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Use of silicomanganese slag and ladle electric steelmaking slag in manufacturing the welding fluxes for surfacing the mining equipment

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Abstract. The possibility of manufacturing a welding flux based on silicomanganese slag and ladle electric steelmaking slag is discussed. Silicomanganese slag and ladle electric steelmaking slag were used in the experiments. Flux additive was introduced in a ratio of 5, 10, 20, 30, 50% to the silicomanganese slag. The possibility in principal of using technogenic wastes of metallurgical production is shown: slag from silicomanganese production and flux additives based on ladle electric steelmaking slag as surfacing flux. It is determined that in connection with the low concentration of iron oxide and increased basicity, it is possible to use this material for alloyed metal deposition. The analysis of the contamination level with nonmetallic inclusions and an increase in the sulfur content in the welded metal showed that without quality deterioration it is possible to introduce a flux-additive based on the ladle slag of steelmaking production in the amount not exceeding 20%. Increase in the flux additive in the amount not more than 20% worsens the welding quality, the number of non-metallic inclusions increases, as well as the sulfur content. When increasing the amount of the flux additive over 30%, the appearance of the welded layer deteriorates.

1. Introduction
The important and promising direction in welding production is the development and use of new welding fluxes based on the waste of metallurgical production. When surfacing the fluxes with an increased content of basic oxides and a low FeO content are used [1-10].

In recent years, a number of studies using technogenic wastes has been carried out. A number of studies are devoted to improving the composition of welding fluxes for mining equipment using new flux additives based on technogenic metallurgical wastes (slags and sludges) [11-17]. In particular, new welding fluxes produced using slag from silicomanganese production have been proposed [18, 19]. The use of technogenic metallurgical wastes as initial components for the production of welding fluxes can significantly reduce the cost of production.

2. Methods of research
The chemical composition of the considered welded samples was determined according to state standards GOST 10543-98 by the X-ray fluorescence method on XRF-1800 spectrometer and by the atomic-emission method using DFS-71 spectrometer. Investigation of longitudinal samples of the deposited layer for the presence of nonmetallic inclusions was performed in accordance with GOST 1778-70 using the optical microscope OLYMPUS GX-51 in a bright field in the range of magnifications × 100.

3. Results and discussion

In this paper, we considered the possibility of using silicomanganese slag produced by the West Siberian Metallurgical Plant with a chemical composition, wt%: Al_2O_3 6.91-9.62%, CaO 22.85-31.70 %, SiO_2 46.46-48.16 %, FeO 0.27-0.81 %, MgO 6.48-7.92 %, MnO 8.01-8.43%, F 0.28-0.76%, Na_2O 0.26-0.36% K_2O до 0.6 2 %, S 0.15-0.17 %, P 0.01 %. With ladle slag from electric steelmaking production of rail steel by JSC “EVRAZ ZSMK” with the chemical composition, wt%: 1.31% FeO, 0.22% MnO, 36.19% CaO, 36.26% SiO_2, 6.17% Al_2O_3, 11.30% MgO, 0.28% Na_2O, 0% K_2O, 3.34% F, <0.12% C, 1.26% S, 0.02% P.

Slag from silicomanganese production of fraction 0.45-2.5 mm was mixed with a flux-additive from ladle electric steel-smelting slag and a mixture with liquid glass.

The production of flux additives was carried out in the following way: a ladle electric steelmaking slag with fraction less than 0.2 mm was mixed with a liquid glass in a ratio of 62% and 38%, respectively. After this, the mixture was kept at room temperature for 24 hours, followed by drying in the oven at 350 °C, then the mixture was cooled, crushed and sieved with a fraction 0.45-2.5 mm.

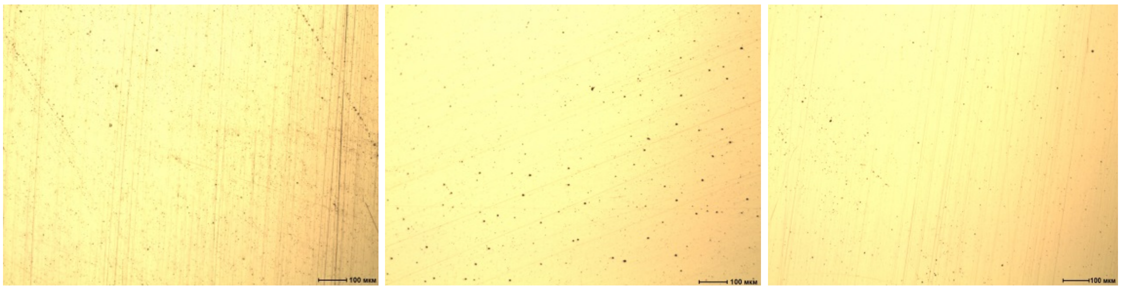
In the experiments a flux additive with a chemical composition was used, wt. %: FeO – 0.84; MnO – 0.06; CaO – 35.47; Al_2O_3 – 4.71; MgO – 5.01; Na_2O – 1.92; K_2O – 0.11; S – 0.98; P – 0.013; Cr_2O_3 – 0.04; TiO – 0.33. The flux-additive was mixed with silicomanganese slag in various ratios (table 1).

