Determination through Use of ATND Method of Impact Strength of 359.0 Alloy Modified With Strontium

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Abstract
The paper presents a method for determination of impact strength of the 359.0 alloy modified with strontium, based on the ATND method and regression analysis performed as early as at the stage of its preparation (melting). Method of Thermal-Voltage-Derivative Analysis (ATND in short) allows registration of voltage and temperature curves, on which one can observe a thermal and voltage effects being results of crystallization of phases and eutectic mixtures, present on the curves in form of characteristic "peaks". Values of the temperatures and voltages, which can be read out for the characteristic points, constitute the basis for the regression analysis to obtain mathematical relationships presenting effect of changes of their values on change of impact strength of the 359.0 (AlSi9Mg) alloy. It has enabled determination of impact strength of the 359.0 alloy, using equation estimating characteristic points of the ATND method, in experimental conditions at significance level of $\propto = 0{,}05$.

Keywords: silumins, modification, thermal analysis, impact strength, regression analysis.

1. Introduction

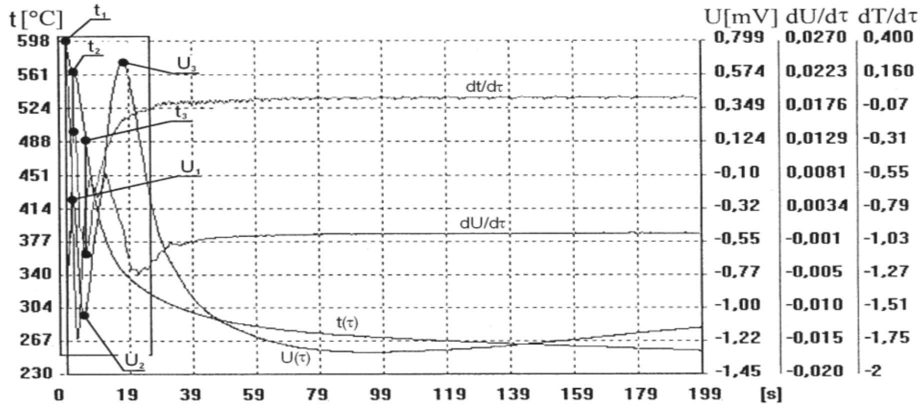
Among alloys of non-ferrous metals, aluminum alloys have found the broadest application in foundry industry. Silumins belong to the most common alloys on base of aluminum, i.e. alloys from the Al-Si system [1]. This is connected with a number of advantages – both operational and technological ones – of this group of the alloys. Silumins belong to alloys which are characterized by: low specific gravity, good thermal conductivity, good corrosion resistance, satisfactory strength parameters in normal and increased temperatures, as well as relatively low price and excellent technological properties. The most important aluminum silicon alloys are based on the aluminum-silicon system, especially the hypoeutectic alloys with composition ranging from 7 to 11 wt. % silicon. Quite a significant disadvantage from a technical point of view is their tendency to form coarse structure, which adversely affects mechanical properties of the castings. Modification is the most effective way to enable optimal structure of the castings, providing improvements in their functional properties. Quality of the modification is dependent on correct dosage of inoculant, metal temperature and time elapsing from the modification to solidification of the alloy [1-3].Registration of crystallization processes of the alloy at stage of its preparation is directly related to implementation of theory of crystallization in control of technological processes, enabling obtainment of a suitable structure of the material, which determine its application for to a given requirements [2,4,5]. Methods employed to registration of crystallization of the alloys based on analysis of temperature change (thermal ones - ATD, DTA), electrical conductivity change (electric ones - AED) and method of thermal-voltage-derivative analysis (ATND method) enable registration of a phenomena arisen in result of solidification of the alloys [6-8]. Among materials testing, impact strength tests are the most sensitive methods to determination of strength effects connected with proper application of modification treatments of hyper- and hypo-eutectic silumins [9].Growth of the impact strength of alloys is directly connected with change of shape of crystals of eutectic silicone resulted from the modification.

