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## Experience in the use of technogenic materials for the production of fluxes used for forming rolls surfacing

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**Abstract.** The article contains the results of studies on the feasibility of using slag from silicium manganese production and flux additives based on aluminum purification waste products in the manufacture of welding fluxes for surfacing forming rolls. Based on the conducted experimental studies, the regularities of the influence of fractional and component composition of welding fluxes made using the above-mentioned technogenic wastes on the mechanical properties and quality of the microstructure of the deposited metal layer were established. In particular, it is shown that the maximum impact strength is achieved at a specific fraction content less than 0.45 mm in the charge for welding flux production at a level of 15 to 30%. It was established that with the additional use of liquid glass as a binder component in the charge for the production of welding fluxes, the highest mechanical properties of the weld metal layer are achieved at a flow rate of liquid glass within 20-30% of the mass of the charge. It is shown that the increase in the proportion of the flux additive from 2% to 8% in the charge for the production of welding fluxes causes the increase in the impact strength of the weld metal layer by more than 2 times and leads to the decrease in contamination with nonmetallic inclusions. The technology of rolls surfacing using the developed new fluxes has undergone industrial testing and has been introduced into production.

### 1. Introduction

In recent years, technologies have been actively introduced to restore the working surface of forming rolls by arc surfacing under a flux. The use of deposition can significantly increase the durability of the forming rolls gauges, which causes a reduction in the specific consumption of rolls for the production of rolled products, a reduction in the duration of downtime due to the increase in the duration of the overhaul period, and, ultimately, reduces the cost of finished rolled products while increasing the productivity of rolling mills. In addition, increasing the durability of forming rolls positively affects the quality of finished products.

According to the available literature and production data [1-4], the efficiency and quality of the surfacing work is largely determined by the welding-technological properties of the flux cored wires and welding fluxes used. On the basis of earlier studies with the participation of the authors [5, 6], new compositions of powder wires for surfacing forming rolls have been developed, the distinctive feature of which is the introduction of technogenic waste into the initial charge, namely carbon-fluorine-containing dust. As part of the development of the field for improving the composition of surfacing materials using technogenic waste, new welding fluxes have been proposed [7, 8], in the manufacture of which slag of silicomanganese of the following composition was used, %: 6.91-9.62  $\text{Al}_2\text{O}_3$ ; 22.85-31.70  $\text{CaO}$ ; 46.46-48.16  $\text{SiO}_2$ ; 0.27-0.81  $\text{FeO}$ ; 6.48-7.92  $\text{MgO}$ ; 8.01-8.43  $\text{MnO}$ ; 0.28-0.76  $\text{F}$ ; 0.26-0.36



Na<sub>2</sub>O; to 0.62 K<sub>2</sub>O; 0.15-0.17 S; 0.01 P. It should be noted that single attempts to use slag, which forms manganese-containing ferroalloys, for the production of welding materials have also been undertaken by a number of foreign researchers [9].

## 2. Methods of research

In order to substantiate the optimal component and fractional composition of the fluxes, a series of experimental studies was carried out. The deposition under flux of various compositions was produced on samples of 500×75 mm in size with a thickness of 16 mm made of steel grade 09G2S. At the same time, Sv-08GA wire was used using the ASAW-1250 welding tractor in the following conditions: I<sub>w</sub> = 700 A; U<sub>a</sub> = 30 V; V<sub>w</sub> = 35 m/h. Metallographic studies of microsections were carried out using an optical microscope OLYMPUS GX-51 in a bright field at various magnifications after etching in an alcoholic nitric acid solution as well as in a solution of hydrofluoric acid. The chemical composition of the weld metal was determined using an XRF-1800 X-ray fluorescence spectrometer and atomic emission spectrometer DFS-71.

