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FORMATION OF LOW-CARBON WIRE ROD STRUCTURE UNDER SHS CONDITIONS USING MAGNETIC COERCIMETRIC CONTROL

The article discusses the use of a self-propagating high-temperature synthesis of SHS of solid chemical compounds – it is a new technological process that possible to obtain a material with a given structure based on carrying out an exothermic reaction of interaction of reagents in the combustion regime. The influence of cold deformation and intermediate annealing under SHS conditions on the structure, magnetic and mechanical properties of low-carbon steel is determined. The use of magnetic coercimetric control possible to control changes in the structure and mechanical properties of during technological cycle for low-carbon welded wire in production conditions.

Keywords: mechanical properties, cold deformation, anneal in SHS conditions, coercimetric force, special boundaries, size of grain

Introduction. Technical progress involves the introduction of new technologies for the manufacture of welding wire which is used not only for welding but also for surfacing. For the manufacture of welding wire requires a quality workpiece, it should not consist of segments and gaps and must comply with the requirements of regulatory documentation.

The state standard 2246-70 sets requirements for the chemical composition of wire 08G2S. Alloying elements such as vanadium V, tungsten W, aluminum Al, and a number of other alloyed wire 08G2C is usually not alloyed. It is permissible to have manganese in the amount of from 0.65 to 2.1%. If the usual wire is made, the copper content in it cannot be more than 0.25%. Standards allow a content of up to 0.01% nitrogen. This hardware is used not only for welding, but also for surfacing.

The essence of the SHS method is to carry out an exothermic reaction in the mode of propagation of the combustion wave with the formation of combustion products in the form of compounds and materials of practical value and having valuable characteristics.

This synthesis of materials differs significantly from standard methods of powder metallurgy, based on the sintering of chemically inert compounds and have a number of obvious advantages, among which are the following:

– formation of active chemical and thermal zones, which allows to intensify the transformation of reagents and leads to the formation of the necessary goods;

– the use of less expensive chemical energy (thermal separation in exothermic reactions) instead of electricity to achieve the high temperatures required in obtaining products;

– use of relatively simple equipment (instead of furnaces and other heating devices);

– the use in the process of rapid layer-by-layer heating of large volumes of reagents instead of slow heating through the walls from external heat sources.

From this point of view, SHS processes should find practical application in all cases where there are no restrictions related to raw materials or economic considerations [1,2].

The results of works in which at different cooling modes researches of structure and special borders in steels 09G2S, and 3ps [3,5] were carried out. But in these works magnetic properties and their influence on structure of low-carbon steels were not studied. In works [4,6] the eutectoid steel U8 is investigated. The author of work [7] found that with increasing austenitization temperature increases the number of special boundaries in the final structure, which leads to a decrease in the energy of the grain boundary complex. But this paper also did not study the effect of coercive force, namely the magnitude of coercive force, on special low-energy boundaries. The results of these works formed the basis of their practical application in the study of the structure and properties of wire obtained in industrial conditions.

Materials and methods of control. The wire rod was examined diameter 7.0 mm produced by PJSC «ArcelorMittal Kryvyi Rih» of the following chemical composition (tabl. 1).

Table 1 – Chemical composition of wire rod

Carbon	Manganese	Silicon	Sulfur	Phosphor	Chromium	Nickel	Copper
0.06	0.70	0.25	0.025	0.30	0.30	0.30	0.30

The scheme of production drawing is as follows:

The initial blank blank diameter 7.0 mm was stretched through the caliber diameter 3.3 mm; then the wire diameter 3.3 mm was annealed in a furnace under SHS conditions at a temperature 1023 K for eight hours. After annealing under SHS conditions, this wire was stretched through a caliber of diameter 1.2 mm. Mechanical tensile tests of wire samples were performed in accordance with the state standard 1797 on a TTM-500 test machine.