2. Methodology of the research

The ATND method consists in permanent measurement of temperature and electric voltage generated on probes during the crystallization, as well as phase transformations of solidified alloy. During the measurement are recorded generated voltage and temperature of investigated test pieces. Run of the crystallization is presented in form of a diagram generated during solidification of the alloy [6,8]. The 359.0 (AlSi9Mg) alloy is rated among hypo-eutectic silumins. It features very good cast properties and is designed for castings with complicated shapes and high strength. Investigated alloy was melted in crucible resistance furnace and refined with Rafal 1 preparation in quantity of 0,4% mass of charge. After completion of the refinement one removed oxides and slag from the metal-level, and performed treatment of modification of the alloy with strontium, using AlSr10 master alloy in quantity 0,6% mass of charge (0,06% Sr).Investigated alloy was poured into metallic mould, which was adapted to control of crystallization course with use of the ATND method.

In the Fig. 1 is presented a diagram showing course of the crystallization of refined and modified alloy, recorded during the testing, with marked characteristic points.

a)



b)

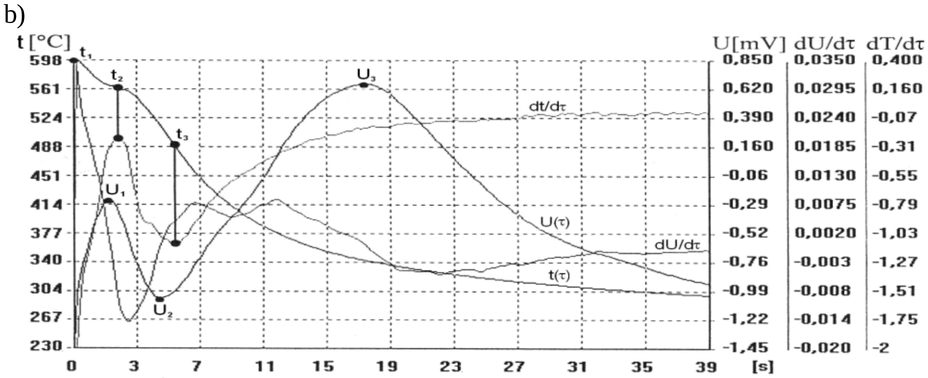


Figure 1. Crystallization curves and characteristic points of refined and modified 359.0 alloy from the ATND analysis: a) full range of crystallization process, b) extension marked area

Marked characteristic points (Fig. 1) for the ATND method are:

a) points on thermal curve $t_1 \div t_3$,

b) points on voltage curve $U_1 \div U_3$.

The next stage of the testing consisted in tests of impact strength of the investigated silumin. The impact test was performed with use of Charpy pendulum machine on notched-bar test pieces.After performed impact test one carried out regression analysis with use of the "Statistica" computer software developed by StatSoft, and determined correlation between change of characteristic points of the ATND method and impact strength of the investigated alloy.

3. Description of Obtained Results

Obtained values of the impact strength were contained within range from 3,4 to 14,4 J/cm^2. Average value of the impact strength after treatment of the refinement amounted to 4,3 J/cm^2, while after refinement and modification amounted to 12,9 J/cm^2.After input of the independent variables (temperature and voltage) and dependent variable (impact strength) one obtained the relation (1) describing effect of the input data on the impact strength of refined alloy, as well as relation (2) presenting effect of the input data on the impact strength of refined and modified alloy.

$$KCV = 4{,}26 - 0{,}01t_1 + 0{,}01t_3 + 0{,}34U_1 - 0{,}69U_3 \pm 0{,}31 \text{ [J/cm}^2\text{]} \quad (1)$$

$$R = 0{,}74;\ R^2 = 0{,}64$$

The relation (1) contains a free term and 4 variables which satisfy condition of significance. Remaining independent variables were neglected due to not fulfilled condition of significance.

$$KCV = -8{,}49 + 0{,}04t_3 + 3{,}42U_1 - 2{,}7U_2 \pm 0{,}43 \text{ [J/cm}^2\text{]} \quad (2)$$

$$R = 0{,}78;\ R^2 = 0{,}61$$

The relation (2) contains a free term and 3 variables satisfying condition of significance. Remaining independent variables were neglected as not fulfilling condition of significance.

In the Fig. 2 are presented exemplary values of the impact strength, observed and anticipated on base of the relation (1) and relation (2).

