1992

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OPTIMAL DESIGN OF AN ACCUMULATOR IN A ROLLING PISTON TYPE ROTARY COMPRESSOR

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KEY WORDS :DESIGN OF EXPERIMENTS, EFFECTIVE FACTOR, INTERACTION, MAIN FACTOR, INDEPENDENT FACTOR, THE TABLE OF ORTHOGONAL ARRAYS,TWO-WAY FACTORIAL DESIGN, LINE AND DOT DIAGRAM, ANALYSIS OF VARIANCE, CONFIDENCE INTERVAL

ABSTRACT

The suction process of a rotary compressor comes with gas pulsation by the rapid and cyclic suction. Because it has an effect on suction loss and mass flow rate, the gas pulsation acts as an important factor on EER. Especially the structure of an accumulator is related to the condition of gas pulsation. So the purpose of this paper is to do an optimal design by using "design of experiments" of an accumulator. We used design of experiments to find the main factors by two-way factorial design with the table of orthogonal arrays. And by using the main factors and interactions, the experiments for optimal design were worked.

1.INTRODUCTION

It is generally well known that the accumulator of rolling piston-type rotary compressors is designed to prevent the suction of liquid refrigerant and the noise by the gas pulsation which is unavoidable in high speed compressors. So the geometry of an accumulator affects on the gas pulsation, and it changes not only noise level but also energy efficiency. Therefore if we make use of the gas pulsation, we can induce the overcharge of refrigerant gas in the suction process. By the fact that the overcharge reduces the suction loss and increases the volumetric efficiency, it increases the energy efficiency ratio(EER) on the whole.

Even though a lot of research has been done for the improvement of EER, there are few papers related to the accumulator. For this reason, we tried to find which design factors are effective on the performance of a compressor by experiments. And with that result, we decided the optimal geometry of an accumulator . First for the extraction of effective factors, we used 60Hz, 7400 Btu/hr class rotary compressors of the room airconditioners of GOLDSTAR CO.. By using experiments, the most effective factors on EER were found by design of experiments. The design of experiments means a planning method of experiments. It plans experiments, data acquisition, management of statistical data,analysis of data to get the most effective and maximum informations by the minimum experiments. The extracted effective factors and interactions were different for cooling capacity, input power and EER respectively. We were especially interested in EER in this research. After the extraction of effective factors we decided optimal geometry on the basis of found factors by using the trial and error method. For the reliability of experiments, we made test sets that could change only accumulators without changing main parts of a compressor.

2. EXTRACTION OF EFFECTIVE FACTORS

2.1. EXPERIMENT AND ANAYSIS BY DESIGN OF EXPERIMENTS

In Fig.1, seven design factors which might be affective to the performance were selected. With the factors, design of experiments was conducted even considering interactions. Totally 16 cases of experiments were performed after selecting an appropriate line and dot diagram of the table of orthogonal analysis with two-way factorial design. In the line and dot diagram points mean effective factors and lines represent interactions. Table 2 shows dimensions and shapes of the factors. For the error estimation of a calorimeter, a compressor's performance was measured many times in a test condition. And the result was fairly good with the experimental error of 0.2 %.

2.2. EXPERIMENTAL RESULTS

Table 4 shows the results of experiments conducted randomly. After the analysis of variance, the effectiveness of each factor was determined with the confidence interval of 97.5 %. Table 5 gives the results of the effectiveness, and Table 6 is an analysis table for the direction of design. By Table 5, factors affecting the capacity, input and EER were different each other. The volume of the body , the diameter and the interaction (of the length and the diameter) of the L-Tube were found to be most effective factors.

BODY

The length and the diameter of a body did not affect on EER independently. But the volume of the body, the interaction of the length and the diameter of the body, were known to be much affective. By this fact, the volume of a body seems to be an effective factor for the performance by causing the pulsation of suction gas. In Table 6, it could be known that there is a critical point or volume which is the lowest in EER. But this point can not be fixed, because the point may vary with the capacities or characteristics of compressors.

L-TUBE

The L-Tube's diameter as an independent factor was effective, but the length was not. And the interaction of the length and the diameter, i.e., the volume, was also effective. Also, the length of the L-Tube interacted with the diameter of the body. Reflecting on the facts mentioned above, we can see that the L-Tube has complicated relation with the body. As shown in Table 6, when the length of the L-Tube is proportional to the diameter of the body there was a tendency to increase EER.

3. OPTIMAL DESIGN

Above mentioned effective factors were extracted from the conventional compressors of GOLDSTAR CO.. With the extracted factors we made experiments by varying effective dimensions of accumulators for now-developing compressors.

