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METHOD OF CRYSTALLIZATION HEAT DEFINITION IN TEMPERATURE FUNCTION FOR METAL ALLOYS

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1. Introduction

Change of the matter state of aggregation is strictly connected with heat effects. While changing of liquid state of aggregation to the solid one we must collect the proper quantity of heat energy. In the case of pure metals and some of alloys this change occurs in constant temperature. The heat amount which must be received during this process is called solidification heat (or melting heat) of any substance. Taking into account the most of alloys, the process of state transformation from solid into the liquid one takes place within the range of temperatures. The opportunity of definition of crystallization heat in the certain range of temperatures would afford possibilities for analysis of heat effects during metal alloys crystallization.

2. Description of method

Presented method is based on the data from ATD test (Thermal and Derivation Analysis). During this test the temperature change as well as its time derivative are registered. In order to define the spectral heat function the inverse problem of heat flow is used. The heat process parameters are defined by using the numerical model of measuring probe [2,3] in which temperature changes have been registered. The next step of algorithm is definition of the heat capacity (enthalpy) of alloy in solid and liquid state of aggregation. Then we define the total crystallization heat. In the last stage heat distribution in temperature function is defined. This function is presented in parametric form as linear combination of function:

$$F_1(T) = a_1 \frac{a_2 \cdot \exp(a_2(a_3 - T))}{1 + \exp(a_2(a_3 - T)))^2} + \frac{a_6 \cdot F_2(T)}{1 + \exp(a_7(T - a_8))} \tag{1}$$

where: T – temperature,
a_1, a_2, a_3, a_6, a_7 – parameters,

And function of liquid metal exhaustion:

$$F_2(T) = \frac{1}{1+\exp(a_4(a_5 - T))} \tag{2}$$

where: a_4, a_5 – parameters.
Functions (1), (2) for example parameters are shown on fig. 1, 2.

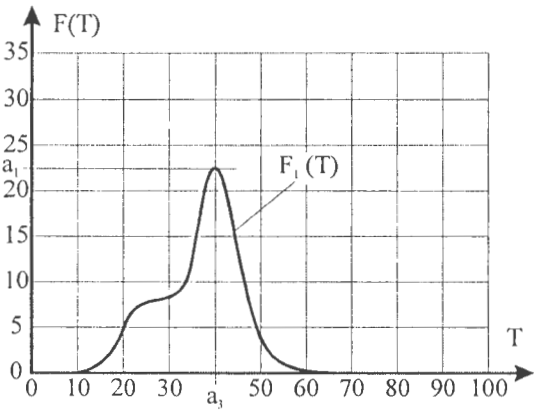

Fig. 1. Function (1) for example parameters

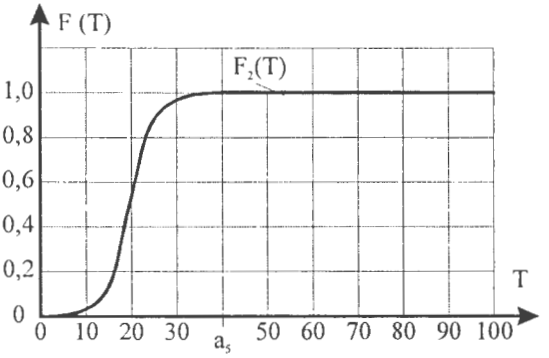

Fig. 2. Function (2) for example parameters

Using the gradient method of optimization the function parameters are chosen in order to minimize the target function [4]:

$$\varepsilon = \frac{\int_0^{t_{cryst}} |T_{sim} - T_{real}|}{t_{cryst}} \tag{3}$$

where: T_{sim} – numerical defined temperature (simulated),

T_{real} – measured temperature,

t_{cryst} – crystallization time.

On fig. 3 a course of measurement and simulation for Al alloy AK-9 has been presented. We can observe good compatibility between temperature and its derivative. Received spectral heat function is shown on the fig. 4.

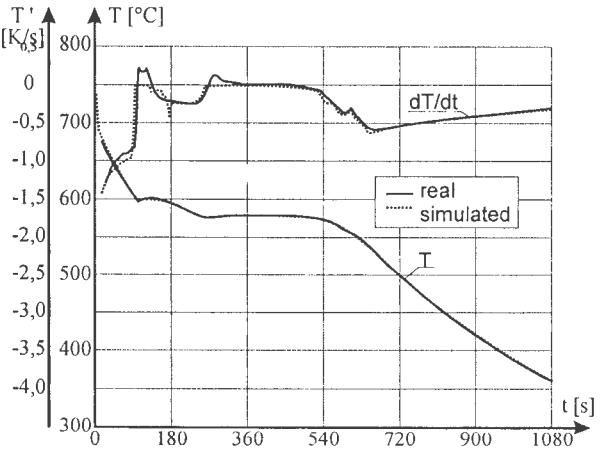

Fig. 3. Crystallization process registered and restored during simulation

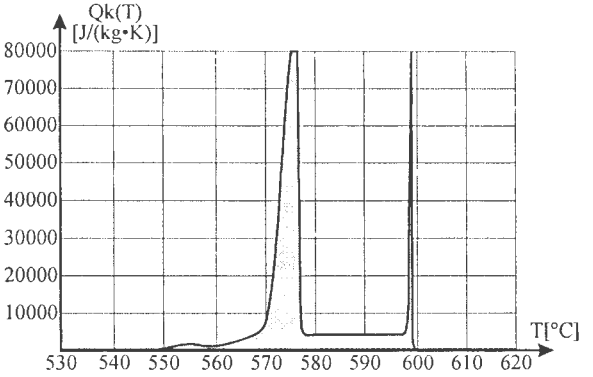

Fig. 4. Spectral heat of crystallization for AK-9 alloy

3. Summary

The method shown above gives the opportunity for detailed analysis of heat effects during crystallization of metal alloys, and enables to restore crystallization processes in computer simulation. There are no technical problems due to using the standard measuring equipment. Calculation method requires to use standard computer system Pentium 200 MHz and specially elaborated software for described calculations. This method has been used many times by the authors in investigations of Al and cast iron alloys.

References

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METODA OKREŚLANIA CIEPŁA KRYSTALIZACJI STOPÓW METALI W FUNKCJI TEMPERATURY

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W artykule przedstawiono metodę określania ciepła krystalizacji stopów metali w funkcji temperatury, nazywanego też ciepłem spektralnym krystalizacji [1]. Dzięki prostej metodzie pomiaru (metoda ATD) oraz opracowanemu algorytmowi obliczeń, możliwe jest wyznaczenie ilości ciepła wydzielającego się w trakcie krystalizacji dla określonych temperatur. Daje to możliwość analizy zjawisk cieplnych zachodzących w trakcie krystalizacji.