PHYSICAL-METALLURGICAL AND WELDING-TECHNOLOGICAL PROPERTIES OF GAS-SHIELDED FLUX-CORED WIRES FOR WELDING OF STRUCTURAL STEELS

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Peculiarities of process of gas-shielded arc welding using flux-cored wire are considered. Given are the data on metallurgical characteristics and classification of the gas-shielded flux-cored wires with different core types as well as examples of their successful application in industry. 6 Ref., 1 Table, 2 Figures.

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Long-term application of solid flux-cored wires in mechanized and automatic gas-shielded welding was mainly caused by their availability and small price. Eventually, understanding of technological and economic advantages of application of the flux-cored wires was verified by the results of analysis of expenses for welding performance and quality of welded joints. This allows the flux-cored wire taking the leading position in performance of welding operations in different branches of industry and building in countries with high level of economic development [1]. Gas-arc welding using the flux-cored wire allows responsing the demands of manufacturers of welding structures, since it differs by versatile, good operation characteristics and high efficiency, that provides for significant reduction of economic expenses.

Today a variety of types of the flux-cored wires are classified on international standards ISO in accordance with class of steel, for which they are designed. Standard ISO 17632 [2] is used for the most widespread classes of normal strength structural steels, and ISO 18276 [3] is applied for high strength ones. Shielding gases for performance of gas-arc welding are classified on standard ISO 14175 [4]. The classification in accordance with indicated standards is further used.

The specialists in area of fusion arc welding know well that change of solid wire to flux-cored one does not require variation of basic technology or application of another equipment. Current welding equipment provide for a wide range of regulation of statistical and dynamic characteristics of power sources with the help of microprocessor technology, that allows setting of the optimum welding parameters for each wire type. Feed mechanisms of the semi-automatic machines are as a rule equipped with two pairs of rolls for reduction of wire pressure, prevention of its deformation or break of geometry, that deteriorate wire feeding through the hoses.

Metallurgical characteristics of gas-shielded flux-cored wires. Established classification of the flux-cored wires on type of flux core, which is included into international standards, divide them on three main types, namely rutile, basic and metallic.

Rutile type (on title of mineral — rutile) includes the wires with basis of a slag system composed of titanium oxides in combination with other oxides (for example, silicates and alumosilicates), formed in melting of low-basicity slags. Change of composition and application of fluxing agents reveal wide capabilities for regulation of technological properties of these wires. They are divided on rutile ones with slowly setting and rapidly setting slag according to the welding technological properties, that determines a possibility of their application for welding of joints in different spatial positions.

Among the basic type are the wires with slag basis core. They include the systems of carbonate-fluoride-oxide type with high portion of oxides of alkaline-earth metals. This due to high basicity of forming slag melt allows providing high refining capability of the slag and reducing level of oxidation of the molten metal. Possibilities of regulation of technological properties of these wires are narrower in comparison with rutile ones due to more globular metal transfer, that, however, can be compensated by application of pulse process of welding.

Wires with metallic core are the wires containing powders of iron, ferroalloys and other metallic powders with insignificant additives of mineral substances, rising arcing stability and improving welding technological properties of the wire. Quantity of the mineral additives makes generally from 0.5 to 1.5 % of wire weight. Welding-technological properties of the flux-cored wires with metallic core are close to the properties of solid ones, but they provide for higher arcing stability and efficiency of melting, insignificant loss of electrode metal and favorable weld formation.

Effect of metallurgical characteristics of the flux-cored wires of indicated types can be evaluated on generalized data of typical content of gases and non-metallic inclusions in the weld metal. The Table shows the data on content of gases and non-metallic inclusions in the weld metal, produced by flux-cored wires with different type of core in Ar + 18 vol.% CO_2 mixture (M21 on ISO 14175 [4]).

Peculiarity of the seamless flux-cored wires is low content of diffusible hydrogen in the deposited metal due to their heat treatment in process of manufacture and tightness of the structure. Content of oxygen in the weld metal depends on composition of non-metallic part of the core (slag system type) and refining properties of the slag. The complex systems of microalloying and melt treatment, allowing reducing metal pollution with the non-metallic inclusions, are used in recent time for reduction of the level of oxygen content and oxide inclusions in the wires with metallic core, where slag volume is insignificant.

