Influence of magnetic-pulse treatment on wear resistance of machine parts

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Abstract. The purpose of the study is*:* the impact of magnetic pulse processing on the performance properties - wear resistance and durability of parts of various units, machines, complexes. *Method* : the method is based on the use of the combined effect of magnetic fields on a mechanical engineering structure. The behavior of parts under the influence of strong magnetic fields is described **.** *Result:* the main advantages of the behavior of the processed material when exposed to a magnetic flux are determined. *Conclusion:* the use of magnetic influence on structural materials is considered a progressive method, which provides a number of advantages compared to other influences. This method allows you to change the structure of the metal itself, and therefore its physical and mechanical properties, which allows you to improve the performance characteristics of not only parts, but also the product as a whole.

1 Introduction

The quality of machine parts determines the most important task in the operation of a particular type of equipment. For many years, scientists have been striving to apply various technologies related to improving the quality of parts, both the surface layer and the structure of the parts as a whole. One of the methods of influencing a structural material is magnetic treatment, that is, the use of a magnetic field to change the structure and properties of the metal. The processing of machine parts using magnetic energy was proposed by N.I. Kargalov. He used ferromagnetic powder on the internal surfaces of pipes. In the sixties of the last century V.A. Shalnov and V.N. Verezub described the use of abrasive-magnetic processing of flat surfaces.

Numerous research and developments in this area belong to scientific teams in Belarus. Scientists are innovators working on the peculiarities of magnetic influence on the processing of parts. N.Ya. Skvorchevsky, V.N Chachin, F.Yu Sakulevich, N.S. Khomich, E.N. Kudinova, V.I., S.P. Prikhodko, V.S. Kobchikov, V.M. Nesterov , E. M. Zheltobryukhov.

2 Statement of the problem

Improving the quality of parts is a top priority for machine builders. Target of this article - to investigate the impact of magnetic pulse processing on the performance properties - wear

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resistance and durability of parts of various units, machines, complexes and products in general.

3 Research methods

The magnetic effect on the aluminum-silicon alloy Al – Si during its solidification was studied. A change in the microstructure of this alloy was revealed. Namely, in the process of exposure to a magnetic field, dendrites were destroyed at the level of the atomic crystal lattice. Silicon atoms were redistributed in the eutectoid state, which led to an improvement in the mechanical properties of the alloy as a whole. It has been determined that magnetic treatment of a metal during heating and cooling leads to grain refinement of this metal [1]. The effect of a magnetic field on alloy cast iron has been studied. Thus, when cooling cast iron containing alloying elements such as chromium, nickel, silicon, the effect of a magnetic field leads to a decrease in the volume of trostite in the alloy [2]. Under the influence of a magnetic field, a eutectoid transformation occurs , transforming the structure of alloy cast iron [3]. Let's consider the chemical composition of austenitic cast iron 4N15D7 (Table 1)

Table 1. Chemical composition of the sample under consideration

C	Si	Mn	Cr	Ni	With u
2.84	2.5 – 2.6	0.54	1.6	15.1	4.7

The effect of a magnetic field on changes in the structure of austenitic cast iron 4N15D7 (Figure 1, 2, 3).

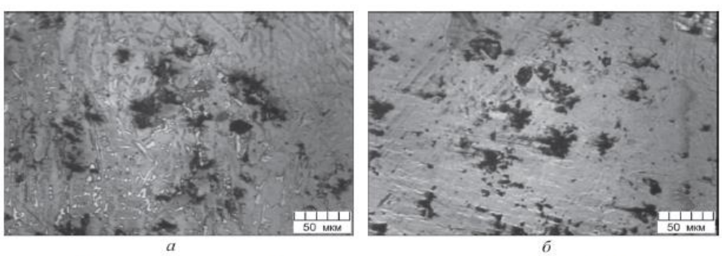

Fig. 1. Microstructure of cast iron samples before exposure to a magnetic field : a) unevenness of the macrostructure across the cross section from the outer edge to the middle of the sample ; b) width of the microstructure uneven zone