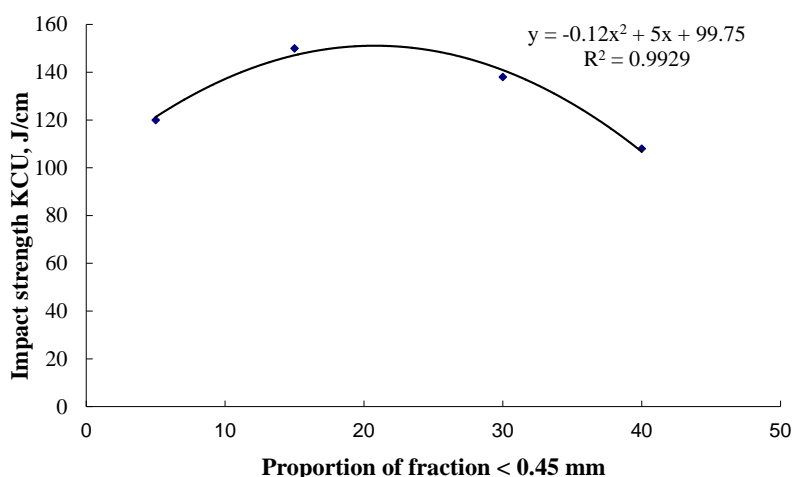
## 3. Results and discussion

At the first stage, the following flux compositions were used in the study (table 1).

**Table 1.** The fractional and component compositions of the investigated fluxes.

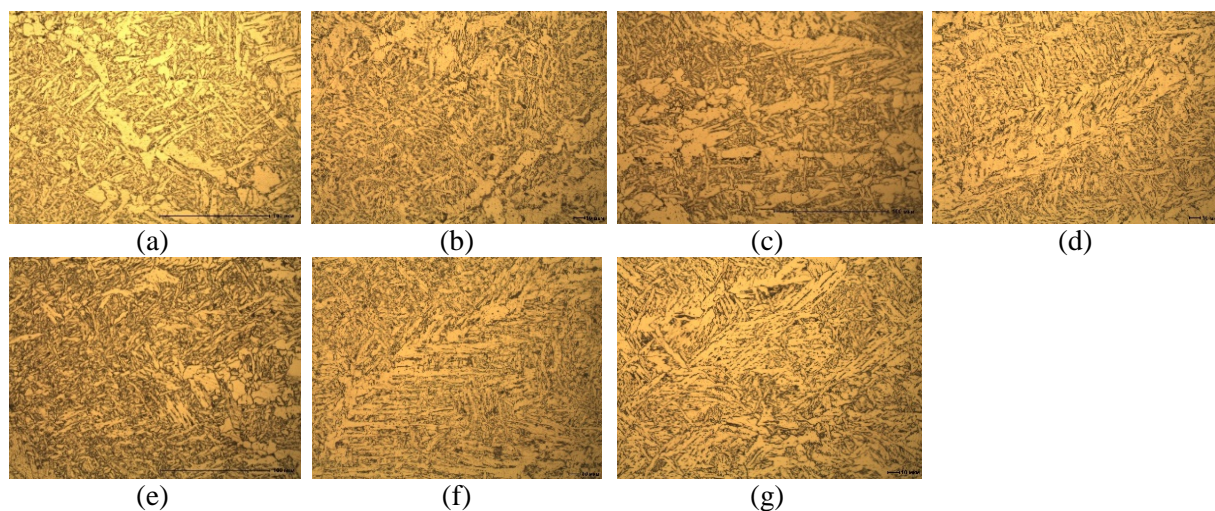
Sample number	Ratio, %, of fractions, mm
1	100 % fractions 0,45 – 2,5
2	95 % of fractions 0.45 – 2.5 + 5 % of fractions <0.45
3	90 % of fractions 0.45 – 2.5 + 10 % of fractions < 0.45
4	85 % of fractions 0.45 – 2.5 + 15 % of fractions < 0.45
5	80 % of fractions 0.45 – 2.5 + 20 % of fractions < 0.45
6	70 % of fractions 0.45 – 2.5 + 30 % of fractions < 0.45
7	60 % of fractions 0.45 – 2.5 + 40 % of fractions < 0.45
8	60 % of silicomanganese slag + 40 % of liquid glass
9	70 % of silicomanganese slag + 30 % of liquid glass
10	80 % of silicomanganese slag + 20 % of liquid glass
11	85 % of silicomanganese slag + 15 % of liquid glass

The results analysis of the samples mechanical tests made it possible to establish that the maximum impact strength at the test temperature 20°C is reached when the flux contains 15-30% of the fraction less than 0.45 mm (figure 1).



