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INFLUENCE OF SURFACING MODES USING FLUX-CORED STRIPS ON CHEMICAL COMPOSITION AND HARDNESS OF DEPOSITED METAL

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The influence of surfacing modes with an open arc using flux-cored strips of different types on chemical composition and hardness of the deposited metal was studied. PL-AN 101 and PL-AN 179 flux-cored strips manufactured on the base of steel strip-sheath, as well as PL-AN 111 strip on the base of nickel sheath were selected as the objects of investigations. Surfacing was performed in A-874N machine with VDU-1201 power source and AD-167 attachment in a wide range of modes. The dependencies of the change of chemical composition of the deposited metal on the value of current, voltage and deposition rate were established. At the same time, change of current values in the range of 600–1100 A has little effect on chemical composition of metal deposited with PL-AN 101 and PL-AN 111 strips, and in surfacing with PL-AN 179 strip it results in increase of the content of almost all alloying elements. Increase of voltage and deposition rate leads to decrease of the degree of alloying for all the types of flux-cored strips and to decrease of deposited metal hardness, and increase of current leads to its growth. 8 Ref., 1 Table, 4 Figures.

Keywords: *flux-cored strip, surfacing modes, chemical composition, hardness*

When obtaining data characterizing the influence of the modes of open-arc surfacing with flux-cored strip on geometrical dimensions of the deposited beads published in [1], the influence of surfacing modes on chemical composition and hardness of the deposited metal was studied in parallel. Investigation of these parameters is an important task, as change of surfacing modes essentially influences the processes of alloying element transition into the weld pool that, in its turn, affects the hardness values and deposited layer performance. This data is required for calculation of flux-cored strips at prediction of the deposited metal compositions.

Known are works [2, 3], in which deposited metal composition was considered in interrelation with transition of alloying components in submerged-arc surfacing, depending on current, voltage and deposition rate. It was shown [4, 5] that in a number of cases an increase of carbon content is observed at increase of welding current, while manganese and silicon content in the deposited metal decreases.

The authors of works [6, 7] note that in flux-cored strip surfacing situations are possible when part of the powder filler passes into the weld pool, bypassing the drop stage. However, as shown by additional studies [6, 8], this is characteristic not for all the flux-cored strip designs. So, one-lock design of flux-cored strip with a tight lock allowed practically totally eliminating spillage of filler powder into the weld pool. Therefore, the industry has now switched to application of mainly this type of flux-cored strips.

Three grades of flux-cored strips were selected for investigations: PL-Np-300Kh25S3N2G2 (PL-AN 101), PL-Np-500Kh40N40S2RTs (PL-AN 111) and PL-Np-400Kh20B7M6V2F (PL-AN 179) of one-lock design of type B to GOST 26467-85 of 16.5×3.8 mm cross-section. Such selection of consumables allowed studying a rather wide range of deposited metal compositions, as PL-AN 101 and PL-AN 179 flux-cored strips are manufactured on the base of steel strip-sheath, and PL-AN 111 strip on the base of nickel strip. Experiments were performed in surfacing machine A-874N, fitted with VDU-1201 power source and AD-167 attachment. Surfacing was performed by separate beads in one layer at reverse polarity direct current (RPDC) at unchanged extension of 50 mm, and rigid external characteristic of the power source. Plates of St3 steel 30 mm thick of 300×400 mm size were used as base metal. Six beads of 200–250 mm length each were deposited on each of the plates. To eliminate the influence of preheating each subsequent bead was deposited after complete cooling of the previous one. Anode-mechanical cutting was used to cut out samples from bead middle portions, which after grinding were used to determine the composition and hardness of the deposited metal. Modes of surfacing with all the mentioned strips are given in the Table.

Surfacing modes

I, A	*U*, V	*v*, m/h
600 ± 25	32 ± I	32 ± 1
750 ± 25	32 ± I	32 ± 1
900 ± 25	32 ± I	32 ± 1
1150 ± 25	32 ± I	32 ± 1
1200 ± 25	32 ± I	32 ± 1
900 ± 25	24 ± I	32 ± 1
900 ± 25	28 ± I	32 ± 1
900 ± 25	36 ± I	32 ± 11
900 ± 25	40 ± I	32 ± 1
900 ± 25	32 ± I	19 ± 1
900 ± 25	32 ± I	40 ± 1
900 ± 25	32 ± I	48 ± 1
900 ± 25	32 ± I	55 ± 1

Chemical composition of the deposited layer was assessed by the spectral method, and deposited metal hardness was determined to GOST 9013–59 as arithmetic mean from not less than 20 measurements. Obtained results are given in the graphic form.

