RESEARCH OF PROPERTIES OF THE METAL OF THE HEAT-AFFECTED ZONE FOR SURFACING BY STAPE ELECTRODE WITH THE CONTROLLED TRANSFER OF THE ELECTRODE METAL

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Abstract: The quality of the deposited layer is determined by the conditions of its formation, as well as the properties of local zones, due to the parameters of the thermal cycle of surfacing (mechanical, microstructural, chemical, etc.). When surfacing the austenitic layer on pearlitic steels, the properties of the heat-affected zone, along with the resistance of the surface layer to corrosion, largely determine the performance and durability of the deposited product. To reduce the amount of heat input and effectively control the structure and properties of the heat-affected zone when restoring working surfaces by submerged arc surfacing, a method for surfacing with a tape electrode with controlled mechanical transfer of electrode metal is proposed.

Studies have shown that the imposition of longitudinal sinusoidal vibrations on the end of the tape electrode can reduce the level of heat input in the heat-affected zone by increasing the efficiency of fusion of the base metal. At the investigated frequency of 50 Hz, the duration of the dots on the boundary of the fusion line and below it in the range 900...1100 °C is less than when surfacing without controlled mechanical transfer. Reducing heat input into the heat-affected zone in the temperature range 900...1100 °C provides a finer-grained structure. The use of forced vibrations of the end of the tape when surfacing a high-alloy austenitic layer on low-carbon steel makes it possible to obtain a finer-grained structure at the fusion boundary in the heat-affected zone. This will increase the resistance of the heat-affected zone to the formation of defects associated with a decrease in its mechanical properties.

Keywords: surfacing, heat-affected zone, microstructural studies, controlled transport, speed, frequency and amplitude of vibrations.

1. Introduction

Control of heat input into the deposited product allows you to optimize the surfacing process, providing high quality deposited metal. The quality of the deposited layer is determined by the conditions of its formation, as well as the properties of local zones, due to the parameters of the thermal cycle of surfacing (mechanical, microstructural, chemical, etc.) [1]. When surfacing the austenitic layer on pearlitic steels, the properties of the heat-affected zone, along with the resistance of the surface layer to corrosion, largely determine the performance and durability of the deposited product.

Structural transformations in the metal of the heat-affected zone are determined by the thermal cycle. In particular, the growth of austenitic grain is affected by the length of stay of the base metal above the temperature A_{c3}+(50...100) °C. The components $\gamma \rightarrow \alpha$ of the transformation are affected by the cooling rate of such a zone from the critical point A_{rI} to the temperature at which martensite begins to form. Therefore, a decrease in the level of heat input will contribute to obtaining a finer-grained structure and increase the resistance of the metal of the heat-affected zone to embrittlement during operation.

Automatic submerged arc welding with a tape electrode is characterized by increased heat input. Therefore, when restoring working surfaces by submerged arc welding, it is necessary to effectively control the structure and properties of the heat-affected zone. For this, a method for surfacing with a tape electrode with controlled mechanical transfer of electrode metal is developed in [2–4].

The controlled heat transfer is ensured by the functional dependence of the change in the power of the heating source in time and space, which is associated both with the law of energy distribution in time and with the change in the path of the source relative to the deposited layer of the product [5–7]. The use of surfacing methods with controlled heat and mass transfer of electrode metal from the end of the tape electrode into the weld pool has the form of a complex dependence. This leads to the fact that the law of variation of thermal power in the base metal occurs with a large number of controlled parameters. This does not allow the use of known methods for variable power sources to calculate the heat distribution in the weld and near-heat zone. At present, there is no information on the effect of controlled mechanical transfer during surfacing with a tape electrode on the change in thermal distribution in the heat-affected zone of the deposited product.

The aim of research is studying the effect of controlled mechanical transfer of electrode metal during surfacing with a tape electrode on the properties of the metal of the heat-affected zone.

To achieve this aim, the following tasks are set:

– study the temperature distribution in the heat-affected zone when surfacing with a tape electrode with controlled mechanical transfer of electrode metal;

– study the effects of controlled mechanical transfer on the structure and properties of the metal of the heat-affected zone;

– establish the effect of controlled transfer of electrode metal on the quality of the deposited products.

2. Methods

The shape of the weld pool when using a tape electrode is considered as an example of comparison with the case of multielectrode surfacing by rowing electrode wires with a common current supply. The current pulse through the cross section of the considered electrode without taking into account the spreading of the current over the area of the tape electrode can be represented in the form of periodic pulses (**Fig. 1**). Based on the constancy of the speed of movement of the arc along the end of the tape electrode, let's take equal pause durations between pulses. During each current pulse, the arc burns in a local area, exerting a thermal effect on the base metal located under this area.

