INVESTIGATION OF PARTICLES EMISSIONS WHEN USING VARIOUS ELECTRODES FOR UNDERWATER WELDING

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Abstract

The article is devoted to the study of the mass and quantitative concentration of suspended particles during underwater welding for sea water from the Ajax Bay (Sea of Japan) using two technological modes with special electrodes for welding and cutting metal. For both processes, the predominance of the PM0.3 fraction in emissions of the smallest particles compared to particles of larger fractions was revealed. The amount of suspended particles when using electrodes for metal cutting is several times higher compared to electrodes for underwater welding. The mass concentration of PM10 particles does not exceed the threshold MPC values established in the Russian Federation, Belarus and the USA.

Keywords: underwater welding, nano- and microparticles, emissions, ecology

I. Introduction

The problem of hydrosphere development cannot be solved without wide application of the latest technologies of underwater metal welding and cutting. The aquatic environment and enormous hydrostatic pressures represent a complex set of conditions for the practical application of welding and other related technologies, which require the creation of labor-intensive and financially expensive research and technologies. Underwater welding and cutting technology is an extremely successful technological solution and is versatile for use in the restoration of almost all types of steel structures in the water environment. Light weight of the equipment, its compactness and reliability, quick mastery by users allowed to perform a significant amount of works both on the territory of Russia and beyond its borders [1, 2]. For example, the practical development of the continental shelf of the world ocean began in the second half of the last century. Now gas and oil production are carried out on an industrial scale. Today the world oil production amounted to 3150 million tons, 30% of which was extracted from the bottom of the world ocean using various technologies of underwater cutting and welding of metals [3].

The main tasks of underwater metal welding and cutting are to make and repair reliable welded structures. The requirements for their quality are constantly increasing, which determines the appropriate process for improving their durability and reliability. Therefore, a significant number of studies [4, 5, 6] is devoted to the study of strength characteristics of welded joints, the introduction of new methods of underwater welding, etc. Applied research in the field of environmental assessment of emissions and discharges into the environment has received little attention. Our study aims to fill this gap. It focuses on the analysis of the concentrations of airborne particulate emissions into the atmospheric air, which, in addition to discharges into the water, are an integral attribute of underwater welding operations.

II. Experimental

An aquarium with dimensions of 1.2x0.6x0.6 m, made of organic glass with a wall thickness of 1 cm, was used as the medium for the underwater welding emission assessment experiment. The volume of seawater was 200 liters. The seawater for the experiments was collected from the surface layer in the water area of Ajax Bay (Sea of Japan) near the campus of Far Eastern Federal University (FEFU, Fig. 1). A 30-liter plastic container was used as a sampling device. The seawater was then transported to the laboratories of the Nanotechnology Research Center of FEFU Polytechnic Institute for further sample preparation.

In the laboratory, the seawater was pre-filtered with coarse cloth filters. Next, the water was exposed to ultraviolet radiation (Siemens Ultra-Clear TWF EDI UV UF TM Water Purification System (Siemens, Munich, Germany)) to eliminate biologically active organisms that could have an indirect effect on the results of the study. After the ultraviolet treatment, the seawater was re-filtered and poured into the aquarium for underwater welding. This procedure was performed twice to conduct the experiment with the electrodes for underwater metal welding and cutting.

