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IMPROVEMENT OF THE COOLING SYSTEM OF MINE COMPRESSOR UNITS

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E-mail: Urunova_76@mail.ru*СОВЕРШЕНСТВОВАНИЕ СИСТЕМ ОХЛАЖДЕНИЯ РУДНИЧНЫХ
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ABSTRACT

The existing cooling systems of compressor units have a number of significant disadvantages due to the peculiarities of their operation. An analysis of the operation of them shows that the undercooling of the air in reciprocating compressors for every 5-6 °C increases the energy consumption for air compression by 1 %, and the productivity decreases by 8-10%, which leads to significant economic losses in the production of compressed air.

This article discusses ways to improve the operating of the cooling system, and offers new technical solutions, the implementation of which will reduce the energy intensity of the operation of compressor units.

АННОТАЦИЯ

Существующие системы охлаждения компрессорных установок имеют ряд существенных недостатков, обусловленных особенностями их эксплуатации. Анализ эксплуатации компрессорных установок показывает, что недоохлаждение воздуха в поршневых компрессорах на каждые 5-6 °C увеличивает расход электроэнергии на сжатие воздуха на 1 %, а производительность снижается на 8-10%, что приводит к ощутимым экономическим потерям при производстве сжатого воздуха.

В данной статье рассмотрены способы улучшения работы, системы охлаждения, предложены новые технические решения, реализация которых позволят снизить энергоёмкости эксплуатации компрессорных установок.

Keywords: compressor, cooling system, temperature, compressed air, heat transfer, intermediate refrigerator, power consumption, feed rate.

Ключевые слова: компрессор, система охлаждения, температура, сжатый воздух, теплопередача, промежуточный холодильник, расход электроэнергии, коэффициент подачи.

In lots of industries, along with electrical energy and pneumatic energy, compressed air power is widely used.

Compressed air, being one of the main types of energy in quarries and mines, is used for powering fans and pumps, in airlift installations for pumping out pulp or

water, drilling, tunneling, mining and loading machines, for pneumatic laying of underground mine workings, in pneumatic balloon supports [1].

The widespread use of compressed air in the mining industry is due to the fact that pneumatic equipment is

safe, especially in mines that are dangerous for gas and dust, in cases where the use of electricity in underground mining is unsafe due to unpredictable gas emissions.

Along with this, pneumoenergy has a number of significant drawbacks. The main disadvantage of compressed air, as an energy carrier, is its high cost relatively to electricity. The reason of it is the consumption of a large amount of electrical energy by compressors in the production of compressed air.

Mining compressors are energy-intensive installations, the share of which in the consumption of electricity in mining enterprises is a significant one [2].

Given such a wide use of pneumatic energy, it is necessary to reduce operating costs by developing resource-saving technical solutions in the production of compressed air in industrial enterprises.

The efficient operation of the compressor unit is largely dependent on cooling. The cooling system of the compressor unit solves three tasks: it reduces the energy consumption of the compression process in the cylinder, eliminates the possibility of ignition of lubricating oils, and improves the operating conditions of the compressor operating units [3, 4]. Violations of the cooling system, as a rule, are associated with a forced stop of the compressor and an increased specific energy consumption for the production of compressed air.

An analysis of the operation of compressor units shows that the undercooling of the air in the intermediate refrigerators of the reciprocating compressor increases

the energy consumption for air compression by 1% for every 5-6 °C [5].

The water used for cooling has a high content of salts and various impurities. In most cases, the total water hardness, reaching more than 20 mg-eq/l, is almost 3 times higher than the permissible values, which is the main reason for the rapid contamination of heat exchange surfaces. The decrease in the intensity of heat exchange processes, due to the growth of deposits in the form of scale, contributes to a decrease in the safety and efficiency of the compressor equipment.

The presence of a 0.1 mm thick scale layer reduces the cooling of the air in the refrigerator by 10-15 %. The scale layer reduces the heat transfer coefficient by adding additional thermal resistance [6].

At the outlet of the intermediate refrigerator, the normal temperature of the compressed air should not exceed the temperature of the cooling water at the inlet by more than 5-10 °C. If the temperature difference increases to 20 °C, the power consumption, all other things being equal, can increase by 14 %. The scale on the inner walls of the tubes dramatically reduces the heat transfer to the cooling water. Figure 1 shows the graphical dependence of the heat transfer coefficient on the thickness of the scale layer [7].