**Figure 1.** The dependence of the impact strength of the welded metal layer on the proportion of fraction <0.45 mm in the flux.

The carried out metallographic analysis made it possible to establish that in the metal structure of all samples ferrite is present in the form of non-equal grains stretched in the direction of heat removal (figure 2).



**Figure 2.** The microstructure of the deposited layer of samples: a – No. 1; b – No. 2; c – No. 3; d – No. 4; e – No. 5; f – No. 6; g – No. 7.

In this case, the transition from a uniform ferrite-pearlite structure to the structure of perlite and ferrite of the vismanthtite orientation is noticeable. It should also be said that in the samples there was no significant change in grain size (table 2).

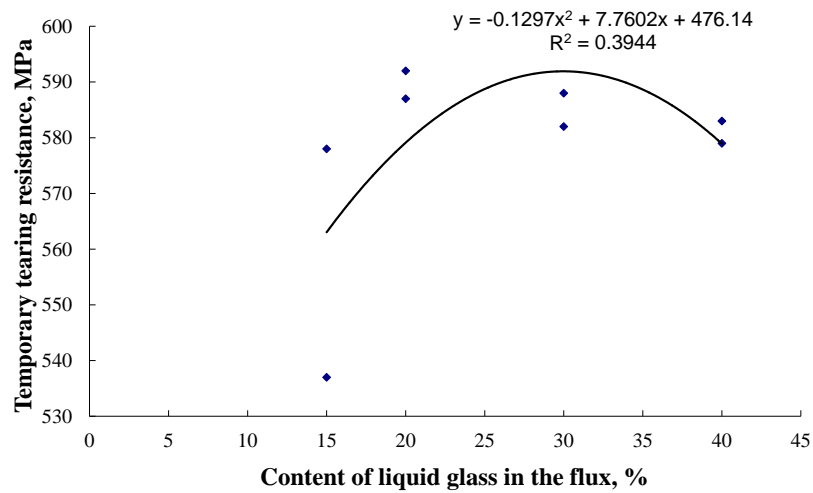
**Table 2.** The grain size of the welded metal layer according to GOST 5639-82.

Sample number	The grain size on the grain scale
1	No. 4, No.5
2	No.5, No.4
3	No.4, No.5, No.6
4	No.4
5	No.5, No.4
6	No.4
7	No.4
8	No.5, No.4
9	No.4, No.5
10	No.4
11	No.4, No.5

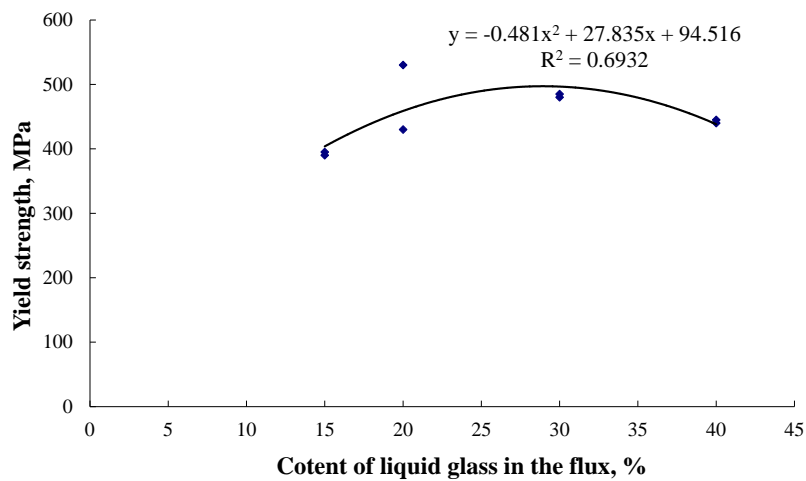
According to the data obtained, the optimal content of liquid glass in the flux from the point of view of ensuring high mechanical properties of the deposited layer is 20-30% (figures 3-5).

