Effect of dispersion hardening on impact resistance of EN AC-AlSi12Cu2Fe silumin

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Abstract

Development of modern technology have generated supply of better and better, more resistant structural materials not attainable earlier. Weight of metal structures is of a great importance, and as a consequence, also weight of materials used for a given structure. More often, for metal structures are used lightweight metals and their alloys, from which aluminum and its alloys have become the most widespread. These alloys, based on Al-Si equilibrium system, contain additional constituents (e.g.: Mg, Cu) enabling, except modification, improvement of mechanical properties obtained in result of heat treatment. The paper presents an effect of modification process and heat treatment on impact resistance of EN AC-AlSi12Cu2Fe alloy. Solutioning and ageing temperatures were selected on base of registered curves of the ATD method. For the neareutectic EN AC-AlSi12Cu2Fe silumin one obtained growth of the impact resistance both due to performed modification treatment and performed heat treatments of the alloy.

Keywords: Al-Si alloys, crystallization, heat treatment, ATD

1. Introduction

Pure aluminum is used rarely, the most often in foundry industry are used silumins (Al-Si alloys) with neareutectic contents of silumin (about 12%), and with various, other alloying additions. These alloys are used in various branches of engineering industries, e.g. automotive, precise, aircraft, household equipment industry, etc. Such broad application of these alloys results from their very good physical-chemical and technological properties. These alloys feature relatively low density, relatively low melting temperature, good thermal and electric conductivity, high mechanical properties (some silumins can be heat treated), and are characterized by good casting properties (good castability, small solidifying shrinkage), good machinability and considerable corrosion resistance [1,2].

Susceptibility to generation of coarse grain structure constitutes a significant disadvantage of these alloys (it concerns mainly alloys made in ceramic moulds and thick-walled castings from metal moulds), what disadvantageously effects on mechanical properties of the alloys.

Return to normal eutectic mixture (fine-grained one) is obtained by means of its refinement (modification), adding inoculants to the metallic bath.

Modification of alloys can effect, depending on type and kind of alloy and inoculants, in many phenomena, e.g.: generation of additional nucleuses of crystallization, generation of inclusions which restrict growth of crystals (structure of alloys is of polycrystalline character), local changes in concentration of elementary substances and surface tension, change of conditions of generation of super-cooled alloy, deoxidation and degassing of the bath, etc. Due to fact that the modification can induce various effects; none general theory of modification was developed up-to-now, whereas numerous theories attempting to describe phenomena connected with modification of the alloys are functioning now [3-8].
Obtained results connected with change of the structure, and hence, change of mechanical and technological properties of the alloy depend on selection of a suitable modifier, its correct dosing and maintenance of proper temperature of the metal in course of modification process [2-3, 6, 9].

Carrying out modification treatment is very important from alloy’s heat treatment point of view, because form of the eutectics mixture effects on susceptibility of eutectic silicon to coalescence and spheroidizing during the heat treatment – phenomena of coalescence and spheroidizing of the eutectic silicon proceed more easily and more quickly when molecules of the eutectic silicon are more dispersed before the heat treatment [10].

Heat treatment used in case of alloys based on Al-Si system with additives of Mg and Cu enables to obtain further improvement of their mechanical properties, comparing to modified alloys.

Temperatures of solutioning and ageing, as well as duration of these treatments constitute main parameters of the heat treatment process (dispersion hardening) of aluminum alloys.

In case of temperature, to determine temperature ranges one can make use of the ATD thermal method of crystallization process analysis [11, 12]. The ATD method, based on analysis of temperature changes course, enables registration of a phenomena arisen in result of melting and solution heat treatment processes of alloys. Implementation of that method enables to determine melting temperature of the material, and the same, permits to determine maximal temperature of the solutioning treatment with elimination of possibility of partial melting of the material (casting). The ATD method can be also used to estimation of mechanical properties of alloys [13, 14].

2. Methodology of the research

In course of the testing one used EN AC-AlSi12Cu2Fe alloy (classified among multicomponent alloys commonly implemented in foundry industry), which was melted in electric resistance furnace.

