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Analysis of weldability of aluminum and aluminum alloys

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ABSTRACT: This article provides an analysis of the weldability of aluminum and aluminum alloys

KEY WORDS: aluminum, welding, duralumin, oxygen, hydrogen

I. INTRODUCTION

Aluminum alloys are used in welded structures for various purposes. Their main advantages as structural materials are low density, high specific strength, and high corrosion resistance.
Pure aluminum, due to its low strength, is used for the manufacture of structures in some cases in the chemical, food and electrical industries. High-purity aluminum is used in new technology industries, including the production of semiconductors. Semi-finished aluminum alloys are mainly used as structural materials.

II. LITERATURE SURVEY

In terms of the ratio of strength and fluidity to density, high-strength aluminum alloys are significantly superior to cast iron, low-carbon and low-alloy steels, pure titanium and are second only to high-alloy high-strength steels and titanium alloys. [1,2]
Aluminum alloys are divided into casting and wrought according to the solubility limit of elements in solid solution. [3]
In welded structures, semi-finished products (sheets, profiles, pipes, etc.) from wrought alloys are mainly used. [4]
The concentration of alloying elements of deformable alloys is less than the solubility limit, and when heated, these alloys can be transferred to a single-phase state, which ensures their high deformability. [5-6]

III. METODOLOGY

Most of the elements that make up aluminum alloys have limited solubility, which changes with temperature. This gives the alloys the ability to be strengthened by heat treatment. In this regard, wrought alloys are divided into alloys that are

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not strengthened by heat treatment (with a concentration of alloying elements below the solubility limit at 20°C), and alloys that are strengthened by heat treatment (with a concentration of alloying elements above this limit).
Deformable alloys that cannot be strengthened by heat treatment include technical aluminum AD1, AD, aluminum-manganese alloy AMts (Al + 1,3% Mn) and the group of alloys of the A1-Mg system: AMg1, AMg2, AMg3 and AMg6. In welded joints, these alloys are capable of maintaining up to 95% of the strength of the base metal with high ductility and high corrosion resistance.
Thermally hardenable wrought aluminum alloys can be divided into several groups.
1. Duralumin alloys based on the Al-Cu-Mg system: D1, D16, D19, VAD1, VD17, M40, D18.
2. Aviali - alloys based on the Al-Mg-Si and Al-Cu-Mg-Si systems: AB, AD31, AD33 AD35, AK6, AK6-1, AK8.
3. Alloys based on the Al - Cu - Mg - Fe - Ni system: AK2, AK4, AK4-1.
4. Alloys based on the Al-Cu-Mn system: D20, D21 and VAD-23 (Al-Cu-Mn-Li-Cd).
5. Alloys based on the Al-Zn-Mg-Cu system: B93, B95, B96, B94.
6. Alloys based on the Al-Mg-Zn system: V92, V92Ts, ACM.
Of the listed alloys, those that can be welded include: AD, AD1, AMts, AMg, AMg3, AMg5V, AMg6, AB, AD31, AD33, AD35, M40, D20, VAD1, V92Ts.
For welding work, wire made of aluminum and aluminum alloys is used in accordance with GOST 7871-75.
The metallurgical features of welding aluminum and its alloys are determined by their interaction with environmental gases, the intensity of evaporation of alloying elements, as well as the characteristics of crystallization under the conditions of the welding process. At 20°C, aluminum oxidation processes proceed according to a parabolic law.
An important characteristic of the aluminum oxide film is its ability to adsorb gases, especially water vapor. The latter is retained by the oxide film until the melting temperature of the metal.
The coefficient of thermal expansion of the oxide film is almost 3 times less than the expansion coefficient of aluminum, therefore, when the metal is heated, cracks form in it. If aluminum contains alloying additives, the composition of the oxide film can change significantly. The resulting complex oxide film in most cases is more friable, hygroscopic and has worse protective properties.
The oxide film on the surface of aluminum and its alloys complicates the welding process. Having a high melting point (2050°C), the oxide film does not melt during the welding process and covers the metal with a durable shell, making it difficult to form a common pool. Due to the high adsorption capacity for gases and water vapor, the oxide film is a source of gases dissolving in the metal and an indirect cause of the occurrence of various types of discontinuities in it. Particles of the oxide film that get into the bath, as well as some of the films from the surface of the base metal that are not destroyed during the welding process, can form oxide inclusions in the seams, reducing the properties of the joints and their performance.
To carry out welding, measures must be taken to destroy and remove the film and protect the metal from re-oxidation. For this purpose, special welding fluxes are used or welding is carried out in an atmosphere of inert protective gases. Due to the high chemical strength of the Al_2O_3 compound, the reduction of aluminum from the oxide under welding conditions is practically impossible. It is also impossible to bind Al_2O_3 into strong compounds with a strong acid or base. Therefore, the action of fluxes for aluminum welding is based on the processes of dissolving and washing off the dispersed oxide film with molten flux. Under conditions of electric arc welding in inert shielding gases, the removal of the oxide film occurs as a result of electrical processes occurring at the cathode (cathode sputtering).
Under these conditions, there is a need to increase the quality requirements for pre-treatment of parts before welding in order to obtain a thin and uniform film over the entire surface of the edges being welded. To prevent additional oxidation and clogging of the bath with oxides, it is necessary to use a high-purity protective gas. The solubility of hydrogen in aluminum changes at different temperatures (fig. 7.3).
The concentration of hydrogen dissolved in a metal [H]p depends on the pressure p_{H_2} of molecular hydrogen that is in equilibrium with it:

