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Research on welding technology for aluminum alloys

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ABSTRACT: This article provides an analysis of the technology of welding aluminum alloys

KEY WORDS: alloy, silumin, duralumin, welding, technology

I. INTRODUCTION

Aluminum is one of the most abundant elements in nature; it has low density, high electrical and thermal conductivity, high corrosion resistance in oxidizing environments and resistance to becoming brittle at low temperatures. Aluminum density 2.7 g/cm^3. The thermal conductivity of aluminum is three times higher than that of mild steel. The melting point of pure aluminum is 657° C. When heated, aluminum easily oxidizes, forming refractory aluminum oxide (Al_2O_3), which melts at temperatures above 2060° C. The refractory film of oxide and the possibility of the formation of pores and crystallization cracks in the weld metal are the main difficulties when welding aluminum.

The reason for the formation of pores in welds is hydrogen, which, due to a sharp change in solubility during the transition of aluminum from a liquid to a solid state, tends to escape into the atmosphere. Crystallization cracks in welds of pure aluminum arise due to the increased silicon content and decrease with the introduction of iron additives into the aluminum.

II. LITERATURE SURVEY

In technology, not only pure aluminum is used, but also its alloys with manganese, magnesium, copper and silicon. Aluminum alloys are stronger than pure aluminum. Cast aluminum alloys (AL grades), containing 4-5% copper (AL7) or 10 to 13% silicon (AL2), or 9,5-11,5% magnesium (AL8), are capable of casting well. Casting alloys of aluminum and silicon are called silumins. [1]

In welded structures, wrought alloys are most widely used: thermally non-hardening aluminum-manganese (AMts), containing from 1 to 1,6% manganese, and aluminum-magnesium (AMg), containing up to 6,8% magnesium. [2]

In aircraft construction, thermally hardenable duralumin alloys (D alloys) are used. Duralumin grade D1 contains: 3,8-4,8% copper, 0,4-0,8% magnesium, 0,4-0,8% manganese, the rest is aluminum. Highly alloyed duralumin D16 contains: 3,8-4,9% copper, 1,2-1,8% magnesium, 0,3-0,9% manganese, the rest is aluminum. [3]

After heat treatment, the D16 alloy has a tensile strength of 420–460 MPa and a relative elongation of 15–17%. [4]

Pure aluminum, AMts, AMg and silumin alloys lend themselves well to welding. Heat-strengthening alloys D are welded worse. This is due to the fact that in the weld of such an alloy the structure of a cast metal is obtained, the strength of which is half that of the base rolled metal. In addition, due to significant shrinkage of the weld metal and its low ductility,

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cracks appear in the seams during the welding process. During welding, the base metal is annealed, which leads to a deterioration in the mechanical properties of the welded joint. [5]
Before welding, the edges are washed for 10 minutes with a solution of 20-25 g of caustic soda and 20-30 g of sodium carbonate per 1 dm^3 of water at a temperature of 65° C, and then in water at room temperature, after which they are etched for 2 minutes in 25% - a solution of orthophosphoric acid (for AMts and AMg alloys) or in a 15% solution of nitric acid (for alloys D and, AMg). After etching, the edges are washed with warm and cold water and wiped dry with a cloth. To avoid new oxidation, the metal is welded no later than 8 hours after preparation. [6]