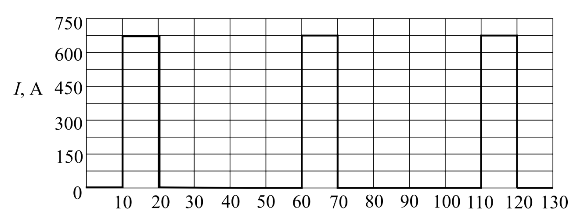

Fig. 1. The melting diagram of the local area of the tape electrode

In addition, the use of controlled transfer of electrode metal during tape surfacing is associated with a change in the position and speed of movement of the electrode end according to the sinusoidal law of motion towards and away from the bath [8]. The dependence of the speed of movement of the electrode end during the surfacing process, taking into account the constant feed rate of the tape electrode, has the form shown in **Fig. 2**. Periodic movement of the end of the tape electrode along the direction of its supply changes the energy characteristics of the arc and, depending on the parameters of this oscillatory motion, leads to a change in the efficiency of melting of the tape electrode and the base metal [9].

Since the distribution of thermal power can be taken uniform across the width of the tape electrode, the heat input into the seam and its distribution along the depth of the heat-affected zone can be considered as an example of a local section of the tape electrode.

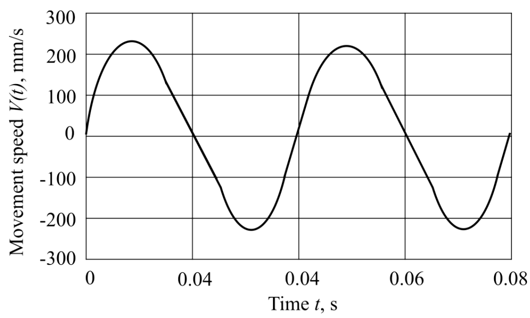

Fig. 2. The change in the speed of movement of the end of the tape electrode

For a periodic moving point source on the surface of a semi-infinite body with a rectangular pulse duration t_p, a period t_c, and a pulse power q_p (averaged power $q_0=q_p t_p/t_c$), where the temperature field is described by the expression [1]:

$$T(x,y,z,\Delta t)=\frac{q_0}{2\pi\lambda R}\exp\left(-\frac{\nu(x+R)}{2a}\right)F(R,\Delta t), \quad (1)$$

where the function F takes into account the influence of the periodicity of the source.

Using (1), let's carry out a comparative calculation of the thermal cycles of heating the points along the depth of the heat-affected zone 2...6 mm using controlled mechanical transfer and without it. In this case, the conditional thermal power of a variable power source with sinusoidal displacements of the anode spot can be adopted higher by 15...20 % with equal actual power with a constant heat source [10].

To compare the calculated data with the experimental results, experimental surfacing of samples of low-carbon steel with Cr18Ni-10Ti tapes is carried out in the modes: welding current strength 320–850 A, arc voltage 28–42 V, surfacing speed 10 m/h, deposition step 10–14 mm As a result, macrostructures of the samples are obtained. By the nature of the fusion line with the base metal, one can judge the uniform distribution of thermal energy along the width of the deposited bead. As well as uniform fusion with the base metal, reducing the likelihood of defects in the weld.

Using microsections, metallographic studies are carried out to determine the effect of the surfacing process with vibrations of the end of the tape electrode on the structure and properties of the austenitic layer deposited on low-carbon steel. The studies are carried out using MIM-8, "Neophot-21" microscopes at magnifications of ×100. The microhardness is determined on a PMT-3 device by pressing a diamond pyramid with an angle at the apex 136° under a load of 100 g into a polished surface of a sample.

3. Results

The nature of the calculated temperature distribution in the local area during surfacing of the anticorrosion coating layer showed that, with distance from the fusion zone, the temperature decreases sharply and does not exceed 400 °C with distance up to 35 mm from the source center. A practically similar character of temperature change is observed along the depth of the base metal (**Fig. 3**). According to those presented in **Fig. 3** of the temperature field data, the penetration depth of the base metal when using controlled transfer does not reach 1.5 mm (**Fig. 3, *b***), since the calculated temperature at this depth near the linear source does not exceed 1500 °C. Calculations also show a decrease in the size of the region of the base metal, which is heated to 1100 °C and above when using controlled transfer. As a result of this, it is possible to qualitatively assess the area of formation of a coarse-grained heat-affected zone in the conditions of surfacing with a tape electrode.