Metallographic studies of the structure were performed on a microscope «Neophot-21» at a magnification of x50…500 and a scanning electron microscope «REM-106I.» In order to prevent blockage of the edges, in the manufacture of sections, the samples were clamped in steel clamps. After sanding on sandpaper, polishing was performed on diamond pastes with successive reduction of grain size to 0.1 μm. The final polishing was performed on the dress in the presence of an aqueous emulsion of chromium oxide. The wire was stretched on a TTM-500 bursting machine. Measurement of coercive force was performed with a semi-automatic coercimeter «KRM-C-K2M» in the middle of the wire.

Setting objectives. Show the influence of structure after cold deformation, annealing in SHS conditions - on mechanical properties, grain size, relative number of special limits and value of coercive force during wire drawing from low-alloy steel grade.

Results and discussion. It is established that the industrial drawing of wire rod caused a change in mechanical properties, grain size, coercive force, and after annealing under SHS conditions the relative number of special boundaries increased. The mechanical properties of steel were presented in table 2

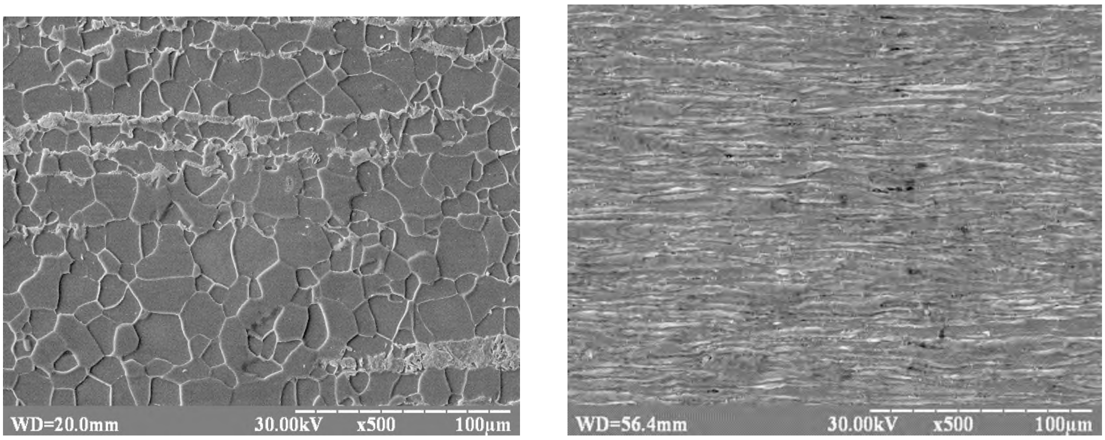
Table 2 – Mechanical properties of wire rod and wire 08G2S

Wire diameter	$\sigma_т$, МПа	$\sigma_в$, МПа	Δ, %	Ψ, %
Diameter 7.0 mm	250	430	42.84	63.06
Diameter 3.3 mm (cold drawing)	673	765	9.64	30.79
Diameter 3.3mm (after annealing in the SHS conditions)	302	553	36.02	68.96
Diameter 1.2 mm	963.72	1042.6	3.95	25.62

The results of the study of the microstructure at the stages of wire production

The finely fibrous structure is the result of elongation and deformation of grains during metal extraction, which is confirmed by the high value of coercive force H_c = 9.1 A/sm is 10.06 μm. Figure 1.b is a result of the final plastic deformation by drawing significantly increased the strength properties of the wire. In the initial state of the wire diameter 7.0 mm, the value of the coercive force was H_c = 5.71 A/sm.

The magnetic properties are sensitive to cold plastic deformation. At cold deformation of a wire at the pass through a calibration of diameter 3.0 mm majestic coercive force increases and makes H_c = 9.28 A/sm. The density of grains increases, they are pulled along the direction of drawing [8].



а) х500 б) х500

Figure 1 – Microstructure of low-alloy steel 08G2S workpiece-wire rod (a), (b) after processing under SHS conditions, end wire diameter 1.2 mm

The most dangerous tensile residual stresses, as they can cause damage to the product. Therefore, annealing was performed under SHS conditions to remove residual stresses [9,10].

