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Intermetallic phases influence on solidification process of fixture brasses

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Abstract: This publication contains a selection of results obtained after thermal and derivative analysis of fixture brasses with variable chemical composition. Authors showed possible relations between characteristic points of TDA curves and the hard inclusions quantity. This would enable implementation of TDA method for quality control of fixture brasses.

Keywords: Fixture brass, Thermal and derivative analysis (TDA), Intermetallic phases

1. INTRODUCTION

In fixture brasses microstructure besides typical components the hard inclusions can be found. They result from interactions between some technological additions and impurities which occur in liquid metal. This intermetallic phases deteriorate all properties of the brass and most of all the machinability, corrosion resistance and castability [1, 3]. All occurring phases give in the cooling process some heat effects. By registration of temperature changes and its first derivative after time we can evaluate some alloy property. This is how the thermal and derivative analysis works. TDA was implemented to control the quality of many different alloys but initially it was used to control the cast iron solidification process.

As was written above, all occurring phases give heat effects on cooling curves. The crystallization of a fixture brass normally containing about 40% Zn and 2% Pb consists of four major effects: the solidification, $\beta \rightarrow \alpha + \beta$ transition, $\beta \rightarrow \beta'$ transition and Pb solidification. All listed effects can be registered in thermal and derivative analysis and these parameters (temperature, derivative value, time – parameters of characteristic points from TDA curves) might be used to quality control of the alloy. Some of the TDA applications to fixture brasses were made earlier [1] by the authors and others [7]. The thesis of this work is that occurrence of intermetallic phases will disturb the cooling and crystallization curves and thus the parameters of this disturbance will be related to quantity and type of the phases.

2. STUDIES

Presented studies are a part of work concerning interaction between alloy addition and impurities and its influence on properties of fixture brasses. Special active experiment was prepared, in which the variable was the content some elements. Their selection and other information are described in article "Hard inclusion in fixture brasses" placed in the same publication. Full experiment enclosed 14 casts with variable chemical composition, in which quantity of the additions did not exceed the level specified in PN.

Alloy was prepared with pure components (Cu, Zn) and preliminary alloys (CuFe, CuSi, CuAl, CuP) in inductive furnace in accordance to foundry practice for copper alloys. Thermo physical conditions for all casts remained constant. Alloy was poured into a metal mould heated to 300°C temperature. Fixture brasses are used mainly for permanent mould casting and thus such method was used. Cooling curve was registered with use of Ni – NiCr thermocouple and Cristaldigraph PC equipment.

From every cast a set of TDA curves was registered which were then used for statistical examination.

3. RESULTS

3.1. Thermal and derivative analysis curves

In figure 1 a TDA diagram for fixture brass is showed. Characteristic points in initial stage of crystallization are indicated by following letters. These are determined as a singular points on crystallization curve and can be easily found.

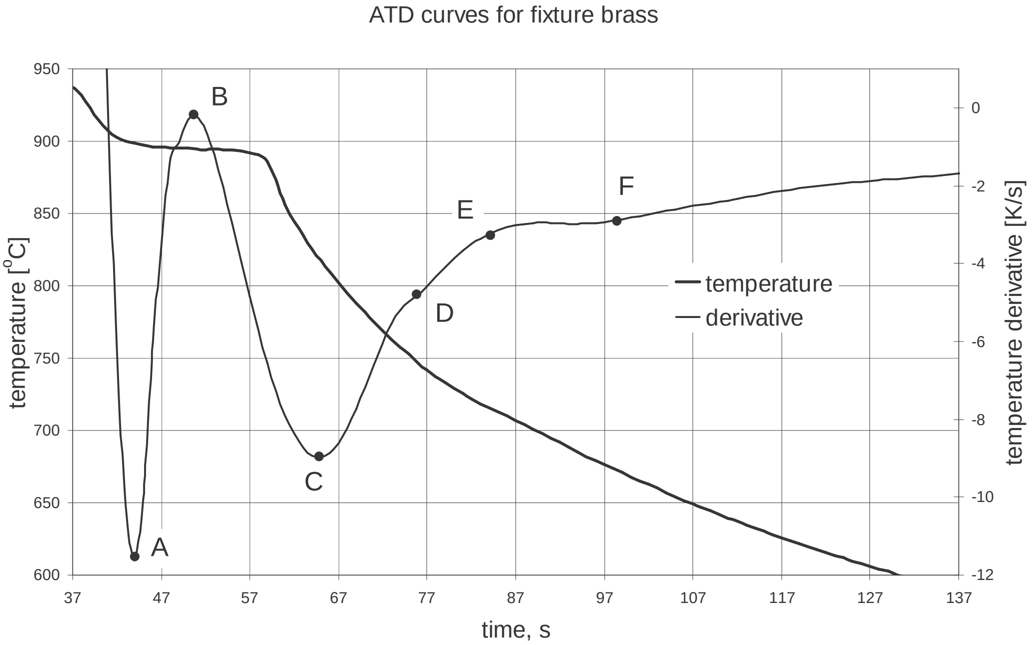

Figure 1. Thermal and derivative analysis curves (cooling T(t) and crystallization dT/dt(t) curve) for fixture brass, letters indicate the characteristic points

