INVESTIGATION OF GRANULOMETRIC AND CHEMICAL COMPOSITION OF SAMPLES OF UNDERWATER WELDING

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Abstract

The article is devoted to the study of granulometric characteristics and chemical composition of samples of underwater welding for sea water from the water area from Ajax Bay (Sea of Japan) and fresh water. A high content of the smallest particles of metal oxides with a dimension of less than 10 μm was revealed.

Keywords: underwater welding, nano- and microparticles, ecology

I. Introduction

The first mention of underwater arc welding and metal cutting using an electrode date back to 1887. However, the laboratory experiments of Professor D. A. Lachinov and N. N. Benardos have not received practical application. They were remembered only by the beginning of the 30s of the twentieth century. K. K. Khrenov managed to create special electrodes suitable for underwater welding and metal cutting, both in fresh and salt water, which was confirmed by natural tests in the Black Sea [1].

At the beginning of 1932, Academician K.K. Khrenov conducted underwater experiments of electric welding with a metal electrode for the first time. On the basis of these studies, the main characteristics of the underwater welding process, the technology of execution were obtained, and electrodes for welding structures under water were developed. In 1936, underwater welding of metal structures was used in practice for the first time on the Black Sea, when the Boris steamer was lifted from a depth of 48 meters.

Welding of metals under water is the main way to obtain a non-split joint of two or more solids, characterized by interatomic bonding and continuity of the structure [2]. Underwater welding and metal cutting is widely used in the construction of modern oil and gas pipelines, as well as during repair and rescue operations on the water.

Nowadays, the need to extract and transport oil and gas along the seabed has led to the creation of underwater marine structures [3]. During construction, and especially during their operation, as a result of the effects of storms and corrosion, metal structural elements require repair. Given the size of oil producing offshore structures, or offshore gas pipelines, it is not

possible to raise them to the surface or repair them in a dry underwater chamber, therefore it is necessary to conduct high-quality welding under water.

It should be noted that the technological process of welding under water includes the gorenje electric arc, as a result of which, the products of metal combustion and electrode coating get into the water. When they come into contact with water, they turn into suspended particles that form a cloud of turbidity around the burning arc. In this article, the dependence of the dynamics of particle size change on the arc burning time is investigated and a chemical analysis of emissions of underwater welding derivatives into the aquatic environment is carried out.

II. Experimental

Seawater for experiments was taken from the water area of Ajax Bay (Sea of Japan), near the FEFU campus. To measure the quantitative composition of suspended particles, a manual laser particle counter AeroTrak Handheld Particle Counter 9306 (manufactured in the USA) was used, which meets all the requirements of ISO 21501-4.

In continuation of the previously conducted studies [4] on atmospheric air pollution by welding and electrochemical industries for the most dangerous processes from a hygienic point of view – depending on the level of the smallest particles of the fraction PM0,3 and PM10 for further studies to measure the fractional composition of suspended particles formed during underwater welding (Fig. 1). The process of manual electric arc welding under water was chosen. This is a process for welding ferrous metal products (metal plate VSt-3sp, S= 8 mm) by manual electric arc welding using Kiswel KR-3000 electrodes with a rutile coating type, diameter 3 mm.

Atmospheric air sampling was carried out in the immediate vicinity at a distance of 1 m from the source of pollution (Fig.1) and at a height of 1.5 m, which corresponds to the level of human respiration.

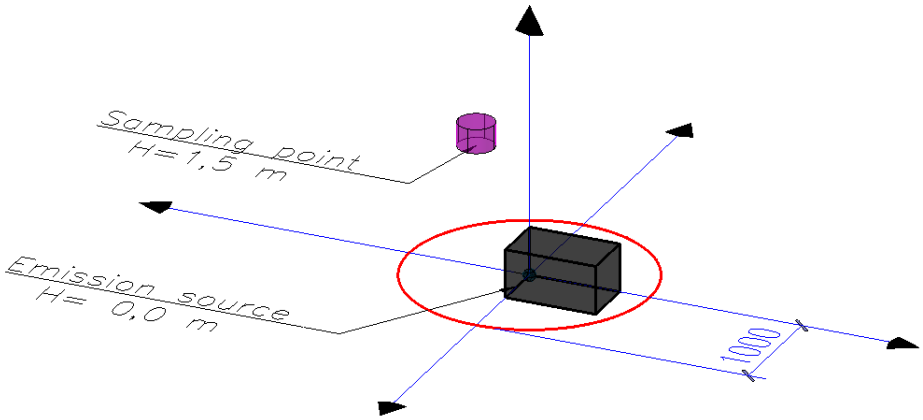

Fig. 1: *Location of sampling points when using the aquarium*

Particle size analysis

To measure the quantitative composition of particles, the laser diffraction method was used, which was used to determine the size of particles and study the dynamics of particle size changes over time. The analysis was carried out on a laser particle analyzer Analysette 22 NanoTec plus (Fritsch GmbH, Germany). The measurements were carried out with a range of fixed particles of 0.01-2000 microns, in 5 repetitions. MaS control software (Fritsch GmbH, Germany) was used to obtain the analysis results. The Mie scattering theory was used to calculate the particle distribution.