$$[H]_p = K\sqrt{p_{H_2}}\,e^{-\frac{Q}{2RT}},$$

where is the molar specific heat of hydrogen dissolution in the metal, J/mol;
T—universal gas constant, J/(mol·K); K is a constant that depends on temperature.
Under real conditions, the partial pressure of molecular hydrogen in the gas phase of the arc is negligible.

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Therefore, the main source of hydrogen dissolving in the weld pool is the reaction between the moisture contained in the oxide film and the metal:

$$2A1+ 3H_2O=Al_2O_3+6H$$

As a result of this reaction, the concentration of atomic hydrogen in the surface layer of the atmosphere in contact with the metal may correspond to the high pressure of molecular hydrogen in equilibrium with the metal. Therefore, in the presence of water vapor in the bath area, the concentration of hydrogen dissolved in the metal may be much higher than the equilibrium one. When cooled, dissolved hydrogen, due to a decrease in solubility, tends to be released from the metal. Bubbles of released hydrogen, not having time to float out of the bath, remain in the seam, forming pores. Therefore, the main measure to combat porosity when welding aluminum is to reduce the concentration of hydrogen dissolved in it to a limit below 0,69—0,7 cm^3/100 g of metal.

The main source of hydrogen dissolving in the weld metal during argon-arc welding is moisture adsorbed by the metal surface and included in the oxide film in the form of hydrated oxides. Its quantity is determined by the condition of the metal surface and depends on its treatment before welding.

Prevention of porosity when welding aluminum can be facilitated by reducing the specific surface area of the filler wire by increasing its diameter and reducing the share of filler metal in the formation of the weld. Rational treatment of the surface of the wire and base metal is used to reduce the thickness of the oxide film and the amount of moisture present in it.

Magnesium increases the solubility of hydrogen in aluminum, so the increased tendency to porosity when welding aluminum-magnesium alloys is explained by a different mechanism of pore formation. On the surface of alloys containing magnesium, there is an oxide film consisting of Al_2O_3 and MgO oxides. Such a film has a greater thickness, lower density due to defects in its structure, and a larger moisture reserve than a film made from Al_2O_3. During the welding process, when the base and filler metals are melted, part of the moisture contained in the internal defects of the film does not have time to react. The film particles entering the bath contain residual moisture, which decomposes with the release of hydrogen. The hydrogen formed in film defects transforms into a molecular form and is then released in the liquid metal of the bath in the form of bubbles, bypassing the dissolution stage.

With this mechanism of pore formation, their total volume (cm^3/100 g) depends on the moisture reserve in the film and the lifetime of the bath, that is, the time during which the bubble can develop unhindered in the volume

$$\sum V_{П} = \frac{k\left(S_0 a_1 + S_{пр} a_2\right)}{F_{ш}\gamma} 100,$$

where S_0 and S_{pr} are the surface areas of the base and filler metal involved in the formation of the weld; k is a coefficient that depends on the heat input and determines the lifetime of the weld pool. With this mechanism of pore formation, as measures to reduce porosity, in addition to the usual ones associated with the use of rational surface treatment of the wire and base metal, as well as reducing the specific surface of the wire involved in the formation of the weld, tightening the regimes becomes an effective measure to combat porosity. However, when the regimes become more stringent, there is a danger of increasing hydrogen pressure in discontinuities, which makes it difficult to perform multi-layer welds and welding.

The crystalline structure of the weld metal determines its mechanical properties. Pure aluminum, when crystallized, has the ability to form a coarse, coarse-crystalline structure in the weld metal.

When welding aluminum alloys, the crystal structure and mechanical properties of the weld metal can vary depending on the composition of the alloy, the filler metal used, welding methods and modes. All welding methods are characterized by high cooling rates and directed heat removal. During crystallization under these conditions, dendritic segregation often develops, which leads to the appearance of eutectic in the metal structure. Eutectic reduces the ductility and strength of the metal. In this regard, crystallization cracks may occur in the seams during the crystallization process.

