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METHOD OF PREVENTING DEPOSITS ON THE INNER SURFACE OF CIRCULATING WATER PIPELINES OF FERROALLOY ELECTRIC FURNACE COOLING SYSTEMS

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The article provides an overview of a promising method of preventing deposits on the inner surface of circulating water pipelines of cooling systems of ferroalloy electric furnaces. There is considered the approach to practical implementation of magnetic treatment of circulating water in the cooling systems for the purpose of eliminating scale of hardness salts in pipelines. There is presented the design of an electromagnetic hydrodynamic water activator, as well as its main parameters. The results of practical testing and processing experimental data are presented. It has been established that the effect of a magnetic field on water is of a complex multifactor nature.

Keywords: ferroalloy electric furnace, pipeline, cooling systems, water hardness, magnetic treatment

INTRODUCTION

Ferroalloy furnaces are used at the metallurgical enterprises of the Kazchrome JSC, a member of the Eurasian Resources Group (ERG). Ferroalloys are imported by the leading manufacturers of stainless steel from China, Japan, the USA, and the countries of the European Union.

The Kazchrome JSC sets the task of developing a method of preventing formation of scale deposits of hardness salts on the walls of pipelines of the ferroalloy furnace cooling system. The proposed method should also ensure removing already formed deposits of scale since it significantly reduces the heat exchange process and the efficiency of the cooling system as a whole. Clogging of the cooling system of ferroalloy electric furnace elements can lead to a serious accident.

At the present moment in time, the chemical method of preparing the cooling water is used. As shown by the operation of the cooling system of elements of ferroalloy electric furnaces of the Kazchrome JSC, this method is not effective enough but it requires significant costs for chemical reagents and equipment for water softening. Over time, various types of scale deposits of hardness salts are formed on the inner surfaces of the circulating water pipelines of the cooling system of ferroalloy electric furnace elements. During the repair process, the technical staff performs chemical and mechanical cleaning, for which the company spends human and financial resources, since they have to carry out maintenance work on the cooling system associated with disassembling and cleaning the system elements from deposits. At the moment, the ion exchange reaction is used in the water treatment system for descaling. All the methods used are quite costly in terms of financial addition and are associated with the use of manual labor, as well as require consumable reagents and expensive equipment. The use of chemical reagents has a negative impact on the environment. In view of the above, the task has been formed to develop a simpler and cheaper method of dealing with deposits. The variant of joint use of the water treatment system and the use of the method of magnetic water treatment and its activation with the use of an electromagnet is considered. This will reduce reagent consumption by up to 60 %.

PRELIMINARY THEORETICAL STUDIES

Inspections of the cooling system of the ferroalloy furnaces of the Kazchrome JSC have shown that stable deposits of calcium and magnesium hardness salts are formed on the inner surfaces of pipelines and system elements despite the fact that at the moment chemical water treatment using reagents is used. This is a fairly well-studied method and it has been tested in practice for many decades, but with all its advantages, the use of chemicals to neutralize scale deposits of hardness salts is not always effective. Accordingly, over time, a rather significant layer of scale is still formed on the surfaces, which leads to decreasing the process of the heat exchange efficiency of the cooling system of the ferroalloy furnace.

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It is seen in the photo that the flow area of the pipeline of the cooling system of the ferroalloy electric furnace is significantly reduced (Figure 1), which reduces its throughput. The photo on the left shows a fragment of the pipeline with deposits, and on the right without them. A stable layer of scale leads to increasing the thermal resistance of the walls of the heat exchangers of the cooling system of a ferroalloy furnace and makes its operation ineffective. There is a danger of detaching a part of the sediments from the general massif and complete blocking of the pipeline, which can lead to disruption of the circulation of water in the cooling system and an accident.

When conducting a study to identify the main cause of scale formation in the cooling system of ferroalloy furnaces, this cause appear to be calcium and magnesium salts, hardness salts [1, 2]. The chemical composition of the investigated scale is as follows: Ca^{2+}, Fe^{3+}, Fe^{2+}, Mg^{2+}, Mn^{2+}. Hard water is characteristic of all the regions of the Republic of Kazakhstan, which causes a layer of scale on any heating surfaces with which it comes into contact. This is a well-known problem and is fairly well documented in the literature. Similar problems are encountered in energy and water supply [3].

Scale formation is also a significant problem for boiler units and heat exchangers of thermal power plants [4]. The use of chemical reagents can partially solve this problem, but their use is associated with significant material costs and requires organization of a chemical water treatment system. The damage to the environment is caused when water containing alkali and acids are discharged into adjacent water bodies.

