Calculations of some thermo-physical properties of aluminum alloys using data of thermal analysis

V B Deev[1,2], O G Prihodko[3], E S Prusov[4], A I Kutsenko[3], Mei Shunqi[1], A A Aksenov[2] and T A Bazlova[2]

[1]Wuhan Textile University, 1 Textile Road, Wuhan, 430073, China

[2]National University of Science and Technology "MISIS", 4 Leninskiy Pr., Moscow, 119049, Russian Federation

[3]Siberian State Industrial University, 42 Kirova Street, Novokuznetsk, 654007, Russian Federation

[4]Vladimir State University named after Alexander and Nikolay Stoletovs, 87 Gorky Street, Vladimir, 600000, Russian Federation

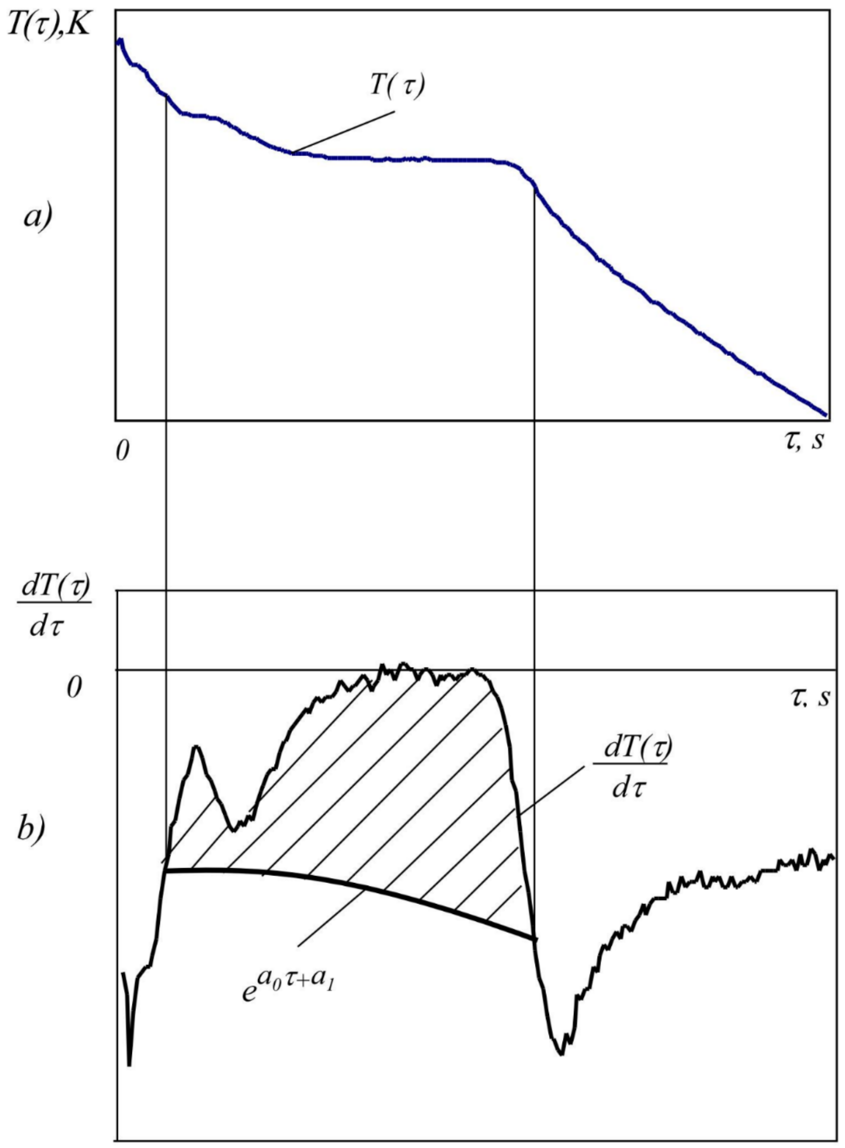
Introduction

Aluminum alloys are one of the most economical and technologically advanced materials used in industrial foundry technologies in the production of lightweight structural parts. The growing requirements for the quality of cast products from aluminum alloys necessitate the development of new and optimization of existing technological processes of melting and casting.

Computer simulation of the crystallization processes of aluminum alloys and the solidification of castings from them is currently widely used both in scientific research practice and in industrial conditions for solving problems of increasing the productivity and quality of manufactured castings. This approach has repeatedly proved its effectiveness, allowing us to predict the influence of different casting and solidification parameters without expensive experimental studies. The accuracy of forecast estimates in the simulation will be largely determined by the accuracy of the experimental determination or theoretical calculation of the thermo-physical properties of aluminum alloys.

The present work describes a technique for calculating the heat of crystallization and heat capacity of aluminum alloys in the range from the temperature of its pouring into the mold to the average temperature of the solidified skin according to the results of thermal analysis.

Methods



Determination of the heat of crystallization of the alloy according to the results of thermal analysis: a) thermal curve; b) the first derivative of the thermal curve.

To determine the coefficients a_0 and a_1 taking into account the initial conditions, we have a system of equations:

$$\begin{cases} a_0\tau_0 + a_1 = \ln\left(dT(\tau_0) \big/ d\tau_0 \right) \\ a_0\tau_1 + a_1 = \ln\left(dT(\tau_1) \big/ d\tau_1 \right) \end{cases}$$

Knowing the coefficients a_0 and a_1, we can determine the cooling rate in the time interval $(\tau_0 - \tau_1)$ by the formula

$$m' = -\frac{1}{T(\tau)} \cdot e^{a_0\tau + a_1}$$

Results and Discussion

$$\begin{cases} L_{cr} = \dfrac{12\tau_f \cdot \left(T_{cr} - T_m^0\right)}{\rho_a \left(\dfrac{1}{\lambda_a} + \dfrac{b}{\lambda_m}\right) R^2} - c_a\left(T_p - 2T_{cr} + \bar{T}_a\right) \\ L_{cr} = \displaystyle\int_{\tau_1}^{\tau_0} \left(-\frac{1}{T(\tau)} \cdot \frac{dT(\tau)}{d\tau} - \frac{1}{T(\tau)} \cdot e^{a_0\tau + a_1}\right) \cdot T(\tau) c_a d\tau \end{cases}$$

The system of equations is determined, and its solution is single-valued under the following assumptions. Since this is a system of two equations, it can be solved with no more than two unknowns. Therefore, in addition to the determined heat of crystallization, it is possible to have one unknown parameter. The heat capacity of the alloy varies over a wide range and has the greatest influence on the calculation results, therefore, factors such as heat capacity, thermal conductivity and density of the mold material, thermal conductivity and density of the alloy are assumed to be constant. Thus, when solving the system of equations, the heat of crystallization of the alloy and its average heat capacity can be determined.

Conclusion

A technique for calculating the heat of crystallization and heat capacity of aluminum alloys based on the results of thermal analysis through the solution of an algebraic system of equations with two unknowns is proposed.

The technique allows to determine thermo-physical properties according to the results of experimental studies not on standard samples, but directly on a real castings. This is an additional positive side of the proposed technique, because the cooling rate of castings in the mold has a significant effect on the formed structure and the casting defects of a multicomponent aluminum alloy during its transition from a liquid state to a solid state and, as a result, on the estimated thermal properties. An additional measurement and recording of the pouring temperature, the initial temperature of the mold, the average temperature of the heated mold layer and the average temperature of the solidified skin of the alloy can significantly increase the accuracy of the predictive estimates of the thermo-physical properties of aluminum alloys.

The calculation algorithm is easily programmed in any algorithmic language or can be implemented using an application package MATLAB for solving technical computing problems.