Assortment of the flux-cored wires for CO_2 welding or welding in Ar + CO_2 mixture includes the wires for welding of structural steel having yield strength of 360–500 [2] and 550–890 MPa [3]. The manufacturers produce the flux-cored wires of 1–2 mm diameter, that allows welding of structures from metal of 2–50 mm thickness and more depending on class of steel being welded.

Peculiarities of gas-arc welding using flux-cored wire. There are three main types of electrode metal transfer in the weld pool during gas-arc welding, namely, short-circuit, drop and spray. Mode of the metal transfer can have mixed nature in some ranges of parameters. Using of current pulse power supplies with programmable control significantly expands the possibilities of regulation of electrode metal transfer, in particular, pulse-spray transfer with controlled surface tension of molten metal. The main methods of control of characteristics of regulated transfer are based on a force balance, determining droplet detachment from electrode wire [5].

Surface tension of the molten metal (pinch effect caused by effect of electromagnetic forces at the end part of electrode) has the main role in transition from drop form to spray one. Composition of the shielding gas has also significant effect. Application of gas mixtures (two- or three-component) allows optimizing chemical activity, ionization potential and thermal conductivity of gas-shielded media [6]. Replacement of carbon dioxide by argon-based mixtures significantly improves the characteristics of metal transfer, i.e. reduce drop size, thus promoting transition from drop to spray-drop transfer. Fundamentally, the spray transfer is also drop, but in form of very fine drops. It is possible to regulate the transfer by means of changing of mode parameters (welding current, wire stickout and arc voltage) for the wires of specific diameters considering received technological characteristics of the welded joint. Change of the core composition allows regulating the arcing characteristics, in particular, the indices of welding process stability using elements and compounds with small ionizing potential and low values of electron work function in the core composition. This results in increase of concentration of positive ions in arc periphery area. In turn, presence of slag melt on the surface of electrode metal provides for the possibility of surface tension control.

Generalized results of analysis of content of gases and non-metallic inclusions in metal deposited with flux-cored wires of different type in shielding gas M21 [4]

Flux-cored wire	[N], wt.%	[O], wt.%	$[H]_{dif}$, $cm^3/100$ g	NMI, vol.%*
Rutile type	0.005–0.008	0.057–0.065	6–15	0.38–0.48
Basic type	0.009–0.011	0.035–0.045	3–5	0.31–0.34
With metallic core	0.004–0.010	0.078–0.083	5–10	0.53–0.61
Seamless	0.009–0.010	0.045–0.057	4–5	0.33–0.44

*On data of metallographic investigations of microsections without etching.

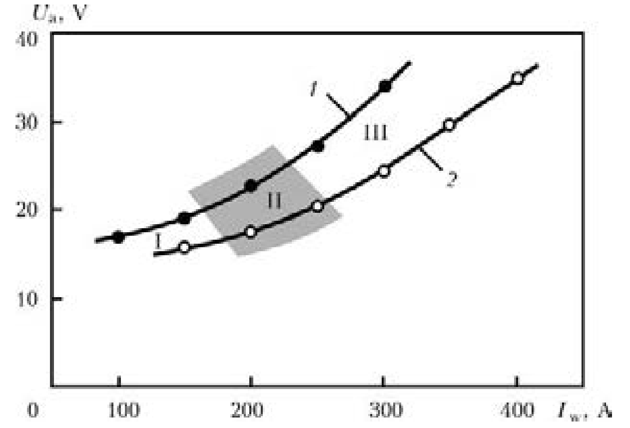

Figure 1. Range of parameters of welding in mixture of gases M21 [4] using flux-cored wires with metallic core type of 1.2 (*1*) and 1.6 (*2*) mm diameter: I — area of drop transfer; II — mixed; III — spray transfer; shaded — area of transition of drop to spray transfer