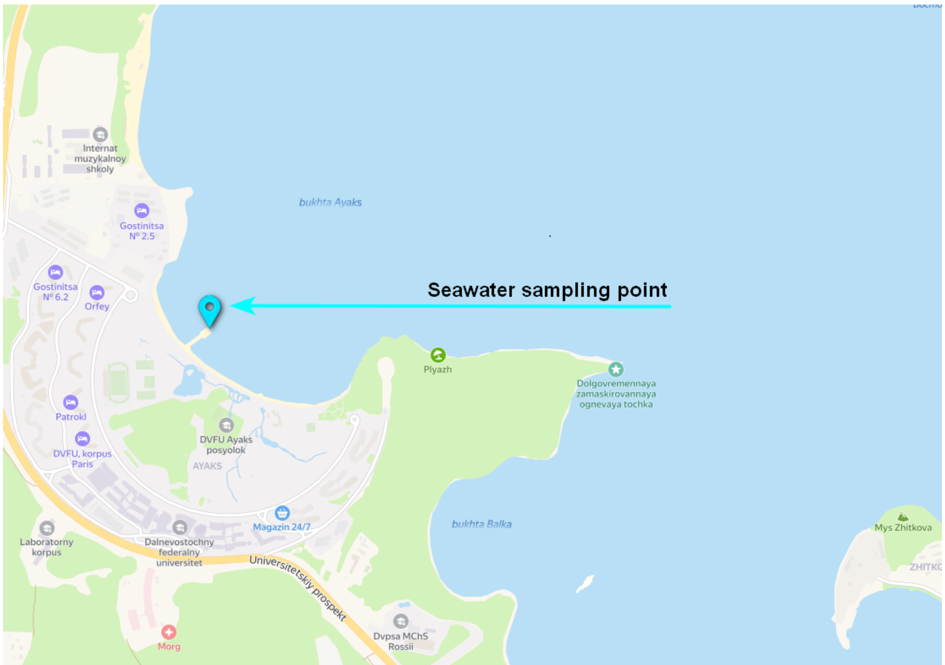

Fig. 1: *Seawater sampling point in the Sea of Japan*

The air sampling time during the underwater welding experiment was 1 minute, which corresponded to the average burn time of 1 electrode. During each series of air sampling, 1 electrode was burned.

1.1. Method for determining the quantitative composition and particle size.

To measure the quantitative composition of airborne particles, we used the AeroTrak Handheld Particle Counter 9306 (USA), which meets all the requirements of ISO 21501-4.

In continuation of the previous research [7] on the morphological structure of solid particles, the present work is dedicated to the study of particle emissions during underwater welding.

We selected the most commonly used technological processes under water in industrial production, using a black metal plate (VSt-3sp, size (200x70x8):

a) Manual arc welding with Arcair electrodes size 5/32X14 (3.97 x 356 mm), Cat. No. 42-984-004.

b) manual cutting with Arcair electrodes size 5/16X14 (8.0 x 356 mm), Cat. No. 42-059-007.

The atmospheric air was sampled in the immediate vicinity of the pollution source (Fig. 2) at a height of 1.5 meters above the floor, which corresponds to the level of human breathing. First, background measurements were made in the room before the experiment, then the measurements were repeated in the middle of the experiment and at the end of the experiment. 2 series of air samples were taken: using electrodes for underwater welding and cutting in sea water (Sea of Japan).

