Application of Taguchi Robust Design Method for Energy Efficiency Ratio and Noise of Compressors

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ABSTRACT

As the concern for a global energy conservation and environmental protection are increased, it became more important thing to correspond with CFC depletion. Many companies have produced CFC-free refrigerators using alternatives refrigerants. Alternative refrigerants have merit such as global warming effect, but also have demerits such as lower efficiency, miscibility, increasing noise and poor reliability problems etc. Then we have to develop more efficient and robust compressors to satisfy a growing world-wide demand.

In this paper, Taguchi robust design method with dynamic signal to noise ratio (SN) and two step optimization process have been used to optimize the head valve system for developing more efficient and low noise compressor. Also this method can be applied to rotary, scroll and other types of compressor.

INTRODUCTION

The past 10 years have seen an international consensus reached that steps should be taken to reduce the emissions of both ozone layer depletion 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 eliminate the emissions of all compounds with a significant ODP and/or GWP. In this standpoint, we must develop higher efficient compressor for refrigeration and air conditioning industry in order to satisfy a growing world-wide specific demand. This paper was to utilize Taguchi robust design method to optimize design process of the head valve system of reciprocating compressor that would affect the energy efficient ratio and noise level. Several parameters that influenced refrigeration capacity were investigated in order to determine the optimization of design process of the head valve system. The dynamic signal to noise ratio (SN) was used as a performance index for each experimental combination to analyze the data to determine significant factor and level at which improvement could be achieved when design parameters were changed or adjusted.

ANALYSIS AND EXPERIMENT

1. Basic Function

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

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

Here, M is the input signals and y is the output responses. Above definition of the basic function is taken by the engineers to be the most correct interpretation of the input/output systematic energy transformation.

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

$$\eta = 10LOG\frac{(S_\beta - V_e)}{2rV_N} \qquad \text{--- (2)}$$

Here , r is a measurement of the magnitude of the input signals.

S_β is the sum of squares of the useful parts.

V_e is the mean square error of non-linearity.

V_N is an error term of non-linearity and linearity.

2. Control and Noise Factors

The most important 8 factors(for example, port diameter and bore height) based on engineer's experience have been chosen as control factors for the experiment. The L18 orthogonal array arrangement adopted in this study is shown in Table 1. Voltages (M1, M2, M3) 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.

3. Experimental Apparatus and Measurement

The experimental apparatus used in this test is shown in Fig.1. Various type of head valve system are assembled into test compressor and input/output electric energies are measured by precise calorimeter.

As well as we measured temperature and pressure of many interesting parts, we recorded those data in hybrid recorder and oscilloscope. Also we measured discharge valve displacement by using eddy-current type gap sensor and then knew cylinder volume in result. Considering above data, we can finally obtained P-V diagram and many useful information about compressor. The experimental raw data is shown in Table 1.

4. Results and Data Analysis

After the raw data are calculated, the final results of SN ratio and sensitivity S are shown in Fig. 2. As shown in Fig. 2, the optimum condition which can provide higher SN and S was determined as follows : A2B3C1D1E3F1G1H2

CONCLUSION

The SN ratio and S adopted in this study to improve EER(about 5%) and reduce noise level(about 3dB) have proven to be very effective. The optimized condition in this study can improve EER during the developing process without increasing noise(Table 2). If this method is used widely to develop the head valve systems of reciprocating compressor or any other important parts for the refrigeration and air conditioning industry , EER and noise level will be improved without increasing development period.

