ARCHIVES of FOUNDRY ENGINEERING

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (1897-3310)
Volume 10
Special Issue
4/2010

61 – 64

12/4

Effect of heat treatment operations on the R_m tensile strength of silumins

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Received 30.06.2010; accepted in revised form 02.07.2010

Abstract

Owing to good technological properties, low weight and good corrosion resistance, aluminum-silicon alloys are widely used as a material for cast machinery components. State of macro- and microstructure of a castings manufactured from Al-Si alloys, which is determined by a shape and distribution of hardening phases, segregation of alloying constituents and impurities, as well as distribution of porosity, create conditions to obtainment of proper mechanical properties. These properties can be improved through modification of the alloy and performed heat treatment operations. The paper presents effect of modification and heat treatment process on the R_m tensile strength of a selected silumins (EN AB-AlSi9Cu3(Fe), EN AB-AlSi12CuNiMg, EN AB-AlSi17Cu1Ni1Mg). Investigated alloys were put to treatments of refining and modification, and next to heat treatment. Temperature range of the heat treatment operations was determined on base of curves from the ATD method. Obtained results illustrate registered curves of melting and solidification from the ATD method and strength tests. On base of performed initial tests one determined parameters of the heat treatment process (temperature and duration of solutionig and ageing treatments) enabling obtainment of improved R_m tensile strength of the investigated alloys.

Keywords: Modification, Heat treatment, ATD, Mechanical properties

1. Introduction

Mechanical and technological properties of castings produced from the Al-Si alloys depend, most of all, upon performed process of melting and pouring, design of the casting and mould, as well as heat treatment. Equally important from mechanical properties point of view is shape and method of distribution of hard and brittle crystals of silicon in plastic metallic matrix of solid solution α (Al) [1-3]. Obtainment of fine-grained structure being characterized by minimal interfacial distance of eutectic mixture, rounding of contours of silicon precipitations and bigger portion of dendrites of plastic phase α creates favorable conditions for growth of tensile strength, elongation and impact resistance. To obtain a suitable structure of alloy, in practice one makes use of processes of refining and modification [1, 3-7].

Heat treatment, except modification, enables improvement of mechanical properties of alloys based on Al-Si equilibrium system- containing additional constituents like (e.g.: Mg, Cu).

Method of performed heat treatment and its effects are in big measure contingent upon morphology of primary structure of the alloys.

In case of the alloys modified in result of soaking treatment is present not only a growth of concentration in solid solution α of elementary substances, which constitute potential source of precipitation processes, but also an advantageous change of morphology of eutectic crystals of silicon – their coalescence and spheroidization. In loaded material, more advantageous distribution of stresses and attenuation of interaction of brittle phase Si as an internal notch, correspond to changed morphology of eutectic crystals of Si, which take form similar to globular one [4].

Obtainment of optimal mechanical properties of a heat treated alloy necessitates selection of suitable parameters of the process such as: temperatures of solutioning and ageing, as well as duration of these treatments. It results not only from technology of the heat treatment process itself, but also is connected with economical aspects of performance of the process, e.g. through shortening of duration of individual treatments. In case of selection of the temperatures, one can make use of the ATD and ATND methods, which enable assessment of quality of the alloy (degree of modification), as well as initial selection of temperature ranges of solutioning and ageing treatments [2, 8-10].

2. Methodology of the research

The tests were performed with use of two commercial alloys: EN AB-AlSi9Cu3(Fe) (EN AB-46000) and EN AB-AlSi12CuNiMg (EN AB-48000), as well as synthetic alloy EN AB-AlSi17Cu1Ni1Mg.

Investigated alloys were melted in electric resistance furnace. Refining treatment was performed after the melting. The AlSi17Cu1Ni1Mg alloy was refined with Rafal 1 in quantity of 0,6% of mass of metallic charge. Other alloys were refined, adding the same raffinate in quantity of 0,4% of mass of metallic charge. Next, the investigated alloys were modified with the AlSr10 master alloy in quantity of 0,4% of mass of the metallic charge (0,04% Sr). Modified alloys were poured to a metal mould, enabling production of standard test pieces of castings used to strength tests. The metal mould was heated to temperature of 250 ^{o}C. Recording of heating and melting process of the investigated alloys was made with use of the ATD Cristaldimat analyser.