3.1. DIMENSION DEVELOPMENT FOR OPTIMAL DESIGN

The diameter of the L-Tube is constrained to the suction diameter of a cylinder. The diameter of an accumulator body is required as small as possible considering the setting in an air-conditioner. Based on the facts mentioned above, we developed dimensions of accumulators as follows.

i) Accumulator body

After fixing the diameter as 47.5, we developed the volumes of accumulators by changing the length.

ii) L-Tube

The diameter of the L-Tube was fixed as 15.8 by considering the suction diameter of a cylinder. So we varied the length only.

iii) Screen & screen holder

To decrease pressure loss as possible, screen mesh of 100x100, 0.1 was used. Screen holder of type 1 in Table 2 was selected.

3.2. EXPERIMENTAL RESULTS AND OPTIMAL DESIGN OF ACCUMULATORS

Experimental results were shown in Fig. 3 and Table 7. According to the results, there was difference of EER over 1 % even for a few experiments.As the length of the L-Tube is increased, cooling capacity and input power are reduced and EER is increased. Especially the reduction of input power by the increase of the length of the L-Tube may result from the effect of pressure pulsation even though the suction friction loss increases. By these factors the variation of EER is not trivial, so we should take account of them in the design of an accumulator. The appropriate design process of an accumulator is as follows.

1) To decide the volume of a body and the diameter of L-Tube by considering the compressor specification and system.

2) To decide the diameter and the length of the body. If possible, long length and small diameter will be available. Because the diameter of the body is less effective on EER than the volume of the body itself is. So the length can be designed within a wider range of variation in a decided volume.

3) To decide the L-Tube's length by trial and error method with varing the L-Tube's length.

If design of experiments is applied, the number of times of experiments will be reduced.

4. CONCLUSION

1) By changing the dimensions and shape of an accumulator, the increase of EER above 1 % compared with the conventional accumulator was gotten.

2) Most effective factors on EER are the volume of the body and the length of the L-Tube among the various design factors and the interactions of an accumulator.

3) Design of experiments was applied in designing an accumulator in view of improvement of EER.

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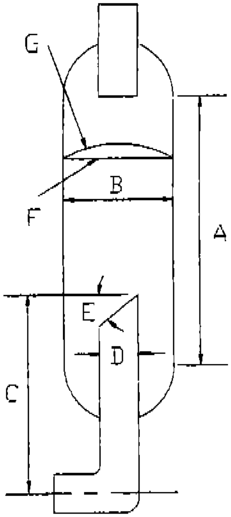


Fig. 1 Factors of accumulator

Table 1. Latin Square

sample number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
3	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0
5	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
6	0	1	1	0	0	1	1	1	1	0	0	1	1	0	0
7	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0
8	0	1	1	1	1	0	0	1	1	0	0	0	0	1	1
9	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
10	1	0	1	0	1	0	1	1	0	1	0	1	0	1	0
11	1	0	1	1	0	1	0	0	1	0	1	1	0	1	0
12	1	0	1	1	0	1	0	1	0	1	0	0	1	0	1
13	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0
14	1	1	0	0	1	1	0	1	0	0	1	1	0	0	1
15	1	1	0	1	0	0	1	0	1	1	0	1	0	0	1
16	1	1	0	1	0	0	1	1	0	0	1	0	1	1	0
	C	E	CE	D	CD	ED	AB	B	BC	G	CG	F	CF	AC	A

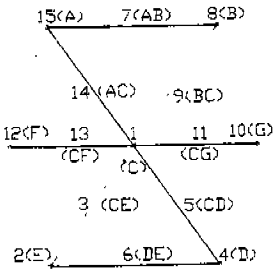


Fig. 2 Line and dot diagram

Table 2. The dimension and shape of each factor
unit [mm]

FACTOR	0 - TYPE	1 - TYPE	REMARKS
A	90	120	Body length
B	50.8	65	Body diameter
C	90	130	L-tube length
D	9.52	12.7	L-tube diameter
E	0°	45°	Section angle
F	Φ0.23,0.18 100 x 100	Φ 0.1 100 x 100	Screen mesh
G			Screen holder type

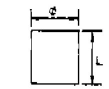
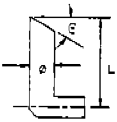
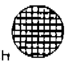
TERMS \ NUMBER			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
BODY		ø	50.8	65	50.8	65	50.8	65	50.8	65	50.8	65	50.8	65	50.8	65	50.8	65
		L	90	120	120	90	120	90	90	120	120	90	90	120	90	120	120	90
L TUBE		θ	0	0	0	0	45	45	45	45	0	0	0	0	45	45	45	45
		ø	9.52	9.52	12.7	12.7	9.52	9.52	12.7	12.7	9.52	9.52	12.7	12.7	9.52	9.52	12.7	12.7
		L	90	90	90	90	90	90	90	90	130	130	130	130	130	130	130	130
SCREEN		ø	0.23 / 0.18	0.1	0.23 / 0.18	0.1	0.1	0.23 / 0.18	0.1	0.23 / 0.18	0.23 / 0.18	0.1	0.23 / 0.18	0.1	0.1	0.23 / 0.18	0.1	0.23 / 0.18
	MESH DIAMETER , ø MESH , #	#	30 x 160	100 x 100	30 x 160	100 x 100	100 x 100	30 x 160	100 x 100	30 x 160	30 x 160	100 x 100	30 x 160	100 x 100	100 x 100	30 x 160	100 x 100	70 x 160
HOLDER	 A B	type	A	B	B	A	A	B	B	A	A	B	B	A	A	B	B	A

