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- USSR -

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Following is a translation of an article by V. L. Grishin in the Russian-language periodical Tsvetnyye Metally (Nonferrous Metals), No 1, Moscow, January 1964, pp 58-62.

Materials made from sintered aluminum powder (SAP) present much interest for various branches of engineering in view of properties which distinguish it from ordinary, high-strength aluminum alloys. The properties and technology of producing this material have been adequately discussed in foreign and native literature [1]. The mechanical properties of SAP-2 are compared in the table with aluminum alloys. To the problem of producing permanent joints from sintered aluminum powder by welding and brazing, very little work has been devoted. In this work special attention is given to obtaining braze joints of SAP and also to the study of their heat resistance.

Mechanical properties of SAP-2 and some aluminum alloys.

(a) Марка сплава	(b) Температура испытания, °C	(c) Механические свойства		
		(d) σ_b , кг/мм ²	(e) σ_s , кг/мм ²	(f) δ , %
(g) САП-2	20	38—44	28—31	4—8
	350	19	8—9	4—7
	500	8—10	5—7	3—4,5
(h) Д-20АТ	20	40	30	10
	350	9	6	20
(i) ВД-17Т	20	50	33	13
	350	11	6	27
(j) Д-16АТ	20	42	28	10
	300	14	11	10

a) alloy grade; b) testing temperature;
 c) mechanical properties; d) tensile strength, kg/mm²; e) yield strength, kg/mm²; f) % elongation; g) SAP-2; h) D-20AT; i) VD-17T; j) D-16AT.

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Brazing sintered aluminum powder has features which distinguish it from brazing ordinary aluminum alloys: 1) the large quantity of aluminum oxides on the surface of the alloy and inside it does not create favorable conditions for wetting of sintered aluminum powder with filler metals; 2) heating SAP-2 for brazing can be done up to temperatures near the melting point of aluminum, which does not deteriorate the mechanical properties of the base metal (as in the case of high-temperature annealing of briquettes); 3) the presence of oxides and the peculiarity of the structure of sintered aluminum powder during heating leads to a more active reaction of filler metals and base metal with each other; 4) when using zinc-base filler metals the coefficient of zinc in SAP-2 is approximately 3.5-4 times higher than in aluminum alloys.

The above-mentioned difficulties of brazing SAP-2 created the necessity to develop new joining methods and the appropriate filler metals and fluxes.

SAP-2 samples (sheet and rods) containing 14% Al_2O_3 were brazed following a high-temperature anneal to remove gases from the base metal and to break up oxide films surrounding the aluminum grains. To study the reaction of braze alloys with SAP-2, certain constituents were vacuum deposited on the surface of the initial metal. These constituents consisted of zinc, tin, and copper).

Thickness of vacuum-deposited layers was 0.1-0.4 mm; subsequent heat treatment was done in air and in argon. Heating temperature for brazing was 230-460° (selected by taking into account the formation of eutectic products in the space between the deposited layer and SAP-2.

The most active reaction was noted in the case of using zinc owing to its high solubility in the solid state in aluminum (at 300°C the solubility is almost 40% by weight).

Abrasive brazing. After mechanical cleaning of the SAP-2 samples with a thickness of 2.0 mm, the samples were heated to 380-500° and the braze area coated. Application of the coating was done with zinc-base rods with a diameter of 3.0 mm.

Zinc alloys containing 4-7% Al (390 C), 4-5% Cu (385 C) and 5% Al, 5% Sn were the best of the tested alloys. The almost instant wetting of braze alloys was observed in the case of pre-coating the SAP-2 surface with zinc, tin, copper and

cadmium. However, to avoid development of corrosion processes it is best to use a zinc coating 0.2-0.3 mm thick.

After coating the layer is cleaned and machined to a dimension of 0.4-0.5 mm. The assembled packets were placed in a clamp device and heated in an inert atmosphere to a temperature 50-70° above the liquidus of the braze alloy being used. To produce quality joints of SAP-2, it is necessary to remove excess filler material and to correctly from the geometric contours of the joint at the moment of filler metal melting. When brazing SAP-2 without pre-coating the metal, a high-quality and strong joint was obtained by using rods of the filler metal which had small particles of asbestos pressed into them. In this case, aluminum oxides were more completely from the SAP-2 surface by rubbing it with the rods and conditions for a good reaction of the filler material with the base metal were improved.

