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DEVELOPMENT OF DIAGNOSTIC PRINCIPLES FOR SCREW COMPRESSOR UNITS

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The purpose of this article is the results of research and diagnostics of the operation of screw compressors and analysis of the results of field operation. The results of field, laboratory and theoretical studies are simultaneously used to substantiate research results and diagnose the operation of screw compressors. At the present stage of scientific and technological progress, the design and control of the operation of screw compressors is carried out using specialized software systems that apply scientific and technical achievements in the field of modeling the objects and processes under study in order to use the results of research and diagnostics of the operation of screw compressors for their widespread implementation in engineering practice.

KEY WORDS: *screw compressor, vibration diagnostics, compressed gas pressure.*

РАЗРАБОТКА ПРИНЦИПОВ ДИАГНОСТИКИ ВИНТОВЫХ КОМПРЕССОРНЫХ УСТАНОВОК

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Целью данной статьи является представление результатов исследований и диагностики работы винтовых компрессоров, а также анализ результатов полевых испытаний. Для обоснования результатов исследований и диагностики работы винтовых компрессоров одновременно используются данные полевых, лабораторных и теоретических исследований. На современном этапе научно-технического прогресса проектиро-

вание и управление работой винтовых компрессоров осуществляется с использованием специализированных программных систем, которые применяют научно-технические достижения в области моделирования исследуемых объектов и процессов с целью использования результатов исследований и диагностики работы винтовых компрессоров для их широкого внедрения в инженерную практику.

КЛЮЧЕВЫЕ СЛОВА: *винтовой компрессор, диагностика вибраций, сжатое давление газа.*

ВИНТТІ КОМПРЕССОРЛЫҚ ҚОНДЫРҒЫЛАРДЫ ДИАГНОСТИКАЛАУ ПРИНЦИПТЕРІН ӘЗІРЛЕУ

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Осы мақаланың мақсаты — винтті компрессорлардың жұмысын зерттеу және диагностикалау нәтижелерін ұсыну, сондай-ақ дала жұмысын талдау. Винтті компрессорлардың жұмысын зерттеу және диагностикалау нәтижелерін негіздеу үшін далалық, лабораториялық және теориялық зерттеулердің нәтижелері бір мезгілде қолданылды. Ғылыми және техникалық прогрестің қазіргі кезеңінде винтті компрессорлардың жобалануы және жұмысын басқару арнайы бағдарламалық жүйелерді қолдану арқылы жүзеге асырылады, олар зерттеліп жатқан объектілер мен процестерді модельдеудегі ғылыми және техникалық жетістіктерді пайдаланады, бұл өз кезегінде винтті компрессорлардың жұмысын зерттеу және диагностика нәтижелерін инженерлік практикада кеңінен қолдануға мүмкіндік береді.

ТҮЙІН СӨЗДЕР: *винтті компрессор, вибрация диагностикасы, газдың қысылған қысымы.*

Introduction. Screw compressor is a compressor having screw rotors with connected teeth. By design, these devices are intended for rotary compressor equipment.

Figure 1 – **Screw pump basic design [1]**

This rotary equipment is widely used in the organization of pneumatic systems. Therefore, let's look at what a screw compressor is from different angles: description, design, principle of operation and other important features will be the focus of our attention. Today they are the most used air compression equipment and have almost completely

replaced other types. (Abdurashitov S.A.) The operating principle of a screw compressor in detail step by step it looks like this:

1. The engine starts the rotors, which, in compliance with the schedule, rotate towards each other;

2. As a result of this movement, atmospheric air is sucked through a filter, in which it is cleaned of mechanical impurities;

3. In the screw block, air is mixed with oil, compressed and enters the oil tank;

4. In the oil tank and separator, compressed air is separated from the oil and goes through the aftercooler to the outlet of the installation, and the oil, after cooling, flows back into the screw block through the oil filter. (Sakun I.A.)

The compression process is automatic and is simple and efficient. And this is another advantage and another reason to use the equipment in question. Compressors are distinguished by the maximum operating pressure of the device:

• low pressure compressors - up to 3.5 bar,

• Medium pressure - up to 15 bar,

• High pressure - up to 35 bar. [2]

Due to their design features and the absence of rubbing elements, screw compressors can be operated for a long time without repairs, with minimal maintenance. According to this indicator, they are significantly superior to piston compressors. The service life of screw compressors exceeds 200 thousand hours (Laing, P O). The maintenance schedule usually only includes the replacement of screw block bearings, filters, and, less often, the oil separator and components of automation systems. The more complex design of screw machines and the presence of automatic control systems necessitate highly qualified repair personnel. Therefore, the repair of these compressors itself will be significantly more expensive than piston ones. [3]

Compressor diagnostics is one of the most necessary measures to maintain equipment in working condition. It includes the following activities:

1. External inspection.

2. Checking operating modes.

3. Measurement of currents and voltages in various operating modes.

4. Check the condition of hoses and connections for leaks.

5. Checking the condition of drive belts and couplings.

6. Checking the oil level and its approximate consumption.

7. Measurement of vibrations of bearings (screw compressors with electric drive) of the screw element and electric motor.

