WEB OF SCIENTIST: INTERNATIONAL SCIENTIFIC RESEARCH JOURNAL
ISSN: 2776-0979, Volume 3, Issue 5, May., 2022

INVESTIGATION OF SUPER-PLASTICITY OF ALUMINUM ALLOYS CONTAINING THE EVTECTIC COMPONENT

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Abstract
Development of alloys and technology for the production of a micro-grain structure based on the Al-Cu-Mg alloy, which makes it possible to achieve a recrystallized grain size of less than 10 μm. the determination of the superplasticity indices of these alloys.

Keywords: micro-grain structure, superplastic deformation, equiaxed crystals, thin-walled products, recrystallized grains.

Introduction

The field of application of aluminum alloys is constantly growing, especially in the aircraft industry, mechanical engineering and the structure of railway cars. The industry strives to facilitate structures without loss of strength characteristics.

Superplastic deformation (SPD) makes it possible to obtain thin-walled products of complex shapes with high surface quality, reduce the number of welds or riveted joints in the structure. Superplastic molding has a number of technological advantages, and the economic benefit of using superplastic molding has been proven in the conditions of mass production, but in conditions of increased molding speeds. The materials existing today with a grain size of about 10 microns, allow the implementation of SPD speeds no higher than 10 -4 s-1, as a result, the time spent on forming one part can reach several hours, which constrains the use of this method in industry.

An increase in the deformation rate by one or two orders of magnitude, which can be realized by reducing the grain size to 1-5 microns, would reduce the molding time of one part to several minutes. In addition, the micrograin structure in the final product makes it possible to obtain an increased level of mechanical properties at room temperature. Thus, the study of alloys of various systems is relevant in order to determine the optimal ratio of structural parameters and the development of technological processing schemes.

Superplasticity is a state that materials exhibit under certain temperature-velocity deformation conditions [1]. Micrograin superplasticity is found in metals and alloys with very small equiaxed crystals (smaller than (10 – 15 microns) at high homologous temperatures (more than 0.5 Tpl.) and at relatively low deformation rates - (10–5 – 10–1) s–1.

An aluminum-based alloy containing eutectic-forming elements Fe, Mn, Ni, Si, additionally alloyed with Zn, Mg and Cu, was studied in order to obtain a micrograin structure by recrystallization controlled by particles of the second phase. The composition of the alloy and the technology of obtaining a micrograin structure are proposed. For the alloy with the smallest recrystallized grain sizes, superplasticity parameters were determined and the mode of hardening heat treatment was selected. A number of compositions based on Al–Fe – Mn – Ni systems were selected for further research using the Thermo–Calc program. Cu, Mg and Zn were also added to the alloys for the possibility of thermal hardening of the alloys. The alloy also includes a Si – eutectic-forming element to increase the volume fraction of particles.

Melting was carried out in a laboratory electric resistance furnace in graphite-chamotte crucibles. After melting aluminum at a temperature of 750 C, ligatures were introduced in the following sequence: Al – Fe, Al – Mn, Al – Cu, Al – Ni, Al – Si, Mg and Zn were wrapped in foil before being introduced into the melt. Magnesium was injected with a bell to the bottom of the melt and kept until completely dissolved. Manganese has a significant effect on the recrystallization process of aluminum alloys.

Manganese is an anti-recrystallizer, which leads to an increase in the recrystallization temperature.

Also, at the final stage of recrystallization, manganese grinds the size of the recrystallized grain [1, 2].

In alloys made using technical aluminum, the recrystallization temperature changes in the same way, but the maximum is shifted towards a lower manganese content. This is consistent with a decrease in the solubility of manganese in solid solution in the presence of iron and silicon impurities. Additives of iron and silicon sharply grind the grain of alloys of the Al – Mn system. Iron and silicon greatly reduce the solubility of manganese in solid solution, and consequently reduce intra-dendritic liquation [3]. In addition, these elements accelerate the decomposition of a supersaturated solid solution of manganese at temperatures corresponding to the temperatures of hot deformation - (400 – 500) ° C. The resulting dispersed particles of manganese phases are the centers of recrystallization and contribute to the formation of a fine-grained structure.

After complete dissolution of the ligatures and removal of slag from the surface, the melt was poured into a water-cooled copper mold with dimensions (100x40x20) mm. After casting into a water-cooled copper mold, the alloys were processed along the following technological chain:

Homogenization annealing mode 460 0c – 8 hours;

Hot deformation at 460 0c by 47 %;

Annealing at a temperature of 520 0c – 12 hours;

Hot deformation at 450 0c by 47 %;

Hot deformation at 450 0c by 70% (total hot deformation 83%);

Heterogenization annealing at a temperature of 350 0c – cooling with a furnace;

Cold rolling by 67%. Then the alloys were subjected to recrystallization annealing at 0.95 Tpl for 30 minutes.

Recrystallization annealing is the final heat treatment of alloys, and the very high plasticity of the alloy makes it possible to harden it by cold deformation. Based on experimental data, the following conclusions can be drawn:

It is shown that coarse particles of the primarily crystallized ferromanganese phases are crushed during hot deformation, and also fragmented and spheroidized during annealing. Alloys and technologies for producing sheets from them with a recrystallized grain size of about 5 microns are proposed. The alloy Al - 1% Fe - 0.6% Mn - 1% Ni - 3.5% Cu - 1.3% Mg - 0.15% Zr has the best superplasticity indicators.

Conclusion

The optimal mode of hardening heat treatment for the alloy Al - 1% Fe - 0.6% Mn - 1% Ni - 3.5% Cu - 1.3% Mg - 0.15% Zr (aging at 210 °C for 3 hours), providing a yield strength of 280 MPa, a tensile strength of 400 MPa and a relative elongation of 14%, has been established.

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