Figure 9. Loading of a 500 t slug catcher surge vessel onto a freighter at Gemlik harbour

roads along this path also had to be stabilised and reinforced in a lot of places. Figure 9 shows the loading of surge vessel onto a freighter.

The heavy lorry has 31 axles. Currently all measures are taken to prepare the harbour for the transport of the 1000 t CO_2 absorber.

The maximum unit loads for «Eurasia» and «Shakhtar» amount to 70 t.

Therefore, they can be handled as is shown in Figure 10. The logistical problems mainly regard the timing. Due to the risk of freezing waters the elements can only be transported from April to October. To minimize storage costs procurement and production planning are precisely coordinated. Currently this causes relatively large problems since the worldwide steel market is suffering from shortages.

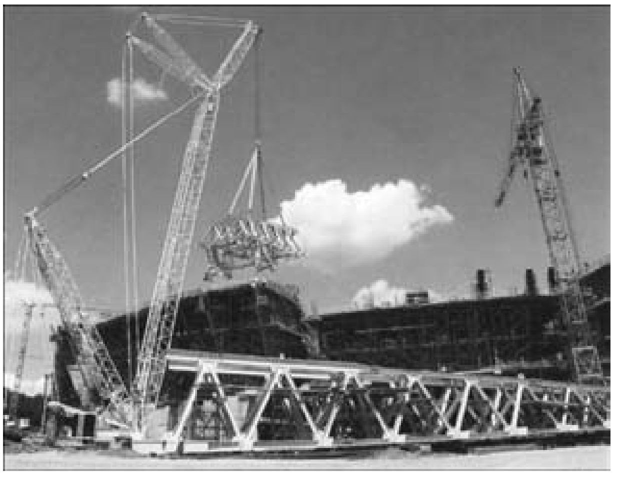

Figure 10. Handling of the roof girders in Donetsk

So, the concerned steel constructions are «Eurasia», the highest apartment and office building in Moscow, and the stadium «Shakhtar» in Donetsk. All projects include wall thicknesses of approximately 200 mm. The production facilities are located in Turkey. For the welding processes both the SAW and the GMAW procedures using flux-cored wires are applied. In addition to the qualitative advantages of the flux-cored wire technology, the economic aspect is also highlighted.

EFFICIENCY OF MELTING OF ELECTRODE WIRE IN SUBMERGED-ARC SURFACING WITH INFLUENCE OF TRANSVERSE MAGNETIC FIELD

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A device has been developed, which generates a transverse magnetic field (TMF), for the process of submerged-arc surfacing using wire. It is shown that in reverse polarity surfacing the impact of a constant and alternating TMF of 50 Hz frequency increases equally the coefficient of melting of electrode wire α_{melt} both of ferromagnetic and nonmagnetic materials. Maximum increase of wire α_{melt} is 20–30 % at the magnitude of transverse component of TMF induction of 30–45 mT.

Keywords: *submerged-arc surfacing, electrode wires, transverse magnetic field, induction, melting coefficient*

Technological peculiarities of arc welding and surfacing process using transverse magnetic field (TMF) are considered in the works [1–8]. It is followed from them that in consumable electrode argon arc welding [2, 3] using electrode wire of 1–1.2 mm diameter and TMF influence, the decrease of penetration depth and increase of weld width are observed. During welding and surfacing using wire of 3 and 4 mm diameter under the flux AN-348A at the impact of TMF of 50 Hz frequency, the penetration depth decreased in 1.5 times and width of a weld (bead) negligibly increased (efficiency of melting wires was not studied) [4]. For surfacing of beads using wire Sv-08GA of 2 mm diameter under the flux AN-348A, the change of frequency TMF in the limits of f = 0–20 Hz and induction of magnetic field B_x = 0–0.015 T (at reverse polarity) the data are given which are not quantitative but qualitative, i.e. only tendency of influence of frequency of induction of TMF on penetration depth of metal and width of a bead was established [5]. In the work [6] it was shown that in surfacing using wire Sv-08A of 4 and 5 mm diameter under the flux AN-348A on the plates of steel St3 under the impact of TMF of 50 Hz frequency, the depth of metal penetration decreased whereas width of a bead increased. It

