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REFINEMENT OF METAL STRUCTURE IN ARC SURFACING UNDER THE EFFECT OF LONGITUDINAL MAGNETIC FIELD

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It is shown that if the deposited iron-based metal contains less than 0.15 % carbon, and more than 16 % chromium, then during its crystallization austenitic dendrites will form at the stage of primary crystallization, and during further cooling austenite will be transformed into ferrite. In this case, ferrite is formed within the boundaries of austenitic dendrites, and further on it does not undergo polymorphic transformations. Taking this statement into account, the deposits were produced using flux-cored wire, which provided carbon content of 0.08 % and that of chromium of 17–19.5 % in the deposits. The deposits were made without the effect of a longitudinal magnetic field and under the effect of this alternating field of 6, 12, 24 and 33 Hz frequency. Studies of macro- and microstructure of the deposited metal showed that under the effect of the magnetic field in the frequency range of 6–24 Hz, a significant decrease in the width and length of dendrites was observed in the deposited metal structure. The conclusion was made that refinement of the structure (of dendrites) during submerged-arc surfacing with wire is caused by movement of liquid metal in the pool under the effect of the magnetic field, and the influence on primary crystallization, and not on the stage of polymorphous transformations of metal in the solid state. 4 Ref., 1 Table, 3 Figures.

Keywords: *arc surfacing, magnetic field, crystallization, dendrite, austenite, ferrite*

Known is a considerable number of works, devoted to study of the features of the process of electric arc welding and surfacing under the effect of a controlling longitudinal magnetic field (LMF). In particular, in [1] it is shown that in welding under the effect of LMF, the melting rate of electrode wire becomes higher, the depth and area of base metal penetration zone is reduced, structure of weld or deposit metal is refined. However, the mechanism of refinement of structural components of welds (deposited metal) under LMF effect has not been unambiguously established. Brief overview of the currently available opinions of researchers on this subject is given in work [2].

In work [2] it is shown that the question about the stage of crystallization of weld metal in welding under LMF effect, at which weld structure refinement occurs, is still not solved. A number of researchers believe that this occurs at primary crystallization of welds, other authors think that this is due to phase transformations in the solid state (polymorphous transformations).

In works [3, 4] it is shown that in low-carbon high-chromium iron-based alloys (less than 0.15 % carbon and more than 16 % chromium) ferrite forms at austenite decomposition at temperature below A_{r3} point (of the order of 700 °C). This ferrite forms at decomposition of austenitic dendrites so that the available boundaries of dendrites (austenite) are preserved. Moreover, the alloy produced after crystallization, does not change its structure at heat treatment (quenching, or heating). Thus, if an alloy of such a composition is deposited under LMF effect and refinement of dendrites (grains) takes place, it will mean that refinement of the deposited metal structure occurred at primary crystallization of molten metal in the weld pool.

The objective of this work is obtaining the following information: at what stage — primary crystallization or that of phase transformations in the solid state does refinement of the structure of welds (deposits) take place in submerged-arc welding (surfacing) with wire under the effect of LMF.

In order to achieve this objective, the following experiment was performed. Reverse polarity submerged-arc surfacing with wires was conducted by automatic machine of ADS-1002 type using a rectifier of VDU-1202 type.

Surfacing was performed on a plate from low-carbon steel VMSt3sp(killed) 20 mm thick (250 mm wide, 400 mm long). First a sublayer was deposited in two passes (see Figure 1 — layer I, II) with 3.6 mm flux-cored wire PP12Kh13 using AN-26P flux.

Surfacing mode was as follows: I_s = 400–420 A; U_a = 32–33 W; v_s = 27 m/h. Bead overlapping — deposition step L was equal to 12–13 mm. Total thickness of the two layers of the sublayer was δ = 6–7 mm

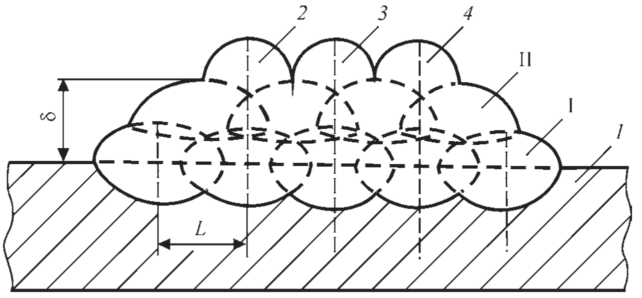

Figure 1. Deposition scheme: I, II — first and second passes of the sublayer, respectively; *1* — base metal; *2–4* — deposited beads

(Figure 1). A bead was deposited on the sublayer with specially made 4 mm flux-cored wire of 10Kh20 type using AN-26P flux under the effect of alternating LMF of 6, 12, 24, 33 Hz frequency. One bead was deposited without the LMF impact. Value of longitudinal component of LMF induction was 25–30 MT (measured before deposition under the electrode end face, which was located at 5 mm distance from the sublayer). LMF input device (ID) consisted of a solenoid with a ferromagnetic core, mounted coaxially with the electrode. The number of turns in the solenoid winding was $W = 150$. Power to LMF ID winding was supplied from a special power source, which generated rectangular current pulses in the winding with pause $t_p = 0.01$ s. LMF ID design is described in detail in work [1].

