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X. Qian
Northern Jiaotong University

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Qian Xinghua, Professor
Mechanical Engineering Dept.
Northern Jiaotong University, Beijing, P. R. China

ABSTRACT

This paper points out the shortcoming of the crankcase's volume not being used in today's single action reciprocating air compressor and introduces the quasi double-action air compressor developed by the author. The new compressor with two courses of charging and bleeding air is being made by using the suction valve and discharge port to take the place of the breathing hole of crankcase used today. Both sides of the piston become the working cavity and the crankcase becomes the supercharger of the head-end cylinder. The traditional circle of a air compressor which is expanding — suction — compression — discharge becomes head-end cylinder: expanding — suction — charge — compression — discharge and crank-end cylinder: expanding — suction — compression — bleeding air.

Keywords: Reciprocating air compressor ; Booster pump of compressor

INTRODUCTION

Most of the air minicompressors are single action reciprocating compressor, the crankcase's volume is not being used, neither the air leaking from piston ring to crankcase is not collected back, nor the wasted work of suction and bleeding air. To fully use the crankcase's volume, the quasi double-action air compressor with crankcase supercharger is developed by the writer.

In this type of compressor, the breathing hole is replaced by the suction valve and discharge port, the crankcase become the supercharger of the cylinder to raise the utilization ratio of cylinder and displacement, it also reduce the specific power. The experiments on seven types nine single action air minicompressor by using the method of the paper show that the maximum increment of displacement is about 15%, the maximum reduction of specific power is about 10%.

THE INTRODUCTION OF THE STRUCTURE OF THE QUASI DOUBLE-ACTION AIR COMPRESSOR WITH THE CRANKCASE SUPERCHARGER

The quasi double-action air compressor with the crankcase supercharger is the development of today's minicompressor. Figure 1 is the structure of today's common air compressor. Piston 3 of this type of air compressor is single action. For a cylinder only on the head-end there is a working cavity 4. The traditional circle (in figure 2. ***a b c d***) is ***ab*** — expanding, ***bc*** — suction, ***cd*** — compression, ***da*** — discharge. The crankcase 1 which is on the other side of the piston 3 is not the working cavity. When the piston move to the crankshaft, the volume of the crankcase is reduced and part of the air in it is discharged by the piston through the breathing hole 2. When the piston move to the head-end, the volume is increased, the air is sucked in by the piston through the breathing hole. The breathing hole 2 on the crankcase is only to balance the inner and outer pressure in order that the pressure difference between the two sides of the piston reaches its minimum. Because the resistance of the breathing hole is Δp and the air pressure is P_S, when the air is sucked in, the pressure of the crankcase is $P_S - \Delta p$ and on the contrary, when the air is discharged, the pressure in it is $P_S + \Delta p$. If the square of the piston is A, the stroke is S and the resistance of the breathing hole is considered as Δp, the piston will do extra useless work: $2\Delta pAS$, which is the square of the ***a' b' c' d'*** in Figure 2. It includes the suction work ΔpAS and discharge work ΔpAS. But actually some air in the cylinder will leak into the crankcase through the piston ring and some oil will be brought out by the air through the breathing hole. So the work wasted in air leaking and oil spurting must be considered. Thus the piston will do more work. According to these reasons we can see the shortcoming of today's air minicompressor is that the function of the change of the crankcase's volume is not being used. Because the crankcase and the cylinder of the reciprocating compressor have the equal piston displacement $V_h = \pi D^2 S/4$ and because both the circles consists the four strokes: expanding — suction — compression — discharge. (The circle of the crankcase is Isochoric expanding ***a'b'*** — Isobaric suction ***b'c'*** — Isochoric compression ***c'd'*** — Isobaric discharge ***d'a'***. see Figure 2), the crankcase and the cylinder have the same function to change the crankcase's volume. That is we can use the change of the volume to change the pressure of the crankcase. Observing the ***P-V*** indicator diagram, we can find that it is totally equal to the indicator diagram of the Lobular Pump. Suppose that if the function of the crankcase can be brought into play to boosting, it will raise the utilization ratio of the cylinder and raise the displacement, it will reduce the specific power, the specific weight of the machine and its size.

