Effect of heat treatment on the mechanical properties of stainless steel wire

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Abstract.
The article is devoted to the study of the mechanical properties of austenitic stainless steel wire with a diameter of 1 mm after heat treatment. Mechanical properties were tested: strength and ductility of hardened and normalized stainless steel. According to the test results, it was found that heat treatment of steel allows obtaining maximum plasticity, while low strength, thus, it seems possible to use this heat treatment as a preparatory operation for the subsequent electric arc spraying of the wire and obtaining a spherical powder.

1. Introduction
The field of application of austenitic stainless steel is wide due to its corrosion and oxidation resistance, durability, high strength and ductility. Products made from it are successfully used not only in the chemical, petrochemical, mining industries, but also in the food and paper pulp sectors of the economy. Austenitic stainless steel is of particular importance for medicine. Medical instruments and products are made from it. This alloy is perfect for use where maximum protection against corrosion is required, for example, in the manufacture of tanks for corrosive solutions, architectural structures in contact with aggressive media, pipes for the food industry and much more [1-6].

At the moment, stainless austenitic steel is increasingly used in additive manufacturing, for the manufacture of parts and products with complex geometry [7]. However, this technology requires spherical powder. Spherical powder for such steels comes out by the method of gas or water spraying, which is obtained of low quality (high content of satellites, low sphericity, etc.) [8-9]. We have developed an installation for electric arc wire spraying and production of high-quality spherical particles [10-11]. This method of producing spherical particles requires wire as the base material. The study of such materials and tracking the regularity of changes in properties at each stage, from the production of wire to powder and the final product, is an urgent task.

The aim of this work is to analyze the mechanical properties of austenitic stainless steel wire with a diameter of 1 mm, depending on the heat treatment.

2. Methods and materials
Austenitic stainless steel wire with a diameter of 1 mm was produced. The chemical composition of the wire is shown in Table 1.
Table 1. The chemical composition.

| C  | Cr  | Ni  | Si  | Mn  | Mo  | P   | S   | N   | Cu  |
|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 0.025 | 18.94 | 11.2 | 0.84 | 1.76 | 2.08 | 0.027 | 0.007 | 0.069 | 0.09 |

The wire was subjected to various heat treatments (quenching and normalization) at temperatures from 900 °C to 1050 °C in a muffle furnace with a maximum temperature of 1100 °C. The holding in the oven occurred for 2 minutes, then the wire was removed from the oven and either left to cool in air (normalization) or cooled in water (quenching).

The tensile strength study was carried out on an INSTRON 3382 universal testing machine with a tensile speed of 1 mm / min. For research, samples 80 mm long were cut from the coil (15 mm for each grip and 50 mm for the working part).

3. Results and discussion
For mechanical tests, 5 samples were tested per one experimental point. The values of the relative elongation, conventional yield stress and ultimate strength were determined. The results can be found in Table 2. For convenience, graphs of the dependence of mechanical properties on the heat treatment mode were built (Figures 1-3).

Table 2. Mechanical properties.

| Heat treatment | Elongation (%) | Yield strength (MPa) | Ultimate tensile stress (MPa) |
|---------------|----------------|----------------------|-----------------------------|
| Original      | 0.8±0.5        | 1353±8               | 1588±8                      |
| 900°C, 2min, air | 50.5±0.5      | 394±8                | 793±8                       |
| 950°C, 2min, air | 51.7±0.5      | 365±8                | 769±8                       |
| 1000°C, 2min, air | 55.4±0.5      | 328±8                | 731±8                       |
| 1050°C, 2min, air | 61.0±0.5      | 300±8                | 715±8                       |
| 900°C, 2min, water | 54.4±0.5     | 387±8                | 789±8                       |
| 950°C, 2min, water | 54.0±0.5     | 351±8                | 773±8                       |
| 1000°C, 2min, water | 58.2±0.5     | 317±8                | 735±8                       |
| 1050°C, 2min, water | 66.4±0.5     | 315±8                | 714±8                       |
Figure 1. Graph of the dependence of the relative elongation of the wire on the heat treatment mode.

Figure 2. Graph of dependence of the ultimate strength of the wire on the heat treatment mode.
Figure 3. Graph of dependence of the yield strength of the wire on the mode of heat treatment

The wire in the initial state was cold-worked and had low ductility (less than 1%) and high strength (1588 MPa). To improve the manufacturability, the wire was subjected to various heat treatments, such as quenching and normalizing at different temperatures. It turned out that the maximum ductility is possessed by the wire subjected to quenching when heated to a temperature of 1050 °C and amounted to 66.4% and also the minimum strength (714 MPa). It can be seen from the graphs that during normalization and quenching, the ultimate strength and yield strength decrease with an increase in the temperature in the furnace, but the plasticity increases.

4. Conclusion
Mechanical properties were tested: strength and ductility of hardened and normalized stainless steel. According to the test results, it was found that heat treatment of steel allows obtaining maximum plasticity, while low strength, thus, it seems possible to use this heat treatment as a preparatory operation for subsequent drawing to obtain a wire of the required diameter suitable for electric arc spraying of a wire and obtaining a spherical powder.

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