The heat treatment was performed for the modified alloys. Temperature ranges of solutioning and ageing treatments were determined on base of recorded heating and melting curves from the ATD method. In the Figs. 1-3 are shown recorded curves from the ATD method of the investigated alloys with marked temperature ranges of the solutioning and ageing treatments.

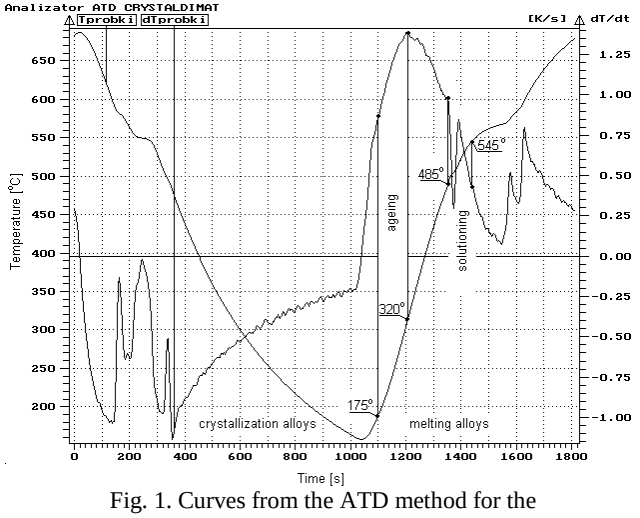

Fig. 1. Curves from the ATD method for the EN AB-AlSi9Cu3(Fe) alloy

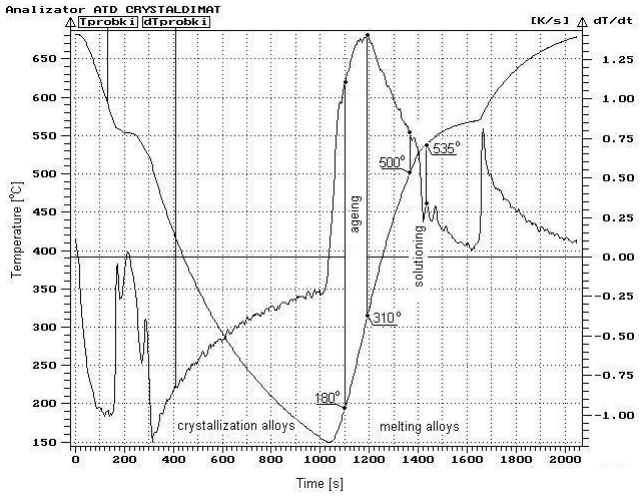

Fig. 2. Curves from the ATD method for the refined and modified EN AB- AlSi12CuNiMg alloy

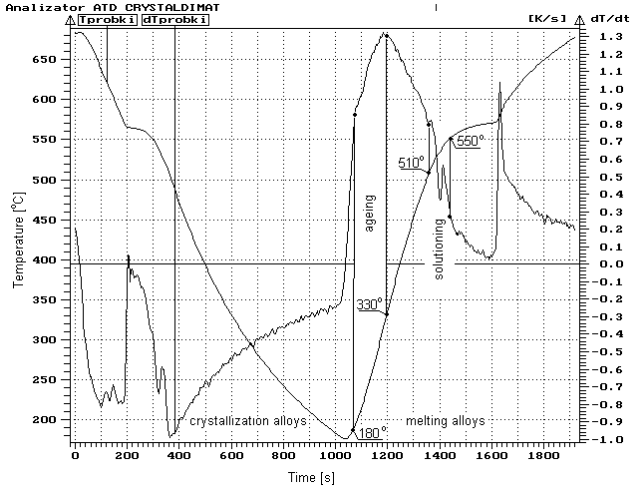

Fig. 3. Curves from the ATD method for the refined and modified EN AB- AlSi17Cu1Ni1Mg alloy