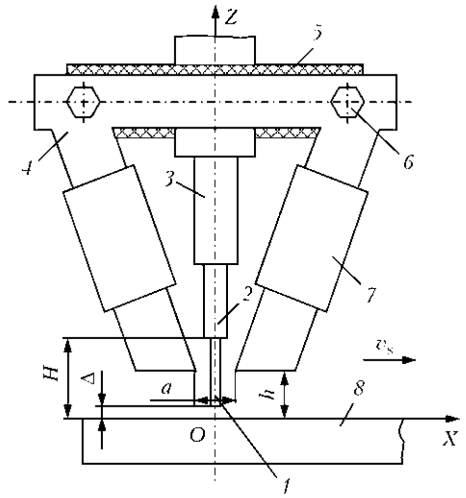

Figure 1. Scheme of the device for generating TMF (see designations in the text)

is also noted that during induction of TMF near the surface of a plate above 18–20 mT, the interruptions of an arc are observed, which did not allow applying higher values of induction. The impact of TMF on the coefficient of melting α_{melt} of 1.8–2 mm diameter wire in submerged-arc surfacing was studied only in the work [7]. It was established that influence of TMF results in negligible increase of α_{melt}, namely from 11.7 to 12.2 g/(A·h). In submerged-arc surfacing the electrode wires of 3–5 mm diameter are usually used, but there are no data about impact of TMF on α_{melt} of such electrodes. This problem required study because efficiency of the surfacing process is determined not only by the sizes of penetration zone of base metal, but also α_{melt} value of electrode.

The aim of this work was investigation of impact of TMF on the coefficient of melting α_{melt} of electrode wire of 3–5 mm diameter in submerged-arc surfacing.

To develop the controlling TMF, the device (Figure 1) was designed which represents a magnetic core *4* consisting of three sections: two inclined ones where coils *7* are located, and horizontal one connected with

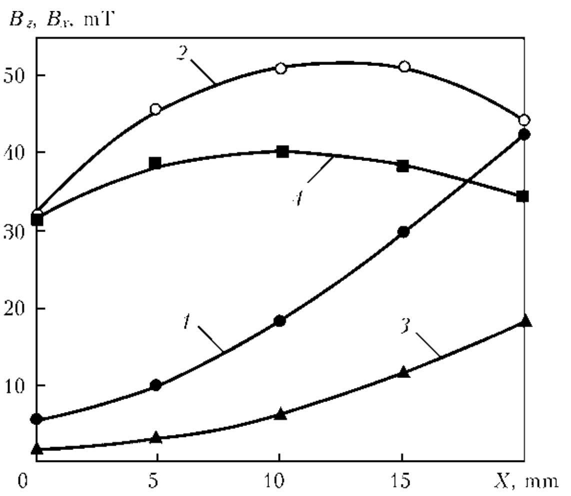

Figure 2. Distribution of components of induction B_z and B_x of TMF along the axis OX (Z = 0, Y = 0, I_{coil} = 60 A): *1*, *3* — B_z; *2*, *4* — B_x; *1*, *2* — constant TMF; *3*, *4* — alternating TMF of 50 Hz frequency

inclined sections using bolted joints *6*. The magnetic core is assembled of plates of electrotechnical steel of 0.5 mm thickness, the cross-section of an assembly is 30 × 20 mm. Two coils are manufactured of two-layer copper insulated wire of 2 mm diameter. The quantity of turns of one coil was 70. The device generating TMF was fixed to the welding machine ADS-1002 using yokes. The magnetic core *4* was isolated from the machine by the isolator *5*. The automatic machine allowed varying the electrode stickout H, i.e. distance between current conducting jaws *2* and plate *8*, and also distance h from the ends of magnetic core *4* to the surface of plate *8*. The design of device allowed changing the distance between lower sections of magnetic core near the electrode edge (parameter a). The electrode wire *1* passed through nozzle *3*. Figure 1 also uses the system of coordinates accepted for study of magnetic field (the beginning of coordinates was located at the surface of a plate under the axis of electrode).

