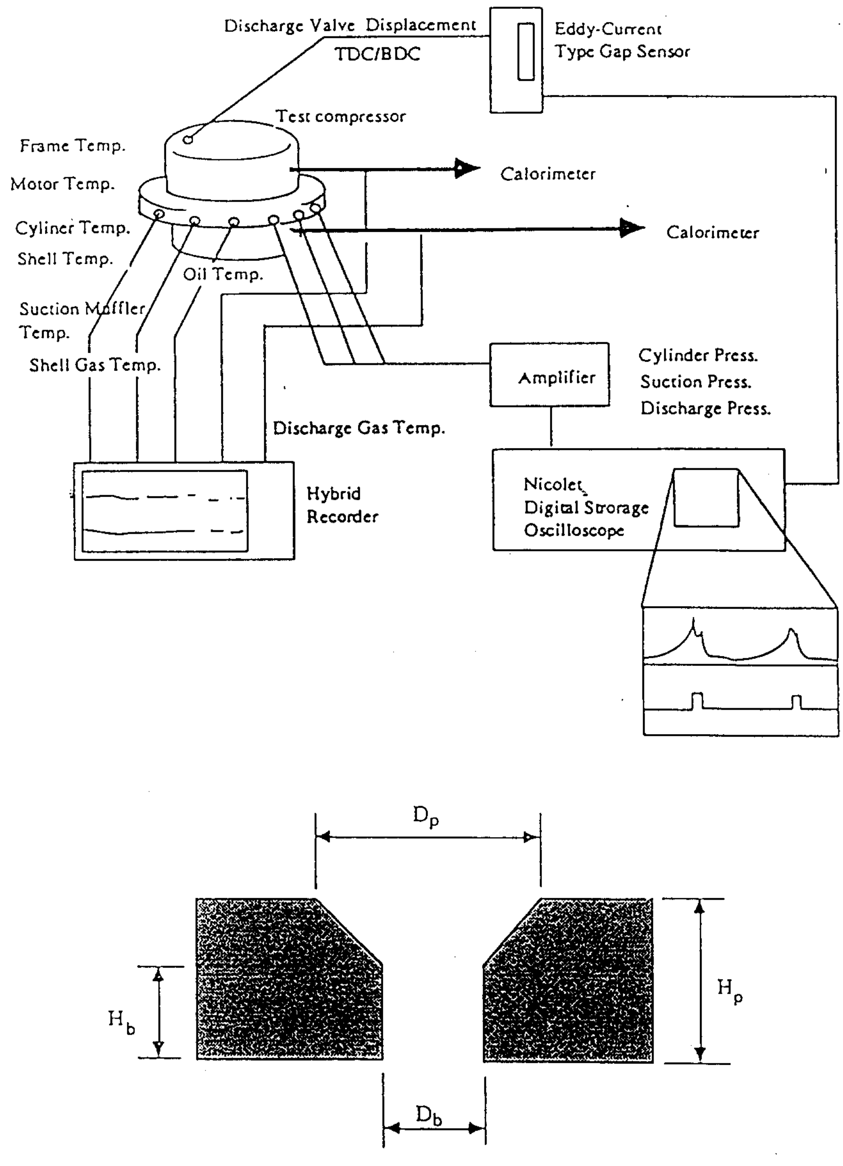

Fig.1 Experimental Apparatus and Valve Related Part

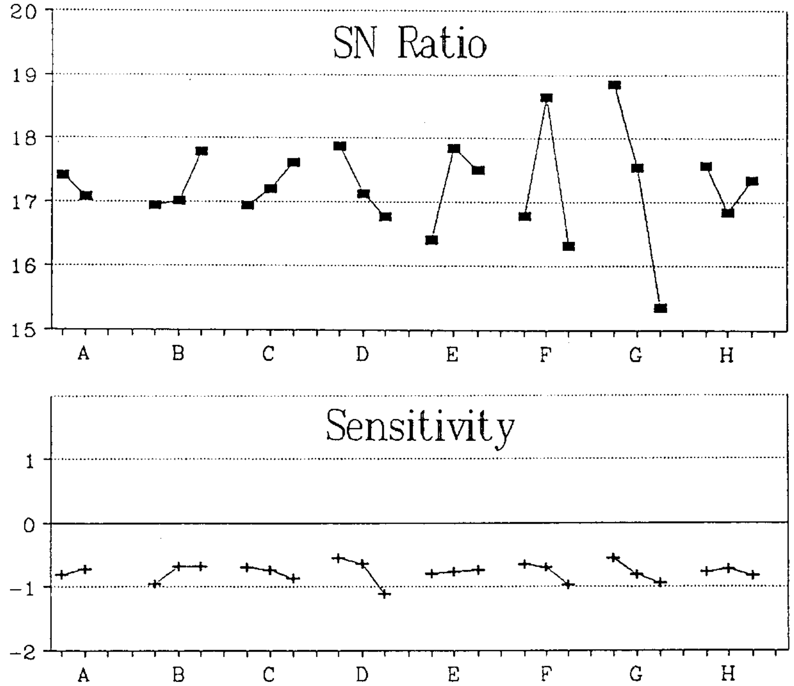

Fig.2 Graph of Factor Effect

Table 5 Confirmation Results

BASED ON Sensitivity Only

CONDITION	LEVEL OF FACTOR	PREDICTED		EXPERIMENT	
		η	S	η	S
OPTIMUM CONDITION	A2 B3 C1 D1 E3 F1 G1 H2	19.80	-0.0670	20.79	-0.1737
CURRENT CONDITION	A1 B1 C1 D1 E1 F1 G1 H1	17.85	-0.3333	17.16	-0.4516
GAIN		1.95	0.2663	3.63	0.2779