Table. 3 Development of parts for experiment

Table 4. Experimental data for the extraction of effective factors

NO.	C C A P	INPUT	E E R
1	99.14	99.48	99.64
2	100.28	100.28	99.98
3	100.14	100.32	99.81
* 4	100.00	100.00	100.00
5	99.87	100.72	99.15
6	99.31	100.51	98.82
7	102.55	99.96	102.59
8	101.30	100.16	101.14
9	101.31	101.50	99.82
10	102.15	102.39	99.75
11	99.31	99.54	99.77
12	100.78	99.44	101.34
13	102.08	101.74	100.25
14	103.51	101.74	101.62
15	99.37	101.85	99.62
16	100.38	99.32	101.06

* Reference Accumulator

Table 5. Results from analysis of variance

TERMS		CCAP	INPUT	EER
BODY	LENGTH			
	DIAMETER	△		
	LENGTH x DIAMETER	○	△	◉
L TUBE	LENGTH	○	○	
	DIAMETER	△	◉	○
	LENGTH x DIAMETER	◉	◉	○
	SECTION ANGLE	○		△
BODY DIA. x L-TUBE LEN.		○		○
SCREEN HOLDER			○	
BODY LEN. x L-TUBE LEN.			△	

◉ Very effective
○ Effective
△ May be effective

Table 6. Analysis of variance of expected values

1) A x B (BODY LENGTH x BODY DIAMETER = BODY VOLUME)

	A O		A 1		SUM
B O	* 1, 7, 11, 13	**39.139	3, 5, 9, 15	38.763	77.902
B O	4, 6, 10, 16	38.884	2, 8, 12, 14	39.317	78.201
SUM		78.023		78.08	156.103

2) D (L-TUBE DIAMETER)

D O	1, 2, 5, 6, 9, 10, 13, 14	77.745	156.103
D 1	3, 4, 7, 8, 11, 12, 15, 16	78.358	

3) C x D (L-TUBE LENGTH x L-TUBE DIAMETER = L-TUBE VOLUME)

	C O		C 1		SUM
D O	1, 3, 5, 7	39.035	9, 10, 13, 14	39.06	77.745
D 1	3, 4, 7, 8	39.264	11, 12, 15, 16	39.094	78.358
SUM		77.949		78.154	156.103

4) B x C (BODY DIAMETER x L-TUBE LENGTH)

	B O		B 1		SUM
C O	1, 3, 5, 7	39.035	2, 4, 6, 8	38.914	77.949
C 1	9, 11, 13, 15	38.867	10, 12, 14, 16	39.287	78.154
SUM		77.902		78.01	156.103

※ A0 , A1 , B0 ...... C1 : Refer to the table 2.

* : Sample number

** : Sum of EER for those sample numbers

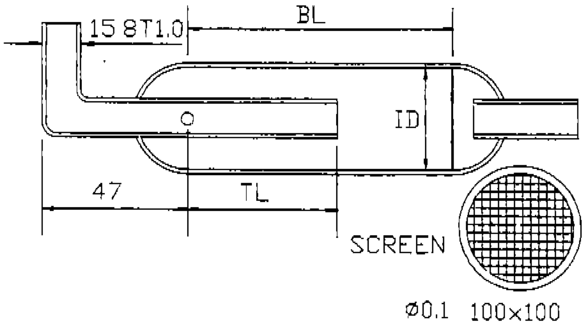


Fig. 3 Dimension developments of accumulator

Table 7. Dimensions of extracted factors for experiments

	ID(mm)	BL(mm)	TL(mm)	INPUT	CCAP	EER
	55.0	113	103	98.86	99.80	100.22
*	61.5	160	103	100.00	100.00	100.00
	47.5	120	70	99.99	100.50	100.54
	47.5	120	80	99.76	100.33	100.58
	47.5	120	100	98.97	99.30	100.28
	47.5	120	120	98.55	99.11	100.53
	47.5	140	100	98.97	99.11	100.93
	47.5	140	120	99.61	100.06	100.51
	47.5	140	140	98.61	99.57	100.96

* Reference dimension