Quality joints were also obtained using ultrasonic vibrations with a frequency of 20-22 kcs. In addition, the active penetration of filler material into the base metal was observed particularly in the grain boundaries which is explained by the conditions which alleviate the course of diffusion processes (Fig. 1).



Fig. 1. Microstructure of brazed SAP-2 joint (abrasive brazing). Braze alloy--Al-5% Cu. Etchant--0,5% HF (X 500).

Resistance brazing. The use of local heating, accomplished on resistance welding machines, makes it possible to produce joints with a somewhat higher thermal stability than in the case of brazing SAP-1.

The effect of increasing heat resistance in this instance is explained by the higher aluminum oxide content with the oxides emanating from the base metal and passing into the braze seam, and also the use of aluminum alloys as an inter-

3.0 mm thick
layer. Thus, the process of brazing SAP-2 on a d.c. machine with interlayers of alloys V95 and D23 with a thickness of 0.6 mm consisted on the average of: brazing current--60 kA; impulse time--0.5 sec; pressure of electrodes during brazing--900 kg; pressure of electrodes during welding 3,000 kg; radius of electrode tips--100 mm.

X-ray inspection of the joints showed that a high-quality seam is obtained without visible defects.

Dip brazing. Best results, as would be expected, were obtained in the case of using a silumin bath. The most suitable fluxes for this purpose were mixtures containing a high content of $ZnCl_2$. Due to the ability of this salt to be decomposed upon heating into zinc and hydrogen chloride by contact with the flux, the SAP-2 sample has a layer of metallic zinc deposited on its surface.

Upon further immersion of the sample into the melt, the layer of zinc and base metal dissolve in the filler metal. In the presence of zinc, dissolution of SAP-2 in silumin takes place much faster; this is explained in that at 500° and higher the solubility of zinc in aluminum is almost 42% (by weight) and the alloy produced during this time reacts more intensely with the melt. Thus, in addition to bath temperature and holding time, flux composition is one of the parameters which affects the solubility of SAP-2 in a molten braze alloy (Fig. 2). To obtain a quality joint of braze alloy with SAP-2, the process parameters must be carefully regulated. Issuing from the uniqueness of the reaction of sintered aluminum powder, containing a higher aluminum oxide percentage than in SAP-1, the parameters of the process of immersion of sheet must not exceed the following magnitudes:

$$\tau_{imm} \leq (20-40)\delta$$

$$t_{melt} \leq t_{braze} + (70-100)$$

where τ_{imm} --immersion time, sec; δ --thickness of part, mm;

t_{braze} --temperature of braze alloy liquidus, °C; t_{melt} --melt temperature, °C.

After obtaining a good coated layer on SAP-2 samples the thickened braze is machined with respect to type of joint being used (butt joint, lap joint, tee joint). After sample preparation brazing is done by melting the coating to produce a firm joint. Melting of "outgrowth" can be accomplished on a standard welding equipment for inert-gas shield welding and

submerged-arc welding and also on butt welding machines of low and medium power. Brazing is done using clamp attachments, which correctly align and clamp edges relative to each other. In the case of using automatic welding machines for producing joints, V-shape setting of edges with a gap for use of a consumable electrode can be done in the event of laying down single and multilayer seams.

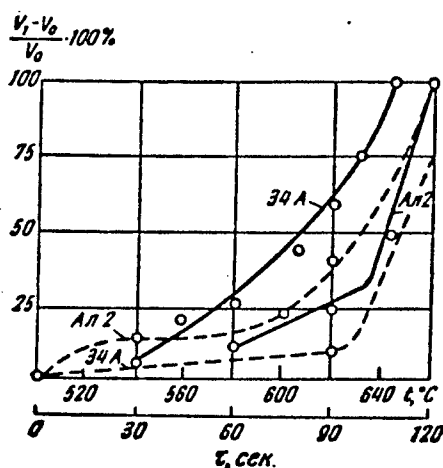


Fig. 2. Effect of process parameters on dissolution of SAP-2 during immersion in braze bath: solid line--effect of temperature; dashed line--effect of holding time.

