



EFFECT OF ADDITIONS OF ALUMINIUM TO FLUX-CORED WIRE ON PROPERTIES OF HIGH-CARBON DEPOSITED METAL

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Crack resistance and porosity of low carbon alloys in hardfacing using self-shielding flux-cored wire was investigated. It was established that alloying the deposited metal with over 0.7 wt.% aluminium leads to increase in its martensite phase content and decrease in its crack resistance. It was shown that maximal hardness of the deposited metal at an insignificant decrease in its crack resistance could be achieved at the 0.5–0.7 wt.% aluminium content.

Keywords: *hardfacing, self-shielding flux-cored wire, deposited metal, aluminium, crack resistance, microstructure, hardness, microhardness*

The E.O. Paton Electric Welding Institute of the NAS of Ukraine developed self-shielding flux-cored wire PP-AN160 intended for wide-layer hardfacing of cast iron crankshafts of automobile engines*. Because of technological peculiarities of wide-layer hardfacing of crankshaft necks and a small diameter of flux-cored wire (1.8 mm), its core cannot contain more than 1.5 % of gas- and slag-forming components. However, this amount is insufficient for reliable shielding of the electrode metal drops and molten weld pool from air oxygen and nitrogen, which in turn leads to formation of porosity in the deposited metal. The main metallurgical method for prevention of porosity caused by air oxygen and nitrogen is adding the required amount of aluminium and/or titanium to the composition of the deposited metal in order to combine gases dissolved in the weld pool into insoluble compounds. An insufficient or excessive content of these elements may either incompletely suppress pore formation or partially participate in alloying and changing of physical-mechanical properties of the deposited metal.

The purpose of the present study was to investigate the effect of aluminium on porosity and properties of a wear-resistant alloy deposited by using self-shielding flux-cored wire PP-AN160.

Experimental self-shielding flux-cored wires with a diameter of 1.8 mm and different weight contents of aluminium in their core were manufactured for investigations. Multilayer hardfacing was performed under the following conditions: $I_h = 170\text{--}180$ A, $U_a = 19\text{--}21$ V, $v_h = 14$ m/h, direct current of reverse polarity. Each next bead was deposited after complete cooling of the previous one. Chemical composition of

the deposited metal (in the third layer) in the investigated specimens was as follows, wt.%: 2.2–2.4 C, 0.7–0.8 Mn, 1.6–1.8 Si, 0.2–0.3 Cr, 0.2–0.3 Ti, 0.035, 0.54, 0.82, 1.50 and 2.20 Al.

As shown by the experiments, independently of the content of aluminium (within the investigated limits) the beads had microcracks formed with a substantial sound effect during cooling of the deposited metal within the 450–250 °C temperature range, which allows them to be classified as cold cracks.

It was found in the course of metallurgical examinations that aluminium exerts a considerable effect on the quantity and morphology of microcracks in the deposited metal, as well as on its porosity. For instance, isolated microcracks and a large quantity of pores up to 2 mm in diameter were detected in the hardfaced specimens containing 0.035 wt.% Al (according to the data of chemical analysis, in the case of the absence of aluminium in the flux-cored wire core). The quantity of microcracks insignificantly grew, and that of pores decreased with increase of the weight content of aluminium to 0.54 %. Further increase of the aluminium content led to growth of length and opening displacement degree of the microcracks, whereas the microcracks affecting both deposited metal and fusion zone metal appeared in the deposited metal containing 2.20 wt.% Al (Figure 1). There were no pores in the specimens of the deposited metal containing over 0.54 wt.% Al.

Structure of the deposited metal containing no aluminium consisted of austenite decomposition products (ferrite-pearlite mixture) and a carbide-cementite phase. The latter had the form of a reinforcing net in section plane.

