State diagnostics of the working fluid in oil pumping station compressors

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Abstract. The article deals with issues related to the analysis of the problem of ensuring or improving the reliability and functional efficiency of compressors of an oil pumping station, as well as optimizing the cost of carrying out routine (maintenance and preventive) work. The issues characterizing the possibilities and diagnostics for evaluating the technical condition of compressors are considered. To determine the state of the working fluid of the compressor, specialized equipment is offered. An example of the proposed installation is shown.

1. Introduction

The operation of modern oil pumping stations is associated with the operation of various types compressors intended for oil gas or air handling [1, 2]. As a result of this process, liquids and gases (oil, oil products and natural gas) are pumped [3, 4].

The technical condition of the compressor (as one of the most critical structural elements) strongly determines the reliability and functional efficiency of the compressor unit [5, 6].

A series of screw compressors failures, which leads to loss of functional quality (transition to inoperable state), is often formed due to changes in the state of the working fluid, which is characterized by a decrease in its basic physical characteristics (kinematic viscosity, flash point) due to the appearance of impurities and changes in the chemical structure of the substance [7-10].

2. Information model of changes in the technical condition of pumping station compressors

The compressor unit of the oil pumping station (for example, the 5VKG-10/6 compressor unit) includes the following main structural elements and technological units [11]:

- a compressor unit, which includes: a compressor, an electric motor, oil filters, an oil separator, pipelines, shut-off and control valves, auxiliary equipment;
- an oil cooler unit, which includes: a cooler, a fan with an electric motor, a diffuser;
- a local automation unit;
- a remote automation unit.

Figure 1 shows the information (analytical) model of reliability (failure model) of the compressor, taking into account its possible technical states: operable and inoperable. To analyze the failure consequences, two types of discrete states of the device are taken [12, 13]:

- u0 is an operable state;
- u1 is an inactive status.

Also, possible ways of transition between the accepted states are indicated.

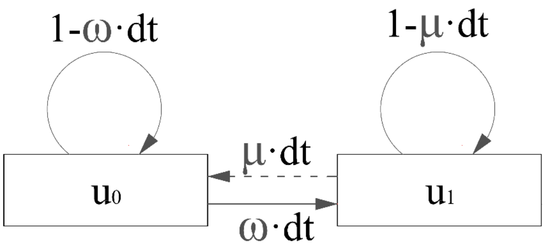

Figure 1. Information model of compressor failures in the oil pumping station.

The transition of the functional operated compressor from the operable state (u_0) to the inactive status (u_1) characterizes a quantitative indicator – a series (intensity) of failures (ω). The reverse transition of the compressor (as a restored technical system) is characterized by a quantitative indicator - the flow (intensity) of the system recovery (μ) [14, 15].

3. Installation for testing the working fluid of the compressor

It is possible to determine the quantitative characteristics of the working fluid, which can lead to the formation of a failures flow, using the developed experimental installation (figure 2).

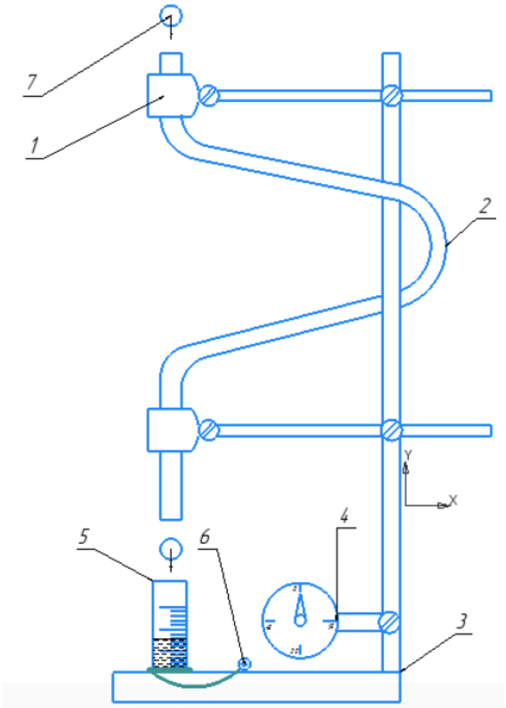

Figure 2. Installation for testing the working fluid (transformer oil) of the compressor: 1 - clamp; 2 - silicone tube; 3 - laboratory tripod; 4 - stopwatch; 5 - flask; 6 - LED with piezo sensor; 7 - ball bearing.