Figure 1 A pipeline fragment with deposits (left) and without them (right)

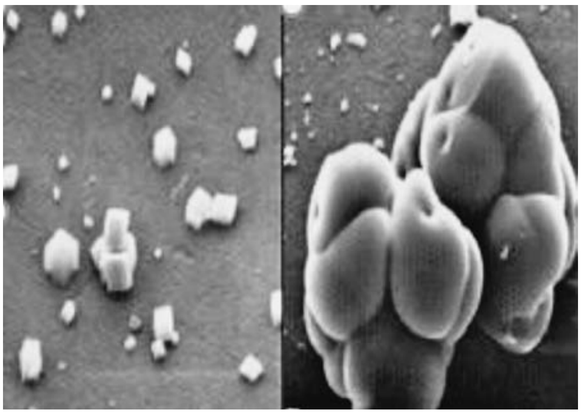


Figure 2 The process of scale growth on the inner surface of the pipeline

The process of carbonate deposits formation on the internal surfaces of pipelines and cooling system elements has been studied. By examining water samples from the cooling system of ferroalloy electric furnaces of the Kazchrome JSC. As the analysis of samples shows, the chemical composition contributes to the formation of scale, since it contains carbonate salts of calcium and magnesium ($CaCO_3$, $MgCO_3$), sulfate ($CaSO_4$), hardness salts, ions of calcium (Ca^{2+}), magnesium (Mg^{2+}) and bicarbonate (HCO^{3-}) that enter the cooling system in dissolved form from groundwater, which determines the presence of hard water in the water supply system of all the regions of Kazakhstan. The process scale growth on the inner surface of the pipeline is presented in Figure 2.

Over time, the entire surface of the pipe will be covered with a layer of scale deposits, which will render additional hydraulic resistance and impede the circulation of circulating water in the cooling system ferroalloy electric furnace of elements. Figure 1 shows a fragment of a pipeline with scale deposits of hardness salts was already shown. It has been found that scale causes not only the problem associated with decreasing the efficiency of the cooling system but also leads to damage of various valves and taps. Scale also deposits on rubber gaskets and seals and reduces their elasticity, as well as contributes to their damage.

ALTERNATIVE METHOD OF PREVENTING DEPOSITS ON THE INTERNAL SURFACE OF PIPELINES

The purpose of this scientific work is to develop an alternative method to prevent deposits on the inner surface of circulating water pipelines of cooling systems for elements of ferroalloy electric furnaces based on the use of an electromagnetic field. The method is based on the well-known principles of using a magnetic field to impact water in order to prevent scale on heat-exchange surfaces and pipelines of various equipment, and to a greater extent energy equipment. But this method is not used for cooling systems of ferroalloy electric furnace elements, therefore there is no experience in manufacturing and using water treatment devices with electromagnets. There are a lot of works that describe the process of the magnetic field effect on water [6]. This method to prevent deposits does not require significant financial investments and the use of high-tech equipment in comparison with the chemical treatment of water.

It is possible to use permanent magnets and electromagnets [6], each option has its own advantages and disadvantages. The use of permanent magnets made of rare earth permanent magnets, in particular neodymium, has been rejected due to their high cost. They also have a low efficiency when working with hard water with high speeds of more than 3 m/s. The capacity of the circulating water cycle is 12 000 m^3, and its flow