It is best that the angle between edges is 40-50° and melting is done using copper spacers; a forming groove is not needed in this case. Melting edges under a layer of flux is undesirable since small quantities of residue of the active constituents cause corrosion processes. When using butt welding machines, machining can be eliminated. Obtaining a good joint in this case is achieved by resistance heating of the edges. Immersion pressure should be minimum for the possible formation of a joint through the layer of braze alloy. Use of the above-described method allows to produce high-quality braze joints with high thermal stability.

Furnace brazing. The strong tendency of sintered aluminum powder toward active erosion in brazes does not permit rapid wetting of the braze alloy on the SAP-2 surface. The formation of a large quantity of macro- and micro-discontinuities during heating brings about active diffusion processes in the aluminum grain boundaries. The use of fluxes in this case is not good since they become contaminated by the oxides and lose their main fluxing properties. This effect of braze

alloys on SAP-2 can be drastically weakened by plating the base metal with various aluminum alloys. This creates a self-induced barrier to the penetration of the braze alloy into the SAP-2 because the process of joining sintered aluminum powder proceeds through a thin sublayer of the second material. The best results were obtained using single and double platings of alloys AMg6, AMts5, V92, and ATsM. Plating thickness was 15-20% that of the SAP-2.

Yet, even from the unique interaction of SAP-2 with brazes at temperatures above 500° , no quality joints were obtained by this method.

Mechanical and corrosion tests of joints. Shear and tear tests were conducted on brazed joints at room and elevated temperatures.

Tests showed that the nature of fracture depends on the method of brazing and also on the geometry and type of braze joint. In resistance brazing rupture of samples in all instances occurred in the base material at a small distance from the joint. This can probably all be explained by the formation of a heat-affected zone with reduced strength properties in view of saturation of the base material with the filler metal and also by joining boundary sections of oxide films. In dip brazing fracture has a different character: in the case of the lap joint and butt joints, with a thickness 30-50% that of the joined sheet, tensile fracture occurs in the heat-affected zone; while in butt joints fracture occurs in the joint. Fracture in the braze joint also occurs in abrasive and furnace brazed joints.

Lap joints are an exception as, in the length of the lap, equal to 6-8 thicknesses of the sheet (furnace brazing by plating) and 13-15 thicknesses (abrasive brazing with zinc-base alloys), fracture of samples occurred in the base metal. Test results are given in Figs. 3 and 4.

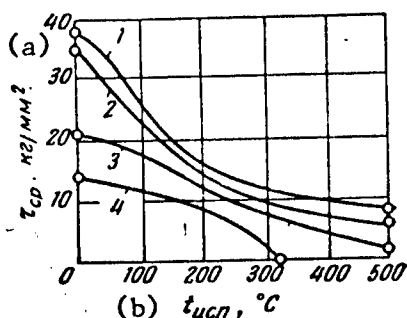


Fig. 3. Relationship of mechanical properties of brazed joints to testing temperature in brazing by different methods: 1--resistance; 2--dip; 3--furnace; 4--abrasive; a--shear strength, kg/mm²; b--testing temperature, $^{\circ}$ C.

Corrosion testing of SAP-2 joints in an aqueous solution of 3% NaCl + 0.1% H₂O₂ for 30 days indicated good properties of

the braze joints. Estimation of the anticorrosion properties of braze joints was done according to loss of joint strength before submersion and after time in the electrolyte. Experiments revealed that in the various methods of SAP-2 brazing, the anticorrosion properties of sintered aluminum powder containing 8-11% Al_2O_3 were best.

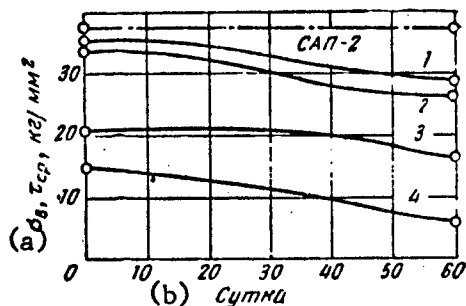


Fig. 4. Effect of holding samples in a solution of 3% NaCl + 0.1% H_2O_2 on loss of strength in shear during tension. Methods: 1--resistance brazing; 2--dip brazing; 3--furnace brazing; 4--abrasive brazing; a--shear strength; b--days.

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