The main changes in the magnetic and mechanical properties of low-carbon steels occur in the range of 773…73 K, this is due to the removal of internal stresses, changes in grain size by their orientation, which leads to a decrease in coercive force, hardness and tensile strength [9,10].

Histogram of the distribution of the magnitude of the coercive force from structural changes.

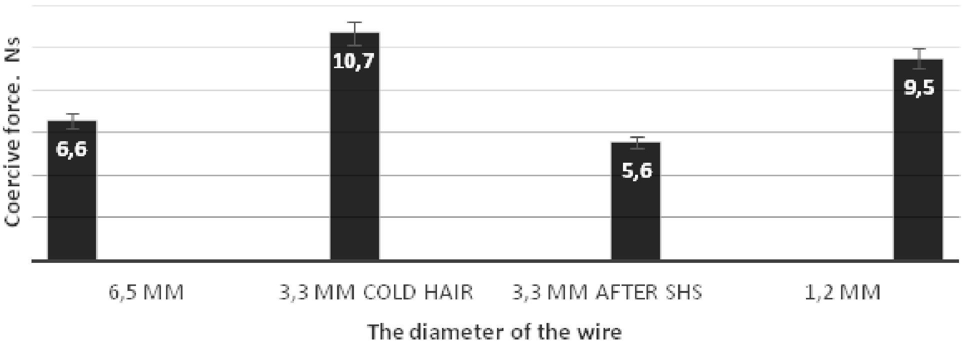


Figure 2 – Histogram of the distribution of the magnitude of the coercive force from the diameter and structure of the wire

After annealing under SHS conditions of the same wire, the value of the coercive force is H_c = 6.76 A/sm. There was a decrease in coercive force by Hc = 27%. The most technological parameter on the temperature regime during wire drawing is determined.

Conclusions. The structure of the workpiece-wire rod is characterized by a grain size of 10.06 μm. The relative number of special limits is 25.08%. It was found that after annealing the cold-deformed wire rod, the grain size in the wire decreased almost twice from 10.60 μm to 5.58 μm, and the relative number of special boundaries increased from 25.06 % to 36.8 %. It is shown that after annealing in the SHS conditions the grain was crushed, the relative number of special limits increased to 35.1 %, the magnetic permeability increased, which led to a decrease in the value of the coercive force by 39.5 %. The magnitude of the coercive force NS allows you to control changes in the structure of the wire at all stages of its production.

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FORMATION OF LOW-CARBON WIRE ROD STRUCTURE UNDER SHS CONDITIONS USING MAGNETIC COERCIMETRIC CONTROL

Formation of the structure of low-carbon wire rod in SHS conditions using magnetic coercimetric control. The article discusses the use of a self-propagating high-temperature synthesis of SHS of solid chemical compounds - this is a new technological process that makes it possible to obtain a material with a given structure based on carrying out an exothermic reaction of interaction of reagents in the form of combustion. The advantages of using SHS are low energy consumption, small-sized equipment is needed, and at the same time there is a high productivity and environmental safety of the SHS process. Introduction of a new technological process for the production of welding wire into production. In the process of its production, the initial billet is successively subjected to cold deformation and annealing under SHS conditions, while changes occur in its structure that affect a number of mechanical and physical properties of the material. The methods of scanning microscopy were used to analyze the microstructure of the welding wire, and measurements of the magnetic properties of the structures were carried out at various stages of the production of the welding wire. The influence of cold deformation and intermediate annealing under SHS conditions on the structure, magnetic and mechanical properties of low-carbon steel is determined. The dependence of the mechanical properties, coercive force, grain size and the number of special boundaries on the modes of cold deformation and annealing under SHS conditions has been established. In the original workpiece, the relative number of special boundaries is 24.05%, and after annealing, the relative number of special boundaries is already 39.5%. The use of a control tool, namely the magnitude of the coercive force Nc, makes it possible to control changes in the structure and mechanical properties of the workpiece throughout the entire technological cycle of manufacturing low-carbon welded wire in production conditions. The most technological process in terms of temperature conditions during wire drawing has been determined.

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