Figure 1 gives the data on chemical composition of the bead deposited with PL-AN 101 flux-cored strip, depending on current, voltage and deposition rate, respectively. At current increase from 600 up to 1200 A, deposited metal composition changes only slightly (Figure 1, *a*). At voltage rise from 24 to 38 V, a noticeable lowering of carbon and chromium content is observed. Silicon content in the deposited layer also decreases. Manganese and nickel content practically does not change here (Figure 1, *b*). Noted lowering of carbon and chromium content is, obviously, related to increase of the fraction of base metal in the deposited metal and greater loss of these elements at the drop stage and in the weld pool, as a result of increase of arc length.

At increase of deposition rate, the content of all the elements in the deposited layer decreases that is, obviously, related to greater spattering losses (Figure 1, *c*).

Figure 2 gives the composition of metal deposited with PL-AN 111 strip, depending on surfacing pa-

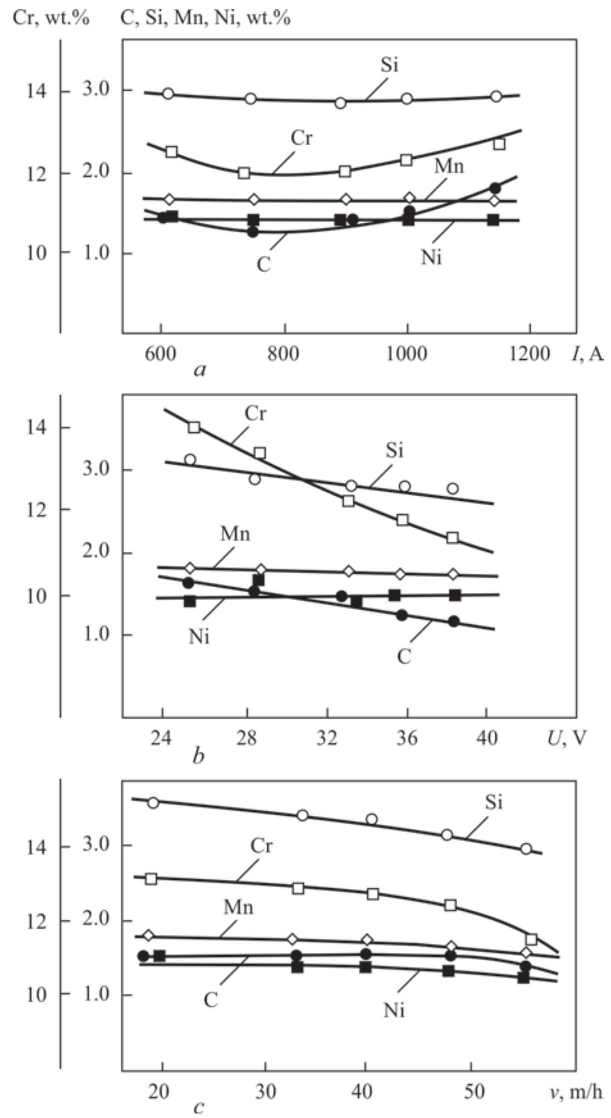

Figure 1. Chemical composition of metal deposited with PL-AN 101 flux-cored strip, depending on surfacing current (*a*), voltage (*b*) and rate (*c*)