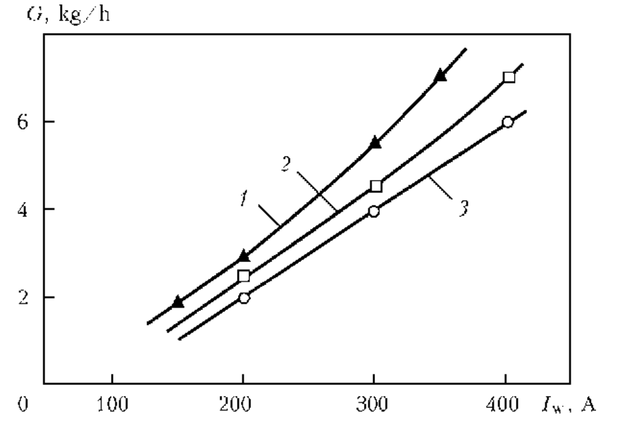

Figure 2. Efficiency of deposition in CO_2 using flux-cored wire of 1.2 mm diameter with metallic core (*1*), rutile (*2*) and solid (*3*) ones in range of applied welding currents

Figure 1 shows an example of dependence of type of metal transfer on diameter of flux-cored wire and mode parameters. Figure 2 illustrates efficiency of deposition using flux-cored wires with different core types in comparison with solid wire in the range of applied currents. Regular nature of melting and transfer of metal provides for high stability of welding parameters in the process of production of welded joints, that is in particular important in automatic and robotic welding.

Technical-economic aspects of application. Gas-shielded flux-cored wire welding has high potential in significant rise of efficiency and quick adjustment to performance of various welded joints of different designation structural steels due to application of more concentrated energy, high current density and possibility of regulation of indices of metal melting and transfer. The current flux-cored wires are successfully used in semi-automatic, automatic and robotic welding of the structures of wide assortment using serial sets of equipment. They have virtually no difference from solid wires on feed indices, safety of electric contact and arc regulation. A single difference is a recommendation to use rollers with female profile in feed mechanisms, in particular, during welding using wires of more than 1.6 mm diameter in order to prevent wire surface deformation and increased wear of contact tips. A procedure of production of welds using flux-cored wire is the same as in using of solid wire, but the welds in flux-cored wire welding have smoother shape of penetration and their geometry is less dependent on welding parameters. It is also necessary to consider that the flux-cored wire provides for higher rate of performance of weld of specified size at smaller energy consumption, minimum spattering independent on form of electrode metal transfer and lager stability of welding parameters. Obviously that indicated advantages of the flux-cored wire compensate increase of expenses on welding consumables.

Reduction of heat input in the base metal during gas-shielded flux-cored wire welding makes its more optimum for joining of steels sensitive to overheating. This is in particular important for the joints of increased and high-strength steels, overheating of HAZ in which is inacceptable. Control of rate of energy input allows solving this problem. If high rate of welding is necessary, then application of automatic or robotic units is recommended. The flux-cored wires with metallic core have the largest efficiency of melting. At that, several passes can be made without removal of slag traces and bevel angle of butt joints can be significantly reduced up to 40° and less.

Large variety of types of the welded joints, size and shapes of metal structures does not allow selecting recommended type of flux-cored wire without reference to specific object. Task of the enterprises, dealing with metal structure manufacture, is to find the optimum solution providing necessary level of welding quality and efficiency. Application of the gas-shielded flux-cored wire welding is one of the ways for solving the tasks of rise of production efficiency, and experience of its application verifies the possibility of improvement of quality of welded structures in many branches of industry and building.

Manufacture of the structures of heavy transport equipment, mining machines, road-building equipment and lifting devices is one of the first areas of successful application of the flux-cored wire with basic type core. Application of robotic welding using flux-cored wire with metallic core expanded in recent years. Welding by flux-cored wires with rutile type core has found wide usage in manufacture of building metal structures, and then in shipbuilding due to high welding-technological indices. Application of semi-automatic process was specifically successful in manufacture of ship panels, where necessity of welding in different spatial positions is combined with requirements to weld shape, penetration and spattering. Similar tasks are now solving in construction of drilling platforms due to application of the gas-shielded flux-cored wires of all types depending on class of steel to be welded, thickness of metal and spatial positions of the welds. Usage of the gas-shielded flux-cored wire is mastered in recent time during production of power installations and construction of main pipelines, where steels of increased and high strength in combination with high indices of ductility and toughness are used. The tendency is also outlined in using of the flux-cored wires in vertical automatic welding of large thickness metal with forced weld formation.

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