III. METODOLOGY

When preparing parts made of aluminum alloys for welding, the welded edges are profiled and surface contaminants and oxides are removed. Degreasing and removal of surface contaminants is carried out using organic solvents or by treatment in special alkaline baths.
White spirit, technical acetone, and RS-1 and RS-2 solvents are used as solvents for degreasing parts made of aluminum alloys.
Degreasing of aluminum alloys can be carried out in an aqueous solution of the following composition: 40-50 g/l technical trisodium phosphate ($Na_3PO_4 \cdot 12H_2O$), 40-50 g/l soda ash (Na_2CO_3), 25-30 g/l liquid glass (Na_2SiO_3). Bath temperature 60-70°C, treatment time 4-5 minutes. Removing the surface oxide film is the most critical operation in the preparation of parts. In this case, the old oxide film obtained as a result of long-term storage and containing a significant amount of adsorbed moisture is mainly removed.
The oxide film can be removed using metal wire brushes with a diameter of 0,1-0,2 mm with a pile length of at least 30 mm or by scraping. After cleaning, the edges are again degreased with a solvent. The duration of storage of parts before welding after cleaning is 2-3 hours. On a larger scale of production, the surfaces of parts are etched.
Etching in alkaline baths is widely used using the following technology: 1) degreasing in a solvent; 2) etching in a bath of an aqueous solution of 45-50 g/l NaOH; bath temperature 60-70°C; etching time 1-2 minutes for unclad materials; if it is necessary to remove technological cladding (for example, on the AMg6 alloy), the etching time is selected at the rate of 0,01 mm in 2,5-3 minutes; 3) rinsing in running hot water (60-80°C), then in cold water; 4) clarification in a 30% aqueous solution of HNO_3 at 20°C for 1-2 minutes or in a 15% aqueous solution of NHO_3 at 60°C for 2 minutes; 5) rinsing in cold running water, then in hot water (60-70°C); 6) drying with hot air (80-90°C).
When welding parts made of aluminum alloys containing high concentrations of magnesium (for example, AMg6 alloy), the edges of the parts and especially their end surfaces must be cleaned with a scraper before welding. The same baths are used to process electrode wire made of aluminum alloys.
In many cases, electrochemical polishing is recommended for finishing filler wire after pickling, especially for alloys containing magnesium. A solution of the following composition is used as an electrolyte: 700 ml of orthophosphoric acid H_3PO_4, 300 ml of sulfuric acid H_2SO_4, 42 g of chromium oxide CrO_3.
During the wire polishing process, the electrolyte temperature is maintained at 95–100°C. When the electrolyte overheats above 100°C, the surface is etched, and when the temperature drops below 90°C, the polishing process stops. The quality of wire preparation is controlled by surfacing process beads with subsequent assessment of the porosity of the weld metal by weighing.
When fusion welding aluminum alloys, the most rational type of joints is butt joints, which can be made using any welding method. To eliminate oxide inclusions in the weld metal, linings with rationally shaped grooves or cutting edges on the back side of the seam are used, which in some cases ensures removal of oxide inclusions from the joint into the forming groove or groove.
The use of fluxes in argon-arc welding, applied to the end surfaces before welding in the form of a dispersed suspension of fluorides in alcohol, also helps to reduce the number of oxide inclusions in the weld metal.
When cutting edges, their opening angle must be limited in order to reduce the volume of deposited metal in the joint, and, consequently, the likelihood of defect formation.
Gas welding. When welding aluminum alloys, it is recommended to use a flame of a gas mixture O_2:C_2H_2=1,1÷1,2. The flame power is selected depending on the thickness of the metal being welded. To protect the metal from oxidation and remove oxides from the edges of the parts being welded, special fluxes are used.
The most common flux is AF-4A with the following composition: 28% NaCl, 50% KCl, 14% ZrCl, 8% NaF. When welding, flux is introduced either with a filler rod, or is pre-applied to the edges in the form of a paste diluted in water. It is impossible to store flux for a long time (more than 8-10 hours) in a diluted state. Welding wire made of aluminum or its alloys is used as a filler metal. The diameter of the filler wire depends on the thickness of the metal being welded.

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Manual electric arc welding of aluminum and its alloys can be carried out with a carbon or coated metal electrode. Carbon electrode welding is used for welding defective castings, welding aluminum tires, and sometimes for welding thin material along flanges. In this case, filler material is used in the form of rods coated with flux. Carbon arc welding is carried out using direct current of direct polarity. Carbon or graphite rods of different diameters can be used as electrodes. More often, arc welding is used with coated metal electrodes, the rods of which are made from welding wire (GOST 7871-75) with coatings made of a mixture of chloride and fluoride salts. A solution of sodium chloride in water or a solution of dextrin is used as a binder, and an aqueous solution of carboxylmethylcellulose (CMC) is also proposed.

OZA-1 electrodes with a rod made of SvA1 wire are used for welding aluminum, and OZA-2 electrodes with a rod made of SvAK5 wire are used for welding defective castings. Welding is carried out using direct current of reverse polarity.

Automatic electric arc welding along a layer of flux is produced with a consumable electrode and is used for butt joints of metal with a thickness of 4 mm and above. The arc is powered by direct current of reverse polarity.