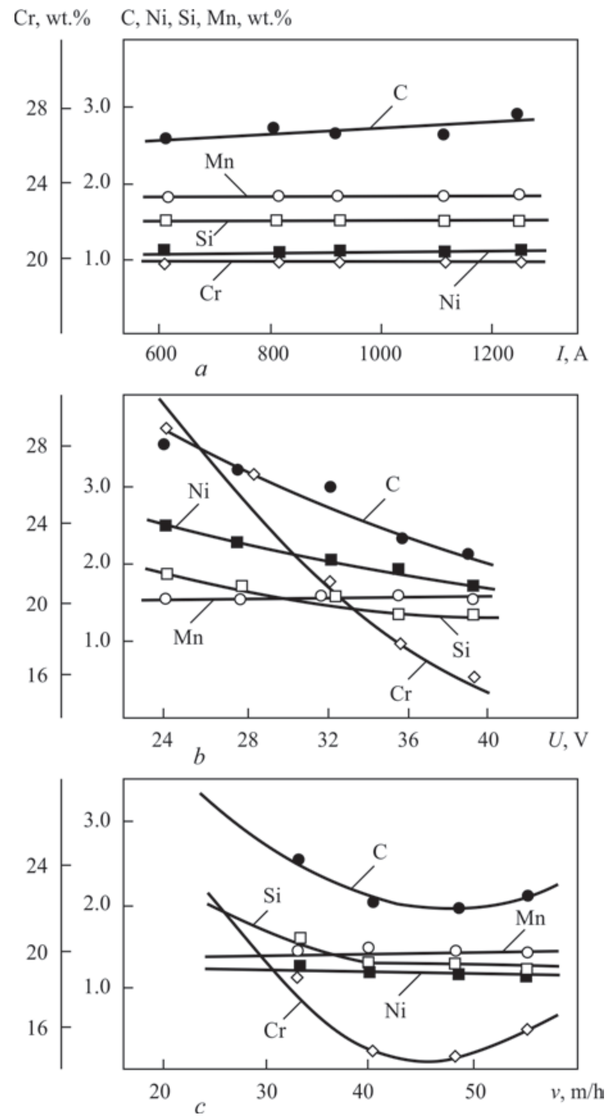

Figure 2. Composition of metal, deposited with PL-AN 111 flux-cored strip, depending on surfacing current (*a*), voltage (*b*) and rate (*c*)

rameters. Change of current in the range from 600 to 1200 A also practically does not influence the composition (Figure 2, *a*). Voltage rise from 24 to 38 V leads, mainly, to lowering of carbon and chromium content that is related to increase of base metal fraction in the deposited metal and alloying element loss (Figure 2, *b*). Minimum carbon and chromium content in the deposited metal corresponds to deposition rate of 40–50 m/h (Figure 2, *c*).

Figure 3 gives chemical composition of metal deposited with PL-AN 179 flux-cored strip, depending on surfacing parameters. Increase of welding current values in the range from 600 up to 1200 A leads to increase of all the alloying elements content in the deposited metal, except for manganese, the content of which somewhat decreases (Figure 3, *a*). Voltage increase leads to lowering of the degree of alloying with carbon, chromium, molybdenum and niobium in the entire considered range from 24 up to 38 V. Manganese and silicon content remains practically unchanged (Figure 3, *b*). Increase of the rate from 19 to 55 m/h leads to lowering of the content of practically all the alloying elements in the deposited layer (Figure 3, *c*).

Figure 4 gives the dependencies of the deposited layer hardness on deposition rate, arc voltage and welding current. One can see from the presented graphs that increase of deposition rate (Figure 4, *c*) and voltage (Figure 4, *b*) lead to lowering of deposited layer hardness, and current increase (Figure 4, *a*) leads to its slight increase.

Considering the obtained results as a whole, the following should be noted. In addition to surfacing modes, the composition of powder-filler and material of sheath-strip have a significant influence on the characteristics of flux-cored strip melting, and, therefore, chemical composition and hardness of the deposited metal. So, in surfacing with PL-AN 111 flux-cored

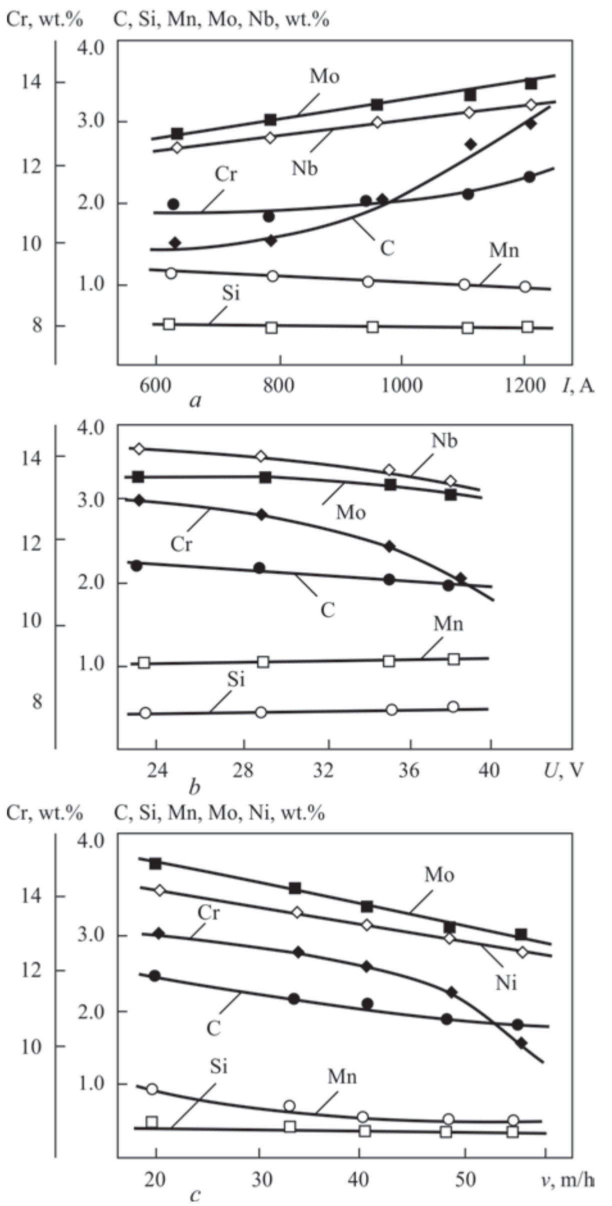

Figure 3. Composition of metal deposited with PL-AN 179 flux-cored strip, depending on surfacing current (*b*) and rate

