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SANITARY-HYGIENIC CHARACTERISTIC OF THE PROCESS OF NONCONSUMABLE ELECTRODE ARGON-ARC WELDING OF 1201 AND 1460 ALUMINIUM ALLOYS

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The work presents the results of studying harmful substances in the air, released during nonconsumable electrode argon-arc welding of 1201 (Al–Cu–Mn) and 1460 (Al–Cu–Li) aluminium alloys. The objective of this work is performance of sanitary-hygienic assessment of the nature of aerosol and gas evolution from these alloys, in order to ensure favourable sanitary-hygienic working conditions for welders. It is shown that for 1460 alloy with lithium the intensity of welding aerosol formation is 1.5 times higher, and ozone concentration exceeds the maximum admissible concentration 3–4 times in the same welding modes. 13 Ref., 4 Tables, 5 Figures.

Keywords: *aluminium-lithium alloys, nonconsumable electrode arc welding, labour safety, harmful substances, welding aerosols*

Advance of technology promotes improvement of welded structures in different sectors of mechanical engineering. The most recent achievements of science and technology are introduced into manufacturing diverse products of modern engineering. This leads to introduction of new modifications of flying vehicles with more efficient tactico-technical and cost parameters, which are capable of preserving the required service functions for a long time in preset modes and application conditions. This is achieved by rational selection of materials and technologies of joining them, in particular, high-strength aluminium alloys. That is why higher requirements are made to the properties of the alloys and their welded joints. When selecting the alloy grade for application in specific structures, correspondence to sanitary and medical requirements is usually taken into account, alongside the main characteristics (specific weight, strength, corrosion properties, etc.) [1].

Among well-known aluminium alloys, a special place is occupied by aluminium-lithium alloys (ALA) Al–Li–Mg (1420, 1421, 1423, 1424) and Al–Li–Cu (1450, 1451, 1460, 1461, 1463, 1464) [1]. They are characterized by low density, higher modulus of elasticity and quite high strength that make them promising for manufacturing light-weight products, particularly, in aerospace industry. Their practical application in flying vehicles allowed reducing the structure weight by 8–15 %, owing to high specific strength and increased modulus of elasticity.

At present the conditions of formation of welding aerosols (WA) and gases, evolving in welding of different grades of steels and iron-based alloys have been comprehensively studied from the viewpoint of sanitary-hygienic requirements [2–4]. A little studied area is WA, forming in welding non-ferrous alloys, in particular, aluminium. Sanitary-hygienic assessment of ALA was performed only at the stage of metallurgical production [5]. As regards welding production, it is practically absent. Therefore, lithium toxicity [6] and mechanism of its compound formation under the conditions of its release in various welding processes, applied in manufacture of aerospace equipment, attract increased interest. It is known that lithium belongs to light-weight materials of higher toxicity [2].

The objective of the work is performance of sanitary-hygienic assessment of the nature of aerosol and gas evolution from 1201 (Al–Cu–Mn) and 1460 (Al–Cu–Li) alloys during nonconsumable tungsten electrode argon-arc welding (TIG-argon).

Investigations were conducted on sheet semi-finished products of high-strength complex aluminium alloys 3.0 mm thick. Automated TIG-argon welding was performed with welding head ASTV-2M from TPS-450 power source of Fronius, Austria. These investigations were conducted in different current modes. For both the alloys, welding current was equal to: I_w = 140, 200 and 260 A. Condition of welding section air was assessed in keeping with the requirements of GOST 12.1.005–88.

Table 1. Chemical composition of aluminium alloys in keeping with GOST 4784–97, wt.%

Alloy grade	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Zr	Li	Sc	Other
1201	0.20	0.30	5.8–6.8	0.2–0.4	0.2	–	0.1	0.02–0.10	0.10–0.25	–	–	(0.05–0.15)V
1460	0.10	0.15	2.6–3.3	0.1	0.1	0.05	0.25	0.01–0.06	0.06–0.15	2.0–2.5	0.05–0.14	(0.008–0.1)Be

Chemical composition of welded metal is given in Table 1.

