

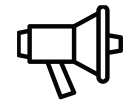
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TECHNOLOGICAL STRENGTH AND PROPERTIES OF METAL OF AUSTENITIC JOINTS DURING WELDING WITH VARIOUS FLUXES

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Abstract: The study examines the effect of different welding fluxes on the technological strength, phase composition, and corrosion resistance of weld metal in automatic welding of steels 0X18H10T, 0X18H12TΦ, and 0X20H12AБΦ up to 120 mm thick. It was established that increased slag acidity and oxidizing ability promote oxidation of alloying elements and reduce δ-ferrite content, decreasing resistance to hot cracking. The most stable results were achieved with flux 48-OΦ-6. Its application ensures optimal phase balance and high corrosion resistance of welded joints. The findings can be used in selecting welding consumables for critical structures operating in aggressive environments.

Key words: austenitic steels; welding fluxes; technological strength; δ-ferrite; hot cracking; intergranular corrosion; submerged arc welding; weld metal phase composition; slag basicity.

INTRODUCTION

When welding austenitic steels, the main conditions determining the choice of welding materials are ensuring technological strength, corrosion resistance and heat resistance of the joints. For automatic welding of austenitic steels, various fluxes are recommended [1-4]: oxygen-free fluoride (AHΦ-5, AHΦ-6), non-oxidizing fluoride (48-OΦ-6, 48-OΦ-10), low-silicon (AH-22, AH-26), oxidizing (AH-18), etc. The required technological strength of the joints is achieved by selecting a wire that ensures the production of a two-phase weld metal or a single-phase weld metal with an increased content of molybdenum or manganese.

The aim of the work is to establish the influence of the type and oxidizing ability of welding fluxes on the chemical composition, phase balance (δ-ferrite content), technological strength, crack resistance and corrosion resistance of the weld metal during automatic welding of thick austenitic and austenitic-ferritic steels.

REVIEW OF LITERATURE ON THE SUBJECT

During the development of automatic welding of steels 0X18H10T, 0X18H12TΦ, 0X20H12AБΦ with thickness up to 120 mm, the influence of various fluxes on the resistance of weld metal to the formation of hot cracks and intercrystalline corrosion was studied, as well as the phase composition and mechanical properties of the deposited metal and multilayer welds made with Ca-04X19H11M3 and Cв-08X19H10M3Б wires with different ferrite phase contents (Table 1) [1,2].

Oxygen-free fluoride fluxes AHΦ -5 and AHΦ-6 form difficult-to-remove slags (especially in the root layers of welds). In this regard, fluxes 48-OΦ-6, 48- OΦ-10 and AH-26, which have slag acidity coefficients (K_k) of

0.23; 0.6 and 1.1, respectively, as well as the oxidizing flux AH-18, developed for welding austenitic steels, were studied [4]. To evaluate the oxidizing properties of slags, various schemes for calculating their acidity coefficient are used (based on the ratio of silica and calcium oxide, based on the ratio of the sum of the weight or molar percentages of acidic oxides to basic ones, etc.). However, such calculations provide an approximate estimate of the properties, since the acidity of the slag is determined by the presence of only free acidic oxides in it and, therefore, it is necessary to take into account the possibility of the formation of various complex compounds in the slag ($\text{FeO}\cdot\text{TiO}$, $\text{FeO}\cdot\text{SiO}_2$, $(\text{FeO})_2\cdot\text{SiO}_2$, etc.) [1].

RESEARCH METHODOLOGY

Neglecting the influence of TiO_2 (due to its low content in fluxes used for welding high-alloy steels), fairly accurate values of slag acidity can be obtained by calculating using the formula [5]

$$K_k = \frac{(\% \text{SiO}_2)}{a(\% \text{CaO}^2) + b(\% \text{MgO}) + c(\% \text{MnO}) + d(\% \text{FeO})}$$

where a, b, c, d are coefficients (no more than one) that take into account the different affinities of the main oxides to SiO_2 (Table 1).