TO CHANGE THE AIR MINICOMPRESSOR TO THE QUASI DOUBLE-ACTION AIR COMPRESSOR WITH CRANKCASE SUPERCHARGER

The Lobular Pump has no suction valve and delivery valve and controls the two courses: suction and discharge with the help of the suction inlet and the discharge port, the ratio of volume (cylinder suction volume divided by cylinder discharge volume) is a constant which is equal to 1, so the indicated power is large. To reduce the indicated power, the writer has changed the crankcase to a so called Lobular Pump with a variable ratio of volume which has suction inlet and discharge port (or delivery valve). Both sides of the piston become the working cavity. This new type of compressor is under the name of the quasi double-action air compressor with the crankcase supercharger.

The Figure 3 is the structure of the new type of compressor. In the new compressor, the breathing hole of the crankcase is abolished, the suction valve 2 and discharge port 3 (or the delivery port) are added. Near the inner dead point of the cylinder 7 about ***h*** high, several charge inlet 6 are opened and connected with the discharge port of the crankcase in a suitable way. In the lubricated compressor, 6 and 3 are connected by the line which has the function of oil elimination. In the non-lubricated compressors, only a slot in the cylinder wall is needed. To improve the boost ratio ε_z of the supercharger, the design of the counter weight, the crankshaft seal, the bearing housing, and the crankcase must be improved to reduce the clearance volume of the crankcase. When the piston moves to the bottom dead center, the deflector passes by the intake port 6, the crankcase and the cylinder are connected, the compressed air in the crankcase intake the cylinder through the line 4 to raise the pressure. Because mean while the piston is very near the bottom dead center, its speed is very close to 0. The velocity of flow of the suction valve of the cylinder is also approximate to 0. (The inertia of the air of the intake line of cylinder is omitted.) According to this reason, we can know that the capacity which go through the suction valve is little affected,but the intake stroke we've got is 2***h*** (1***h*** for piston's moving upward and downward respectively), so the displacement of the compressor is greatly raised.

THE CIRCLE OF THE QUASI DOUBLE-ACTION RECIPROCATING COMPRESSOR

As we know, the circle of today's reciprocating compressor is expanding —suction — compression — discharge, but the quasi double-action air compressor is different from it, the circle of the cylinder is expanding — suction — charge — compression — discharge, the circle of the crankcase supercharger consists expanding — suction — compression — discharge the four strokes.

1. The Circle Of The Crankcase Supercharger

Figure 4 is the circle indicator diagram of the crankcase supercharger. The phase of it is 180^0 out of phase with cylinder, $a'b'$ is the expanding stroke of the clearance volume of the supercharger, $b'c'$ — suction stroke, $c'd'$ — compression stroke, $d'a'$ — discharge stroke. Because the ratio of the relative suction stroke h/S is small, to simplify the problem, the effect of h is neglected. We approximately think that the discharge of the crankcase supercharger is finished on the bottom dead center in the least time. The simplified indicator diagram is Figure 5, $a'b'$ — clearance volume expanding stroke of the crankcase supercharger, $b'c'$ — the suction stroke of the supercharger, $c'd'$ — the compression stroke, $d'a'$ — discharge. The difference between the quasi double-action air compressor and the reciprocating compressor is that $d'a'$ — is Isochoric discharge but not the Isobaric discharge.