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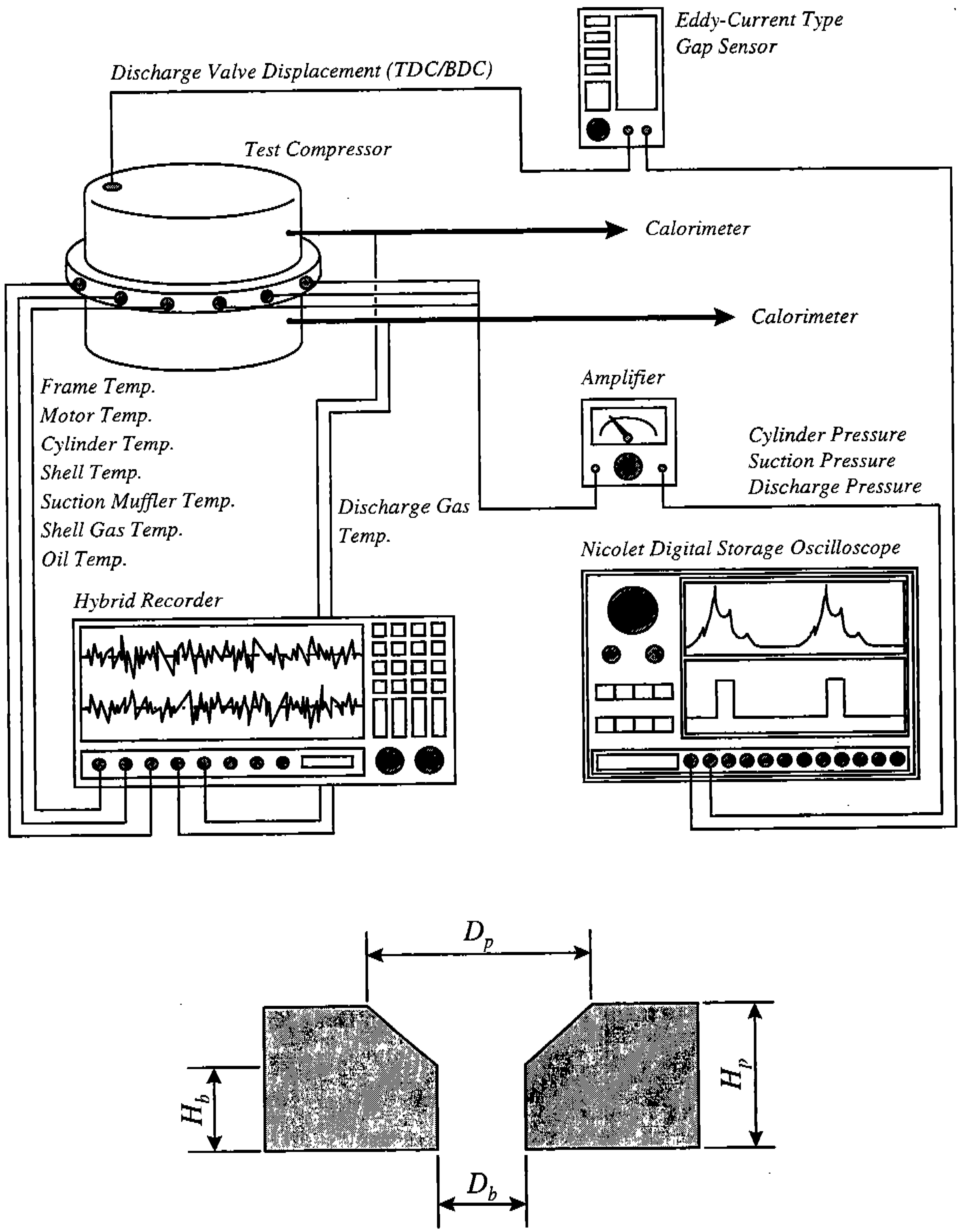

Fig.1 Experimental Apparatus and Valve Related Part

Table 1. Experimental Raw Data

EXP NO.		N1 M1	N1 M2	N1 M3	N2 M1	N2 M2	N2 M3
1	I	9.84	9.93	10.06	9.91	10.00	10.12
	O	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
	O	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
	O	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
	O	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
	O	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
	O	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
	O	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
	O	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
	O	9.67	9.73	9.70	9.77	9.83	9.83
10	I	9.10	9.21	9.36	9.16	9.26	9.40
	O	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
	O	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
	O	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
	O	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
	O	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
	O	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
	O	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
	O	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
	O	8.59	8.66	8.70	8.87	8.87	8.81