Selection of WA samples was performed by air intake by the method of its full capture. Not less than six samples were taken in each welding mode to ensure the validity of the obtained results. WA concentration in working zone air was assessed by gravimetric method [7], and the content of harmful components in WA, such as aluminium, manganese, copper and lithium compounds was determined by the procedure of [8]. Ozone concentration was determined using colorimetric method by selection of respective samples with «Taifun» sampler and absorber with potassium iodide solution. Presence of carbon oxide and nitrogen dioxide was determined using Aquilon 1-1 and Aquilon 1-4 instruments.

Investigation of welding aerosols released into the working zone air at TIG-argon welding of aluminium-lithium alloys.

Results of studying the sanitary-hygienic characteristics in mechanized TIG-argon welding of 1460 and 1201 alloys showed that the composition of main harmful substances of WA, which are released into the working zone air during welding include aluminium, manganese, copper, lithium and other elements.

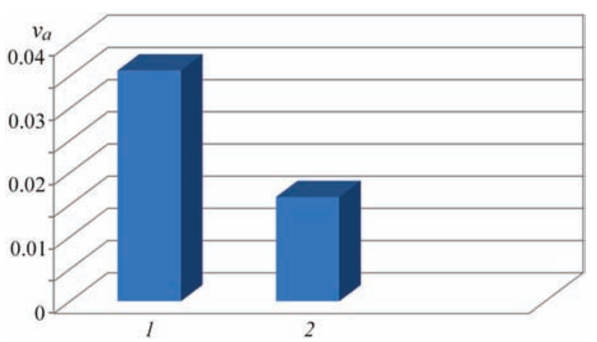

Figure 1. Intensity of WA generation in TIG-argon welding (I_w = = 140 A): *1* — 1460 alloy with Li; *2* — 1201 alloy without Li

For lithium-containing 1460 alloy at welding current I_w = 140 A the intensity of aerosol formation (V_a) is equal to 0.03586. In welding of alloy 1201 without lithium at current I_w = 140 A V_a is equal to 0.0162. Analysis of the results showed that in welding of the studied alloy grades 1460 and 1201 at the same current values (Figure 1) V_a is 3.5 times higher than that of 1460 alloy.

When studying the working zone air (Figure 2), it was found that weight fraction of the main harmful components evolving in WA in welding 1460 alloy in the following modes: I_w = 140 A and I_w = 200 A, is increased at current rise.

Comparison of the results of studying 1460 and 1201 alloys in TIG-argon welding at the same current I_w = 140 A shows that under the conditions of welding the weight fraction of harmful components in WA differs essentially. Weight fraction of the substance of aluminium, manganese and copper in WA composition is much higher in 1201 than that in 1460 alloy (Figure 3).

As refractory tungsten used in TIG welding does not participate in WA formation, and the volume of molten filler wire is quite small, the quantity of metal evaporating in this process is also small.

Studying gases released into the working zone air in TIG-argon welding of aluminium-lithium alloys.

During ALA welding, release of WA into the working zone air is accompanied by generation of harmful welding gases, which also belong to the group of chemically hazardous and harmful production factors [9]. The cause for their formation in electric arc welding is presence of a high temperature welding arc, consisting of an electric discharge and ionized mixture of gases, and metal vapours, as well as their influence on the materials being welded, surrounded by argon and air. Part of the gases forms as a result of running of the process of thermal dissociation of the

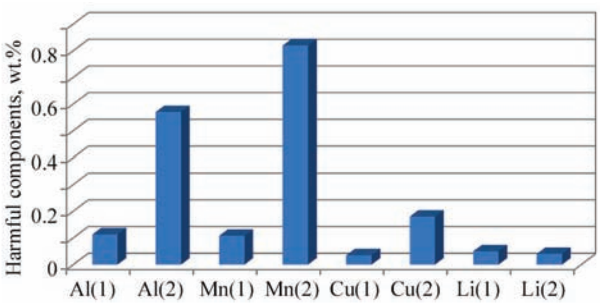

Figure 2. Mass fraction of the main harmful components of 1460 alloy in WA: *1* — I_w = 140; *2* — 200 A

