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Prospective Aluminum alloys for the production of soldered structures

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ABSTRACT

The current state of the industry requires an increase in use of aluminium and aluminium-based alloys. The main advantages of aluminium are its low density (2.7 g/cm^3), high strength characteristics, good thermal and electrical conductivity, processability, and corrosion resistance. Consumers of aluminium are such industries as aviation, shipbuilding, automotive, construction, railway transport, oil and chemical industries. Aluminium material is widely used for the manufacture of ship hulls, frames and containers of railway vehicles, cooling radiators,etc[1].The study of aluminium alloys has shown that their melting under the oxide film and its destruction are not possible with all elements that form eutectic with the soldered metal. The paper will consider prospective aluminium alloys for the production of soldered structures.

Key words: Soldering, aluminium, soldered structures.

1. INTRODUCTION

The properties of aluminium depend on the purity degree. Pure aluminium (99.996%) has a density (at 20°C) of 2698.9 kg/m^3,Tm=660.24°C; Tb is about 2500°C: coefficient of thermal expansion (from 20° to 100°C) is 23.86×10-6; thermal conductivity (at 190°C) is 343 W/m·K, specific heat capacity (at 100°C) is 931.98 J/kg·K.

Pure aluminium has strength (σB=45 MPa, σ0, 2=22 MPa) and plasticity (δ=50÷65%). When heating is carried out, the elastic modulus of aluminium decreases sufficiently at a high speed, aluminiumstructures withinthe temperature of 250-300°C and higher lose stability[3].

Various types of permanent joints can be used during the manufacture of structures made of aluminium and aluminium-based alloys. Soldering is the best way to connect most structures made of aluminium and its alloys.

The advantages of soldering as a method of joining parts are widely known. In relation to aluminium and its alloys, these advantages are effectively used when creating such complex structures as heat exchangers, waveguides, and various devices of the instrument-making industry[4].

2. LITERATURE REVIEW

The main part of soldered structures is made ofAD1 and AM$_C$ alloys, the strength limit of which after soldering does not exceed, as a rule, 80 MPa. The use of these alloys is due to the fact that in the production of soldered structures for responsible purposes, as a rule, eutectic silumin (Sil0 or Sil1) is used as a solder, which has a melting point of 580-585 ^{0}C and along with high technological properties provides high corrosion resistance of soldered joints. Thus, it is necessary to use alloys with a solidus temperature of at least 595 – 600 ^{0}C as the base metal.

Such soldered structures can compete with welded ones, since the smooth transition from the soldered seam (fillet) to the base metal and, as a result, the lack of stress concentration at the junction of parts are tend to increase fatigue strength. Obtaining high-strength soldered structures can be provided by:

- use of high-strength aluminium alloys as the main material (providing the strength of the base metal after soldering at the level of 200 MPa);
- development of new aluminium alloys based on new alloying systems. Among alloys with sufficient strength (tensile strength over 200 MPa) and a relatively high solidus temperature (~ 593 ^{0}C), alloys of the AD31 type of the Al – Mg – Si system are prospective. AD31 alloy has good processability in pressure and cutting processing, is well wetted with solder, has high corrosion resistance, etc.[2].

Of the high-strength alloys, alloy 1935 can be noted. This alloy has a high solidus temperature (~ 600 ^{0}C), quenches in air and strengthens with natural aging. It is technologically possible to use this alloy in a clad state.

Scandium-doped alloys are the most prospectiveamong the alloys with additional dispersion hardening by transition metal phases[5].

3. RESEARCH

To conduct the study, plates made of aluminum alloy of the AMts6 brand are cut in overall dimensions: 100x50x5 mm.

Stages of preparing samples for soldering:

1) Chemical etching of samples before soldering.

Etching of samples is carried out in a solution of sodium hydroxide 50-160 g / liter (15-30% NaOH in 1 liter of water), for the experiment, the concentration of the solution is set at a ratio of 80 g / liter, the temperature of the etching process of the experimental samples is set to 80 ° C. After chemical etching, the samples are washed in running water.

2) Lightening after etching.

The clarification of experimental samples is carried out in a 30% solution of nitric acid (HNO3). After the clarification process, the samples are washed in running water and dried in an oven.

3) Preparation before soldering the solder.

The solder is cleaned and degreased with ethyl alcohol with technical cotton wool.

4) The solder is laid in the solder gap with an overlap of parts.

5) Samples are welded by welding in argon along the contour of the contact of parts (plates), Figure 1.

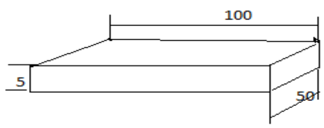

Figure 1: Sketch of the sample for soldering.

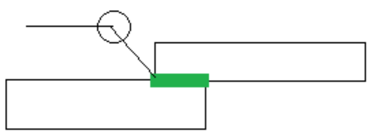

Figure 2: Argon-arc welding of samples. Soldering process

Samples with a welded gap are loaded into the furnace, brought to the required temperature. The soldering temperature is selected depending on the solder used.