On base of performed analysis of the recorded curves from the ATD method one assumed the following temperature ranges of the heat treatment operations of the investigated alloys:

a) EN AB-AlSi9Cu3(Fe):
- solutioning temperature: 485 - 545 ^{o}C,
- ageing temperature: 175 - 320 ^{o}C.

b) EN AB-AlSi12CuNiMg:
- solutioning temperature: 500 - 535 ^{o}C,
- ageing temperature: 180 - 310 ^{o}C.

c) EN AB-AlSi17Cu1Ni1Mg:
- solutioning temperature: 510 - 550 ^{o}C,
- ageing temperature: 180 - 330 ^{o}C.

Duration of solutioning treatments of the investigated alloys amounted from 0,5 to 3 hours, whereas duration of their ageing from 2 to 8 hour.

The test pieces to strength tests were prepared according to the PN-88/H-88002 standard, whereas static strength tests were performed on ZD-20 tester.

3. Description of the obtained results

3.1. EN AB-AlSi9Cu3(Fe) alloy

Tensile strength obtained for the raw alloy (from pig sows) amounted from 213 to 243 MPa. After refining there occurred a slight change of the R_m tensile strength (246-249 MPa). Performed operation of modification of the alloy enabled obtainment of the R_m tensile strength within range of 248-272 MPa.

In the Fig. 4 are shown average values of the R_m tensile strength for the EN AB-AlSi9Cu3(Fe) alloy after the heat treatment.

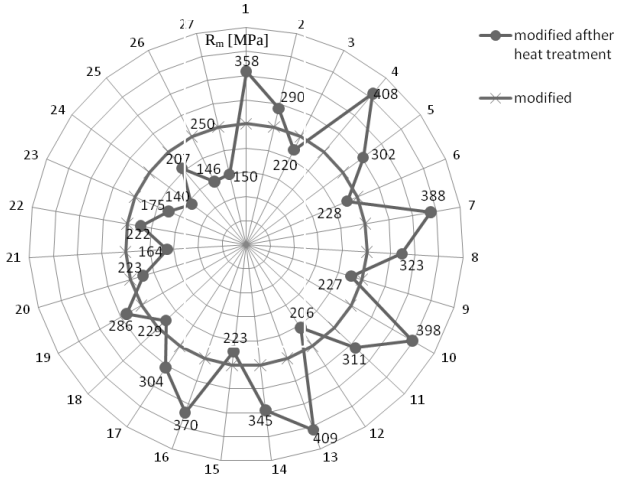

Fig. 4. Change of the R_m tesile strength of the EN AB-AlSi9Cu3(Fe) alloy for individual configurations of the testing plan

Making comparison of the obtained average values of parameters from the test of the alloy after heat treatment and the alloy without heat treatment, one confirmed growth of the R_m tensile strength with 65%.

For the specified parameters (4,7,10,13 - Fig. 4) of the heat treatment there was obtained the best (maximal) R_m tensile strength of the alloy. The highest R_m tensile strength, amounted to 409 MPa, was obtained for the following parameters of the heat treatment operations:

- solutioning temperature - 510 ^oC,
- solutioning duration - 1,5 hour,
- ageing temperature - 240 ^oC,
- ageing duration - 2 hours.

3.2. EN AB-AlSi12CuNiMg alloy

Tensile strength obtained for the raw alloy (from pig sows) amounted from 155 to 159 MPa. After refining there occurred a slight change of the R_m tensile strength (206-220 MPa). Performed operation of modification of the alloy enabled obtainment of the R_m tensile strength within range of 226-228 MPa.

In the Fig. 5 are shown average values of the R_m tensile strength for the EN AB-AlSi12CuNiMg alloy after the heat treatment.