The laboratory bench is equipped with a laboratory tripod with two clamps that fix the beginning of the nozzle and its end. The length of the nozzle is 1 m, the nozzle is twisted around a tripod. The internal diameter of a pipe is $d_{in.p.} = 0.013$ m, external - $d_{ext.p.} = 0.015$ m, the diameter of the ball is $d_{ball} = 0.009$ m with mass $m_{ball} = 0.020$ kg. On the tripod platform there is a flask, at the bottom of which a piezo sensor is soldered. The bottom is sealed to avoid leakage of working fluid. The diameter of the piezo sensor is d_{piezo} = 0.013 m, the flask length is L = 0.007 m, the flask diameter is d_{flask} = 0.022 m. There is also a stopwatch on the stand.

By measuring the time of the ball passage through the silicone tube, it is possible to assume how the friction between materials appears, measuring from fresher transformer oil to worn out. Also, with the help of a piezoelectric sensor, which is connected to the LED, the degree of viscoelasticity is determined when materials collide.

After the ball passes through the pipe, it rolls down and falls into the cavity of the flask, at the bottom of which a piezoelectric transducer connected to the diode is attached. The cavity of the flask is filled with the working fluid being tested. By punching a fluid, its viscoelasticity, namely the throughput, is visually determined. The working fluid, which has lost its physical properties, easily misses the blow, as a result of which the LED lights up.

4. Experimental research and discussion

Tests were carried out with hot oil with a temperature of 600 °C. Six samples of oil with different operating time were tested: 0 motor-h, 2500 motor-h, 3000 motor-h, 3500 motor-h, 4000 motor-h and 5000 motor-h. In this case, it is known in advance that the first 2 oil samples are suitable for use in the compressor, sample 3 is soon subject to replacement. Samples 4 to 6 are unsuitable for work.

Table 1 presents the results of experimental tests with the measured time of the ball passage and the reaction to the penetrating ability.

Table 1. Fluid testing.

Sample	Working hours (motor-h)	Ball passage time (sec.)	Punching response
Sample 1	0	2.47	Reaction is not observed
Sample 2	2500	1.89	Reaction is not observed
Sample 3	3000	1.71	Reaction is weak
Sample 4	3500	1.59	Reaction occurs
Sample 5	4000	1.53	Reaction occurs
Sample 6	5000	1.33	Reaction occurs

From the table it can be seen that over the course of oil usage, changes in its chemical base are visible, namely, the density of the same volume oil changes when exposed to temperature and long-term operation.

The working fluid loses its initial physical properties during operation due to the impact of mechanical loads on it, high temperatures, and therefore the chemical decomposition of the molecular composition, changes in density and viscosity.

For samples of oil no. 1 and no. 2, when the ball falls into the flask, the oil absorbs the energy of the ball. The operating time is low and consistent with the performance. The oil is able to continue working, the viscosity has not changed and elasticity is present.

The test results of sample no. 3 show that the physical characteristics of the oil do not start to decline significantly, the viscoelasticity deteriorates, and the density decreases.

Tests of samples numbered 4 to 6 show that as a result of high operating time, the physicochemical properties of the oil have significantly deteriorated. It is recommended to replace the working fluid in order to avoid undesirable losses in the compressor operation.

As a result of the experiments, it is revealed that the friction and high temperatures that occur during the operation of the compressor lead to a significant deterioration of the oil composition: the lubricating properties weaken and the density deteriorates. All this leads to negative consequences, which can be avoided by the introduction of a plan for preventive maintenance.

5. Conclusion

The authors have investigated the problem of diagnostics of the working fluid quality in station compressors of oil pumping. The unit for testing the working fluid and the scheme for such tests are proposed.

As a result of the experimental studies, it has been proven that the developed approach to diagnostics allows determining the quality of transformer oil with sufficient certainty.

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