Transverse templates 25–30 mm thick were cut out of the deposits. The template surfaces were ground, polished and etched with aqua-regia to study the macro- and microstructure. By the data of chemical analysis in all the deposit samples element content was equal to, wt.%: 0.08 C; 17–19.5 Cr; 0.34–0.36 Si; 0.29–0.30 Mn.

Dendrite dimensions in the deposited metal

Surfacing method	Dendrite dimensions	
	Width, μm	Length, mm
Without LMF	$\frac{130}{100-50}$	$\frac{0.130}{0.100-0.140}$
LMF, *f* = 6 Hz	$\frac{110}{100-150}$	$\frac{0.098}{0.080-0.120}$
LMF, *f* = 12 Hz	$\frac{83}{80-140}$	$\frac{0.100}{0.085-0.115}$
LMF, *f* = 24 Hz	$\frac{90}{80-20}$	$\frac{0.100}{0.080-0.120}$
ПРМП. f = 33 Гц	$\frac{140}{100-200}$	$\frac{0.130}{0.100-0.150}$

Note. The numerator gives average values, the denominator — minimum and maximum values.

Figure 2 shows the appearance of deposit macrostructures in their central part. It is characteristic that a dendritic structure is found at surfacing without LMF impact (Figure 2, *a*). In deposits, produced under the effect of LMF (Figure 2, *b*–*e*), a columnar dendritic structure is observed, oriented normal to the heat removal surface (towards the fusion line). Transverse dimensions of columnar dendrites decreased noticeably in deposits produced under LMF effect.

The microstructure of deposits, the appearance of which is given in Figure 3, was studied for a more detailed investigation of dendrite dimensions. The secant method was used to determine the width of dendrites, the data on which are given in the Table. It is characteristic that the scatter of this value is con-

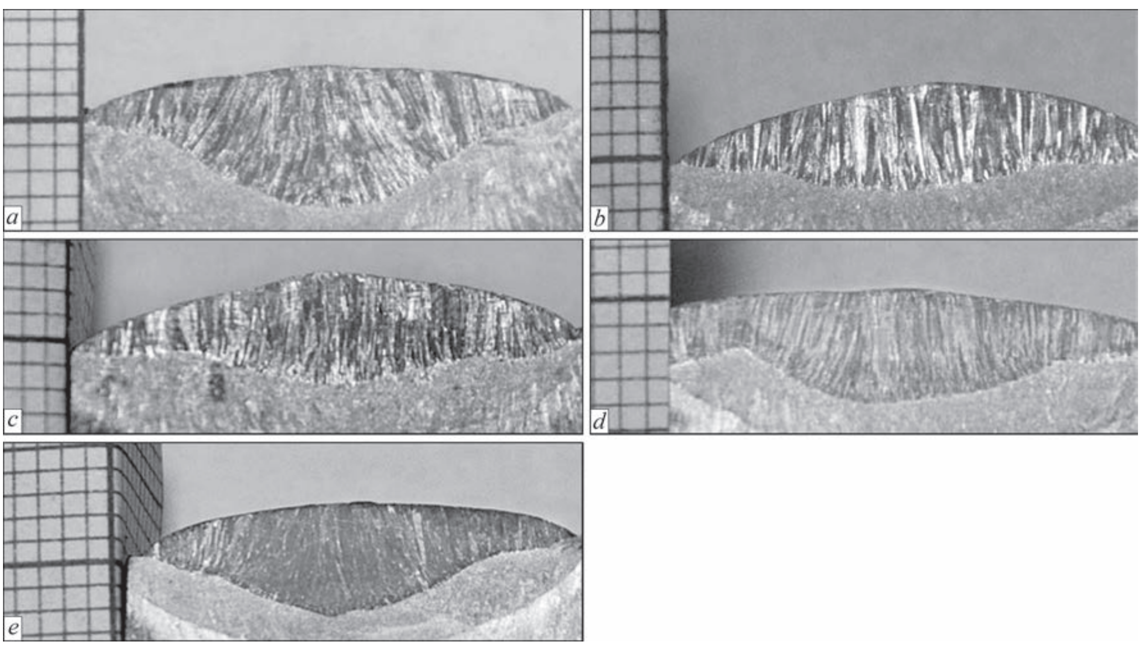

Figure 2. Deposited metal macrostructures: *a* — without LFM; *b*, *c*, *d*, *e* — under the effect of LMF of the following frequency: 6, 12, 24, 33 Hz