To join aluminum, an automatic arc welding process using a consumable electrode under a layer of flux is used. For this purpose, fluxes with reduced electrical conductivity are used. For example, the composition of the ZHA-64 ceramic flux is as follows: 30-44% cryolite, 48-38% potassium chloride, 19-15% sodium chloride, 3-3,5% quartz sand.

The flux is mixed with an aqueous solution of carboxylmethylcellulose (14-16% of the charge weight), rubbed through a sieve and calcined at 280-320°C for 6 hours. Welding is often done with a split electrode. In structures operating in corrosive environments, flux residues must be carefully removed after welding.

Gas shielded arc welding is widely used for welding aluminum and its alloys. Argon with a purity of at least 99,9% or a mixture of argon and helium is used as a shielding gas. When welding with a consumable electrode, argon with the addition of up to 5% O_2 is sometimes used.

The main advantage of the gas tungsten arc welding process is the high stability of the arc. Thanks to this, the process is used when welding thin sheets. It is carried out by alternating current from sources with falling external characteristics. Welding is carried out manually or automatically. Automatic welding is carried out without feeding or with feeding filler wire. When manually welding thin sheets with a non-consumable electrode without an additive (along the flange) or with an additive in one pass, the torch is moved with a forward angle. The angle of inclination of the burner to the flat surface of the part is about 60°. The filler wire is fed at the smallest possible angle to the flat surface of the part.

In mechanized or automatic welding with a non-consumable electrode, the torch is positioned at right angles to the surface of the part, and the filler wire is fed so that the end of the wire rests on the edge of the weld pool; the feed speed varies from 4-6 to 30-40 m/h depending on the thickness of the material.

Expansion of technological capabilities when welding metal of large thicknesses is achieved through the use of the method of submerged arc welding with a tungsten electrode. The method allows you to weld material up to 20 mm thick in one pass. In this case, special tungsten electrodes with yttrium and tantalum additives and welding torches with improved protection of the welding zone are used. When submerged arc welding of aluminum alloys, power sources of the IPD-1000 type are used.

Consumable electrode welding in shielding gas is used for material with a thickness of more than 3 mm. To power the arc when welding with a consumable electrode, direct current sources with a rigid external current-voltage characteristic are used. Welding is carried out using a current of reverse polarity, which ensures reliable destruction of the oxide film due to cathode sputtering and normal formation of seams. Welding can be performed semi-automatically or automatically on backing plates with a forming groove. The advantage of the consumable electrode welding process is high productivity, which increases with increasing metal thickness.

Semi-automatic welding with a consumable electrode is possible in various spatial positions and allows you to replace the less advanced process of welding aluminum alloys with coated electrodes (semiautomatic machines with a pull-type feed mechanism are recommended).

Pulse-arc welding with a consumable electrode expands the possibility of welding aluminum alloys in various spatial positions. At the same time, the formation of seams is improved, the residence time of the metal of the weld pool in the molten state is regulated, and hence the occurrence of metallurgical reactions.

In plasma welding (compressed arc), the energy concentration in the heating spot is high, which makes this type of welding promising for joining aluminum alloys. The advantage of plasma welding is high speed, a significant reduction in the heat-affected zone, process stability, due to which control and maintenance of a constant arc length are not required, which makes manual welding easier. During plasma welding, due to deep penetration, the share of the base metal in the formation of the seam sharply increases. However, it is necessary to ensure the accuracy of assembling parts for welding and guiding the torch along the joint. For aluminum alloys it is necessary to use plasma welding with DC arc power.

When plasma welding with direct current of reverse polarity, torches with enhanced forced cooling of the tungsten electrode are used.

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Using a low-current compressed arc (microplasma), it is possible to weld aluminum alloys with a thickness of 0,2-1,5 mm at a current strength of 10-100 A. For microplasma welding, argon with a purity of at least 99,98% is used; Helium with a purity of 99,95% is used as a shielding gas. Helium, protecting the weld pool from the atmosphere, impedes the development of the ionization front in the radial direction, and additionally compresses the arc, making it spatially stable. Welding torches are designed for the use of lanthanum tungsten electrodes with a diameter of 0,8–1,5 mm.

IV.CONCLUSION

The results of the research performed provided the necessary basis for the development of welding technology for aluminum alloys

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