

Investigation of the Effectiveness of Anaerobic Materials to Improve the Design of a Gas Distribution Mechanism for a Hermetic Compressor

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Abstract

This work is devoted to the description of a new design solution for the gas distribution mechanism of a reciprocating compressor. The study of the factors that have a significant effect on the vibration and noise performance of hermetic refrigerant compressors allows the authors to conclude that the world leaders in the cost and sales of compressors are manufacturers whose products have a sound power level in the range of 32-36 dBA. The authors propose a new design solution for a unified valve plate for use in a parametric range of hermetic piston refrigerant compressors of the SKO series. The proposed valve train contains a 1.015 mm thick composite valve plate containing five 0.203-mm Sandvik 20-C valve steel plates that are bonded with anaerobic adhesives. Laboratory studies revealed the advantages of SKO compressors in terms of the average sound power level at 4.8-5.54 dBA; supply coefficient (refrigeration coefficient) decreased by 27.4 ÷ 14.4%. Such results were achieved due to the use of anaerobic adhesives, which made it possible, instead of a machined valve plate, to use a composite 1.015 mm thick and provide a stronger contact between the surfaces of the plates.

Key-words: Tape Valve, Reciprocating Compressor, Technical Condition Monitoring, Hermetic Refrigerant Compressor, Acoustic Radiation, Gas Distribution Mechanism.

1. Introduction

The efficiency of refrigeration equipment is primarily determined by the technical condition of the reciprocating refrigeration compressor. In recent years, there has been a stable trend of resource-

saving refrigeration equipment and the expansion of its functionality, on the other hand, leads to an increase in the sound power level of equipment. The source of noise in household refrigeration equipment is a hermetically sealed freon compressor. Analysis of vibration and noise indicators of small compressors allows us to conclude that the world leaders in the cost and sales of compressors are manufacturers whose compressors have a sound power level in the range of 32 - 36 dBA. Compressors with a noise figure in the range of 40-44 dBA have a significantly lower turnover and demand. Thus, reducing the sound power level of a hermetic compressor improves the technical level of refrigeration technology and its competitiveness in the market (Molodova et al., 2015; Naberezhnykh et al., 2012).

1.1. Final Stage

According to studies of gas distribution mechanisms compressor (Kotov et al., 2013; Demenev et al., 2015, 2017) formulated conclusions: the expected effect of the noise figure was 17% relative dissipation of sound energy with the noise damping force valve mechanism.

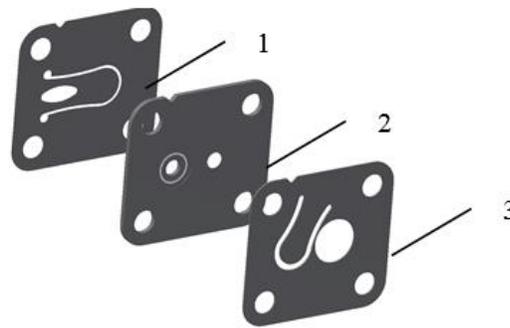
1.2. Figures

The scientific hypothesis of the article is that the proposed by the authors design of the gas distribution mechanism, containing removable seats on the suction and discharge sides and a composite valve plate, consisting of a package of plates, which are joined together with anaerobic adhesives. The design of the new valve mechanism should ensure a decrease in the sound power level for the parametric range of compressors of the SKO series from 39 dBa to 35 dBa. All parts of the new valve train (suction and discharge valves, suction and discharge side seats, composite valve plate plates) are manufactured from "Sandvik 20-C" valve tape in 0.153 and 0.203 mm thicknesses.

2. Units

Monolithic valve plate (2), Figure 1 plate is most often made of cast iron. Cyclic collision of self-acting suction and discharge valves with seats on the monolithic valve plate leads to the formation of a vibro-acoustic signal. Radiation of this signal to the environment when the compressor is running often results in increased noise in refrigeration equipment.