Investigated alloy was refined with Rafal 1 in quantity of 0,4% of mass of the metallic charge, and next modified with AlSi10 master alloy in quantity of 0,6% of mass of the metallic charge.

Registration of heating and melting of the investigated alloy was performed with use of the ATD Cristaldimat analyser.

Heat treatment was performed for the modified alloy. Temperatures of solutioning and ageing treatments were determined on base of registered heating and solutioning curves of the ATD method.

One assumed the following temperature ranges of heat treatments of the investigated alloy:
- solutioning temperature: 525 - 555°C,
- ageing temperature: 180 - 340°C.

Duration of solutioning and ageing treatment amounted to from 0,5 up to 3 hour.

In the Fig. 1 are shown registered curves of the ATD method for the investigated alloy with marked temperature ranges of the solutioning and ageing treatments.

3. Description of achieved results of own researches

Impact resistance of raw alloy (from pig saw) amounted to 2,6 \(\pm 4,0\) kJ/m\(^2\). After refining there occurred a slight change of impact resistance of the alloy, which amounted to 2,7 \(\pm 4,5\) kJ/m\(^2\). Refined and modified alloy was characterized by growth of the impact resistance amounted to 5,7 \(\pm 7,0\) kJ/m\(^2\). After the heat treatment the impact resistance amounted to 4,2 \(\pm 13,8\) kJ/m\(^2\). In the Fig. 2 is shown an impact of refining treatments and heat treatment on change of impact resistance of the EN AC-AlSi12Cu2Fe silumin.

![Fig. 1. Curves of the ATD method for the investigated alloy](image)

In course of the solutioning treatment, temperature of the treatment was monitored through permanent recording of temperature inside the furnace and temperature of the sample.

For refined alloy, refined and modified alloy, and alloy after heat treatment one performed measurement of impact resistance on Charpy impact tester.

![Fig. 2. Effect of performed heat treatments of EN AC-AlSi12Cu2Fe silumin](image)
In the Figs. 3-5 is shown an effect of solutioning and ageing treatment’s duration and temperature on change of impact resistance of investigated alloy.

Change of material’s structure after performed heat treatment is also directly connected with change of its tensile strength and elongation. In the Fig. 6 is shown an effect of tensile strength change $R_m$ and elongation $A_5$ change on KCV impact resistance of the investigated alloy.
High impact resistance of the investigated alloy, obtained in result of performed heat treatment is simultaneously connected with its tensile strength $R_m$ having value of 270 to 320 MPa, and elongation $A_5$ having level of 3-4.5% (Fig. 6).

4. Conclusions

Modification and heat treatment have effect on improvement of impact resistance of EN AC-AlSi12Cu2Fe silumin.

The highest impact resistance, $KCV = 13.8 \text{ kJ/m}^2$, was obtained for specimens of the alloy which was solution heat treated in temperature of 555°C for 1.5 hour, and next ageing treated in temperature of 250°C during period of 3 hour.

Impact resistance of the investigated alloy reached its the highest values for:
- solutioning temperature amounted to from 540 up to 555°C,
- solutioning duration from 0.5 up to 1.5 hour,
- ageing temperature from 180 to 250°C,
- ageing duration from 1 do 2 hour.

The lowest value of the $KCV$ impact resistance of the alloy after heat treatment was obtained for specimens of the alloy solution heat treated in temperature of 555°C for 3 hour, and next ageing treated in temperature of 180°C for the period of 3 hour.

Impact resistance of the investigated alloy attains its lowest values for:
- solutioning temperature amounted to from 4.2 – 4.7 kJ/m².

Maintaining suitable ranges of temperatures and durations of solutioning and ageing treatments is a precondition of optimal impact resistance of the alloy, enabling simultaneously to shorten time of the heat treatment to an indispensable minimum.

Performance of a further investigations shall be connected with necessity of determination of an effect of selected parameters of dispersion hardening on technological properties of AC-AlSi12Cu2Fe silumin.

References