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IMPROVEMENT OF QUALITY OF SECONDARY ALUMINIUM ALLOYS IN CONDITIONS OF MASS PRODUCTION

POPRAWA WŁAŚCIWOŚCI WTÓRNYCH STOPÓW ALUMINIUM W WARUNKACH PRODUKCJI MASOWEJ

The ways of quality improvement of a secondary cast aluminium alloys are considered. It is shown that the treatment of liquid metal by the complex modifier gives an opportunity to change the shape of intermetallic phases and rise mechanical properties of a secondary aluminium alloys.

Keywords: aluminium alloys, intermetallic phases, mechanical properties

Zbadano sposoby poprawy jakości wtórnie odlewanych stopów aluminium. Wykazano, że zastosowanie złożonego modyfikatora przy obróbce metali ciekłych umożliwia zmianę kształtu fazy międzymetalicznej i poprawę właściwości mechanicznych stopów aluminiowych.

1. Introduction

Due to low density, good corrosion resistance and sufficiently high specific strength aluminium alloys take the second place among structural materials after iron-based alloys (steels and cast irons). Two processes of aluminium production coexist in the world now: 1) primary aluminium production from alumina by electrolysis; 2) secondary aluminium production from a breakage and waste products by remelting.

The main advantage of the first process is high quality of production, the main disadvantage – the high consumption of the electric power. In spite of the fact that within 20-th century power inputs in electrolysis have decreased on average level from 50 up to 14 kW*h/kg of aluminium (Fig. 1), their share in the cost price of production remains 25–30%. Moreover, expenses for carbon anodes contribute about 15% of the cost price. Allocation of great amount of carbonic oxides and dioxides of carbon as a result of combustion of the carbon anodes may be also referred to serious drawbacks of classical technology of primary aluminium manufacturing.

Works aimed on elimination of the mentioned disadvantages are constantly conducted in the world. According to the data of International aluminium institute [1], the most perspective from the point of view of increase in energy consumption efficiency and improvement of ecological conditions are the technologies providing application of the inert anode from aluminium bronze (release of hotbed gases is eliminated), the moistened cathode of boron-carbon composites (distance between electrodes, voltage between them and, accordingly, the consumption of the electric power are reduced), low-temperature (about 350°C) reduction of alumina in ionic liquids, etc. It is expected, that new technologies will allow to decrease power consumption up to 9.5 kW*h/kg, while theoretical, necessary for aluminium oxide dissociation level, is 6.34 kW*h/kg of metal.

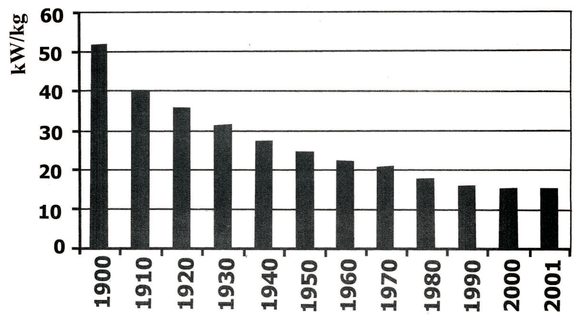

Fig. 1. Specific expenses of the electric power for reception of primary aluminium

Because of the fact that new electrolysis technologies demand significant funds and time for their development and introduction, and also in connection with that

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after their realization power consumption will remains high enough and will come to 17–20% from the cost price of manufacture, utilization of secondary aluminium is rather perspective. Power consumption on alloys production from secondary aluminium by melting in electric furnaces amounts near 0.4 kW*h/kg [2], that in 35 times lower, than while manufacturing of primary aluminium by electrolysis.

The most large-scale consumers of aluminium in the world and, accordingly, suppliers of its scrap, are: mechanical engineering, transport, civil engineering (construction) and the food-processing industry (Table 1).

TABLE 1

Scrap formation in manufacture and application of aluminium products [3]

Branch	Product	Life cycle, years	Formation of scrap in manufacture, %	Coefficient of scrap collection, %	Ratio of cast and defor-mable alloys
Transport	passenger plane	25–30	100–122	85–90	90/10
	automobile	12–15	25–43	50–85	20/80
Construction	window frame	40–50	11–18	85–95	100/0
The foot-processing industry	tin for drinks	0.2–0.5	30–33	20–91	100/0
	foil	0.2–1.0	10–20	10–30	100/0
Mechanical engineering	household appliances	7–10	40–70	50–85	50/50

During the period from 1990 to 2004, production of primary aluminium in the developed countries has been reduced by 10% at significant growth of secondary alloy production that ensure growth of the general consumption of aluminium by 30%. At the same time every third kg of consumed metal has been obtained by recycling [3].

