International Compressor Engineering Conference | School of Mechanical Engineering

1990

The Impact of S/D Ratio on Compressor Performances

T. Cui
Xi'an Jiaotong University

THE IMPACT OF S/D RATIO ON COMPRESSOR PERFORMANCES

Cui Tiansheng

Division of Compressor
Xi'an Jiaotong University
Xi'an Shaanxi Province
China

ABSTRACT

S/D ratio is an important structural parameter of a reciprocating compressor. Proper determination of S/D ratio is a problem to be studied in compressor design. The author has made numerous repeated experimental studies on a vertical and variable S/D ratio testing machine, and a variable curve is obtained, thus the impact of the alteration of S/D ratio on compressor performances is known initially.

INTRODUCTION

The cylindycal diameter D and travel S, i.e. the value of S/D is an important structural parameter of reciprocating compressors. Proper determination of S/D ratio will raise the reliability and economy of the compressors. The determination of the optimal geometry (S/D) of a two stage, double-acting reciprocating compressors had been studed by P.I.PLASTININ etc. Some experiment investigation has been made in this paper to study the impact of S/D on the performance of small-type, one stage, single-acting reciprocating compressors.

TEST UNIT AND METHOD

1. Test Unit

The changeable S/D test unit consists of a crankshaft case welded by steel plate, a combined crankshaft, steel connecting rods, and a group of cylinders and adjustable spacers. The test unit is driven by a D.C. motor controlled by SCR. There are three connecting rods with different length and three cylinders to meet the requirements of various of S/D. The valves are reed-type one. The test unit is air coold. The constitution of crankshaft and crank is shown in Fig.1-2.

The crankshaft is connected the crank by bolts and cylindrical pin. The variation of S/D can be shorn by matching cylindrical pin with different crankshaft and crank travel adjusting holes. The combination and graduation of adjusting holes are shown in table 1 and table 2.

Table 1 The combination of the test unit

S/D	0.444	0.5	0.556	0.611	0.667	0.722	0.778	0.833	0.889	0.944	1
Combination of crankshaft and crank	01	A3	02	03	B1	04	C2	05	06	07	08
Connecting rod	100 mm			140 mm				185 mm			
Cylinder	S.S.C	S.S.C and 2.5mm spacer	S.S.C and 5mm spacer	M.S.C	M.S.C and 2.5mm spacer	M.S.C and 5mm spacer	M.S.C and 2.5mm and 5mm	B.S.C	B.S.C. and 2.5mm spacer	B.S.C and 5mm spacer	B.S.C and 2.5mm and 5mm

Nots: S.S.C is small-size cylinder; M.S.C is medium-size cylinder; B.S.C is big-size cylinder.

Table 2 The graduation of adjusting holes

graduation pasition (see Fig.1-2)	1	A	2	3	B	4	C	5	6	7	8
angle	0°	29.6°	43.7°	55.8°	67.4°	78.9°	90.9°	103.8°	118.5°	136.9°	180°

2. Method of Experimental Study

First of all, the theoretical discharge rate such as 0.075, 0.1, 0.15, 0.2 m^3/min, etc are determined, then, according to the formula $N = 4Q/\pi D^2 S \lambda$ (suppose discharge coefficient $\lambda = 0.6$), rotating speed N be calculated. The actual discharge rate corresponding to different S/D is controlled by adjusting the rotating speed. During the test, keep the intake temperature (24°C) and the pressure ratio (8) constant, and measure the power, the discharge rate, the temperature of discharge valve chamber, the noise and vibration of the unit. Because discharge temperature, noise, and vibration are affected by rotating speed, they are measured under the conditions of the same rotating speed and different S/D.

THE TEST RESULTS AND ANALYSIS

The variation curves of the data treated by smooting method are shown in Fig.3-13.

When S/D value increases without changing rotating speed, the discharge rate changes, and the discharge temperature changes nonlinearly (Fig.3). The main reason for this is that the greater the S/D value, the greater the discharge rate, and the less the heat transfer in the same time interval. In Fig.4, it is obvious that the discharge temperature rises with the increase of discharge rate when the S/D value is constant. Meanwhile, for a certain discharge rate, the discharge temperture increases nonlinearly with the S/D value. This is because at the same discharge rate, the rotating speed of the testing compressor decreases with the increase of S/D value (the conditions where the rotating speed charges with the travel and discharge rate, see table 3), and the heat transfer time between the gas in the cylinder and the cylinder wall and the piston top prolongs correspondingly, leading to the rise of gas temperature; in addition, the frictional work increases with the S/D value, causing the rise of gas temperature, too.