2. The Circle Of The Cylinder

Figure 6 is the circle indicator diagram of the cylinder, the circle is a — b — e — f — g — h — a (in this figure a—b—c—d is the circle before adding the suction port), ab — the clearance volume expanding process of the cylinder, be — suction process, ef — when the piston near the bottom dead center, the air in the supercharger goes into cylinder, fg — when the piston starts moving upwards, the air moves into cylinder from the supercharger, efg — a continual suction process in a circle, gh — the process of inner compression, ha — discharge process. Because h/S is small, we can ignore the effect of h and approximately think that the suction process of the cylinder is finished at the bottom dead center in the least time and the compression process of piston starts at it. Figure 7 is the simplified indicator diagram. ab — clearance volume expanding process, bc — suction process, cg — charge process (outer compression process), gh — inner compression process, ha — discharge process. (a—b—c—d—a is the circle before adding the charge inlet 6). The quasi double-action compressor differs from today's reciprocating compressor by adding a charge process. The final pressure P_S' of the outer compression c—g is the result of charge and boosting of the crankcase supercharger to cylinder. P_S'/P_S is the boosting ratio. So the inner pressure ratio reduces from P_d/P_S to P_d/P_S' and suction capacity increase from V_S to V_S'.

THE EFFECT OF THE EXPERIMENT

The experiment has been done on the V2.2-0.24/10, V2.2-0.3/7, 2V-0.3/7, Z-0.3/7, 2V-0.6/7, Z-1/10, CZ-20/30F seven types nine single-action compressors. Under the conditions of striking to the original size of machine, the rotation speed, the cylinder's diameter and the stroke, the displacement is increased and specific power is reduced by using this method of this paper. The maximum increment of the displacement is about 15% and the maximum reduction of the specific power is about 10%. The displacement of the Z-0.3/7, 2V-0.3/7, 2V-0.6/7 are all beyond 0.36 m/min, 0.67 m/min.

CONCLUSION

It is possible that the crankcase of the air minicompressor is used as the supercharger of itself and it proves that today's minicompressor has great potentialities of saving energy. The development of the quasi double-action air compressor with the crankcase supercharger provides a new way of saving energy for today's air minicompressor.

Change the traditional circle of the reciprocating compressor from the four strokes: expanding — suction — compression — discharge to the five strokes: expanding — suction — charge — compression — discharge. This leads to the increment of the utilization ratio η_V, the volume coefficient λ_V and the volume displacement V_S.

$$\Delta\eta_V = [(\frac{P_S'}{P_S})^{\frac{1}{m}} - 1]$$

$$\Delta\lambda_V = (1+\alpha)[(\frac{P_S'}{P_S})^{\frac{1}{m}} - 1]$$

$$\Delta V_S = (V_0 + V_h)[(\frac{P_S'}{P_S})^{\frac{1}{m}} - 1]$$

α — relative clearance volume, V_0 — clearance volume, m — expansion exponent.

It also brings advantages: low specific power, long life, small size.

Increasing the displacement of today's minicompressor by using the method of the paper, the technology will be simpler than the technologies of increasing the cylinder diameter, increasing the crank radius or increasing the rotation speed. The cost is small.

The method can be applied to other gas compressors.