It should be noted that a significant drawback of the developed fluxes is an increase in the level of contamination of the welded layer by nonmetallic inclusions, since the studied fluxes are oxidizing and are built on the principles of silica-manganese-oxidation-reduction processes.

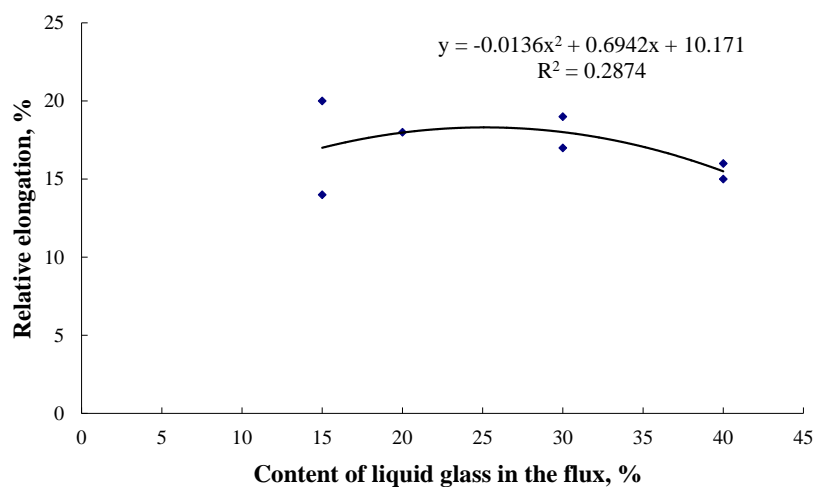
In order to eliminate this shortcoming, the effectiveness of introducing a FD-UFS additive made on the basis of gas cleaning waste from aluminum production in the amount of 2, 4.6 and 8% in the new flux was conducted.



**Figure 3.** Dependence of the temporary tearing resistance of the welded metal layer on the content of liquid glass in the flux.



**Figure 4.** Dependence of the yield strength of the welded metal layer on the content of liquid glass in the flux.



**Figure 5.** Dependence of the relative elongation of the welded metal layer on the content of liquid glass in the flux.



Chemical composition of FD-UFS additive, %: 21-46  $\text{Al}_2\text{O}_3$ ; 18-27 F; 8-15  $\text{Na}_2\text{O}$ ; 0,4-6  $\text{K}_2\text{O}$ ; 0,7-2,3  $\text{CaO}$ ; 0,5-2,5  $\text{SiO}_2$ ; 2,1-3,3  $\text{Fe}_2\text{O}_3$ ; 12,5-30,2  $\text{C}_{\text{tot}}$ ; 0,07-0,9  $\text{MnO}$ ; 0,06-0,9  $\text{MgO}$ ; 0,09-0,19 S; 0,10-0,18 P. The chemical composition of fluxes using this additive is given in table 3.

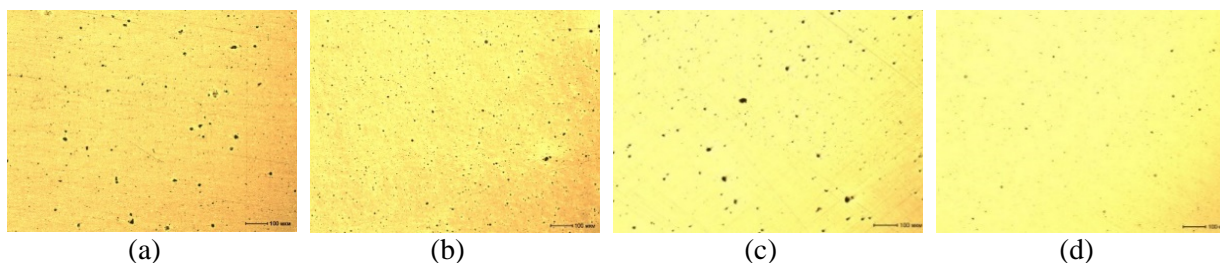
**Table 3.** Chemical composition of the studied mixtures of fluxes, %.