As established as a result of metallurgical examinations, alloying with aluminium within the investigated ranges does not have a substantial effect on the degree of dispersion of the solid-solution dendritic structure, but changes the spatial structure of the carbide-cementite phase. At 0.035 wt.% Al, it is formed not in all regions of the inter-arm spacing of dendrites. Therefore, it has the form (in section plane) of a bro-

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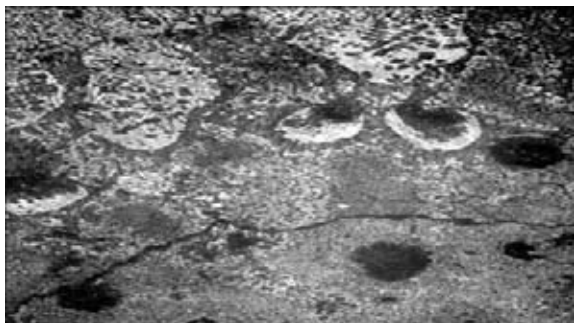


Figure 1. Microcrack in fusion zone of deposited metal containing 2.2 wt.% Al ($\times 160$)

ken net. Its branching grows with increase of the aluminium content.

Phase composition of the deposited metal also undergoes changes. Increase of the aluminium content to 0.50 wt.% leads to formation of approximately 3 % of martensite in structure of the deposited metal. Increase of the aluminium content to 2.20 % causes growth of the martensite content in structure of the deposited metal to 18 %. It is likely that formation of martensite is one of the causes of lowering of the level of crack resistance of the deposited metal at a weight content of aluminium above 0.50 %.

In addition to structural transformations, alloying with aluminium is also accompanied by a change in hardness of the deposited metal and its main phase components (austenite decomposition products and carbide-cementite net). As seen from Figure 2, the curves have maxima at a weight content of aluminium in the deposited metal equal to 0.7–0.9 %. Increase in hardness HV of the deposited metal and microhardness HV_a of solid-solution grains with increase of the aluminium content to the indicated level is caused by growing dispersion of the carbide-cementite phase and, probably, by participation of aluminium in strengthening of solid-solution ferrite (austenite de-

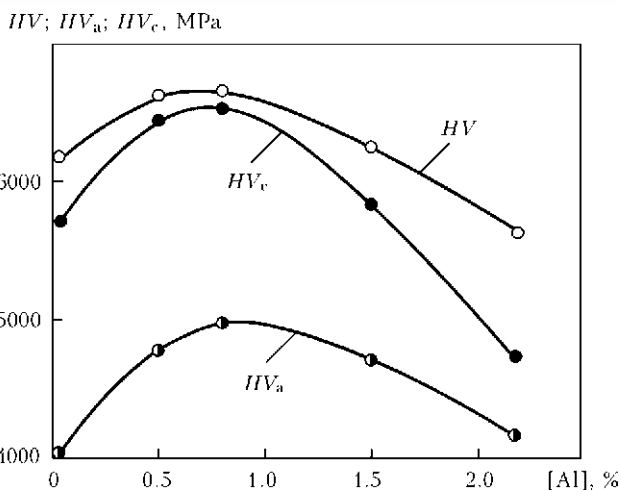


Figure 2. Effect of aluminium on hardness HV of deposited metal, microhardness HV_a of solid-solution grains and microhardness HV_c of carbide-cementite phase

composition products). The graphitising effect of aluminium shows up with further increase in its weight content. This results in decrease of the cementite content, thus leading to decrease in hardness HV of the deposited metal and microhardness HV_a of solid-solution grains. Despite the fact that alloying with aluminium is accompanied by formation of martensite which has a relatively low hardness (4600–4900 MPa), it cannot act as obstacle to further decrease in HV . The cause of decrease in microhardness HV_c of the carbide-cementite phase is likely to be related to a change in stoichiometric composition of carbide components of the deposited metal caused by alloying with aluminium.

It can be concluded on the basis of the investigations conducted that the maximal hardness, absence of porosity and satisfactory microcrack resistance are characteristic of the deposited metal containing about 0.5–0.7 wt.% Al.