Chemical analysis of particles

MS ISP method of water analysis after underwater welding.

After a laboratory experiment on underwater welding of materials, small dark-colored particles formed as a result of this process were clearly observed in seawater samples. The transfer to the dissolved state of these particles consisted of the following steps.

Step-1. Concentrated HNO3 (distilled near the boiling point) up to 5% by volume and concentrated HF (suprapur class) up to 0.25% by volume were added to a 50 ml test tube with seawater after underwater welding.

Step-2. A week later, the acidified aqueous solution was placed in an ultrasonic bath, where the temperature rose under ultrasonic exposure. At a temperature of 45-55 ° C and exposure to ultrasound, the acidified aqueous solution was kept for about 2 hours. When the temperature increased, the ultrasonic bath was turned off until the set temperature was reached, and the downtime was not taken into account. As a result of the procedure, small solid particles were dissolved.

Step-3. After cooling the solution to room temperature, its aliquot was diluted five times with deionized water.

Similarly, blank samples were exposed, which were samples of seawater prior to the relevant underwater welding experiments.

Further, on the Agilent 7700x device, in the mode of high-salt introduction "HMI" (High Matrix Introduction), mass spectrometric with inductively coupled plasma (MS ICP) determination of the following elements by the corresponding analytical masses took place:

– Group-1: Li (7), Be (9), B (11), Co (59), Ni (60), Cu (63), Zn (66), Ga (71), Rb (85), Sr (88), Y (89), Zr (90), Nb (93), Mo (98), Ag (107), Pd (108, to adjust the overlay on Mo), Cd (114), In – internal standard (115), Sn (118), Sb (121), Te (125), Cs (133), Ba (137), La (139), Ce (140), Pr (141), Nd (146), Sm (147), Eu (151), "BaO"-interference (154, for Eu overlay correction), "BaOH"-interference (155, for Eu overlay correction), Gd (157), Tb (159), Dy (163), Ho (165), Er (166), Tm (169), Yb (172), Lu (175), Hf (178), Ta (181), W (184), Re (187), Tl (205), Pb (208), Bi (209), Th (232) and U (238);

– Group-2: Al (27), Si (28), Sc (45), Ti (47), V (51), Cr (52), Mn (55), Ge (72), As (75) and In – internal standard (115);

– Group-3: Na (23), Mg (24), P (31), S (34), K (39), Ca (44), Fe (56), Se (78) and In – internal standard (115).

Group-1 was filmed in c mode passively operating octopole reaction system, that is, without the introduction of any collision and (or) reaction gas. Group-2 and group-3 are in low–energy helium (4.3 ml/min – helium flow; 3 V – potential barrier) and high-energy (10 ml/min – helium flow; 7 V – potential barrier) modes, respectively.

The following mathematical adjustments of mass spectral overlays were carried out:

– By finding the correction coefficient for Ru-containing and Mo-free solution, Ru isobars were subtracted at the 98th mass of Mo. Similarly, Sn isobars were taken into account at the 114th mass of Cd.

– At the 115th mass In, Sn overlays were adjusted based on the theoretical coefficients of the prevalence of Sn isotopes at the 115th and 118th masses.

– Isobaric overlays of oxides and hydroxides of Ba on the 151st analytical mass of Eu were taken into account according to the principles described in the work [7] with the following changes.

1. By obtaining the actual coefficients, the technique was adapted for the "HMI" mode from the mode focused on the introduction of low-mineralized samples.

2. Instead of the matrix approach, based on five equations (masses: 151-155), a matrix approach with three equations (masses) was used (as it turned out to be more accurate).: 151, 154 and 155).

3. The coefficients of formation of barium oxides and hydroxides were not found for each sample separately, but were calculated for Ba-containing and Eu-free solutions and transferred to other analytical solutions without changes.