From the graph shown in Fig. 1, it is observed that, with an increase in the thickness of the scale layer, the heat transfer coefficient deteriorates.

Figure 1. Change in the heat transfer coefficient depending on the thickness of the scale layer

Frequent formation of contamination on the heat exchange surfaces, a decrease in the intensity of heat exchange, observed due to the formation of a layer of scale on the walls of intermediate and end refrigerators can lead to spontaneous combustion of carbon-oil deposits in air communications, which is the cause of detonation explosions.

In order to improve the energy efficiency of operation of reciprocating compressor units, based on the factors, we offer the following technical solutions.

Increasing the efficiency of the cooling system of compressor units is possible due to the intensification of the heat exchange process between the cooled (compressed air) and the cooling (water) heat carriers. This is

primarily realized by preventing scale and sludge deposits in refrigerators. To date, the softening of water hardness is achieved by chemical means. The chemical method of preventing the formation of scale is effective, however, it requires constant costs, strongly pollutes the environment and harms the health of service personnel. Prevention of scale formation is possible due to electromagnetic treatment of recycled cooling water [8].

We have developed an installation for electromagnetic treatment of circulating water in the laboratory. In order to determine the effectiveness of the developed installation of electromagnetic treatment of circulating water, we conducted experimental tests. A schematic view of the experimental setup is shown in Figure 2.

Figure 2. Schematic view of an experimental setup for testing an electromagnetic water treatment device.
1-tank with an electric heater, 2-temperature controller, 3-circulation pump, 4-device for electromagnetic water treatment, 5-point for measuring the temperature of water, 6-valve, 7-metal pipe, 8-tank with water

Experimental work was carried out in two stages. The first stage of experimental research was carried out without the use of a device for electromagnetic water treatment. The second stage is using a device for electromagnetic water treatment. The duration of the experimental work for each cycle was 48 hours, and the average water hardness was 25 mg-eq/l.

The main objective of the experimental work was to establish the dependence of the formation of a scale

layer on the surface of a metal pipe on the temperature of the circulating water, with the use of a device for electromagnetic water treatment and without it.

The experimental tests made it possible to obtain the dependence of the scale formation on the metal surface on the temperature of the circulating water with and without the use of a device for electromagnetic water treatment, the graphical dependence is shown in Fig. 3.

Figure 3. Graphical dependence of the formation of scale thickness on the temperature of the circulating water.
1-without using a device for electromagnetic water treatment, 2- using a device for electromagnetic water treatment

From the graph shown in Fig. 3, it is clear that electromagnetic treatment of circulating water reduces the formation of scale on metal surfaces by an average of 70-80%.

Figure 4 shows a microscopic photograph of the metal pipe inner surface after the experimental work

is completed. Analysis of the microscopic photographs shows that the use of electromagnetic processing reduces the formation of a layer of scale on the walls of the metal pipe.

a)

б)

Figure 4. Microscopic photograph of a metal pipe wall.

a) operation of the pipe without using a device for electromagnetic water treatment,

b) using a device for electromagnetic water treatment.

From Figure 4, it is obvious that the scale layer on the walls of the metal pipe shown in Figures 5a is much thicker than that shown in Figures 5b. This makes it possible to conclude that the use of a device for electromagnetic water treatment helps to reduce the formation of scale on the surfaces of heat exchangers.

The performed studies of the influence of the intake air temperature on the efficiency of the piston compressor allow us to conclude that an increase in the temperature of the air entering the compressor cylinder leads to a decrease in the compressor performance and an increase in the energy costs of compression.

For example, for reciprocating compressors with a capacity of 100 m³ / min and a drive power of 630 kW, an increase in air temperature for every 1°C leads to a decrease in the efficiency by 0.15-0.17%.

The implementation of our proposed technical solutions at the compressor units of mining enterprises helps to reduce the energy costs of the air compression process in the cylinder by an average of 4-5%, and rise the compressor performance by up to 8%, depending on the operating conditions. And also to exclude emergency situations and to increase operational indicators of working units of the compressor, as a result reducing the cost of production of compressed air.

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