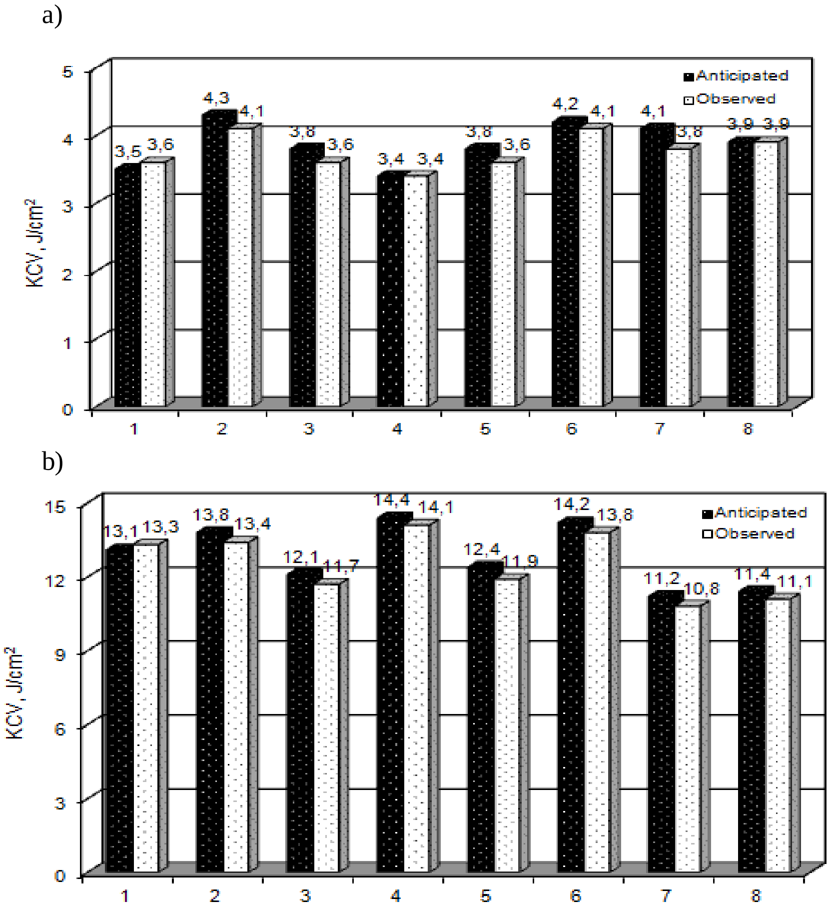


Figure 2. Exemplary values of the impact strength, observed and anticipated on base of the: a) relation (1) and b) relation (2)

Change of course of the crystallization of investigated alloy, connected with performed treatment of refinement and modification, is presented in the Fig. 3.

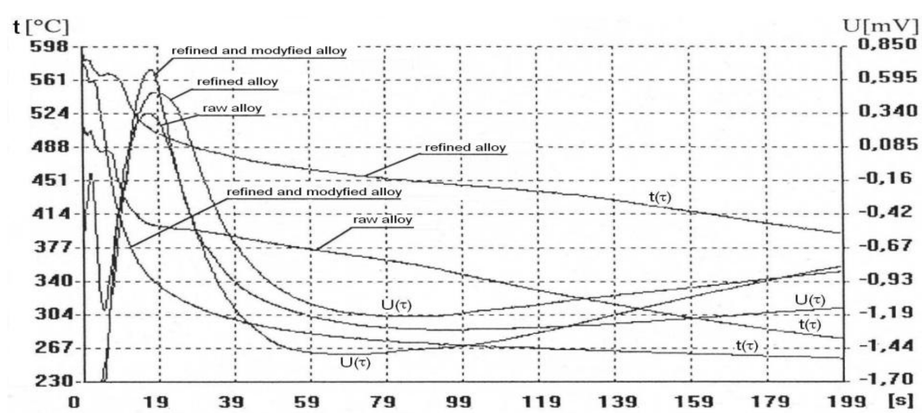


Figure 3. Representative curves from the ATND method for the 359.0 alloy

4. Conclusions

Performed tests enabled description of the KCV impact strength of refined and modified 359.0 (AlSi9Mg) alloy with equations (1) and (2), basing on characteristic points of the ATND method in experimental conditions, what enabled prompt assessment of quality of the alloy in aspect of change of its impact strength and extent of the modification (Fig. 3) as early as in stage of its preparation.

References

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