The statistical sample consisted of 3 measurements for each experiment. Then the samples were transported to the laboratory of the REC "Nanotechnology" of the FEFU Polytechnic Institute for further research.

III. Results and discussion

It is known that the penetration of industrial aerosol particles through respirators increases with increasing flow velocity regardless of the type of particles and that the particle size is a significant factor affecting the penetration of combustible particles [5]. That is why the experimental work considered particles with a dimension of up to 10 microns, which have the greatest penetrating power [6] and are able to settle deep into the lungs of welders and workers of related specialties. Table 3 shows data on the mass and quantitative composition of suspended solid particles of welding aerosol during an experiment with seawater.

Table 1: *Welding spray. Quantitative composition of suspended particles (qty/cubic meter)*

Respirator number	**PM 0,3**	**PM 0,5**	**PM 1**	**PM 3**	**PM 5**	**PM 10**
◎	◎◎◎◎◎◎	◎◎◎◎◎	◎◎◎◎	◎◎◎	◎◎◎	◎◎

Table 2: *Particle size analysis. Results of granulometric analysis of welding aerosol samples*

Particle fraction range	0	15	30	45	60	exp	ctrl
	Particle size distribution, %						
<0,1 μM	15,36	9,67	9,01	13,96	5,46	0,00	0,00
0,1-1 μM	11,26	12,17	7,63	11,43	11,56	0,00	0,00
1-10 μM	34,49	32,68	16,79	36,34	25,32	0,01	7,84
10-50 μM	38,58	3,05	22,05	18,15	49,62	0,23	18,41
50-100 μM	0,02	0,00	0,00	0,01	0,58	0,18	0,09
100-250 μM	0,00	0,00	0,00	0,00	0,00	1,14	0,75
250-500 μM	0,00	0,01	0,00	0,00	0,00	4,57	4,68
500-1000 μM	0,28	23,60	21,25	10,86	2,39	4,82	6,22
1000-1500 μM	0,01	17,91	21,81	8,80	4,57	12,05	4,23
>1500 μM	0,00	0,92	1,46	0,45	0,51	77,02	57,77

Chemical analysis of particles

Results of determination of the concentration of elements in seawater, mcg/l (ppb). The concentrations were determined by inductively coupled plasma mass spectrometry on an Agilent 7700 x spectrometer (Agilent Techn., USA) [5]

Table 3: *Chemical composition*

Concentration, ppb	Svarka*1	Svarka*2	Fon
7 Li	144	150	140
9 Be	≤ 0,057	≤ 0,057	0
11 B	4815	5944	4849
23 Na	9020554	9773710	9398281
24 Mg	1119792	1181197	1166314
27 Al	487	492	92

28 Si	≤ 16000	28697	16578
31 P	86	145	123
34 S	533411	559774	562796
39 K	346340	368331	359836
44 Ca	434272	454397	457236
45 Sc	0	0	0
47 Ti	778	788	2
51 V	4	5	2
52 Cr	5	6	2
55 Mn	291	294	7
56 Fe	5671	5813	99
59 Co	1	1	1
60 Ni	8	9	6
63 Cu	71	67	59
66 Zn	538	519	33
71 Ga	0	0	0
72 Ge	0	1	0
75 As	2	2	2
78 Se	1	0	1
85 Rb	101	95	97
88 Sr	7418	7141	7304
89 Y	0	0	0
90 Zr	6	5	0
93 Nb	3	3	0
98 Mo	12	11	11
107 Ag	0	0	0
114 Cd	2	2	0
118 Sn	5	4	1
121 Sb	1	1	1
125 Te	≤ 0,19	0	≤ 0,19
133 Cs	0	0	0
137 Ba	17	16	9
139 La	0	0	0
140 Ce	0	0	0
141 Pr	0	0	0
146 Nd	0	0	0
147 Sm	0	0	0
151 Eu	0	0	0
157 Gd	0	0	0
159 Tb	0	0	0
163 Dy	0	0	0
165 Ho	0	0	0
166 Er	0	0	0
169 Tm	0	0	≤ 0,00044
172 Yb	0	0	≤ 0,0022
175 Lu	0	0	0
178 Hf	0	0	0
181 Ta	0	0	≤ 0,027
184 W	1	1	0
187 Re	0	0	0
205 Tl	0	0	0
208 Pb	4	3	1
209 Bi	0	0	0

232 Th	0	0	0
238 U	3	3	3

V. Conclusions

The results obtained indicate further work will be continued in the field of studying the toxicological effects of solid particles of underwater welding on representatives of marine biota and hydrobionts.

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