It is well known, that the basic problem of recycling is poorer quality of alloys in comparison with those obtained from primary aluminium. It may be explained by the fact that metal proceeding for remelting is polluted substantially with extraneous materials – plastics, oils, parts of other structural materials. In this connection, secondary alloys of aluminium contain a great amount of intermetallide phases, nonmetallic inclusions, dissolved gases, specify by heterogeneity of structure and consequently considerably yield to primary ones in service and mechanical properties.

The analysis of the scientific and technical literature and pilot production shows, that the basic technological processes providing high quality of secondary aluminium alloys, are:

- Sorting of scrap, that ensures obtaining of required structure with minimum of undesirable impurities (iron, magnesium, etc.) in alloys (as a rule, in form of bars);
- Refining, alloying and modifying of alloys with the purpose of gas content and porosity reduction, management of sizes and shape of structural components, increase of density, mechanical and service properties;
- Melting in direct current arc furnaces provides an opportunity to reject processes of refining and modifying, to decrease expenses on remelting in three times in comparison with gas furnaces, to receive high quality of alloys.

By the example of the most widespread aluminium alloys, given below, certain results of research in recycling technology improvement are presented.

The “Aluminium alloys scrap classifier after primary processing” has been developed and introduced by Zaporozhye national technical university and Zaporozhye non-ferrous alloys works [4], which, in contrast to actual standard DSTU 3211-95, provided more detailed breakdown of scrap to classes and subclasses. It has ensured to manufacture of metal suitable by chemical composition on 100%, to reduce iron content in it from 0.7–1.2 up to 0.6–0.9% as well as other undesirable impurities, to decrease expenses on remelting.

Silumins represent alloys with heterophase structure, iron-bearing phases in which due to predominantly covalent bonds and directed crystallization have the lamellar and needle shape. These inclusions are stress concentrators and result in essential decrease of mechanical properties. In this connection, iron content in silumins used in defense and aviation industries of the USA is not allowed to exceed 0.2% [5].

As it is shown in the work of Nemenenok B.M [6], one of possible methods of change of iron-bearing phases and eutectic silicon crystallization nature may be connected with introduction of surface-active impurities in melted silumin. Atoms of those impurities, being adsorbed on a surface of growing crystals, weaken covalent bond component between their atoms and as a result exclude aligned growth of iron-bearing and silicon phases. In particular, refining of β-phase Al_5SiFe after alloying of silumins by manganese, lame and molybdenum, and also after modifying by sulfur, selenium and tellurium is determined. As seen from the results of tests presented in Fig. 2 [6], increase of iron content in silumin AlSi9 from 0.05 to 1.1% results in reduction of relative elongation from 7.3 to 4.2% in a cast condition and from 5.7 up to 1.4% after heat treatment, that is in 1.4–2.4 times correspondently. At the same time, alloying of AlSi9Cu2 by manganese in amount of 0.2–0.3% results in increase of plasticity approximately to the same degree (Fig. 3), that allows to assert that manganese neutralize negative influence of iron.

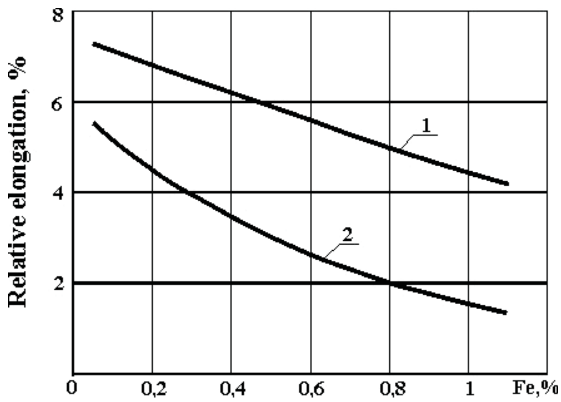


Fig. 2. Influence of iron on relative elongation of silumin (9.7% Si, 0.25% Mn) in as-cast condition (1) and after heat treatment by mode T6 (2)