Table 3

S.mm \ N.r/min \ $Q m^3$/min	0.075	0.1	0.15	0.2
40	491	655	982	1310
45	437	582	873	1164
50	393	524	786	1048
55	357	476	714	953
60	327	437	654	873
65	302	403	605	806
70	281	374	561	748
75	262	349	524	699
80	246	328	491	655
85	231	308	462	616
90	218	291	437	582

Fig.5-7 illustrates how the vibration changes with the S/D value when the rotating speed is 900 r/min and 1200 r/min respectively. The vibration increase linearly with the S/D value, this is because of the action of inertia and overturning moment.

The noise of the unit increases with S/D value. There are two main reasous: (1) the vibration of the unit increases with S/D value, (2) the beat sound of the value and sound of gas flow increase.

When theoretical discharge rate is respectively 0.075, 0.1, 0.15, 0.2 m^3/min, the change of actual discharge rate (it changes into discharge Coefficient λ), power and specific power are shown in Fig.9-12. From these figures, it is known that they do not vary linearly.

The influence of the change of S/D value on discharge rate can be simply analysed with the formula of discharge rate: $Q = \pi/4\ D^2\ S\ N \lambda_v \lambda_p \lambda_T \lambda_l$. For a certain theoretical discharge rate, when D is determined, there will be a decrease in N if S increases, this in turn will influence pressure coefficient λ_p, leakage coefficient λ_i and temperature coefficient λ_T . Fig.13 shows the change of volume coefficient λ_V with S/D. All these factors influence the change of discharge rate.

From the formula of indicated power $w = 1/60\ N\ P_s\ \lambda_v\ V_h \frac{n}{n-1} \{[\varepsilon(1+\delta)]^{\frac{n-1}{n}} - 1\}$ it is known that at a certain cylindrical diameter D, rotating speed N, intake pressure P and pressure ratio ε , the indicated power increases with increase of S.

Meanwhile, the increase of S causes the increase of friction work, and λ_v influences the indicated power as shown in Fig.13. Besides, owing to the values of resistance loss δ and polytrpic exponent are uncertain, they influence the indicated power to varying degrees. This is because the comprehensive action of the above factors on power causes the nonlinear increase of power.

As the nonlinearity of Q (λ) and W, the specific power does not vary linearly with S/D. From Fig.9-12, it can be seen that there is a better range of S/D from 0.556 to 0.833, in which the specific power varies less and better.

The tested compressor is of single cylinder and vertical type, air cooled and single stage, if the compressor is changed into V-type or W-type, the theoretical discharge rate will change correspondingly into 0.3, 0.4, 0.45, 0.6, 0.9 m^3/min etc. Therefore is can be inferred that the relation of variation between the better range of S/D, discharge temperature, vibration, noise and S/D value is also applicable to these kind of compressors.

CONCLUSIONS

1. For a given rotating speed of a compressor its discharge temperature increase nonlinearly with S/D; for a given discharge rate, its discharge temperature increases nonlinearly with S/D, and the higher the discharge rate, the higher the discharge temperature.
2. For a constant rotating speed, the vibration of the unit varies linearly with S/D, so does the noise and the increase extent is small.
3. For a certain theoretical discharge rate, if the absolute clearance is constant, the actual discharge rate (or discharge coefficient) and power increase nonlinearly with S/D value. Within the range of 0.556--0.833 of S/D, the specific power is smaller, and this range may be called a better range. This deduction is applicable to any compressor whose discharge rate is below 1 m^3/min. Therefore with a discharge rate lower than 1 m^3/min, the choice of S/D value should be taken within the above range as best as one can.

REFERENCES

[1] P.I.PLASTININ and A.K.TVALCHRELIDZE "Determination of The Optimal Geometry of a Two Stage Reciprocating Compressor Using a Mathematical Model" Proceedings of University of Strathclyde, Glasgow. 1978.

[2] Yu Yongzhang "The Reciprocating Compressor" Mechanical Industry Press, Beijing 1982.

[3] Beijing Industrial Callege :Programming Library in Common Use" 1983.