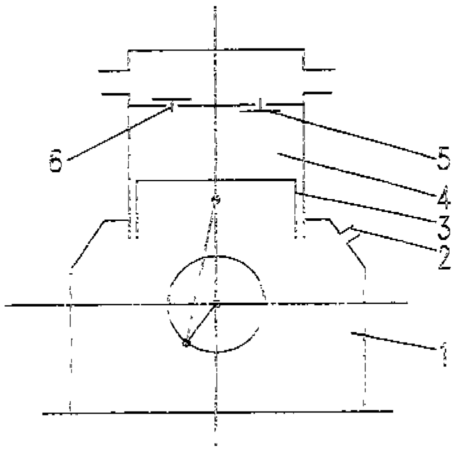

Fig. 1 The structure of the single action air compressor

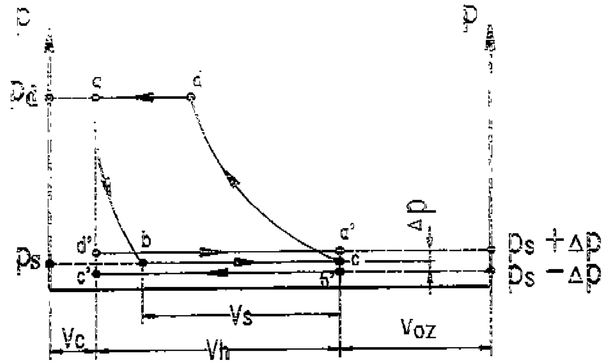

Fig. 2 The indicator diagram of the head end and crank end of the single action air compressor

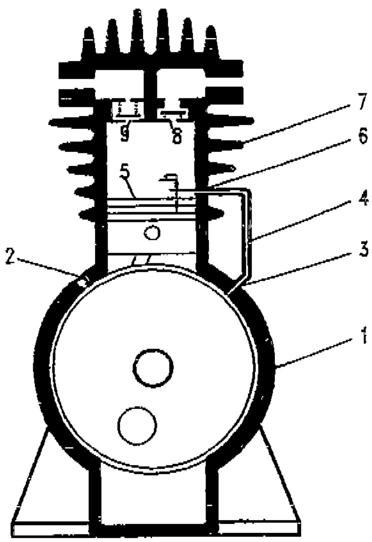

Fig. 3 The structure of the quasi double-action air compressor

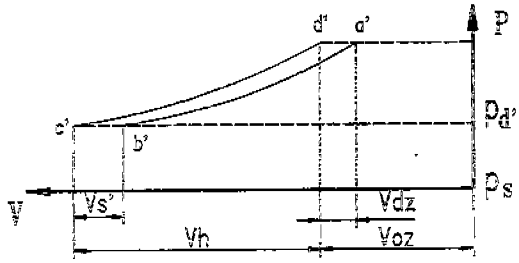

Fig. 4 The circle indicator diagram of the crankcase supercharger
Vh— the stroke volume
Vs'—suction volume
Voz—clearance volume
Vdz—the displacement of the crankcase supercharger

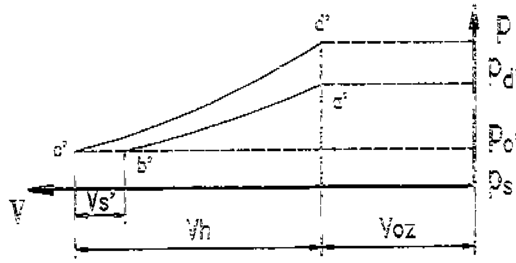

Fig. 5 The simplified circle indicator diagram of the crankcase supercharger

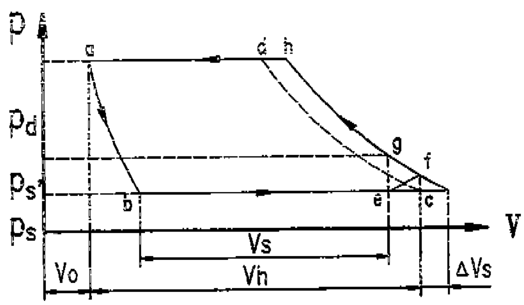

Fig. 6 The circle indicator diagram of the head end cylinder

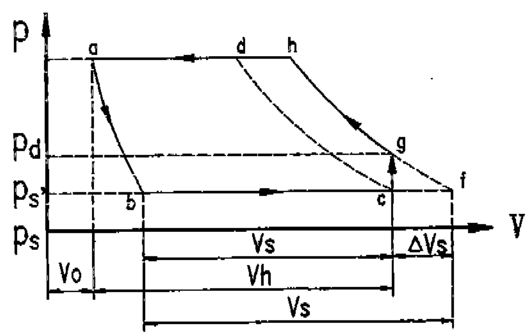

Fig. 7 The simplified circle indicator diagram of the head end cylinder