The study of the possibility of using different compositions of welding fluxes was carried out in laboratory conditions on the welding tractor ASAW-1250 in the surfacing mode: I = 680 A; U = 28 V; V = 28 m/h. Submerged-arc welding was carried out on samples 300 × 150 mm of 20 mm thickness from sheet steel grade 09G2S using wire Sv-08GA with diameter 4 mm.

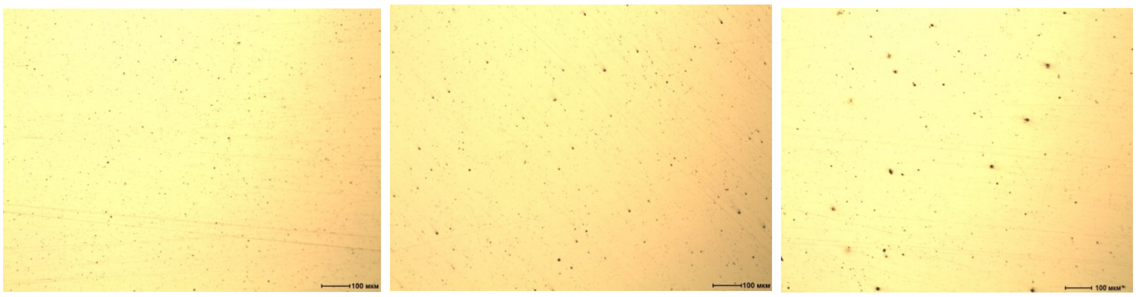
Table 1. Ratio of silicomanganese slag and flux-additive, %.

Flux marking	Silicomanganese slag (SiMn), wt %	Flux-additive, wt %
90	100	0
91	95	5
92	90	10
93	80	20
94	70	30
95	50	50

The appearance of the welded beads is satisfactory for surfacing with a flux additive content up to 30%. The chemical compositions of fluxes, slag crusts, and weld metal are given in tables 2-4, respectively. The metallographic study was carried out on micro-sections without etching by OLYMPUS GX-51 optical microscope with a magnification × 100. The type of nonmetallic inclusions in the welded bead zone is shown in figure 1, the evaluation of nonmetallic inclusions, carried out in accordance with GOST 1778-70, is given in table 5.



(a) (b) (c)



(d) (e) (f)

Samples: a) 90; b) 91; c) 92; d) 93; e) 94; f) 95

Figure 1. Non-metallic inclusions in the zone of welded samples.

Table 2. Chemical composition of the flux.

Flux	Mass fraction of elements, %						
	FeO	MnO	CaO	SiO_2	Al_2O_3	MgO	Na_2O
90	0.50	7.97	31.34	46.09	6.61	5.74	0.40
91	0.38	7.59	32.71	45.04	6.60	4.34	1.07
92	0.42	7.28	33.12	45.10	6.33	4.52	1.40
93	0.42	6.90	32.06	46.20	6.85	4.03	1.40
94	0.57	4.62	34.03	43.80	5.09	4.58	3.28
95	0.74	2.58	35.64	43.33	5.19	4.92	3.99

Continuation of **table 2.**

Flux	Mass fraction of elements, %						
	K_2O	S	P	ZnO	Cr_2O_3	F	TiO_2
90	0.01	0.33	0.011	0.004	0.05	0.45	0.07
91	0.081	0.28	0.012	0.003	0.031	0.77	0.10
92	0.082	0.32	0.011	0.003	0.029	0.87	0.11
93	0.082	0.34	0.011	0.003	0.024	0.89	0.11
94	0.14	0.54	0.012	0.004	0.036	1.63	0.17
95	0.17	0.73	0.013	0.005	0.041	1.99	0.21

Table 3. The chemical composition of slag crusts.

Flux	Mass fraction of elements, %						
	FeO	MnO	CaO	SiO_2	Al_2O_3	MgO	Na_2O
90	1.69	7.78	32.35	42.50	6.59	5.55	0.30
91	1.54	7.61	32.42	44.28	7.87	4.28	0.59
92	1.62	7.04	32.47	43.39	6.63	4.24	0.89
93	1.78	6.36	33.10	43.13	7.23	4.38	1.19
94	1.69	5.34	33.28	44.55	6.05	4.64	2.05
95	1.66	3.90	34.48	44.61	5.59	4.87	2.78

Continuation of **table 3.**

Flux	Mass fraction of elements, %						
	K_2O	S	P	ZnO	Cr_2O_3	F	TiO_2
90	0.01	0.21	0.011	0.012	0.04	0.37	0.07
91	0.001	0.16	0.011	0.003	0.033	0.53	0.094
92	0.081	0.20	0.011	0.004	0.033	0.68	0.11
93	0.088	0.23	0.012	0.004	0.034	0.83	0.12
94	0.11	0.33	0.011	0.005	0.032	1.24	0.15
95	0.14	0.46	0.012	0.005	0.036	1.66	0.17

Table 4. The chemical composition of the welded beads.