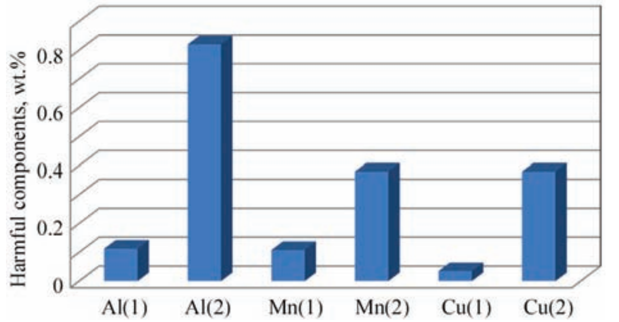

Figure 3. Mass fraction of harmful components in WA at I_w = = 140 A; *1* — 1460 alloy; *2* — 1201 alloy

Table 2. Maximum admissible concentrations (MAC) of the main gases in working zone air

Substance	MAC, mg/m^3	Class of hazard
Nitrogen dioxide	2	3
Ozone	0.1	1
Carbon oxide	20	4

components of materials being welded which evaporate in the welding zone, others form from the molecules of ambient gas medium as a result of the impact of ultraviolet radiation (UVR) of the welding arc [10]. Composition of the forming mixture of harmful gases depends on chemical composition of welding materials, shielding gases and air. Carbon oxide, nitrogen oxides and ozone are the most common in the composition of welding gases. Their characteristics are given in GOST 12.1.005–88 [11]. Toxic gases tend to affect the respiratory tract, lungs and human mucous tissues. In terms of the degree of the effect on the body, ozone is considered to be extremely hazardous (1st class of hazard). Nitrogen dioxide belongs to the 3rd class of moderately hazardous substances, carbon oxide — to the 4th class of low-hazard substances (Table 2).

Chemical kinetics of the studied substances points to the decisive role of UVR in the process of formation of such toxic gases as ozone and nitrogen oxides. Another factor, determining the volume of gases formed in welding, are overall dimensions of the weld pool under the high-temperature welding zone, as it is exactly carbon oxide that forms in the welding zone volume, and nitrogen oxide forms on the boundary of its contact with ambient air. UVR intensity is determined by temperature and welding current values. Therefore, it is anticipated that generation of ozone and nitrogen dioxide will largely depend on welding mode level [12]. Thus, the most noticeable impact of welding current will determine the process of formation of the respective ozone and nitrogen dioxide. It is anticipated that variation of carbon monoxide concentration will be not so significant, and its volume, either, due to the welding zone dimensions.

Results of investigations of the level of CO and NO_2 concentration in the welder's workplace in argon-arc welding of 1460 ALA, depending on the welding mode, are given in Table 3, allowing for the error. As shown by their analysis, welding current value has a significant influence on the process of formation of nitrogen dioxide, raising its concentration to the level, exceeding MAC. Carbon monoxide concentration practically does not change. According to the data in Figure 4, dependence of nitrogen dioxide concentration on welding current is approximated with a high degree of accuracy by a parabola, and, therefore, the volume of the forming toxic gas increases considerably at increase of current, accompanying the welding process. At intensive welding modes, with more than 200 A currents, NO_2 concentration in the working zone is higher than MAC.

Table 3. CO and NO_2 concentration in the workplace at argon-arc welding of 1460 ALA in different welding modes

Welding current *I*, A	Mass concentration, mg/m^3	
	CO	NO_2
140	0.4 ± 0.7	1.1 ± 0.5
200	0.5 ± 0.8	1.3 ± 0.5
260	0.5 ± 0.8	2.5 ± 0.6

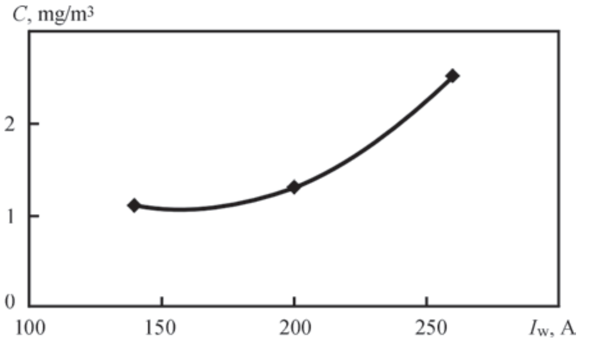

Figure 4. Dependence of mass concentration of nitrogen dioxide in the workplace in argon-arc of 1460 ALA

Analysis of sanitary-hygienic characteristics obtained under the conditions of mechanized TIG-argon welding, showed that the main cause for ozone generation during welding operations is photodissociation of air oxygen molecules, running under the impact of welding arc UVR (Table 4).