The physical interpretation of these points can be as follows: A – start of sample solidification, B – maximal heat effect of solidification (stable liquidus point of the alloy), C – end of sample solidification, D – start of $\beta \rightarrow \alpha + \beta$ transition, E – maximal heat effect of $\beta \rightarrow \alpha + \beta$ transition (stable $\beta \rightarrow \alpha + \beta$ transition temperature), F – end of $\beta \rightarrow \alpha + \beta$ transition. When alloy chemical composition and thermo physical conditions are favorable for one phase matrix the TDA curves are slightly different (no D, E, F points, figure 2). As you can see thermal and derivative analysis can be easily implement to evaluation of the matrix microstructure [1]. It is so because the heat effects concern with the matrix changes or significant and the error range is relatively low.

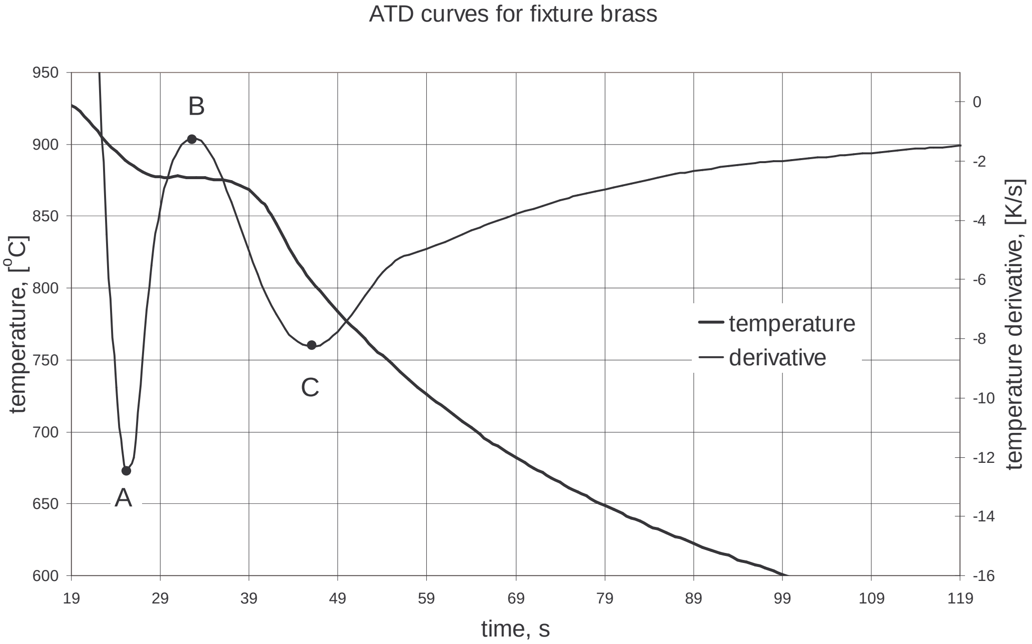

Figure 2. Thermal and derivative analysis curves (cooling T(t) and crystallization dT/dt(t) curve) for fixture brass with matrix containing only β' phase, letters indicate the characteristic points

3.2. Statistical analysis

Registered in thermal and derivative curves was next used in statistical analysis with results of qualitative analysis for intermetallic phases. This data allowed to create relations between the two group of variables. Below some of the results are presented. Besides the intermetallic phases influence also a relation between the chemical composition and characteristic points was studied.

- Hard inclusions content HI in function of characteristic temperatures

$$HI = 33,28 + 0,014 \times [T_D] - 0,0572 \times [T_F] - 0,0255 \times [T_A - T_C] \quad \text{[\% of volume]} \qquad (1)$$

correlation coefficient R = 0,9914

- Temperature of sample solidification start T_A in function of chemical composition

$$T_A = 877,66 - 29,698 \times [Si] + 81,821 \times [Fe] \quad [^{o}C] \qquad (2)$$

correlation coefficient R = 0,822

4. SUMMARY

Presented studies showed that intermetallic phases have a significant influence on thermal and derivative analysis curves. As seen from equation (1) relation bonds the hard inclusions quantity with start and end temperatures for $\beta \rightarrow \alpha + \beta$ transition (T_D and T_F), what can mean that the matrix structure has an influence on hard inclusions content. It is in agreement with other results which show that α phase occurrence cause higher intermetallic phases content. Probably because the β phase has greater potential for impurities solubility. Equation (1) shows also intermetallic phases quantity relation with solidification range $T_A - T_C$. Together with indicated in equation (2) iron influence on temperature T_A it can mean that these phases give nucleation possibilities. Similar conclusions are presented in [3, 9].

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