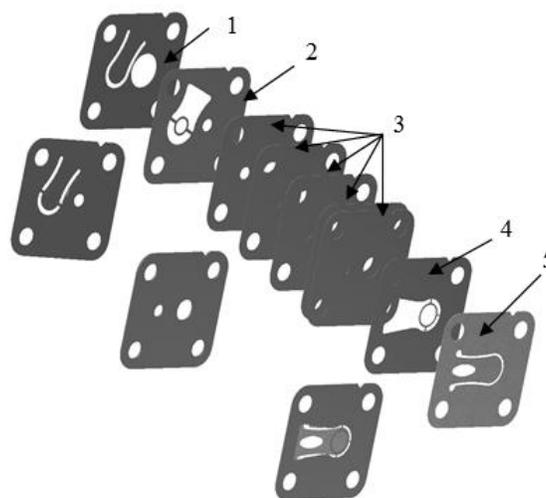
Figure 1 - A typical valve mechanism of a reciprocating compressor series "S-KO", "K-VO", produced under license from Sanyo (US patent No. 4573880)



2.1. Construction

The new design solution (Figure 2) differs from the standard design (Figure 1) by the use of a central valve plate without seats (3), made of polished “Sandvic 20 - C” with a thickness of 0.203 x 5 mm. Suction (4) and discharge (2) seats are mated with such a valve plate, which are made on a self-acting elastic movable petal in accordance with the patent (Naberezhnykh *et al.*, 2017). On the one hand, the seats are tightly closed by the suction (5) and discharge (1) valves, and on the other hand, they are tightly mated along the discharge and suction openings of the valve plate without seats (3).

Figure 2 - Upgraded gas distribution mechanism



Each of the suction and discharge seats (2 and 4) is made in the form of a closed thin band, the width of the walls for the model range is no more than 0.4 and no less than 0.2 mm. Thin bridges to the main body of the self-acting elastic petals connect the above saddles. The width of the thin bridges is not 0.4 mm.

2.2. Materials and Methods

Manufacturing a valve plate is a rather laborious production. The machining of a cast iron blank for a typical valve plate (2) (Figure 1) requires special EDM equipment. This takes a lot of time. The new 9-plate valve plate design should be made of Sandvic-20C (3) (Figure 1) steel by stamping or laser cutting, which greatly reduces material costs and labor intensity. After that, the plates should be cleaned and the surfaces should be degreased. On each plate, glue is applied on both sides in equal portions and, if necessary, pre-apply the activator. To glue the plates, we use anaerobic adhesives from Chester Molecular E-80, B-36, or CH-06 cyanoacrylate glue with an activator. After drying, the plate packs are checked for bond strength in the tumbling drum.

The surface of the monolithic valve plate on both sides and the surface of each self-acting resilient petal with suction and discharge seats are separated by a sealing and vibration-insulating oil film, due to which “elastic” shock absorption and noise reduction by a significant amount occur.

The proposed design of the valve mechanism allows to reduce the actual costs of the main production resources. A quantitative analysis of these resources was carried out according to index indicators, which include: the mass of the material, the number of pieces of equipment and service workers, additional consumables, productivity per shift and the cost of manufacturing a unit. The complex indicator of technological and economic efficiency of the new design exceeds a typical valve plate by 27%.

2.3. Construction requirements

The key regulator of the suction and discharge processes in a reciprocating compressor is the gas distribution mechanism implemented in self-acting petal valves. Therefore, the influence on its indicator

power is possible only by optimizing the design parameters of the self-acting locking elements of the mechanism. Consequently, the efficiency and reliability of the compressor, as well as vibration-acoustic parameters, depend on the correct setting of the processes.

The following requirements are imposed on the self-acting valves of the gas distribution mechanism: to have a sufficiently large equivalent area necessary for the energy losses in them to be minimal; have the ability to quickly open at a slight overpressure, ensure timely closure at the end of suction and discharge; tight fit (tightness) of the valve shut-off elements; be tight when closed, have a small volume of dead space, have strength and durability; have low resistances during suction and discharge; reliable operation under shock loads for a long time.

2.4. Other Recommendations

It is not possible to model valves that meet all of these requirements 100%, since the gas velocities in the valve must be reduced to reduce hydraulic losses, but this requires an increase in the size or number of valves, and this is limited by design and in spite of the desire to reduce the volume of dead space. An actual problem for reciprocating compressors in general and for hermetic freon compressors in particular is dead space, or dead space - a small free space in the cylinder in which compressed steam remains when the piston reaches its end position at the end of the discharge stroke. When the piston moves in the opposite direction in the cylinder, the gas, which is in the dead space under high discharge pressure, begins to expand, fills the cylinder and thus makes it difficult to suck in a new portion of steam. As a result, less refrigerant gas flows into the cylinder than theoretically. This can be viewed as a loss in compressor performance compared to theoretical values.