This is exactly the process that causes release of atomic oxygen with its subsequent attachment to oxygen molecule. Influence of arc UVR on O_2 molecules also leads to increase of ozone generation intensity, depending on the wave length of radiation, generated by the welding arc [13].

Results of studying the quantity of ozone in the working zone air showed that its concentration depends on electric current value in welding. The larger it is, the higher the gas concentration (Figure 5). For 1460 alloy at I_w = 140 A the concentration is just 0.13 mg/m^3, and at I_w = 260 A — 49 mg/m^3, and in all the studied welding current modes it exceeds MAC.

Table 4. Ozone content in working zone air in TIG-argon welding of 1460 and 1201 alloys

Number	Welding mode		Ozone, mg/m^3
	I_w, A	U_a, V	
1460 alloy			
1	140	12–15	0.13
2	260	12–15	0.49
1201 alloy			
3	140	12–15	0.04
4	260	12–15	0.08

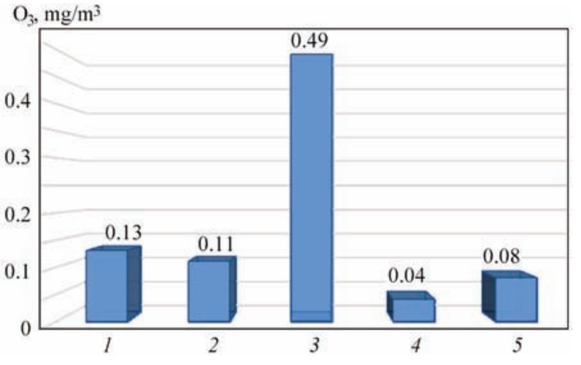

Figure 5. Dependence of ozone concentration on the mode of TIG-argon welding of 1460 alloy (*1* — I_w = 140; *2* — 200; *3* — 260 A) and 1201 (*4* — I_w = 140; *5* — 260 *A*)

The level of ozone concentration in welding 1201 alloy is much lower, being within MAC range, but it also rises with current increase in welding.

Thus, when studying the sanitary-hygienic conditions of performance of TIG-argon welding of 1460 ALA, it was found that the process is accompanied by formation of toxic gases in the workplace, namely nitrogen dioxide and carbon monoxide. Mass concentration of carbon monoxide of approximately 1 mg/m^3 in the range of welding currents of 140–260 A is much lower than its MAC, and mass concentration of nitrogen dioxide strongly depends on current and exceeds its MAC at high values. Welding current increase leads to increase of ozone concentration for 1460 and 1201 alloys. Here, for 1460 alloy ozone concentration is much (3 to 4 times) higher than MAC. It is found that UVR is the main factor of toxic gas generation in the working zone in TIG welding of the studied aluminium alloys.

Generalization of the derived results of sanitary-hygienic assessment of the processes running in the working zone in TIG-argon welding of 1201 and 1460 alloys showed that the working zone air contains WA with complex chemical composition of elements, as well as toxic gases. The air mixture composition includes the following aerosols and gases: aluminium, lithium, manganese, copper, ozone, carbon oxide, nitrogen dioxide, and other compounds. In other words, welder's labour conditions are still unsatisfactory. In order to provide more favourable labour conditions, it is necessary to additionally take a number of known preventive measures for protection of welder's breathing organs from deleterious impact of WA elements and toxic gases.

In order to provide favourable sanitary-hygienic conditions of welder's labour during work performance and ensure a considerable service life of a welded structure from aluminium-lithium alloys, it is necessary to further study the toxicity of individual WA components and to develop a system of technological recommendations, which will reduce the risk of toxic aerosol formation.

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