Before the soldering process, a thermocouple is attached to the samples to control the heating. Upon reaching the soldering temperature, the samples are kept for 10 minutes. Then we unload the samples from the furnace and cool in air.

In the course of the study, a series of experiments were conducted with different soldering modes with different solders, their heating rates are presented in Table 1, Table 2.

Table 1: Heating rate when using STEMET 1501 solder

$T,^0C$	t, мин: сек
100	-
200	-
300	0:40
400	2:30
500	6:50
600	20:00
610	25:00
610	35:00

Table 2: Heating rate when using Al-Si-Ge

$T,^0C$	t, мин: сек
100	-
200	0:30
300	0:53
400	1:43
500	3:44
600	11:02
610	14:07
610	24:07

After the cooling process, the brazed samples are cut into 10 mm samples to obtain more samples with a soldered seam, as shown in Figure 1.

Samples located around the perimeter of the weld do not used in further research. The remaining welds are cut as shown in Figure 1.

his is necessary for testing soldered samples for shear and for further study of their structure.

As a result of the studies, the modes of autovacuum brazing of aluminum samples using solders of the Al-Si-Ge and Al-Zn systems were checked, and data on the strength and microhardness of the compounds were also obtained. In the case of autovacuum brazing of aluminum, Al-Si-Ge system solders did not form a compound; these samples were not considered further.

During the process of soldering aluminum samples using a zinc billet as solder, the phenomenon of solder interaction with the base metal was noted, as can be seen from Figure 2.

When considering the macrostructure, it is clearly seen how zinc interacts with aluminum, Figure 3.

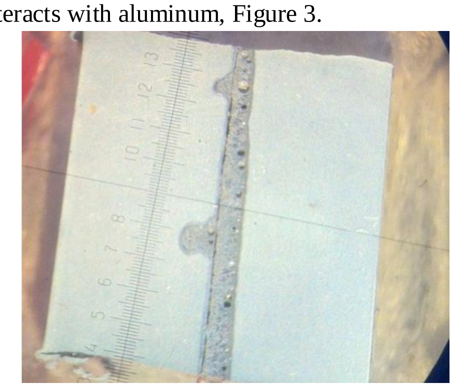

Figure 3: A thin section of an aluminum sample with solder system Al-Zn

4. RESULT AND DISCUSSION

The research results conducted at the Austrian research centre of light alloys (LKR ARCS) showed that the addition of scandium to alloys 3003, 3004, 3005 can significantly (1.5 – 2 times) increase the strength of these alloys and it is about 200 MPa.

In many studies of the process contact melting occurs one of the modes: stationary, non-stationary-diffusion, convective, diffusion-kinetic and pulse.

When conducting the experiment, the minimum deviation of the samples'overall dimensions and the minimum temperature jumps must be observed. The result of contact-reactive melting is shown in figure 4.

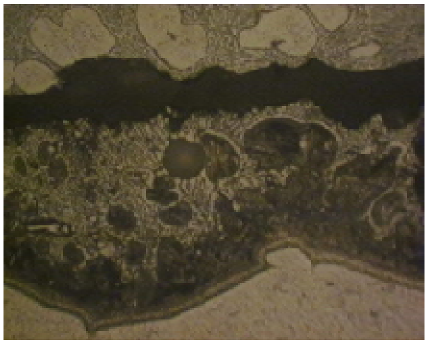

Figure 4: Contact-reactive melting when soldering aluminium with zinc.

Among the granulated alloys, the most interesting for use ofsoldered structures is alloy 01419, whose solidus temperature is 647 ^{0}C. This alloy is complexly alloyed with transition metals that form a complex hardening phase that is significantly more stable than Al3Sc(Zr), Al7Cr, Al3Zr phases. Based on the research carried out on the manufacturability of the alloy type 01419 for soldering, the alloy specially designed for soldering - 01419P has been developed.[6].

Thus, if the strength of alloys of Al – Mg – Si, Al – Mn – Mg – Si - Cu system after soldering depends on the probability of burning of the base metal and the cooling rate after soldering, the strength of aluminium alloys with scandium additives and alloys of Al – PM system depends on the soldering method that characterizes a certain thermal cycle. For example, the mechanical properties of soldered joints made of alloy 01419P for various soldering methods are shown in table.3.

Table 3: Mechanical properties of soldered joints made of alloy 01419P

Soldering technique	σв, MPa	σ0,2, MPa	δ, %
Salt bath	250-260	200-210	18-20
Furnace	240-250	190-200	18-21
Vacuum	230-240	170-200	19-21

5. CONCLUSION

The use of aluminium alloys, alloyed with scandium, granulated aluminium alloy 01419P, alloy AD31 and some others in combination with solders of Al – Si – Ge system provides the ultimate strength of the main material of the soldered structure at the level of 200 MPa.

The use of composite granulated solders for soldering aluminium alloys significantly increases the strength of soldered seams and improves the manufacturability of soldered joints.

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