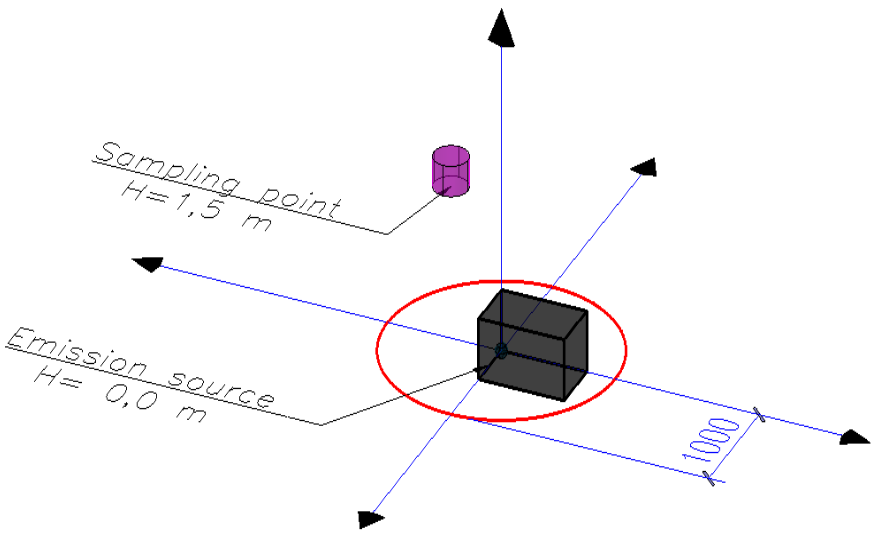

Fig. 2: *Location of sampling points when using the aquarium*

Gravimetric method of particle concentration analysis

In order to determine the mass concentration of fine aerosol particles in the air of the working area above the aquarium, a gravimetric method of measurement was chosen, using an aspirator-type sampler "Aspirator PU" (Russia). Aerosol filters based on Petrianov's filter cloth made of perchlorvinyl fiber (filter type AFA-VP-20-1 of TU 95 1892-89 without binder, with a working surface of 20 cm^2, Kimry Gorky factory) were used. These filters are characterized by high collection efficiency due to electrostatic attraction of aerosol particles to the charged filter fibers; for 0.1 μm particles, the slippage factor in the AFA filter is only 0.1%.

During the experiment, this sampler was equipped with an additional attachment for sampling airborne particles of PM10 fraction. Two filters were used simultaneously for each electrode, collecting the total volume of deposited particles and separately the volume of PM10 particles.

The height of the sampler attachment corresponded to the human breathing level - 1.5 meters above the ground.

The first sampler was equipped with an attachment for sampling the PM10 fraction taken from a similar LVS 3.1 aspirator (Ingeniero Nobert Derenda, Germany). The measured range of airborne particles for the filters of this attachment is from 0.45 μm to 10.0 μm. The upper limit of the particle fraction (PM10) was chosen because particles of this size are the most dangerous to human health, being the cause of respiratory diseases [8, 9]. The specific measurement of the PM10 fraction reflects the current trend in the control of airborne particles [10,11].

The second sampler was equipped with a particle sampling attachment with no fractional range restriction.

Prior to sampling, the filters were pre-dried in a 0.8 cm thick glass drying cabinet where a constant temperature (20°C) and humidity (20%) were maintained for 24 hours, then each filter was weighed five times on a Sartorius (Germany) electronic balance to determine the arithmetic mean.

The dust content in the air was measured by weighing the filters on analytical balance before and after sampling. Each filter was weighed five times on Sartorius (Germany) electronic balance and the arithmetic mean was determined. The obtained difference in weight of the filters before and after the air sampling procedure corresponded to the deposited mass of airborne particles.

III. Results and discussion

Quantitative composition of airborne particles (amount/m^3).

Analyzing the data obtained from the AeroTrak 9306 Handheld Particle Counter (Table 1), we can conclude that the PM0.3 particle fraction was dominant in the pre-experiment background air. Their number was many times greater than all other particles combined.

Table 1: *Quantitative composition of airborne particles when using electrodes for underwater welding*

Process	H (height) meters	Sampling time, minutes	PM0.3	PM0.5	PM1	PM3	PM5	PM10
Welding	1.5	0	205265	16968	2172	484	246	53
Welding		0.5	935745	658018	313010	24899	4040	67
Welding		1	1201110	632230	210468	12543	1963	56
Cutting	1.5	0	516293	55396	6498	738	296	58
Cutting		0.5	1871490	198209	48571	3145	721	55
Cutting		1	2515331	1632711	536164	17559	1198	45

The data obtained during underwater welding with Arcair electrode size 5/32X14 are presented in the form of a graph (Fig. 3). The results of the measurements made in the middle of the experiment (30 sec. from the moment of the beginning of the electrode burning), when half (50% of the initial length) of the welding electrode was left, show a quantitative increase of the particles in the atmospheric air from 4.5 to 144 times of the initial values, depending on the fraction. In addition, we observed the maximum increase in particles of the same PM0.3 fraction.