In this work the constant or alternating TMF of 50 Hz working frequency was applied to control the electrode drops transfer, as far as such magnetic fields are the most simple to be realized in practice. To generate the mentioned magnetic fields in the coils of device the direct current from the welding rectifier VSZh-303 or alternate current from the welding transformer TM-402 was passed. In the zone of electrode drop and arc the measurements of induction components B_x and B_z were conducted using milliteslameter of the type EM-4305 with Hall sensor at measuring base 1 × 1 mm for the constant TMF and F-4356 type was used for alternating TMF. The measurements were carried out at Z = 0, Y = 0 in the points X = 0, 5, 10 and 20 mm. The distance from the edge of the electrode to the surface of the plate Δ were preserved constant (Δ = 5 mm). The electrode stickout was H = 25 mm (h = 25 mm), and the distance between the lower ends of magnetic core along the horizontal was a = 35 mm. In the investigations of the induction of the magnetic field, the wires Sv-08GA and Sv-12Kh18N10T of 4 mm diameter were used and in capacity of base metal the plates of the steel 09G2S and 12Kh18N10T were used.

Figure 2 shows distribution of components of induction of B_x and B_z of constant and alternating TMF of 50 Hz frequency using welding wire Sv-08GA (ferromagnetic) of 4 mm diameter and base metal — the plate of steel 12Kh18N10T (non-magnetic material) at the current in coils I_{coil} = 60 A. The distribution of B_z induction of constant and alternating TMF of 50 Hz frequency bears incremental character depending on distance from the axis OZ to the poles of the device along the axis OX. In the zone under the end of electrode the component of induction B_z (Figure 2, curves *1*, *3*) is much smaller than B_x (Figure 2, curves *2*, *4*). It was also established that components of induction B_z and B_x practically increase in a linear way (in all points along the axis OX) at increase of direct or alternate current of 50 Hz frequency in the coils of a device generating TMF.

The results of investigations about the influence of ferromagnetic properties of electrode wires and base metal on the components of induction B_x of constant and alternating TMF of 50 Hz frequency at the current in the coils I_{coil} = 60 A are presented in Figure 3. The obtained data show that using ferromagnetic wire and ferromagnetic plate of the component of the induction B_x in the zone under the end of the electrode is negligible, about 4 mT (Figure 3, *a*, curve *1*). Using ferromagnetic wire Sv-08GA and plates of non-magnetic steel 12Kh18N10T, the component of induction B_x in the zone under the end of electrode has a value of an order 30–40 mT. Using electrode wire and base metal of non-magnetic materials the level of induction B_x of constant TMF (Figure 3, *a*, curve *3*) is similar to the level, observed while using wire of ferromagnetic material Sv-08GA and base metal of non-magnetic steel 12Kh18N10T (Figure 3, *a*, curve *2*). We supposed that level of induction $B_x \approx$ 30–40 mT in the zone under the end of electrode is sufficient for control of transfer of electrode metal drops.

The similar ferromagnetic properties of base and electrode materials influence the level of induction of alternating TMF of 50 Hz frequency. The component of induction B_x using electrode wire and base metal of non-magnetic materials practically coincides with the level obtained using ferromagnetic wire Sv-08GA and non-magnetic base metal of the steel 12Kh18N10T (Figure 3, *b*, curves *2*, *3*) and is considerably higher than that using ferromagnetic base metal and wire (Figure 3, *b*, curve *1*), and this level of induction B_x (30–40 mT) is also sufficient to control the transfer of electrode drops in arc surfacing.

The influence of TMF on the coefficient of electrode metal melting α_{melt} in arc surfacing was defined according to the standard methods (by weighing method). The experimental surfacing procedures were performed using automatic machine ADS-1002 with the speed of electrode supply from the rectifier VDU-1202 independent of arc voltage (with falling external characteristics) at the reversed polarity on the plates of steel 12Kh18N10T. The wire Sv-08GA of 4 mm diameter and flux AN-348A, and flux AN-26P were used during surfacing using wire Sv-12Kh18N10T. The surfacing procedures were performed with and without impact of constant or alternating TMF of 50 Hz frequency. The recording parameters of surfacing mode (I_s, U_a) was performed using the devices of N390 type. In all experiments the parameters of the mode of surfacing without TMF were set preliminary according to the pointed indicators, and for d_e = 4 mm they were I_s = 480–520 A, U_a = 30–32 V, and v_s = 27 m/h. As far as during switching TMF the current of surfacing was decreased, the speed of electrode wire feed was increased to maintain arc voltage in the limits of U_a = = 30–32 V. The process of surfacing was not less than 30 s. Three surfacing operations were performed under each condition.