Flux	Mass fraction of elements, %						
	C	Si	Mn	Cr	Ni	Cu	Ti
90	0.07	0.43	1.16	0.05	0.11	0.14	-
91	0.04	0.44	1.30	0.04	0.08	0.13	0.001
92	0.04	0.42	1.30	0.04	0.09	0.13	0.001
93	0.04	0.41	1.22	0.04	0.09	0.13	-
94	0.04	0.38	1.25	0.04	0.08	0.13	-
95	0.04	0.35	1.22	0.04	0.09	0.12	-

Continuation of **table 4.**

Flux	Mass fraction of elements, %					
	V	Mo	Al	Nb	S	P
90	0.007	0.021	-	0.003	0.019	0.012
91	0.002	0.01	0.002	0.010	0.019	0.012
92	0.003	0.01	-	0.010	0.024	0.011
93	0.001	0.01	-	0.11	0.031	0.010
94	0.002	0.01	-	0.011	0.033	0.009
95	-	0.01	-	0.011	0.036	0.008

Table 5. Non-metallic inclusions in the zone of welded seams.

Sample	Non-metallic inclusions, point	
	nondeformable silicates	spot oxides
90	1b.2b	1a
91	2b.1b	2a.1a
92	1b.2b	1a.2a
93	1b. rare 2b	1a
94	1b. rare 2b	1a
95	2b.3b. rare 4b	1a.2a

Thus, due to the low concentration of iron oxide and increased basicity it is possible to use this material for depositing alloyed metal. The analysis of the contamination level with nonmetallic inclusions and an increase in the sulfur content in the welded metal showed that it is possible to introduce a flux additive based on the ladle slag of steelmaking production without quality deterioration in the amount not exceeding 20%.

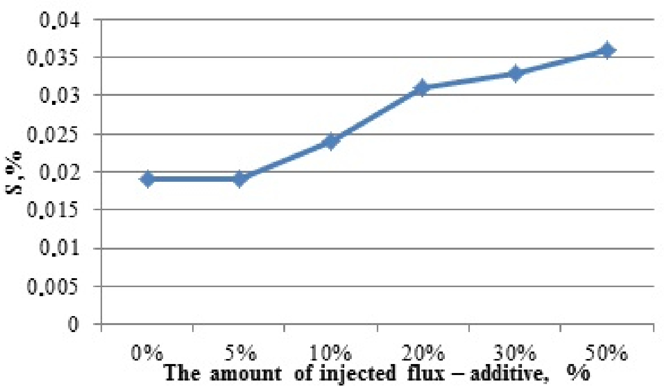


Figure 2. The effect of the additive introduced into the deposited layer on the sulfur concentration.

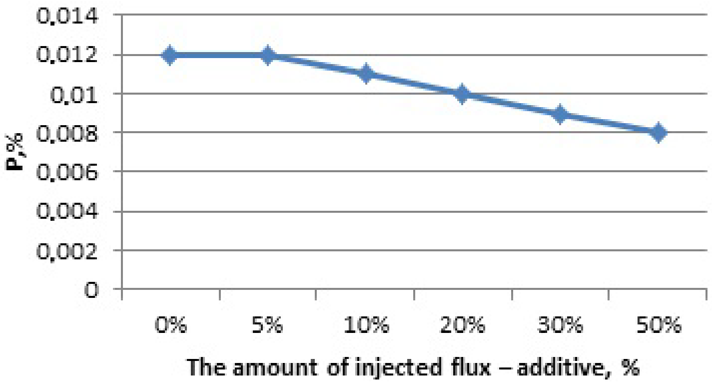


Figure 3. The effect of the additive introduced into the deposited layer on the phosphorus concentration.

4. Conclusions

1) The possibility in principal of using technogenic wastes from metallurgical production is shown: silicomanganese slag and flux additives based on ladle electric steelmaking slag as surfacing flux for the mining industry.

2) When exceeding the amount of the introduced flux additive over 30% the appearance of the welded layer deteriorates.

3) The introduction of the flux additive increases the sulfur content and reduces the phosphorus content in the deposited layer.

4) When the amount of the flux-additive exceeds more than 20%, the quality of the weld metal deteriorates, the number of non-metallic inclusions increases, as well as the sulfur content.

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