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Study of hydrogen concentration in the weld seam during welding of mining equipment

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Abstract. The study of the hydrogen content in the weld during the welding of mining equipment was carried out. It was found that with an increase in current strength, voltage and welding rate, a decrease in the hydrogen concentration in the welded joint of the samples is possible. The obtained welded samples meet the requirements for the hydrogen content – the hydrogen concentration in all samples is less than 2 cm^3/100g.

1. Introduction

Submerged arc welding is the leading technological process in the manufacture of large-sized welded metal structures of mining equipment. At the same time, an important direction in welding production is the development of new welding fluxes that provide the required physical and chemical parameters with a lower cost [1-4]. The solution to this problem can be found through the use of metallurgical production waste as welding fluxes, which, along with the costs reduction in the manufacture of fluxes, increase the quality of the weld by reducing the concentration of hydrogen [5-8].

Earlier, in previous works, the possibility of using silicomanganese slag as welding fluxes was considered [9-13]. The study of the influence of welding modes on the hydrogen content in welded seams was carried out using the equipment of the Scientific and Production Center "Welding Processes and Technologies".

2. Research methods

In this study, for the welded structures of mining equipment made of steel 09G2S, we used slag from the production of silicomanganese fraction from 0.45 to 2.5 mm with the chemical composition shown in table 1.

Table 1. Chemical composition of the flux based on the slag produced by silicomanganese.

Mass fraction of elements, %												
FeO	MnO	CaO	SiO_2	Al_2O_3	MgO	S	P	ZnO	C	F	TiO_2	Cr_2O_3
0.42	16.22	29.00	41.34	6.53	1.33	0.24	0.022	0.008	0.031	0.31	0.15	0.025

When developing the technology, the welding of the samples was carried out after drying the welding flux at a temperature of 250-300 °C for 3 hours, using steel plates of 09G2S steel 20 mm thick by Sv-08GA welding wire using an ASAW-1250 automatic welding tractor. Welding modes of samples were selected by the method of full-factor mathematical planning of the experiment. The obtained samples were investigated for chemical composition by the X-ray fluorescence method on the XRF-1800 spectrometer and by the atomic emission method on the DFS-71 spectrometer. The determination of the chemical composition of the weld metal was carried out by chemical methods: for carbon content according to GOST 12344-2003, sulfur according to GOST 12345-2001 and phosphorus according to GOST 12347-77.

3. Results and discussion

When developing the technology for producing welded joints with low gas saturation, the hydrogen concentration in the weld was also determined. Measurements of the hydrogen content in the welded seam were carried out on a Gasochrome 3101 chromatograph.

The modes of welding the samples are presented in table 2. For welding the reference sample, the following mode was used: 700A-30B-30 cm/min. The chemical composition of the welds is shown in table 3.

Table 2. Modes of welding samples.

Experiment number	Current strength, A	Voltage, V	Welding ratio, cm/min	Heat input, J/cm
0 (comparison sample)	700	30	30	42000
1	600	28	28	36000
2	600	30	32	33750
3	600	32	30	38400
4	650	28	32	34125
5	650	30	30	39000
6	650	32	28	44571
7	700	28	30	39200
8	700	30	28	45000
9	700	32	32	42000

Table 3. Chemical composition of welds.

Sample No.	Mass fraction of elements, wt%											
	C	Si	Mn	Cr	Ni	Cu	Ti	Mo	Al	S	P	H, $cm^3/100g$
0	0.11	0.41	1.16	0.05	0.31	0.15	0.002	0.10	0.009.	0.014	0.014	1.1
1	0.07	0.48	1.24	0.05	0.43	0.16	0.001	0.14	0.012	0.013	0.016	1.2
2	0.08	0.54	1.38	0.06	0.28	0.17	0.003	0.08	0.018	0.014	0.014	1.1
3	0.08	0.51	1.31	0.06	0.32	0.15	0.001	0.10	0.014	0.014	0.013	1.4
4	0.08	0.49	1.20	0.05	0.45	0.17	0.002	0.16	0.013	0.011	0.015	1.1
5	0.07	0.50	1.26	0.05	0.43	0.17	0.003	0.14	0.002	0.012	0.018	1.1
6	0.07	0.49	1.25	0.05	0.40	0.16	0.002	0.13	-	0.012	0.015	1.0
7	0.09	0.50	1.23	0.04	0.41	0.13	0.001	0.14	0.014	0.011	0.011	1.3
8	0.09	0.50	1.31	0.06	0.31	0.17	0.001	0.09	0.019	0.014	0.013	1.0
9	0.07	0.53	1.27	0.05	0.37	0.15	0.002	0.12	0.010	0.015	0.016	0.9

All selected samples meet the requirements for hydrogen content – hydrogen concentration in all samples is less than 2 $cm^3/100g$. The dependences of the hydrogen content in the weld on the welding modes are shown in figures 1-3.

The use of mathematical and statistical methods made it possible to construct a mathematical model of the influence of technological modes (current strength, voltage during welding, welding speed) on the hydrogen content in the weld. Regression analysis of the influence of the welding modes of the samples, with the parameters: I – current strength, A; U – voltage, V; V is the welding rate, cm/min; E – heat input, J/cm is represented by the following equations:

For hydrogen: $H2, (cm^3/100g) = 3.26+0.02274\cdot I+0.504\cdot V-0.000406\cdot E$; $R2 = 0.70378$

For hydrogen, taking into account heat input:

H2, (cm^3/100g) = -20.0253+0.0526·I+1.1505·U-0.001193·I·U-0.4094·V-0.000307·E; R2 = 0.97092

The hydrogen content in the welds indicates that, other things being equal, the hydrogen concentration depends on the amperage, voltage and welding speed. The dependences of the hydrogen content in the weld on the welding modes are shown in figures 1-3.