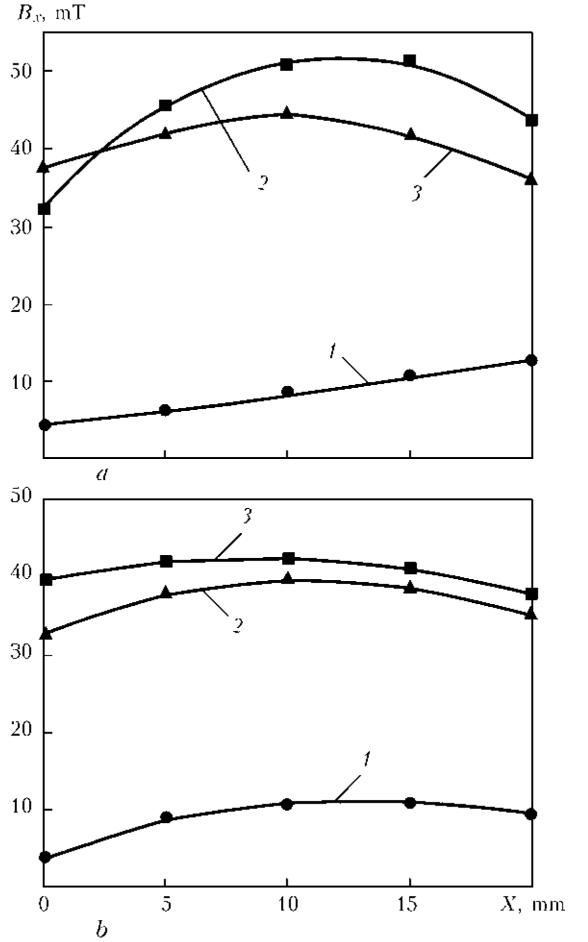

Figure 3. Distribution of induction B_x of constant (*a*) and alternating TMF of 50 Hz frequency (*b*) along the axis *OX* depending on ferromagnetic properties of welding wire of 4 mm diameter and base metal (Z = 0, Y = 0, I_{coil} = 60 A): *1*, *2* — wire Sv-08GA; *3* — Sv-12Kh18N10T; *1* — plate 09G2S; *2*, *3* — 12Kh18N10T

The data of investigations showed that during surfacing with the impact of both constant and alternating TMF of 50 Hz frequency and using ferromagnetic wire Sv-08GA at increase of induction B_x of TMF, the coefficient of its melting α_{melt} grows and at B_x = = 40–45 mT reaches maximal values (of about 17.5 g/(A·h)), while during surfacing without impact of TMF its values were 12.5–13.0 g/(A·h). Here α_{melt} of electrodes of ferromagnetic material (Sv-12Kh18N10T) grows at increase of induction of both constant and alternating TMF of 50 Hz frequency.

The increase of α_{melt} values of wires during surfacing with the impact of constant TMF is somewhat higher than during surfacing with the impact of alternating TMF of 50 Hz frequency (Figure 4, *a*). The maximal relative increase in α_{melt} ($\Delta\alpha_{melt}/\alpha_{melt}$) of wires of 4 and 5 mm diameters in surfacing with the impact of constant TMF is 27–30 % at the level of field induction B_x = 40–45 mT, and for the wires of 3 mm diameter it is 23–25 % at the level of induction B_x = 30–35 mT.