Table 2. Head-Valve System Flexibility Tests

Model	Cooling Capacity (Kcal/Hr.)	Noise (dBA)
A	7.8 % Up	X : 39.5 , Y : 34.1
B	4.7 % Up	Not Conducted
C	5.0 % Up	Not Conducted
Test Condition : R-134a , Viscosity 32G Ps / Pd = 0.14 / 13.96 Kgf / Cm , Voltage Changed 60 Hz		

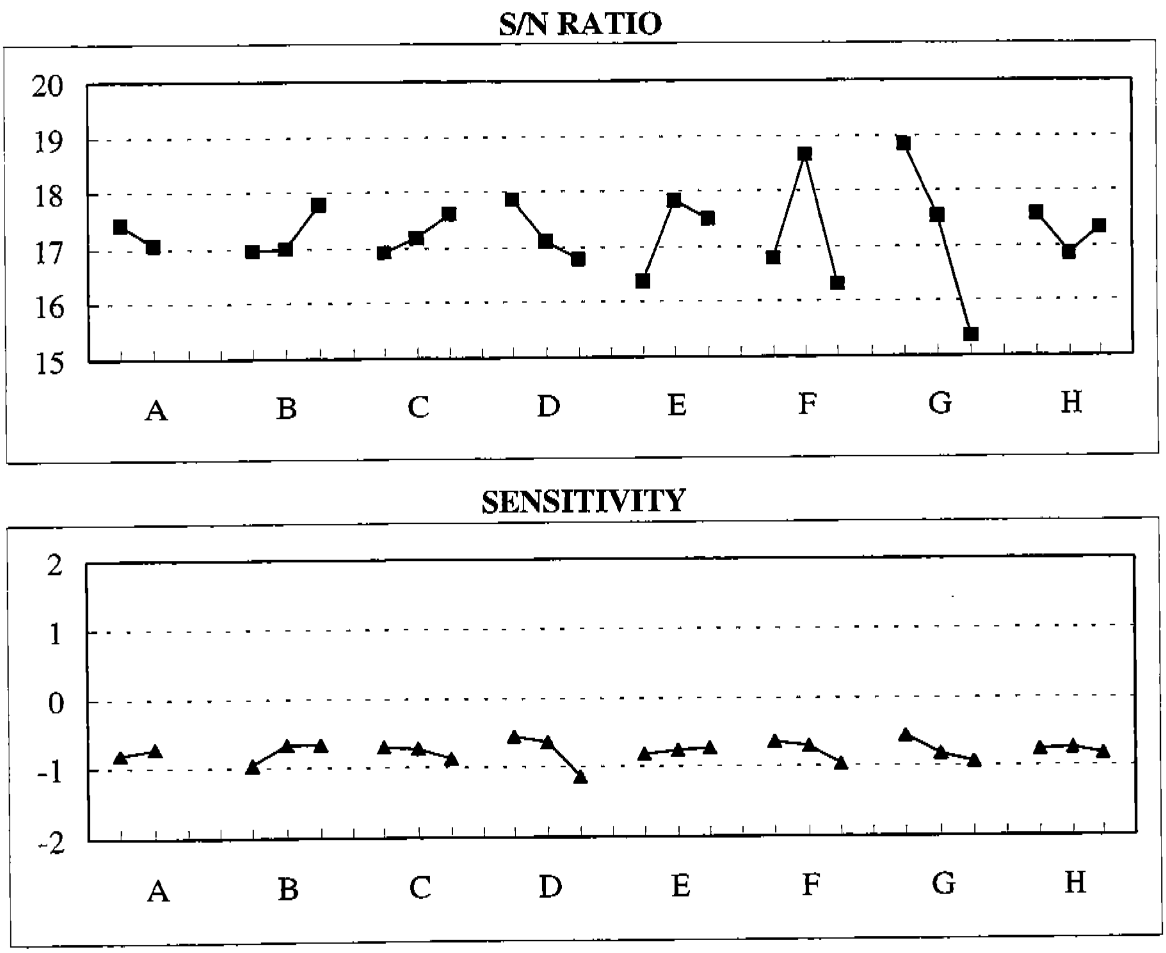

Fig. 2 Graph of Factor Effect