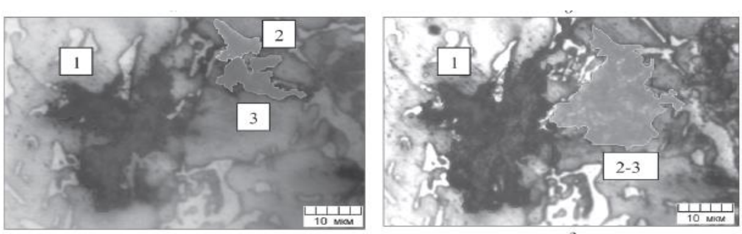

Fig. 2. Microstructure of cast iron samples after two cycles of exposure to a magnetic field.

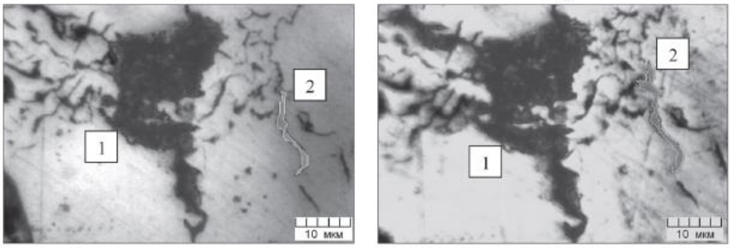

Fig. 3. Microstructure of cast iron samples after six cycles of exposure to a magnetic field.

From the above figures it can be seen that even with double exposure to the metal, growth of graphite inclusions is observed. And the greater the impact the magnetic field has on the metal being tested, the larger the area of graphite inclusions. With sixfold exposure, graphite inclusions reach 7 - 20%.

4 Result

Experiments on the effects of magnetic fields were carried out not only on metal when it was heated or cooled, but also on already manufactured parts, as well as blocks assembled from them. For example, when treated with a magnetic field, a block of sliding bearings undergoes modernization, which makes it possible to improve such significant qualities as durability and reliability [4].

The use of a magnetic field to improve the characteristics of metal structures and parts increases their plastic deformation. The processes of redistribution of chemical elements during melting of alloys change the microstructure of the metal. The influence of a magnetic field on the atomic-crystalline structure of a material makes it possible to improve metal forming processes. It is noted that magnetic treatment is a promising method of influencing not only the structure of the metal, but also improving the roughness of the surface layer of parts. From the point of view of economic and environmental feasibility, the magnetic treatment method replaces more aggressive methods. Unlike existing mechanical, chemical, electromechanical, and abrasive processing of parts, the applied magnetic processing does not have a destructive effect on the environment, improves environmental performance and maintains resource conservation [5].

Thus, when processing a single crystal of silicon, the use of a magnetic field leads to easier polishing of the material being processed. Allows you to reduce fluidity and crystal lattice defects.

Many scientists show an unwavering interest in the change in the nature of the state of a material under the influence of magnetic influence. It is noted that when a titanium alloy is subjected to a magnetic effect, during a phase transformation of the crystal lattice, its compaction occurs - its density increases.

The effect of magnetic processing is widely used in the production of parts by casting. Foundry production has many disadvantages, such as strong thermal radiation, loss of metal, and not always the desired quality of the finished product. Scientists searching for casting problems created a magnetodynamic pump, which made a revolutionary breakthrough in the technology of automatically filling molds with liquid metal. The pump was easy to operate, pumping liquid metal through a pipe instead of water under the influence of a magnetic field. Moving through the pipe, the hot metal filled the casting molds with high precision and versatility. The use of a magnetodynamic pump made it possible to modernize labor-intensive work in foundries and improve labor safety. The developed foundry technology made it possible to increase the strength characteristics of products, quality, wear resistance, and, consequently, the durability of parts subsequently manufactured from the resulting castings (Figure 4).