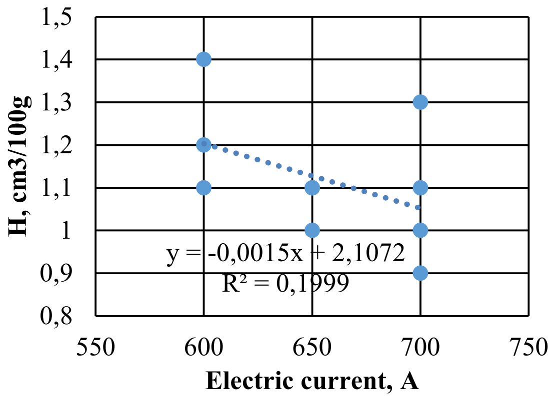

Figure 1. Dependence of the hydrogen content in the welds on the change in the electric current during welding.

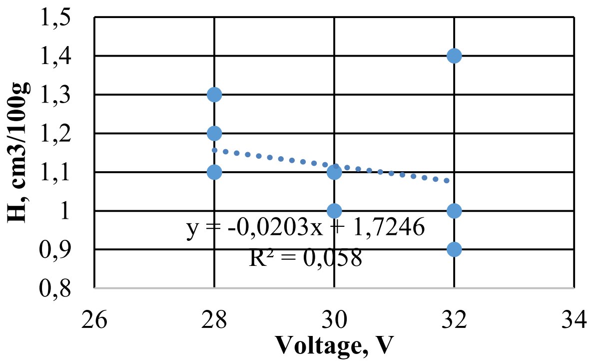

Figure 2. Dependence of the hydrogen content in welded joints with a change in welding voltage.

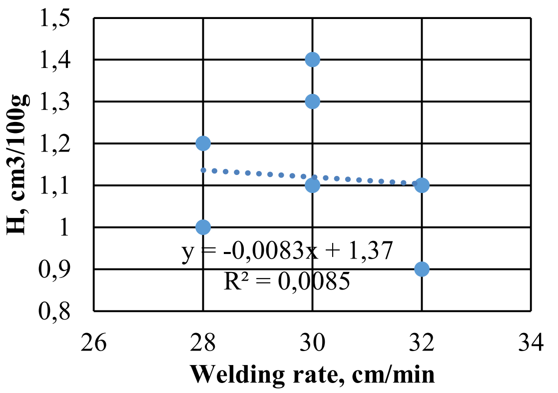

Figure 3. Dependence of hydrogen content in welds with changing welding rate.

4. Conclusion

According to the results of the studies carried out, the data were obtained on the effect of welding modes on the hydrogen content in the weld. It was found that with an increase in current strength, voltage and welding rate, it is possible to reduce the hydrogen concentration in the weld.

The obtained welded samples meet the requirements for the hydrogen content – the hydrogen concentration in all samples is less than 2 $cm^3/100g$.

References

[1] Brusnitsyn Yu D and M Yu Brusnitsyn 2000 *Use of Phase Equilibrium Diagrams of Non-metallic Systems for Diagnostics and Development of Welding Consumables* (St. Petersburg: TsNII KM “Prometey”) p 41
[2] Kartashev M F, Naumov S V et al 2018 *Proc. of Int. Sci. and Tech. Youth. Conf.* (Tomsk) pp 174–175
[3] Kalinnikov V T, Nikolaev A I and Malyshevsky V A 2009 *Proc. of the Int. Sci. and Tech. Conf. Petraniev Readings: “Welding Materials”* (St. Petersburg) pp 80-89
[4] Kokorin V N 2003 *Economy, Ecology and Society of Russia in the 21st Century* (SP-b TSU) pp 273–274
[5] Kozyrev N A and Kryukov R E 2017 *Innovations in the Fuel and Energy Complex and Mechanical Engineering* (Kemerovo) pp 128–133
[6] Kislov A I, Mikhno A R and Kozyrev N A 2018 *Proc. of the All-Russian Sci. Conf. of Students, Postgraduates and Young Scientists* (Novokuznetsk: SibSIU) pp 208-210
[7] Mikhno A R, Kryukov R E et al 2019 *Welding in Russia – 2019: Current State and Prospects: Abstracts of the International Conference* (Tomsk) pp 187–188
[8] Kozyrev N A and Kryukov R E 2017 *Innovations in the Fuel and Energy Complex and Mechanical Engineering* (Kemerovo) pp 134-139
[9] Kozyrev N A, Kryukov R E et al 2016 *IOP Conf. Series: MSE* **150** 012032
[10] Kozyrev N A, Kryukov R E et al 2016 *IOP Conference Series: MSE* **125** 012034
[11] Kozyrev N A, Mikhno A R et al 2018 *IOP Conference Series: EES* **206** 012032
[12] Kryukov R E and Kozyrev N A 2019 *Fundamentals of Creating Carbon-containing Welding and Surfacing Materials* (Tomsk: TPU) p 359
[13] Kozyrev N A, Mikhno A R et al 2019 *Metallurgy: Technology, Innovation, Quality. Metallurgy* (Novokuznetsk) pp 322–328