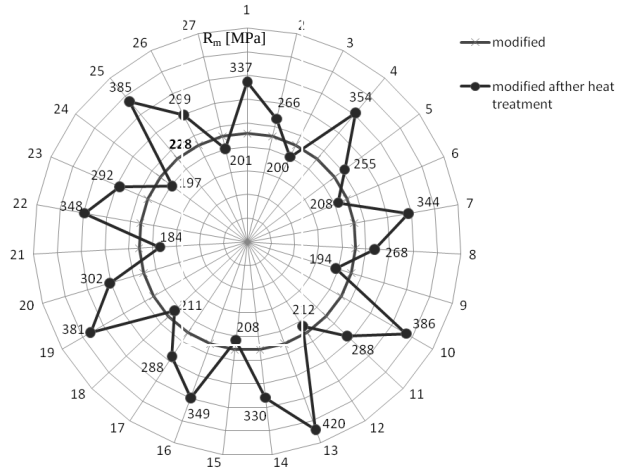

Fig. 5. Change of the R_m tesile strength of the EN AB-AlSi12CuNiMg alloy for individual configurations of the testing plan

Making comparison of the obtained average values of parameters from the test of the alloy after heat treatment and the alloy without heat treatment, one confirmed growth of the R_m tensile strength with 84%.

For the specified parameters (10,13,19,25 - Fig. 5) of the heat treatment there was obtained the best (maximal) R_m tensile strength of the alloy. The highest R_m tensile strength, amounted to 420 MPa, was obtained for the following parameters of the heat treatment operations:

- solutioning temperature - 520 ^oC,
- solutioning duration - 1,5 hour,
- ageing temperature - 180 ^oC,
- ageing duration - 5 hours.

3.3. EN AB-AlSi17Cu1Ni1Mg alloy

Tensile strength obtained for the raw alloy (from pig sows) amounted from 143 to 158 MPa. After refining there occurred a slight change of the R_m tensile strength (144-198 MPa). Modification of the alloy resulted in drop of the R_m tensile strength, which amounted to 165 - 175 MPa.

In the Fig. 6 are shown average values of the R_m tensile strength for the EN AB-AlSi17Cu1Ni1Mg alloy after the heat treatment.

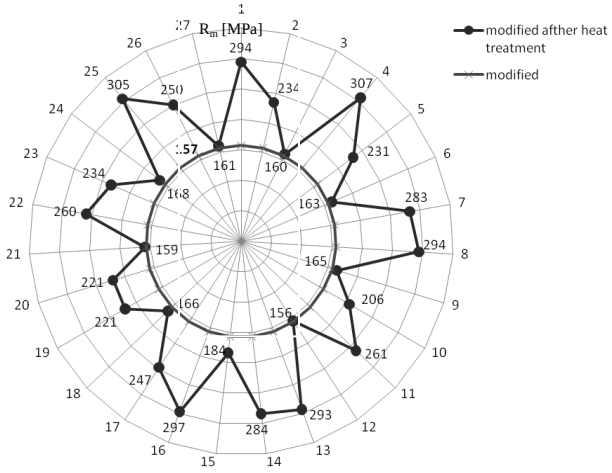

Fig. 6. Change of the R_m tensile strength of the EN AB-AlSi17Cu1Ni1Mg alloy for individual configurations of the testing plan

Making comparison of the obtained average values of parameters from the test of the alloy after heat treatment and the alloy without heat treatment, one confirmed growth of the R_m tensile strength with 95%.

For the specified parameters (4,8,13,16,25 - Fig. 6) of the heat treatment there was obtained the best (maximal) R_m tensile strength of the alloy. The highest R_m tensile strength, amounted to 307 MPa, was obtained for the following parameters of the heat treatment operations:

- solutioning temperature - 510 ^oC,
- solutioning duration - 1,5 hour,
- ageing temperature - 180 ^oC,
- ageing duration - 8 hours.

4. Conclusions

Suitable selection of heat treatment parameters of silumins, i.e. temperature and duration of the solutioning and ageing treatments, is a condition of obtainment of improved R_m tensile strength.

Usage of the ATD method enables preliminary selection of solutioning and ageing temperatures, taking into consideration a possibility of determination of their maximal values.

Performed investigations have enabled determination of suitable parameters of the heat treatment aimed at improvement of the R_m tensile strength.

Further investigations could concern a complex assessment of an effect of the heat treatment on mechanical and technological properties of the alloys.

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