Table 1. Compositions of welding wire and deposited metal¹

Wire grade (steel)	Material	Flux brand	Element content in %									
			C	Si	Mn	Cr	Ni	Mo	Nb	N	S	P
Св-04Х19Н11М3 (0Х18Н10Т)	Wire 1	-	0,06	0,32	1,46	18,20	12,25	2,28	-	0,033	0,007	0,016
	Welded metal	48-ОФ-6	0,06	0,35	1,27	18,19	12,20	2,25	-	0,036	0,005	0,020
	metal	48-ОФ-10	0,06	0,56	1,06	17,65	12,05	2,18	-	0,045	0,010	0,023
	Weld	48-ОФ-10	0,06	0,36	1,12	18,09	11,87	2,24	-	0,046	0,008	0,017
	Wire 2	-	0,06	0,25	1,39	18,14	12,00	2,46	-	0,035	0,009	0,016
	Welded metal	48-ОФ-6	0,05	0,27	1,22	18,14	11,84	2,33	-	0,036	0,008	0,016
	metal	AH-26	0,05	0,73	0,96	16,47	12,02	2,35	-	0,036	0,018	0,018
	Weld	AH-26	0,06	0,78	1,13	17,25	12,03	2,25	-	0,036	0,010	0,012
	Wire 3	-	0,05	0,35	1,56	18,00	11,52	2,48	-	0,045	0,007	0,025
	Welded metal	48-ОФ-6	0,07	0,35	1,34	17,85	11,54	2,15	-	0,046	0,006	0,046
	metal	AH-18	0,07	0,20	0,83	14,40	11,40	2,15	-	0,049	0,013	0,046
	Weld	AH-18	0,08	0,31	1,12	16,36	11,76	1,41	-	0,027	0,018	0,022
Св-08Х19Н10М3Б (0Х18Н12ТФ)	Wire 5	-	0,08	0,35	1,47	18,81	10,75	2,50	1,02	0,043	0,003	0,018
	Welded metal	48-ОФ-6	0,09	0,31	1,30	18,60	10,50	2,32	0,83	0,048	0,007	0,032
	metal	AH-18	0,08	0,20	0,83	15,08	10,80	2,30	0,54	0,054	0,010	0,031
	Weld	AH-18	0,10	0,26	1,12	16,31	10,26	2,00	0,38	0,047	0,009	0,033

Furthermore, it should be taken into account that amphoteric oxides (Al_2O_3 , Cr_2O_3 , etc.) also form complex compounds with acidic oxides when basic oxides are deficient, and vice versa. Thus, they can behave as basic or acidic in slags of various compositions [1].

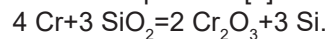
Welding and surfacing of plates (with V-shaped groove) with a thickness of 16, 60 and 120 mm and annular shells with a diameter of 510 mm and a wall thickness of 60 mm were carried out at an arc linear energy of 5-6 kcal/cm with breaks (for cooling below 100°C) after the application of each bead. To control the chemical and phase composition of the deposited metal and welds made under different fluxes, the data are given in table 1. The ferrite content in the wire was determined by the formula given in [6].

ANALYSIS AND RESULTS

It was established that of all the fluxes studied, only flux 48-ОФ-6, which has the lowest oxidizing capacity ($K_k=0.23$), ensures a chemical composition of the deposited metal that is practically identical to the original composition of the wire. This preserves the required amount of ferrite phase (table 1), which guarantees the technological strength of the deposited metal in multilayer welds when welding austenitic and austenitic-ferritic steels.

¹ Source: developed by the author.

All butt joints of plates in shells with a thickness of 16 to 120 mm, using Cв-04X19H11M3 and Cв-08X19H10M3Б wires under 48-ОФ-6 flux, did not have macro and microcracks and had high resistance to intercrystalline corrosion when tested in the initial state after welding (table 2). Fluxes 48-ОФ-10 and AH-26 significantly oxidize chromium, manganese and other alloying elements (except nickel), and also increase the silicon content in the metal due to the silicon reduction process [7]:



When welding 16 mm thick plates made of 0X18H10T and 0X18H12TΦ steels with wires of both grades under 48-ОФ-10 and AH-26 fluxes, both technological strength and corrosion resistance of welded joints are ensured (Table 2) [2].