8. Blowing heat exchangers (radiators) if necessary.

9. Check the functionality of the injectors (opening pressure, spray pattern), if necessary.

10. Compression measurement if necessary.

11. Drawing up a report with recommendations for scheduled repairs.

Methods and materials. In this article we will consider vibration diagnostic method. Vibration diagnostics is a method for diagnosing technical systems and equipment, based on the analysis of vibration parameters created by operating equipment. Periodic vibration measurements allow timely detection of wear on compressor parts. Vibration diagnostics are also recommended after repairs to assess the quality of work and the correct installation

of equipment components. Most damage to equipment parts results from mechanical vibrations. The advantages of analyzing vibration signals are their versatility; at the moment, vibration diagnostics is one of the main methods of non-destructive testing and technical diagnostics. Vibration is the mechanical vibrations of the body. During vibration diagnostics, the following parameters are analyzed:

• Vibration velocity – the speed of a movement or system under the influence of vibrations.

• Vibration displacement – displacement of a point or system under the influence of vibrations.

• Vibration acceleration – acceleration of the movement of a point or system under the influence of vibrations

Vibration diagnostics, like other methods of technical diagnostics, solves the problem of finding faults and assessing the technical condition of the object under study. Vibration diagnostics usually examines the time signal or vibration spectrum of a particular piece of equipment.

• In the low-frequency range, parameters of vibration displacement are measured more often,

• In mid-frequency vibration speed,

• And in high-frequency vibration acceleration.

Results and discussion. Let's consider the vibration spectrum of a compressor without serious defects, measured on one of the compressor bearings:

Here in *figure 2*, F1 is the rotation frequency of the electric motor and the drive screw (in our case, 48 Hz), and F3 is the gearing frequency (238 Hz). The spectrum of a defect-free

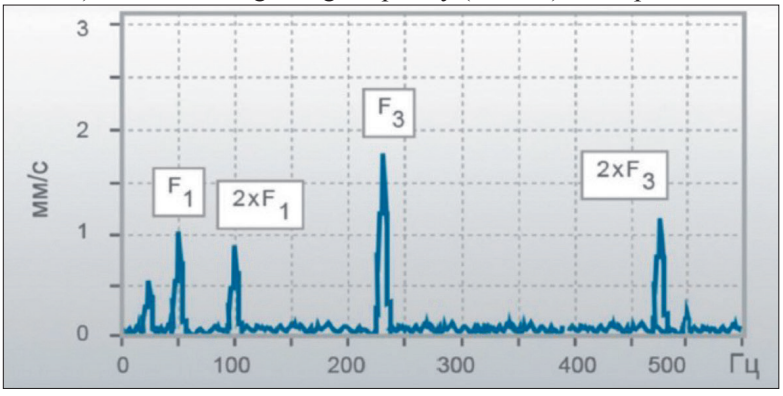

Figure 2 – **The first model of the rotation frequency of the electric motor and the drive screw**

screw compressor always contains harmonics (up to the 4th) of the gearing frequency and their presence does not indicate the presence of defects. The spectrum Figure. also shows a small oil harmonic and two harmonics of the input shaft rotation speed.

In the case of defects in the working surface of the screws, lateral harmonics appear near the gearing harmonics see *Figure 3*, due to their modulation by the rotational speed of the screw with the surface defect. The depth of the defect is usually assessed by the ratio of the amplitude of the lateral harmonic to the amplitude of the first harmonic of the gearing, and if this ratio exceeds the value (0.2), then the compressor defect is considered

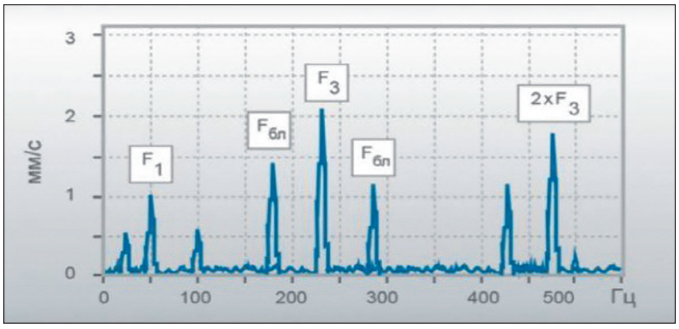

Figure 3 – **The second model of the rotation frequency of the electric motor and the drive screw**

"alarming". The location of the defect is determined by the magnitude of the frequency shift of the lateral harmonics relative to the gearing frequency. This shift is always equal to the rotation speed of the shaft with the more worn surface.