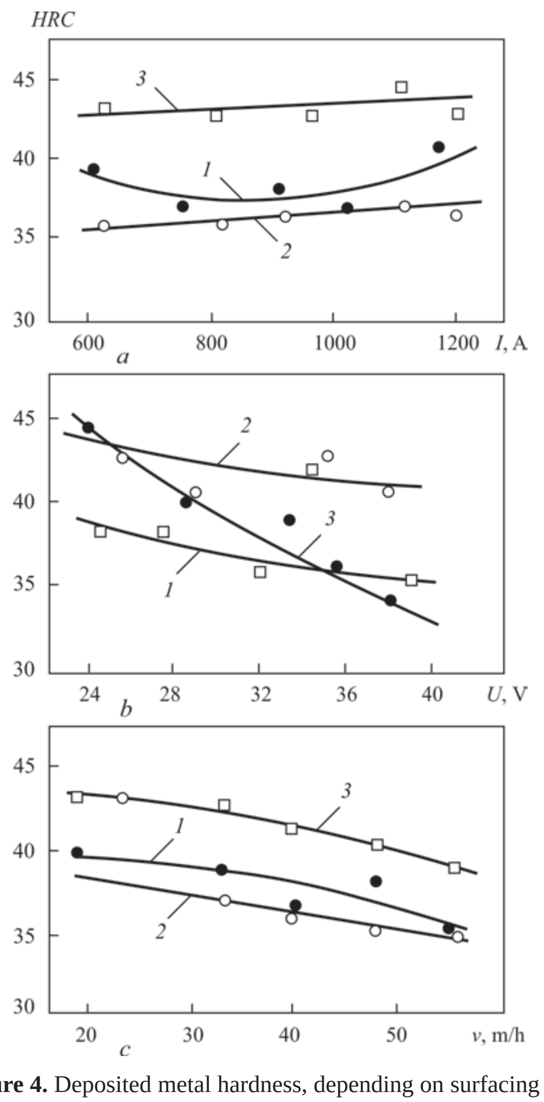

Figure 4. Deposited metal hardness, depending on surfacing current (*a*), voltage (*b*) and rate (*c*) (*1* — PL-AN 101; *2* — PL-AN 111; *3* — PL-AN 179)

strip, manufactured on the base of nickel strip-sheath, all the studied characteristics differ considerably from the data obtained in surfacing with PL-AN 101 and PL-AN 179 flux-cored strips, manufactured from steel strip-sheath. In our opinion, this is related to lower, by approximately 1.5 times, ohmic resistance of nickel, compared to low-alloyed steel.

In surfacing with PL-AN 101 flux-cored strip, current rise leads to a slight change of the deposited metal composition, and voltage rise — to a significant reduction of the content of chromium, carbon, and silicon at stable values of the content of manganese and nickel. Voltage increase usually leads to larger arc gap that causes greater loss of the main alloying components at the drop stage.

Current increase in surfacing with PL-AN 179 flux-cored strip leads to increase of the content of all alloying elements and carbon at a stable content of manganese and silicon. Voltage increase only slightly influences the alloying element content, but markedly lowers carbon content. In this case, we observed a similar, but less pronounced effect, as in the previous case.

In surfacing with PL-AN 111 flux-cored strip, change of current values only slightly influences the deposited metal composition, and increase of voltage values leads to a considerable lowering of the content of chromium, carbon and nickel at stable values of silicon and manganese that is also related to increase of alloying element losses at the drop stage.

Increase of deposition rate does not influence the content of silicon and manganese for all the types of flux-cored strips. Here, lowering of alloying for PL-AN 179 strip and to a smaller degree for PL-AN 101 strip is observed. For metal deposited with PL-AN 111 strip, increase of the rate leads to reduction of carbon and chromium, that is the consequence of increase of base metal fraction in the deposited layer.

Some inconsistency of the results of the influence of surfacing mode parameters on chemical composition of the deposited metal, produced with application of PL-AN 101 and PL-AN 179 flux-cored strips in our opinion is also attributable to considerable differences between the compositions of powder filler of the above strips. The base of the charge of PL-AN 101 strip is complex-alloyed master alloy, characterized by a lower melting temperature, than that of PL-AN 179 strip, consisting of refractory element components, such as tungsten, niobium, vanadium, and molybdenum.

Hardness of metal deposited with the studied flux-cored strips, correlates well with its chemical composition.

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