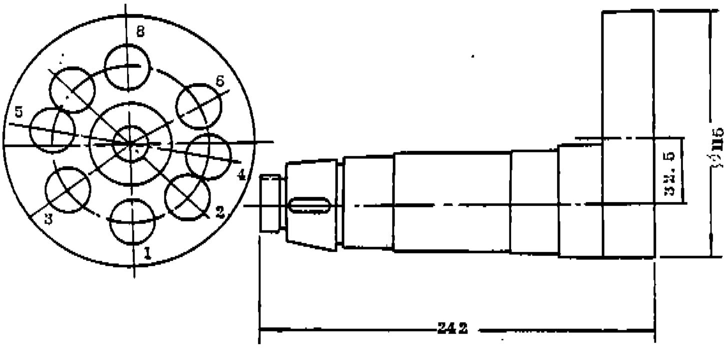

Fig. 1 Crankshaft

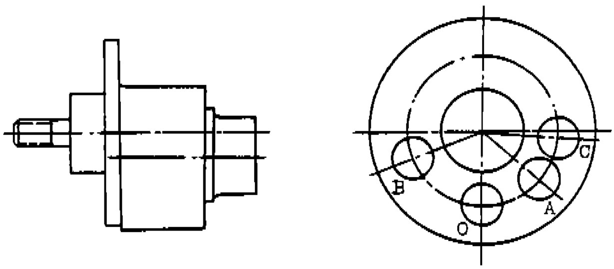

Fig. 2 Crank

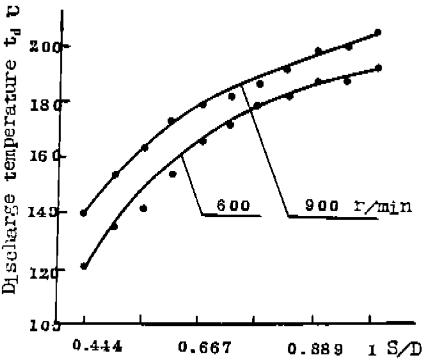

Fig. 3 The variation curve of the temperature of discharge valve chamber versus S/D

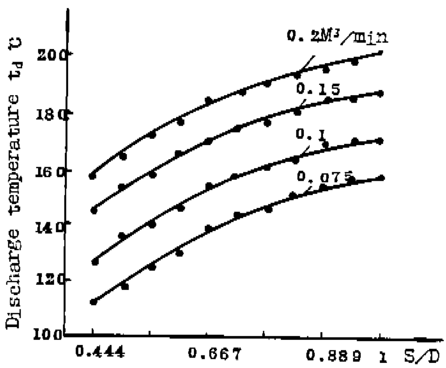

Fig. 4 The variation curve discharge temperature t_d versus S/D at different discharge rate