Table 2. Mechanical properties and corrosion resistance of welded joints²

Steel grade	Thickness in mm	Wire	Mechanical properties				Weld resistance to intergranular corrosion using the AM method (ГОСТ 6032-58)
			Flux	$\sigma_{0,2}$ in kgf/mm ²	σ_B in kgf/mm ²	a_H in kgf·m/cm ²	
0X18H10T	120	Cв-04X19H11M3	48-ОФ-6	31,8-36,4	57,8-58,9	9,8-16,0	Racks
	60		48-ОФ-10	36,9-39,5	59,4-60,6	8,4-16,5	Racks
	60		AH-26	38,2-38,9	58,1-58,3	13,4-19,1	Racks
	16		AH-26	-	57,3-61,3	17,1-19,4	Racks
	16		AH-18	-	47,5-56,0	10,4-13,9	Not resistant
0X18H12TΦ	16	Cв-04X19H11M3	AH-26	-	60,8-63,8	14,2-16,9	Racks
	60	Cв-08X19H10M3Б	AH-18	43,3-48,4	63,0-63,5	11,2-14,1	Racks
0X20H12АБФ	60	Cв-08X19H10M3Б	AH-18	45,3-52,8	64,7-65,7	14,4-15,1	Racks

When welding thick steels (60 mm), the seams had hot cracks. With increasing flux acidity, the silicon reduction process intensifies, the amount of silicon in the deposited metal increases, and the technological strength decreases. When welding and surfacing with oxidizing flux AH-18, which contains a significant amount of iron oxides (hematite), all alloying elements (except nickel) are oxidized to an even greater extent than with flux AH-26 ($K_k = 1,1$), due to the release of free oxygen during the dissociation of hematite.

It is important to note that silicon is also oxidized. Strong oxidation of ferritizing elements leads, as shown by magnetic and metallographic studies, to the complete disappearance of the ferrite phase in the metal in the case where, when welding was carried out using wire Cв-04X19H11M3 with a ferrite content at the upper limit of the grade composition (table 1). The absence of a silicon-reduction process did not prevent the formation of hot cracks in the welds of 16 mm thick 0X18H10T steel joints. The single-phase structure of the weld metal in this case became susceptible to intercrystalline corrosion (table 2).

The obtained results are consistent with the data of work [4]. The use of wire Cв-08X19H10M3Б with an even higher ferrite content, which provided up to 6-8% of the α -phase in the deposited metal during welding under flux 48-ОФ-6, made it possible to obtain a two-phase deposited metal under flux AH-18, which had 1,5-2% ferrite (table 1).

This ensured corrosion resistance of the joints when welding 0X18H12TΦ and 0X20H12АБФ steels, which had an austenitic-ferritic structure (table 2), but did not exclude the formation of hot cracks in the seams in a number of cases. In terms of technological characteristics (bead formation, slag separability, etc.), flux 48-ОФ-6 has the best properties of all the fluxes studied [8].

The strength properties of welded joints with a thickness of 16 mm were tested on tensile specimens of type XIII according to ИСО 4136-89, and with thicknesses of 60 and 120 mm - on specimens of type III, which were cut along the cross-section of the welds with a metal thickness of 60 mm from the root and upper layers, and with a thickness of 120 mm from the root, middle and upper layers. All specimens of this type failed through the base metal at a distance of 15-30 mm from the weld. The impact toughness of the weld metal was determined using Ménage notched specimens. Table 2 shows the ultimate values from 3-5 specimens tested for each combination.

² Source: developed by the author.

CONCLUSIONS AND SUGGESTIONS

Thus, the mechanical properties of welded joints are independent of the flux grade used (provided there are no cracks in the specimens) and are directly dependent on the composition of the wire used. As the amount of the second phase in the wire (and consequently in the weld) increases, the strength properties of the joints increase (table 2).

When automatically welding austenitic and austenitic-ferritic steels 0X18H10T, 0X18H12TФ and 0X20H12АБФ with a thickness of up to 120 mm using Св-04X19H11M3 and Св-08X19H10M3Б wires, stable technological strength, corrosion resistance and mechanical properties of the joints are ensured only when using fluoride non-oxidizing flux 48-ОФ-6. Flux 48-ОФ-6 has been introduced into production and is successfully used in the manufacture of large-sized units (with wall thicknesses up to 120 mm) operating in aggressive environments at elevated temperatures and pressures.

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