Designers try to keep dead space to a minimum. In modern compressors, it is 3-4% of the total cylinder volume, and only in rare cases can it be reduced to 1.5-2%.

Fast reliable fastening and sealing of the connected units simplifies the technology and reduces the labor intensity of manufacturing the compressor gas distribution unit. Anaerobic products have high structural and technological properties and can be successfully used to connect the component parts of the valve plate (3) (Figure 2). The technology of using anaerobic adhesives includes the choice of material, the preparation of the surfaces to be joined and the application of the selected material.

For the correct selection of anaerobic glue, three main parameters must be taken into account:

1. The size of the gap in the joint.
2. Working temperature of the joint.
3. Required breaking force.

In addition, the following parameters affect the conditions for using anaerobic materials:

1. Part material (to determine the need to use the Activator)
2. Required polymerization time (time period after which the unit can be used)
3. The presence of a chemically aggressive environment (not recommended for use in contact with ammonia, chlorine, pure oxygen)
4. Ambient temperature (to start the polymerization process at least 5 °C)
5. Surface roughness (Rz 15-40 microns)

Before applying the material, it is necessary to clean the surfaces of parts from dirt, corrosion, grease. For better cleaning, use the cleaner "Chester F3" or "Chester F7"

Advantages and Disadvantages of Anaerobic Adhesives and Sealants (Tulinov and Ivanov, 2018; Ivanov, 2020a, 2020b, 2020c; Ivanov and Tulinov, 2019; Nabatnikov et al., 2017; Pavlyuk, 2017; Kakuevitskiy et al., 1990; Deynega, 1990)

- allows you to replace mechanical fixing methods (lock washers, cotter pins), traditional seals, "gaskets", to abandon welding and press fit;

- provide stronger contact between surfaces than mechanical clamps;
- fast curing without air speeds up the assembly process;
- resistant to oils, solvents and other processing agents.

3. Results

An improved valve plate has been investigated and developed, and a decrease in the sound power level from 38-39 dBA to 34-35 dBA has been achieved.

A unified new valve plate has been created for the parametric range of hermetic reciprocating compressors of the “SKO” series. The new valve train contains a 1.015 mm composite valve plate containing nine 0.203 mm “Sandvik 20-C” valve steel plates that are bonded with anaerobic adhesives.

EFELE anaerobic adhesives have several advantages over other formulations and traditional methods of fixing, sealing and sealing.

4. Discussion

According to the results of the study (Table 1), the following conclusions were formulated: the sound power level of compressors “S-KO 120N5” (No. 3122) with a composite valve plate decreases on average by $(3.433 + 2.6075) / 2 = 3.0203$ dBA; the refrigerating capacity of compressors of the “S-KO 120N5” type (No. 3122) with a new valve plate increases on average by $(6.3 + 7.6) / 2 = 6.59$ W, i.e. by 5.2%; the efficiency factor of compressors of the “S-KO 120N5” type (No. 3122) with a patented valve plate increases on average by $(0.04 + 0.0607) / 2 = 0.05035$ W, i.e. by 4.2%. From the data presented in Table 1, it can be seen that the average sound power level of the “S-KO” compressors is 4.8-kZ, 54 dBA higher. The supply coefficient (refrigeration coefficient) is less by $27.4 \div 14.4\%$. Thermoenergetic efficiency is less by $11.9 \div 11.1\%$. The cost of “S-KO” compressors on the market is less than $15 \div 25$ USD than that of similar compressors.

Table 1 - The results of the compressor

Parameters.	Serial valve plate.	New valve plate.	Δ	$\Delta, \%$
No / TYPE of compressor	No. 3122 / S KO 120N5			
Sound power level, dBA	39.81	36,37	-3,43	9,4
Cooling capacity, W (-23.3 ° C)	133.7	139,9	6,3	4,7
Power consumption, W	113.8	116	2,2	1,9
Cooling coefficient, W / W	1.17	1,21	0,04	3,42

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