Investigation of the impulse impact effect in the process of additive manufacturing of metal products by plasma cladding

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Abstract. Additive technologies (AT) or layered synthesis technologies are one of the most dynamically developing areas of "digital" production. A common problem of additive technologies is ensuring the proper microstructure of the synthesized material and the eliminating defects. The use of filler wire as a working material eliminates the problems associated with the low productivity of existing methods, the high cost of the equipment used, the limited types of materials used, due to the use of powder systems. Products made of stainless chromium-nickel steels are widely used in various industries. The main problem of additive technologies is to ensure the properties of the laminates are not lower than those obtained by traditional methods. Characteristic defects of laminated materials obtained by surfacing are increased porosity, non-metallic inclusions, a decrease in ductility, and for high-alloy steels, a loss of special properties. This predetermined the development of research in the field of additional technological measures to improve the final properties of the product. This paper presents the results of a study of the effect of ultrasonic vibrations on the structure and properties of the deposited steel 12Cr18Ni10Ti. For welding was used the wire 12Cr18Ni10Ti, process was carried out by plasma arc in a protective argon gas. It was found that ultrasonic treatment has an effect on the final grain size, structure formation and hardness, as well as on the geometry of the deposited layer. Studies show that the use of ultrasonic vibrations in the process of surfacing can be applied in the design of equipment for the implementation of processes of additive production.

1. Introduction
One of the development ways in modern engineering is improve durability of manufactured products [1]. Recently, additive technologies have become common, but their widespread introduction into production is discouraged by insufficient information about the effect of layer-by-layer metal surfacing on the properties of finished products and the lack of technological recommendations for producing a defect-free structure and required mechanical properties. This predetermined the need to search for technological methods that provide necessary properties of the metal of products during additive manufacturing [2-3].

Obtaining a fine-grained structure of the surfaced metal allows, as practice shows, to provide high mechanical properties of the welded joint, as well as to increase the technological strength, corrosion
resistance and other special properties, increase the service life of the product as a whole [4]. Application of various impacts on the molten pool during surfacing is one of the possible mechanisms for modifying the deposited metal [5].

The existing specifics of cast metal crystallization during welding and surfacing allow us to establish the harmonic frequency of solidification of the metal. Some researchers believe that the main reason for cyclicity of crystallization is the release of latent heat of melting that inhibits the advance of the solidification front, others consider concentration overcooling in front of the interface boundary, and still others consider the periodic heat supply to the boundary to be the reason. However, there is still no consensus [6].

Currently, there is a number of technological methods enabling to influence crystallization of the metal during welding and surfacing in order to obtain a grinding structure. For these purposes we use: vibration of the welded product, energy input from a pulsed heat source, pulsed filler wire in different spatial positions, sources with modulation of the welding current acting on the liquid metal of the tail section of the pool, as well as, in some cases, the input of separate heat sources influencing the heat-affected zone near the seam axial line, external electromagnetic effects on the melt, both in continuous and in pulsating mode with different frequencies of the magnetic field, etc.

Some authors attributed the conditions for the formation of the weld metal structure to the effect of heat supply on the solidification front. Other researchers believed that vibrations of the molten metal in the welding pool played a significant role in the formation of the structure.

2. Research methodology
For manufacturing critical structures, steel grade 12Cr18Ni10Ti is most often used among high-alloy steels. This can be explained by the fact that austenitic chromium-nickel steels, such as steel 12Cr18Ni10Ti, have high ductility and resilience, high mechanical properties at low temperatures, resistance to oxidation in air and in the atmosphere of fuel combustion products at temperatures below 900 °C and good weldability. However, having a unique complex of physical and mechanical properties, the steel under consideration has several disadvantages: relatively low strength and hardness, susceptibility of intercrystalline corrosion of the welds. The authors in [7] established that ultrasonic action has the most favorable effect at a 30 mm distance from the waveguide.

This paper proposes a method for improving the quality of deposited layers of steel 12Cr18Ni10Ti with layer-by-layer plasma surfacing during additive manufacturing of parts. To study the possibilities of modifying the structure, we used an impulse impact action on the deposited material on a EWM Tetrix 400 Plasma welding machine.

Plasma surfacing was made on 10 mm thick plates of steel 12Cr18Ni10Ti. The plasma arc was performed according to the mode given in Table 1. The impulse impact is applied directly in the arc gap.

| Middle surfacing current, A | Surfacing voltage, V | Plasma argon consumption, l/min | Feed rate, m/min | Action frequency, Hz | Distance from sample to welding torch nozzle section h, mm |
|---------------------------|---------------------|-------------------------------|-----------------|----------------------|---------------------------------|
| 195                       | 22                  | 3                             | 2.5             | 0-15000              | 10                              |
Figure 1. Samples of plasma surfacing. 1 – 15000 Hz; 2 – 10000 Hz; 3 – 5000 Hz; 4 – 1000 Hz; 5 – 500 Hz; 6 – 50 Hz; 7 – not frequency

3. Results and its consideration
At the first stage, the comparative parameters are the width and height of the deposited bead, relative deviations in width and height. These studies will help to understand the stability of the roll formation over time and to choose the optimal mode for layer-by-layer synthesis. Table 2 shows the results of measurements of the geometric parameters of the rollers depending on the frequency.

| № sample | Weld width, mm | Weld height, mm | Width relative deviations, % | Height relative deviations, % |
|----------|----------------|----------------|-----------------------------|------------------------------|
| 1        | 8.27-8.84      | 1.12-1.37      | 93.55                       | 81.75                        |
| 2        | 7.57-9.14      | 1.14-1.35      | 82.82                       | 84.44                        |
| 3        | 8.08-8.92      | 1.02-1.41      | 90.58                       | 72.34                        |
| 4        | 8.28-9.68      | 1.06-1.55      | 85.53                       | 68.38                        |
| 5        | 8.63-8.82      | 1.11-1.27      | 97.84                       | 87.40                        |
| 6        | 7.78-9.26      | 1.06-1.55      | 84.01                       | 68.38                        |
| 7        | 8.15-10.17     | 1.02-1.38      | 80.13                       | 73.91                        |

4. Conclusions
1. Studies of the effect of impulse action during the surfacing cycle on the constancy of the geometry of the deposited bead have been carried out;
2. It was found that the greatest stability in the formation of a single bead, all other conditions being equal, is provided by modes 1 and 5, which corresponds to frequencies of 15000 Hz and 500 Hz;
3. For the final summing up, more detailed studies of metallography of the seams with the measurement of the micro hardness of characteristic areas and grain size are required.

Presumably, mode 1 should provide a more finely dispersed structure due to high-frequency exposure, due to which a large number of new crystallization centers are formed.

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