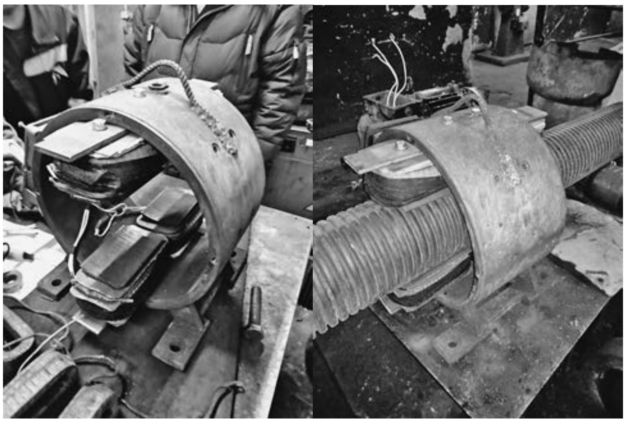


Figure 3 The appearance of an electromagnetic hydro-dynamic water activator

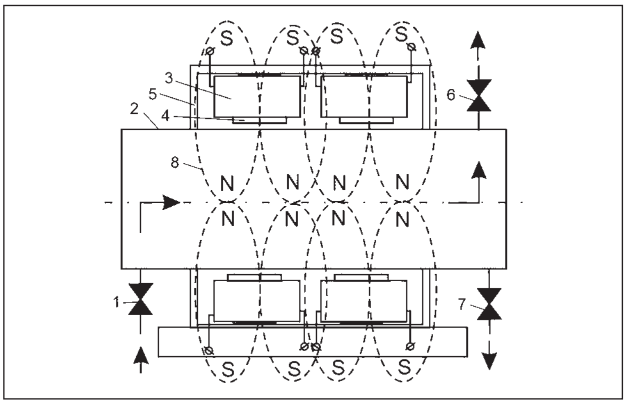


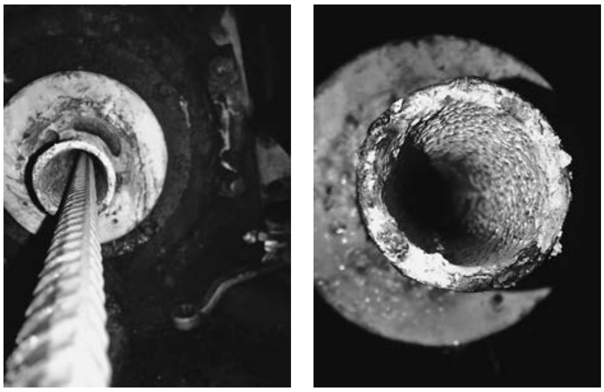
Figure 4 The water activator design:
1 - inlet valve, 2 - activator body made of non-magnetic material, 3 - electromagnet coil, 4 - electromagnet core, 5 - body for fastening electromagnets, 6 - outlet valve, 7 - valve for sludge release and blowing, 8 - propagation of magnetic field lines

rate is 9 600 m^3/ hour. Higher ambient temperatures reduce the service life of permanent magnets to 5 – 7 years. Another problem is that the magnets are placed inside the flow path of the pipeline and over time become covered with a layer of silt. An alternative to a permanent magnet is the use of an electromagnet that developes a sufficiently powerful magnetic field, the strength of which can be adjusted. Electromagnets are placed outside and do not come into contact with water. It can also be noted that electromagnets do not degrade over time, they are easy to maintain and operate. It is an environment-friendly way to produce soft water.

A prototype of a hydrodynamic water activator based on the electromagnetic system of a DC motor has been developed. There are used coils of electromagnets of the main poles in the amount of 4 pieces. The appearance of the water activator is shown in Figure 3.

Figure 4 shows a diagram of an electromagnetic hydrodynamic water activator. The electromagnet coils are powered by a controlled three-phase rectifier.

The voltage of the direct current electrical network is 220 V, the current consumption is within 2 A, respectively, the total power consumption is about 440 W.



a) b)

Figure 5 The cooling channel,
(a) channel completely cleaned by mechanical means before starting the experiment,
(b) the channel state after 6 months of continuous operation and treated water supply

Through the inlet valve water enters the activator body made of a non-magnetic material; for this, a piece of plastic pipe with the diameter of 100 mm is used. DC electric coils develops a magnetic field that is amplified by a steel core. The solenoid coils are placed in the stator housing of the DC motor. At the outlet of the activator, there are two valves, one for connection to the cooling system, and the other for dumping the formed deposits. This is necessary for cleaning the flow path of the activator and blowing from the sludge formation.

PRACTICAL APPROVAL RESULTS AND CONCLUSION

The method has been practically tested in production. An electromagnetic hydrodynamic water activator was mounted in the pipe break of the cooling system of the ferroalloy furnace. Figure 5 shows a photo of a fragment of the cooling system pipeline, on the left there is shown a channel mechanically cleaned from deposits before starting the experiments. The photo on the right shows the same channel after 6 months of operation. It is seen that the channel has remained clean. Deposits only cover it with a thin film within 1 mm, which is not essential.

In practical experiments, two water activators were used mounted in series in the immediate vicinity of the water inlet into the cooling system of a ferroalloy electric furnace. In the course of the experiments, 50 water samples were taken for analyzing. The results were processed by methods of mathematical statistics with the confidence level of 0,95 (Student's coefficient was 2,00957). Water intake was carried out before the activator and after it at the outlet from the furnace cooling system.

The consumption of chemical reagents has been reduced by 60 %. The results of the analyzes have shown changes in the parameters of water hardness: at the inlet to the activator 9,3 mEq/L and at the outlet 5,95 mEq/L. the acidity values pH were 6,9 at the inlet to the activator, pH 8,4 at the outlet. It can be concluded that using an electromagnet to activate water increases pH, reduces the content of dissolved iron, manganese in water, reduces water hardness. The magnetic field intensifies the development of the sludge formation process and accelerates the process of sedimentation of suspended particles; allows removing all kinds of suspensions from the water. It accelerates and transforms the process of crystallization of hardness salts with their transfer into a liquid stream. There has been noted decreasing the intensity of scale formation, as well as washing out of old scale, reducing the corrosion of internal pipe surfaces. As a result, there has been achieved saving of reagents and their consumption was reduced to 60 %.

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Note: Translated from Russian into English by N. Drak, translator of Karaganda Technical University