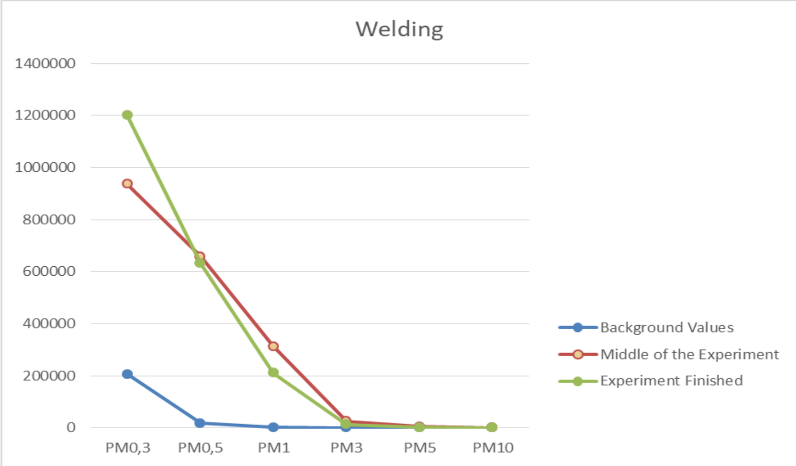

Fig. 3: *Graph of the quantitative composition of airborne particles in the ambient air during underwater welding*

The results of the measurements after the burning of the electrode (1 min) show a further increase (28%) in the number of suspended particles of the PM0.3 fraction compared to the values for 30 sec. These particles are the smallest and can remain suspended in the air for a long time. Note the decrease (from 5% to 50%) of the airborne particles of the larger fractions. This fact indicates dynamic sedimentation of airborne particles of PM0.5-PM10 fractions.

Let's further consider the results of measurements made with the cutting electrode Arcair size 5/16X14 (8.0 x 356 mm), which show the same tendency of increase of the number of the smallest particles in the atmospheric air as for the underwater welding electrode. As can be seen from Fig. 4, the atmospheric air is dominated by particles of PM0.3 fraction, the number of which is many times higher than the sum of particles of larger fractions. If we compare in detail the particles of the same fraction but in different periods of the experiment, we see that in the middle of the experiment the number of particles up to PM0.3 was almost twice higher than the background value, and at the end of the experiment the number of particles of this fraction was 5 times higher than the background values. The values of the number of particles after 60 seconds are superior to the values of the measurements at 30 seconds for all fractions, in contrast to the data of the underwater welding experiment.

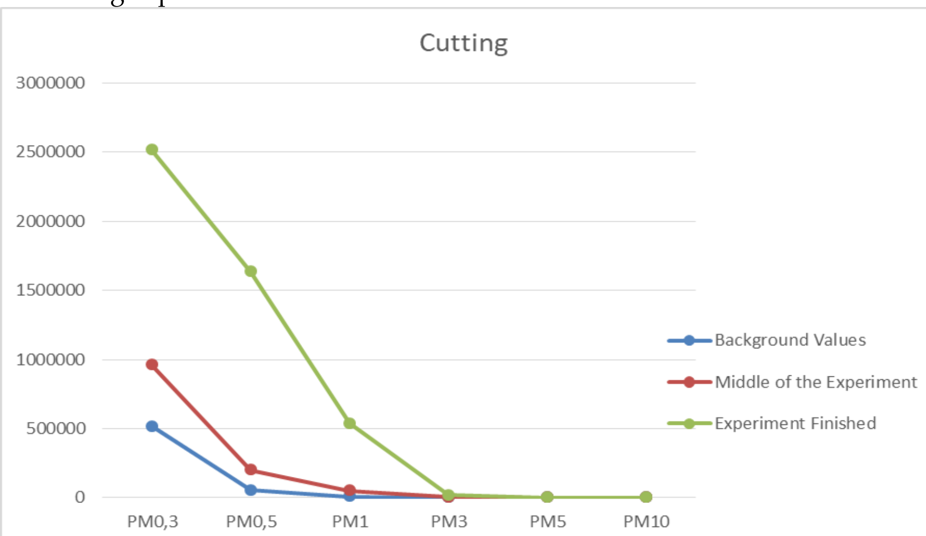

Fig. 4: *Graph of the quantitative composition of airborne particles in the ambient air during underwater cutting*

This fact may be due to the lighter weight of the particles, which affects the effect of gravitational forces, requiring a longer settling time. The second factor explaining this fact may be a greater momentum of particle emissions, as the process of underwater metal cutting was accompanied by more intense bubbling of water and release of air bubbles.