This *figure 4* shows the vibration spectrum of the sliding bearing with increased clearance measured in the direction perpendicular to the plane passing through the axial lines of the screws.

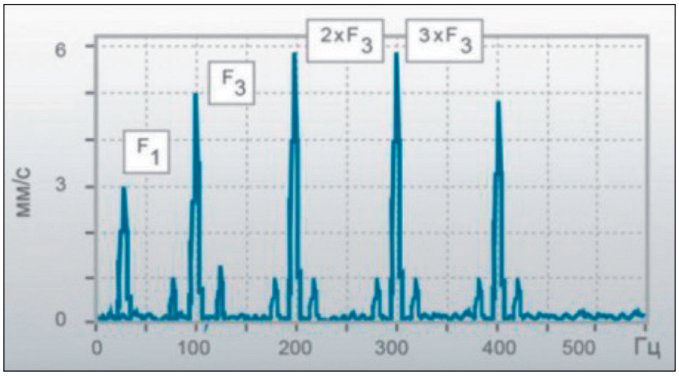

Figure 4 – **Increased clearances in bearings**

Unlike the standard spectra of sliding bearings with an increased gap, in which a number of harmonics with a rotor speed are present, in this case there are a number of dentate frequency harmonics (with almost the same amplitude of the first 3-5 harmonics), and there may be no reverse frequency harmonics at all. It can also be seen on the spectrum that all dentate frequency harmonics have sidebands due to defects in the working surfaces of the screws, and which we have already mentioned above.

Periodic dynamic axial forces caused by "gas flow rupture" at the compressor working zone outlet cause secondary side harmonics to appear in the vibration spectrum (marked with "2" in *Figure 4*) near the side harmonics of the gear frequency (marked with "1" in Figure). The appearance of level 2 harmonics is a specific feature of only screw compressors and is a good diagnostic sign of the presence of defects in the surface of screws in the axial direction. Due to the fact that the frequency shift between harmonics of the 1st and 2nd level is only a few hertz, it can only be detected using an analyzer having a resolution of at least 1600 bands.

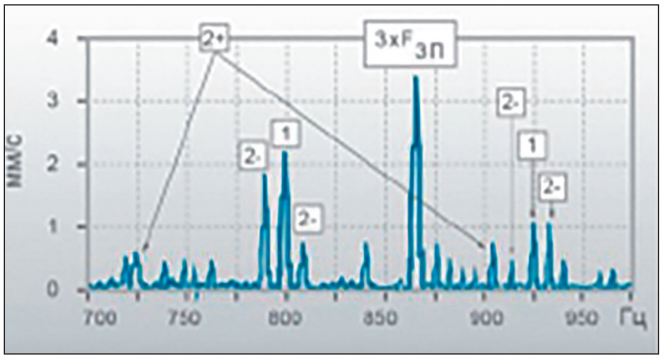

Figure 5 – **Axial vibration of screw compressors**

As you can see, the vibration diagnostics of screw compressors requires the operator to have a deep theoretical knowledge of the dynamic processes of vibration in compressors, as well as experience in interpreting sufficiently complex spectra. Vibration diagnostics of screw compressors revealed the following defects of the screw pair:

• poor axial installation and fixing of the position of the screws;

• increase of gaps between screws caused, as a rule, by general wear of screws or bearing bearings;

• increase of clearances in sliding bearings in which working screws rotate;

• wear of gears connecting screws.

Conclusion. Having considered in detail the screw compressors, the device and the principle of operation, one simple conclusion can be drawn. This is quite reliable, productive, safe and convenient equipment, especially compared to piston Any vibration contains harmonics of various frequencies. [4] By analyzing the amplitudes of these harmonics, you can obtain information about the state of the equipment. Vibration diagnostics of objects are carried out in three stages: primary description of the vibration state of the object, identification of signs and decision-making. In the conclusions, we can say that the vibration diagnostic method has such advantages as:

• Ability to detect hidden defects.

• Obtaining information on the conditions of equipment located in hard-to-reach places

• Monitoring and obtaining information about the defect at the stages of its appearance

• Short diagnosis time.

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