Improving the crystalline structure of weld metal when welding aluminum and some of its alloys can be achieved by modification during the welding process. Therefore, special wires with additives of modifiers (Zr, Ti, B) are increasingly used as a filler metal in welding. The introduction of these elements in small quantities makes it possible to improve the crystalline structure of the weld metal and reduce their tendency to crack. Stirring the metal of the weld pool during the welding process using an external magnetic field also reduces the tendency of the weld metal to crack.

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When choosing a filler metal, one should also take into account the possibility of various chemical compounds appearing in the weld metal structure. When welding aluminum alloys, including magnesium, using filler wire containing silicon, needle-shaped Mg_2Si precipitates appear in the weld metal and especially in the fusion zone, reducing the plastic properties of the welded joints. Insignificant additions of sodium, which can enter the weld metal through fluxes, adversely affect the properties of compounds made from alloys of the Al-Mg system.

The properties of welded joints also depend on the processes occurring in the heat-affected zones. When welding pure aluminum and alloys that are not hardened by heat treatment, grain growth and some softening caused by the removal of cold hardening are observed in the heat-affected zone. Grain growth and softening of cold-worked metal during welding vary depending on the welding method, modes and degree of previous cold-working of the alloy. The weldability of Al-Mg alloys is complicated by their increased sensitivity to heat and their tendency to form porosity and swelling in areas of the base metal immediately adjacent to the weld.

The ability of these alloys to form porosity in heat-affected zones is associated with the presence of molecular hydrogen in the ingots. After processing such ingots (pressing or rolling), discontinuities form in the metal in the form of channels or collectors in which hydrogen is under high pressure. To check the quality of the metal intended for welding, it is recommended to conduct a special test. Welded structures made of aluminum and its alloys are prone to warping, which is explained by the relatively high coefficient of thermal expansion. Reducing deformations in structures can be achieved through the use of technological measures (selection of an appropriate welding method, selection of optimal modes, heating, rational order of seams, etc.).

IV.CONCLUSION

The results of the research performed provided the necessary basis for choosing the optimal method for welding aluminum and aluminum alloys.

REFERENCES

[1]. Ermatov Z.D. Welding of special steels and alloys. T: Fan va texnologiyalar nashriyot-matbaa uyi, 2023. - 180 p.

[2]. Ermatov Z.D., Dunyashin N.S., Galperin L.V., Nikitin V.N., Sadykov Zh.N. Fusion welding technology and equipment. T: Fan va texnologiyalar nashriyot-matbaa uyi, 2023. -220 p.

[3]. Khudoyorov S.S., Dunyashin N.S., Ermatov Z.D., Sadikov J.N., Saidakhmatov A.S., Abdurakhmonov M.M. Study interaction of metal with complex gases containing oxygen in manual arc welding// International Journal Of Advanced Research in Science, Engineering and Technology – India, 2023. – Vol.10, № 1 (January). – pp. 20324 – 20328

[4]. Verkhoturov A.D. Methodology for the creation of welding consumables: monograph - Khabarovsk: Publishing House of the Far Eastern State University of Railway Engineering, 2009. - 128 p.

[5]. Khudoyorov S.S., Galperin L.V, Dunyashin N.S., Ermatov Z.D., Saidakhmatov A.S., Abdurakhmonov M.M. Study interaction of molten metal and slag in arc welding// International Journal Of Advanced Research in Science, Engineering and Technology – India, 2022. – Vol.9, № 9 (September). – pp. 19771 – 19775

[6]. Khudoyorov S.S., Galperin L.V., Dunyashin N.S., Ermatov Z.D., Saidakhmatov A.S., Abdurakhmonov M.M. Study of the refining process in electric arc welding// International Journal Of Advanced Research in Science, Engineering and Technology – India, 2022. – Vol.9, № 12 (December). – pp. 20244 – 20249

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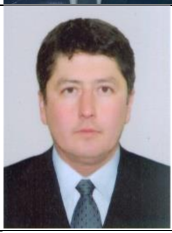
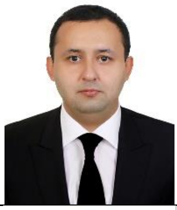
	**Sadikov Jaxongir Nasirdjanovich** , Associate Professor, Doctor of Philosophy in Technical Sciences (PhD), was born March 10, 1975 year in Tashkent city, Republic of Uzbekistan. Has more than 20 published scientific works in the form of articles, journals, theses and tutorials. Currently works as researcher at the department of "Engineering technology" in Tashkent State Technical University
	**Khudoyorov Sardor Sadullaevich**, Associate Professor, Doctor of Philosophy in Technical Sciences (PhD), was born March 7, 1989 year in Tashkent city, Republic of Uzbekistan. Has more than 50 published scientific works in the form of articles, journals, theses and tutorials. Currently works at the department of "Technological machines and equipment" in Tashkent State Technical University.
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