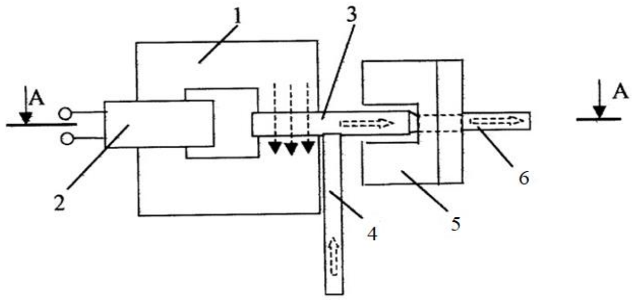

Fig. 4. General view of the magnetodynamic pump, in section: 1 - magnetic circuit with a gap; 2 - excitation winding; 3 – metal pipeline; 4-inlet pipe; 5 - outlet pipe; 6 - U-shaped magnetic circuit.

The method concerns the casting of magnesium and its alloys using a magnetohydrodynamic pump. The metal path and the active zone of the pump are preheated with electric current . Liquid magnesium is supplied to the core and the metal begins to drain. At the same time, an electric current is passed through the metal. Current density is determined by formula (1)

$$j \geq \frac{kQ}{\mu_o \pi R^3 \sqrt{\chi\eta}},$$

where j is the current density in the metal, A/m2; k = 2.61 103 - empirical coefficient; Q - casting productivity kg/s; μo = 4π10-7 - magnetic constant, H/m; R is the radius of the channel for transporting metal, m; χ - electrical conductivity of molten magnesium, Ohm m-1; η - dynamic viscosity of the metal, N s/m2. At this value of current density, the turbulence of the metal flow is suppressed and non-conducting inclusions are actively separated from the melt. This reduces the number of inclusions in magnesium ingots. The invention relates to non-ferrous metallurgy and can be used in the casting of magnesium and magnesium alloys.

There is a known method of casting magnesium and magnesium alloys using centrifugal pumps, described by V.S. Astulov. The method makes it possible to transport liquid magnesium through a closed metal pipeline and provides conditions for creating a fully mechanized technology for casting magnesium and magnesium alloys.

However, the quality of the metal obtained by casting this method is very low. This is due to the design features of the pump - rotation of the impeller at a high angular speed (600-1200 rpm) leads to vibration of the shaft and pump housing and, accordingly, the metal in the mixer. As a result, the metal in the mixer is mixed with sediment and oxide particles exfoliated from the mixer. As a result, the resulting ingots have a high degree of contamination with non-metallic inclusions.

A much more advanced and efficient method of casting magnesium and its alloys are methods based on the use of electromagnetic pumps that do not have moving or rotating parts. These pumps are a special type of magnetohydrodynamic (MHD) devices designed for transporting electrically conductive liquids and, first of all, liquid metals. In magnesium metallurgy, the most widely used are magnetic-dynamic MHD pumps, which have been successfully used in the casting of primary magnesium and alloys for about 30 years.

Another method of casting magnesium and magnesium alloys using a magnetic-dynamic pump is the most effective and closest to the claimed method and was chosen as a prototype. The essence of the method is as follows. The metal path and the pump are first heated by electric current to a temperature of 700-750oC. Then liquid magnesium from the mixer, using a vacuum system (vacuum 500 mm water column), is supplied to the active zone of the MHD pump, where the metal is exposed to an electromagnetic force, through which it is transported and poured into ingots. The method, in comparison with the centrifugal casting method, makes it possible to reduce defects in ingot contamination by oxide and salt (flux) inclusions by three to four times. This effect is due to the absence of moving and rotating parts in MHD pumps. The metal obtained in this way for a long time fully satisfied the requirements of the then existing level of science and technology [6].

In recent years, these requirements have increased significantly, and the quality of the metal in terms of the content of non-metallic inclusions and, in particular, the content of magnesium oxide no longer meets the requirements of consumers. Thus, as a result of systematic studies of the quality of magnesium using metallographic analysis methods, it was established that the content of magnesium oxide inclusions in the metal varies widely: from 5 to 50 units / cm2. In some cases, the inclusion content reaches 1000-1100 units /cm2. The bulk of inclusions has a size of 10-40 microns. Thus, the main disadvantage of the prototype method is the fairly high content of non-metallic inclusions, in particular inclusions of magnesium oxide.