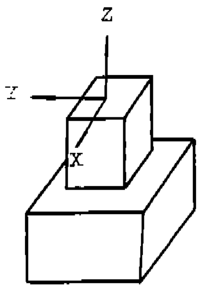

Fig. 5 The diagram of vibration measuring point

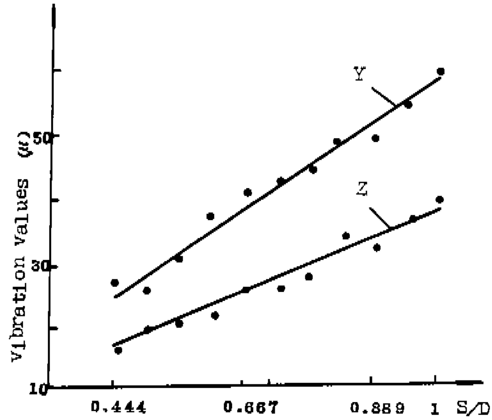

Fig. 6 The variation curve of vibration versus S/D at the speed of 900 r/min

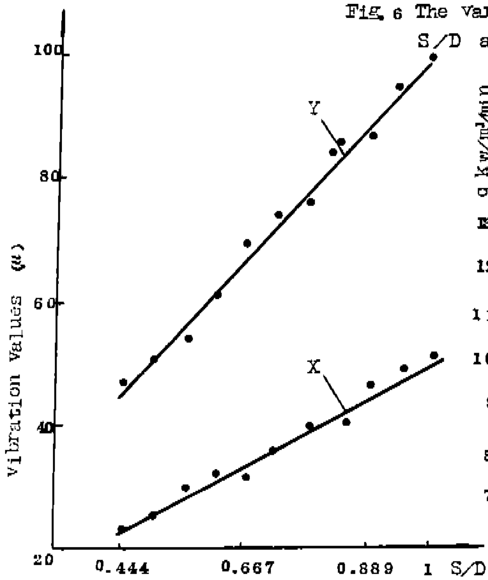

Fig. 7 The variation curve of vibration versus S/D at the speed of 1200 r/min

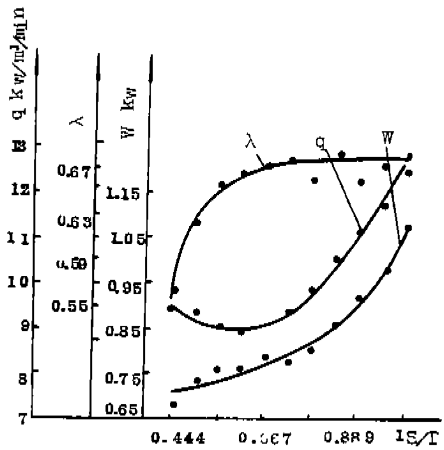

Fig. 9 The variation curve of discharge coefficient (λ) power (w), and specific power (q) versus S/D (0.075 m³/min)

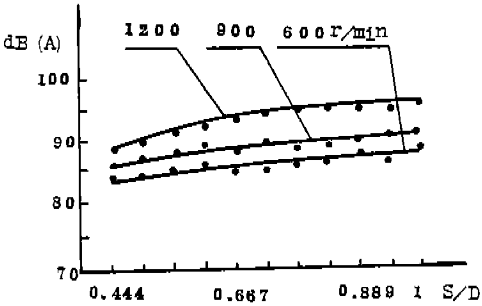

Fig. 8 The vairation of noise versus S/D

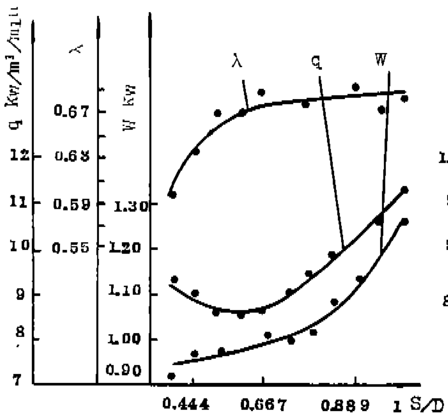

Fig. 10 The variation curve of discharge coefficient (λ), power (w), and specific power (q) versus S/D (0.1 m³/min)

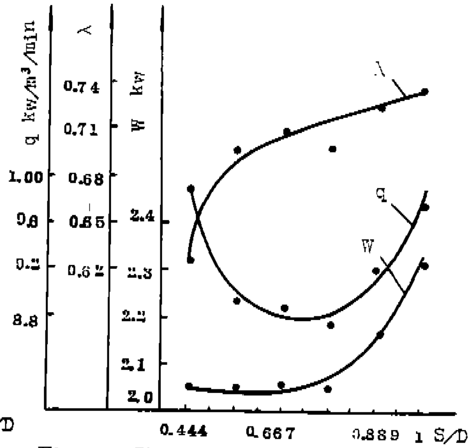

Fig. 11 The variation curve of discharge coefficient (λ), power (w), and specific power (q) versus S/D (0.15 m³/min)

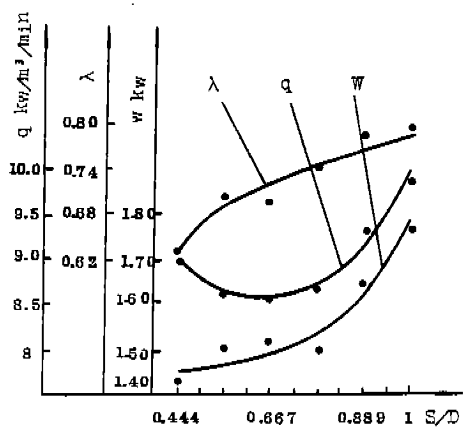

Fig. 12 The variation curve of discharge coefficient (λ), power (w), and specific power (q) versus S/D (0.2 m³/min)

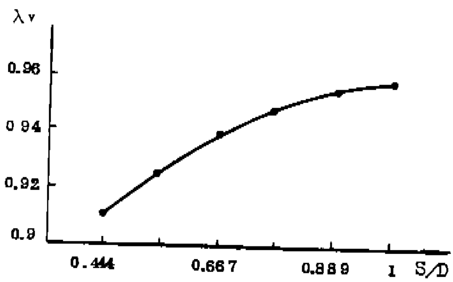

Fig. 13 The variation carve of valumetaic coefficient (λ_v) versus S/D