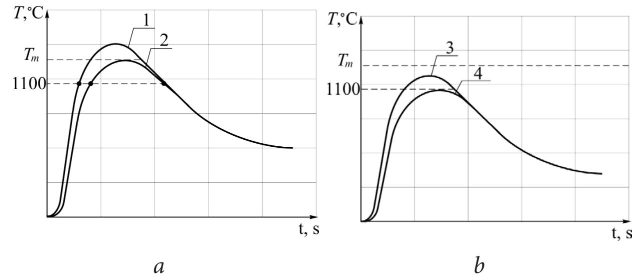

Fig. 3. The thermal heating cycle for the local area of the heat-affected zone: *a* – at *z*=1.5 mm 0 Hz; *b* – at z=3.0 mm 0 Hz; 1, 3 – 0 Hz; 2, 4 – 50 Hz

Metallographic studies show that the structure of all samples is characterized by uniform penetration, symmetrical HAZ and the absence of discontinuities, and the base has a homogeneous fine-grained macrostructure.

An analysis of the microstructure (**Fig. 4, *a*, *b***) and microhardness measurements (**Fig. 5**) of the samples indicates the presence of a carbide network along the boundaries of austenitic grains and dendritic segregation in the surfacing layers.

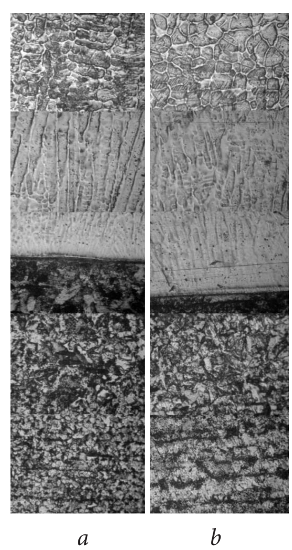

Fig. 4. Change in the microstructure along the depth of the deposited metal Cr25Ni22NMn4Mo2 at VSt3sq: *a* – without forced oscillations; *b* – vibration frequency 50 s^{-1} along the depth of the deposited metal Cr25Ni22NMn4Mo2 at VSt3sq, ×100

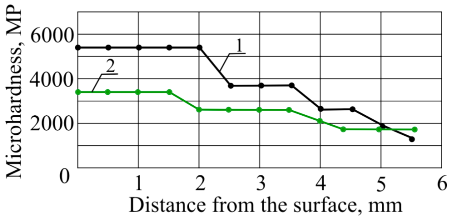

Fig. 5. Change in the microhardness along the depth of the deposited metal Cr25Ni22NMn4Mo2 at VSt3sq: 1 – microhardness distribution along the depth of the deposited metal without forced vibrations; 2 – microhardness distribution along the depth of the deposited metal with forced vibrations, frequency 50 s^{-1}

Thus, in the first layer, an austenite structure with distinctly etched grain boundaries and a network of chromium carbides is observed; closer to the fusion zone, the number of austenite columnar crystallites increases and the carbide network becomes thinner. A dendritic segregation is clearly visible in this overlay layer: the dendrite body is darker, the interdendritic spaces are lighter, which indicates different chemical activity when interacting with the etching reagent.

Microhardness measurements (**Fig. 5**) show that in the state after surfacing, its values vary significantly, and a decrease in microhardness in the fusion zone is also observed, which is explained by the presence of chemical heterogeneity. High values of the microhardness of the deposited metal are explained by the presence of a large number of hardening phases in the austenitic matrix (carbides and carbonitrides).

4. Discussion and conclusions

Thus, the studies show that the imposition of longitudinal sinusoidal vibrations on the end of the tape electrode allows to reduce the level of heat input in the heat-affected zone by increasing the efficiency of fusion of the base metal. At the investigated frequency of 50 Hz, the duration of the dots on the boundary of the fusion line and below it in the range 900...1100 °C is less than when surfacing without controlled mechanical transfer. Reducing heat input into the heat-affected zone in the temperature range 900...1100 °C provides a finer-grained structure.

Macro and microstructures, as well as the nature of the change in the microhardness of the deposited metal Cr25Ni22NMn4Mo2 are studied. The use of forced vibrations of the tape end when surfacing a high-alloy austenitic layer on low-carbon steel makes it possible to obtain a finer-grained structure at the fusion boundary in the heat-affected zone. And also, to increase the resistance of the heat-affected zone to the formation of defects associated with a decrease in its mechanical properties.

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