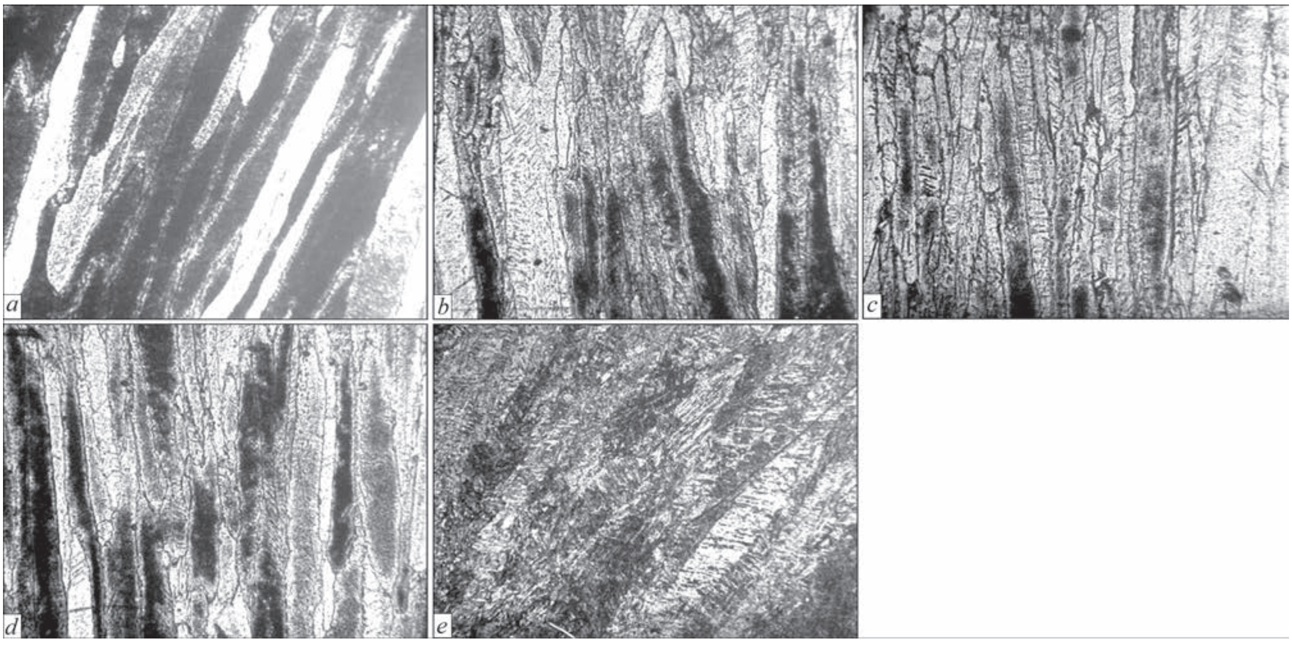

Figure 3. Microstructures of deposited metal (×60): *a* — without LMF; *b, c, d, e* — under the effect of LMF of 6, 12, 24, 33 Hz frequency, respectively

siderable for deposits made without LMF impact and under the effect of LMF. Average values of dendrite width are as follows: without LMF impact — 130 μm, under LMF effect: f = 6 Hz — 110 μm; 12 Hz — 83 μm; 24 Hz — 90 μm; 33 Hz — 140 μm. Thus, in the frequency range of 12–24 Hz, the dendrite width decreased considerably (from 130 to 83–90 μm). At 33 Hz frequency this size is not smaller than in deposits made without LMF impact. This is associated with the fact that at 33 Hz frequency of LMF the metal molten in the pool did not move under the impact of alternating LMF, because of its inertia; the melt moved at lower LMF frequencies (right down to 24 Hz inclusive). The length of dendrites in the photo of deposit microstructures was also measured. The table data showed that the average length of dendrites in the deposits made without LMF impact, is equal to 0.13 mm, and decreases to values of the order of 0.10 mm in deposits, made under the effect of LMF of 6–24 Hz frequency. In deposits made under the effect of LMF of 33 Hz frequency, the length of dendrites is the same as in the deposits, made without LMF impact. As all the deposits contained: < 0.1 % C; > 16 % Cr, then, as was noted above, the effect of structure refinement in the deposits, made under the impact of LMF, was obtained at the stage of primary crystallization of liquid pool metal in arc surfacing. Thus, refinement of the structure (of dendrites) in submerged-arc surfacing with wire is associated with LMF impact (movement of liquid pool metal) at the stage of primary crystallization, and not at the stage of phase transformations of metal in the solid state (polymorphous transformations).

Conclusions

1. A significant reduction of the width and length of dendrites in the deposits is observed in submerged-arc surfacing with wire of iron-based alloy with 0.08 % C and 17–19.5 % Cr, under the effect of an alternating magnetic field of 6–24 Hz frequency.

2. Refinement of structural components in the metal of deposits in submerged-arc surfacing with wire under the effect of controlling longitudinal magnetic field is due to the process of this field impact on the stage of primary crystallization of liquid pool metal, and not on the stage of polymorphous transformations of metal in the solid state.

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