The content of FD-UFS additive in the flux, %	FeO	MnO	Ca	$\text{SiO}_2$	$\text{Al}_2\text{O}_3$	MgO	$\text{Na}_2\text{O}$	$\text{K}_2\text{O}$	S	P	ZnO	F
2	0.40	8.01	15.80	50.08	11.55	7.39	0.77	0.63	0.22	0.008	0.002	1.30
4	0.91	7.90	17.72	46.63	10.32	6.63	1.10	0.68	0.24	0.01	–	1.95
6	0.81	7.68	16.79	43.64	11.27	5.71	2.25	0.65	0.34	0.01	0.003	4.04
8	0.46	7.46	16.00	43.64	11.86	5.56	2.30	0.60	0.33	0.01	0.002	3.96

The results of metallographic studies of the deposited layer of samples using a flux with the addition of FD-UFS (table 4, figure 6) indicate a decrease in contamination with nonmetallic inclusions with an increase in the proportion of this flux additive in an amount up to 8%. It should be noted that there are no brittle silicates in the structure of the metal.

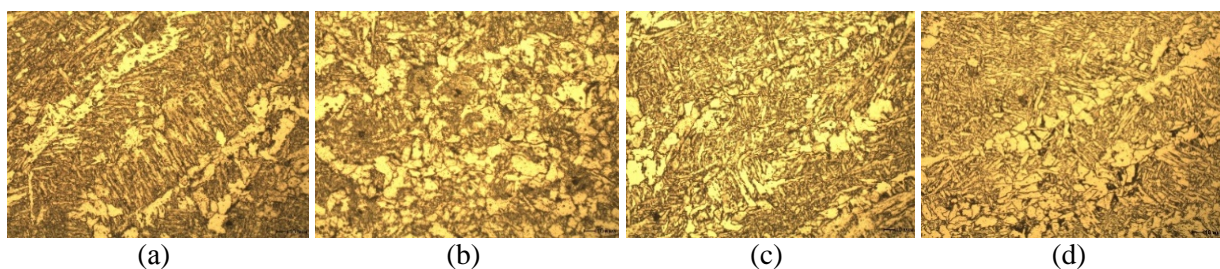
**Table 4.** Non-metallic inclusions in the deposited layer.

Content of FD-UFS additive in the flux, %	Content of nonmetallic inclusions, point	
	non-deforming silicates	point oxides
2	2b, 4b, 5a	1a, 2a
4	2b, 4b	1a, 2a
6	2b, 4b, 1b	1a, 2a
8	2b	1a, 2a



**Figure 6.** Non-metallic inclusions in the weld zone of samples with a flux additive in the amount of: 2% (a); 4% (b); 6% (c); 8% (d).

The analysis of the microstructure of the deposited layer showed that the introduction of a flux additive of FD-UFS grade in the amount of up to 8% does not affect the size and morphology of the structural components (figure 7).



**Figure 7.** Microstructure of welded joints of samples with a flux-additive in the amount: 2% (a); 4% (b); 6% (c); 8% (d).

A study of the mechanical properties of the samples showed that when the amount of the FD-UFS additive is increased from 2% to 8%, the impact strength increases by more than 2 times. The technology of surfacing rolls using the developed new fluxes has undergone trial-industrial testing and has been introduced into production.

#### 4. Conclusion

The experimental studies have shown the efficiency of simultaneous use of slag from the production of silicomanganese and flux additives based on gas purification waste from aluminum production during manufacture of welding fluxes for surfacing forming rolls. The optimum fractional and component composition of the charge for the production of welding fluxes based on these technogenic wastes is determined, which ensures the improvement of operational and structural characteristics of the welded metal layer.

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