Comparative analysis of suspended particles during underwater welding and metal cutting leads to he conclusion of higher emission of particles into the atmospheric air when using an electrode for cutting in comparison with an electrode for underwater welding. Quantitative concentration of particles of fractions PM0.3; PM0.5; PM1; PM3 during underwater metal cutting is 2-2.5 times higher than content of airborne particles in comparison with underwater welding. This fact indicates high particle emission for this technological process, which is connected with high inclusion of material of the destroyed metal product in emissions.

1.3.Mass concentration of emissions from underwater welding and cutting of metals

The gravimetric method of analysis of the average daily concentration of suspended particles showed a significant presence of the PM10 fraction in the air, whose share in the total mass of particles deposited on the filters was 46.6% for underwater welding and 68.9% for underwater metal cutting.

The mass content of particles when cutting metals underwater was higher than when using electrodes for underwater welding by 2.85 times for the PM10 fraction and by 1.93 times for the total mass of deposited particles.

The mass content of particles from underwater metal cutting was 2.85 times higher for the PM10 fraction and 1.93 times higher for the total mass of deposited particles compared to the use of underwater welding electrodes.

It should be noted that the obtained values of mass concentrations of airborne particles of PM10 fraction do not exceed the MPC limits established in different countries. In Table 2 we have given the standards of Russia, Belarus and the USA on the presence of particles in the atmospheric air, which is safe for humans. The obtained data show that the mass concentration of airborne particles in the air (mg/cubic meter) is safe for people both when burning an electrode for underwater welding and when using an electrode for underwater metal cutting.

Table 2: *Mass average daily concentration of microparticles*

No.	Process	Electrode	PM10 concentration, mg/cubic meter	Concentration of all ambient particles, mg/cubic meter	GN 2.1.6.3492-17 (Russia)	GN No.37 (Belarus)	USEPA NAAQS (USA)
1	Welding	Arcair size 5/32X14 (3.97 x 356 mm) Cat. No. 42-984-004	0.014	0.03	0.06	0.05	0.05
2	Cutting	Arcair size 5/16X14(8.0 x 356 mm) Cat. No. 42-059-007	0.04	0.058			

IV. Conclusions

The analysis of the data of the measurements of the quantitative composition of the airborne particles in the air shows an absolute excess of the content of the smallest particles of the PM0.3 fraction in comparison with the particles of the larger fractions PM0.5-PM10. The number of particles in this fraction (PM0.3) is greater than the number of particles in all other fractions combined (PM0.5-PM10). The sedimentation of PM0.5-PM10 was observed during the experiment with an electrode for underwater welding as opposed to electrodes for underwater metal cutting. Quantitative content of suspended particles for underwater cutting is 2-2.5 times higher in comparison with particle emission during burning of underwater welding electrode.

The results of measurements of mass concentration of airborne particles of PM10 fraction when using electrodes for underwater welding and underwater metal cutting show that the limit values of MPC established in Russia, Belarus and the USA are not exceeded. The mass content of particles when using the electrode for underwater metal cutting is 2 times higher in comparison with the emissions when using underwater welding electrodes.

It should be noted that these are data from laboratory studies where the water depth above the level of the exposed metal plate was 20-30 cm. When working under real conditions in the open sea, the depth will be much greater, minimizing emissions into the air due to deposition of particles in the water. Therefore, future studies will be aimed at assessing the toxicological impact of particulate matter from underwater welding on marine hydrobionts.

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