The choice of these conditions for casting magnesium and magnesium alloys is due to the following. It has been experimentally established that the influence of an electromagnetic pump on the quality of the cast metal is passive (in general, this applies to any type of casting: siphon casting, casting under inert gas pressure, casting with a centrifugal pump, etc.) and consists in maintaining the quality of the metal in dispensing container (mixer). At the same time, molten magnesium always contains fine-crystalline (≈10-40 μm) particles of magnesium oxide, carried out of the slurry zone by convective flows due to viscous friction forces. Together with the metal, these particles, passing through the metal flow path of the pump, enter the cast ingots, deteriorating the quality of the latter. Therefore, to improve the quality of ingots based on non-metallic inclusions, it is necessary to create conditions for the separation of these inclusions from the metal during its transportation along the metal path . An analysis of the metal transportation conditions showed that its flow mode is turbulent (Reynolds number $Re > 2300$). This makes it difficult to create conditions favorable for separation: the separated particle will immediately be drawn deeper into the flow. Therefore, to solve the problem, it is necessary to fulfill two conditions: laminate the flow, make the flow laminar, i.e. suppress turbulence and create conditions for the separation of non-metallic inclusions from metal.

An analysis of various methods that make it possible to fulfill these conditions has shown that the simplest and most effective method is to pass an electric current of a given density through the metal. In this case, the following processes occur in the metal. An electric current passing through metal creates an axisymmetric magnetic field around itself. As a result of the interaction of electric current with its own magnetic field, electromagnetic forces arise in the metal, which are always directed, regardless of the direction of the electric current, towards the axis of the metal path. These forces suppress flow turbulence and create excess electromagnetic pressure in the metal. Note that the magnitude of electromagnetic forces is proportional to the electrical conductivity of the material, and since the electrical conductivity of the molten metal is four orders of magnitude higher than the electrical conductivity of salt inclusions, and oxide inclusions are not electrically conductive, then, accordingly, electromagnetic forces affect only the metal component of the melt. As a result, non-conducting (oxides) and weakly conducting (chlorides, fluorides, etc.) inclusions are squeezed out of the melt under the influence of excess electromagnetic pressure.

The method of magnetic influence on the alloy used in this way allows an order of magnitude to reduce the number of non-conducting inclusions in cast ingots of magnesium and magnesium alloys, is easy to operate and can be recommended for implementation not only in magnesium metallurgy, but also in the production of other metals and alloys. The objective of the invention is to develop a method for casting magnesium and magnesium alloys, which makes it possible to significantly reduce the content of non-metallic inclusions in magnesium ingots and its alloys. Patent No. 2135324 " Method of casting magnesium and magnesium alloys " was developed by inventors A.I. Kulinsky, V.V. Kursenko , L.A. Shchepin, V.S. Babin, S.A. Shundikov at the titanium -magnesium plant of the open joint-stock company "AVISMA"

The method of casting magnesium and its alloys is achieved by heating the metal path and the pump with current. Also, the supply of liquid magnesium or its alloy to the active zone of a magnetic-dynamic pump, the effect of electromagnetic force on the metal, transportation and casting of metal. What is new is that during transportation, an electric current is constantly passed through the metal, the density of which is determined by formula (1).

5 Conclusion

Magnetic impact technologies have given rise to breakthrough technical solutions in the creation of various products in the aerospace, electrical, electronic, shipbuilding, nuclear, and oil-producing industries of the domestic industry.

Magnetic influence provides great opportunities: its ability to change physical and mechanical properties is beyond doubt. Changes occur in the metal even at the level of the phase state of the metal. The effect of a magnetic field on machine parts has great promise regarding the possibility of obtaining a certain set of operational characteristics, thereby increasing the reliability, durability and performance characteristics of parts and machines.

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