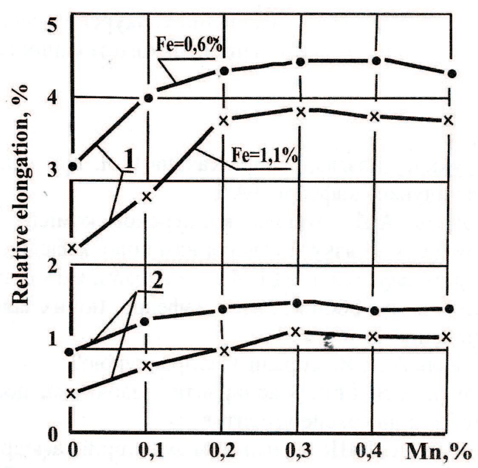


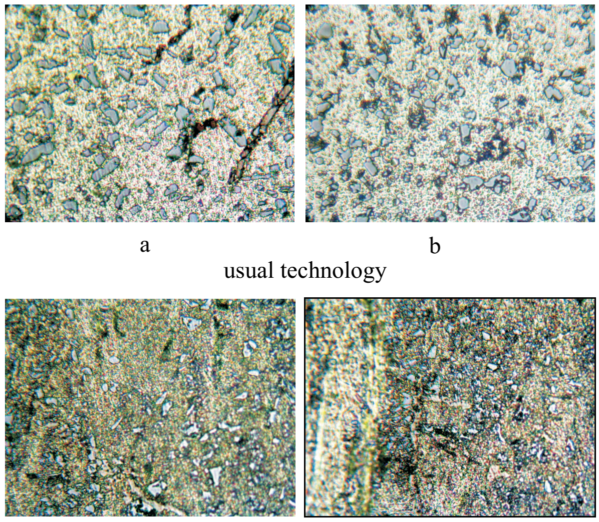
Fig. 3. Influence of manganese and iron on relative elongation of silumin, containing 9.7% Si, 0.25% Mn and 1.5% Cu, in as-cast condition (1) and after heat treatment by mode T6 (2)

According to the same data [6], modifying by sulfur in amount of 0.05% appeared equivalent to processing by liquid flux of standard composition: 40% KCl, 35% NaCl, 15% Na_3AlF_6 and 10% NaF. At joint application of sulfur and a flux their positive influence on strength and plasticity of silumin AlSi9 was summarized (Table 2).

TABLE 2

Results of industrial melting of alloy AK9

Variant of processing	Mechanical properties			
	as-cast condition		after T6	
	σ_U, MPa	R_E, %	σ_U, MPa	R_E, %
Initial alloy	181	2.9	252	1.5
0.05% S	196	3.8	270	2.5
0.5% of a flux	194	3.9	267	2.7
0.05% S of +0.5% of a flux	206	5.5	271	3.5



a b

usual technology

c d

experimental technology

Fig. 4. Structure of alloys AlSi9Cu2: a, b – as-cast condition; c, d – after T5

With the aim of complex influence on gas content and structure of secondary aluminium alloys a refining flux [7] has been developed, which containes: 3–10% S, 10–15% KCl of 30–40% NaCl, 1.5–5% Na_2CO_3, 0.5–0.8% SiC and AlF_3 – the rest. Chlorides of K and Na and fluoride of Al have provided formation of protective film on melt surface and its refinement from gases and nonmetallic inclusions. Gaseous sulfur (the flux was blown into the melt by the help of nitrogen) promoted refinement of the melt by adsorption method, the carbonate dissociation slowed down the rate of sulfur oxidation, refined the melt by means of CO_2 bubbles, and also together with gaseous sulfur promoted increase in a liquid metal – slag contact surface. Ultra disperse silicon carbide (the sizes of particles were about 10 microns) has provided enough quantity of crystallization centers that has resulted in reduction of dendrite axes of the first order length in 3 times and to increase in their amount on the sectional area surface in 1.8–2 times. Modifying of eutectic and decrease of shape parameter of β phase

Al_5SiFe particles from 2…16 to 1…5 (Fig. 4) also occurred. In table 3 the results of alloy AK9M2 tests produced in industrial flame furnace EHW5000 under an integument flux (33% KCl + 67% NaCl) and subjected to refinement by a standard flux (45% NaCl + 15% KCl + 40% AlF_3 (variant 1) and offered flux (variant 2) are depicted in Table 3.

TABLE 3

Mechanical properties of alloy AlSi9Cu2

Variant	As-cast condition				After T5			
	σ_U, MPa	R_E, %	KC, MJ/m^2	HRB	σ_U, MPa	R_E, %	KC, MJ/m^2	HRB
1	123	3.2	0.09	46	191	2.4	0.10	63
2	146	3.4	0.08	71	259	2.8	0.11	72

As it is clear from the data submitted, the experimental technology of refinement and modifying has ensured higher properties of an alloy in comparison with existing technology.

Scientific and technical firm "ЭКТА" (Russia) has developed direct current arc furnaces of (ДППТ) of the new generation, intended for melting of various alloys, including aluminium. According to the information of firm [2], ДППТ have a number of technical and economic advantages in comparison with flame and induction furnaces, due to high speed of fusion and tightness of oven space. In particular, degassing and refinement are required only in case of strongly polluted scrap utilization: alloys possess homogeneous and fine-grained structure due to intensive magneto-dynamic stirring while modifying isn't needed; high quality alloys may be produced from secondary materials; the general expenses for production of Al alloys are lower in ДППТ in 3.6 times as compared with the alloys, melted in gas furnaces.

In general, the literature analysis and analysis of experimental-industrial data shows, that modern technologies of metallurgical conversion allow to obtain high-quality aluminium alloys with mechanical and service properties on the level of primary alloys, utilizing up to 100% of waste products and scrap as charge materials.

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