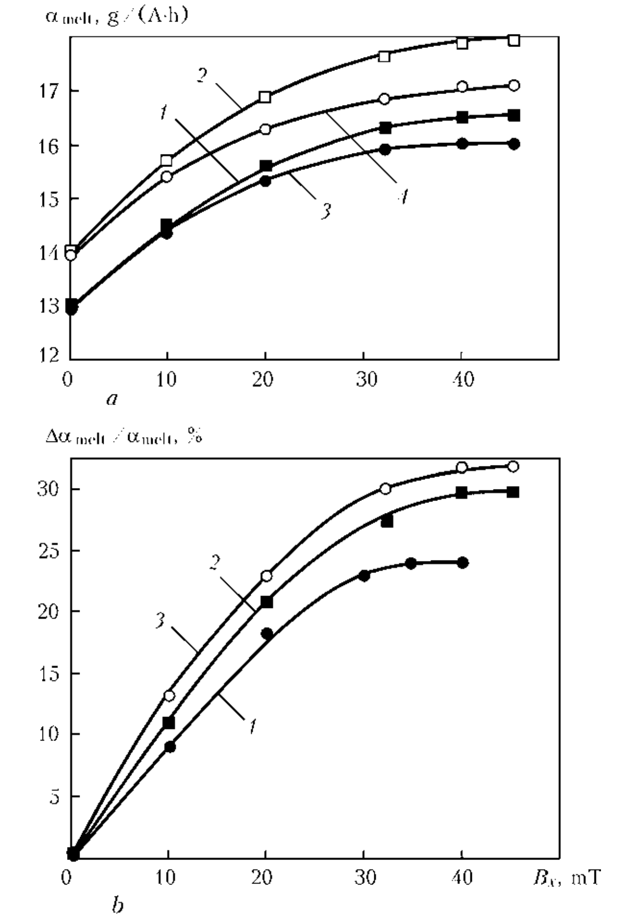

Figure 4. Influence of component of induction B_x of TMF on α_{melt} of electrode wires of 4 mm diameter (*a*) and increase in coefficient of melting of electrode wires $\Delta\alpha_{melt}/\alpha_{melt}$ (*b*): *a*: *1*, *3* — Sv-08GA; *2*, *4* — Sv-12Kh18N10T; *1*, *2* — constant TMF; *3*, *4* — alternating TMF of 50 Hz frequency; *b*: wire Sv-08GA, alternating TMF of 50 Hz frequency; *1* — d_e = 3 mm, I_s = 340–350 A; *2* — d_e = 4 mm, I_s = 460–480 A; *3* — d_e = 5 mm, I_s = 700–720 A

For the alternating TMF of 50 Hz frequency the relative increase in α_{melt} is accordingly 30, 25 and 20 % for the electrode diameters 5, 4 and 3 mm (Figure 4, *b*).

As is known [8, 9] the maximal increase in α_{melt} of a wire of 4 and 5 mm diameter in submerged-arc surfacing with the impact of longitudinal magnetic field (LMF) reaches 30 % (at reversed polarity of the process). Therefore, in submerged-arc surfacing at reversed polarity applying the impact of TMF the level of α_{melt} of wires grows practically to the same extent as in surfacing with the impact of LMF. It should be noted that during submerged-arc surfacing the impact of LMF does not increase the α_{melt} value of wires of non-magnetic materials [9], while the impact of TMF increases the α_{melt} value of wires both of ferromagnetic and non-magnetic materials.

The increase of α_{melt} of wires in surfacing in LMF occurs as a result of destroying (removal from the electrode end) of rotating drops [10]. At the impact of the constant TMF the drops are removed from the electrode end (in a horizontal plane along the axis *OY*) under the action of electromagnetic force, formed by interaction of surfacing current (direction along the axis *OZ*) with the component of induction B_x of TMF directed along the axis *OX*. During surfacing at TMF of 50 Hz frequency the direction of electromagnetic force is changed influencing the electrode drop (by 180° along the axis *OY*). The efficiency of impact of electromagnetic force on the removal of electrode drops from the electrode end during surfacing with alternating TMF of 50 Hz frequency is probably less than during surfacing at constant TMF. This fact in our opinion stipulates the less effective increase of α_{melt} of electrodes during surfacing with the impact of constant TMF.

The process of arc surfacing at the reversed polarity using wire under flux with the impact of TMF allows reducing consumption of electric power for surfacing by 20–30 %, i.e. it is a power saving process.

CONCLUSIONS

1. In submerged-arc surfacing the increase of induction of both constant and alternating TMF of 50 Hz frequency in the zone under the electrode end results in growth of a coefficient of melting of wires of ferromagnetic and non-magnetic materials.

2. Maximal relative increase in α_{melt} of wires of 4 and 5 mm diameters during surfacing by impact of constant TMF is 27–30 % at the level of induction of field B_x = 40–45 mT, and for the wires of 3 mm diameter it is 23–25 % at B_x = 30–35 mT. For alternating TMF of 50 Hz frequency the relative increase in α_{melt} is 30, 25 and 20 %, respectively, for diameters 5, 4 and 3 mm.

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