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EXPERIMENTAL AND NUMERICAL DETERMINATION OF TEMPERATURE DISTIBUTION IN SOLIDIFYING CASTING

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Abstract. The thermal processes proceeding in a system casting-mould are considered. The casting is made from cast iron. The temperature and its time derivative at the central point of sample casting have been obtained experimentally. Using finite difference method the temperature distribution in the domain considered has been determined. Next, the calculated and measured cooling curves have been compared. The good agreement between these curves has been observed.

1. Experimental determination of temperature field

To determine the temperature in the solidifying cast iron the experimental researches have been realized. The heat cast of hypo-eutectic grey cast iron of Zl200--Zl250 class has been prepared. The charge material has been chosen according to the rules concerning the smelting of cast iron in the induction furnace. In the test casting the thermocouple PtRh-Pt has been installed as shown in Figure 1. The thermocouple has been connected to the registering apparatus.

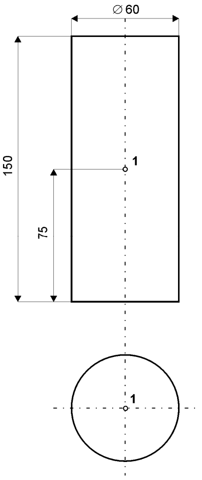

Fig. 1. Sampling casting (cylinder)

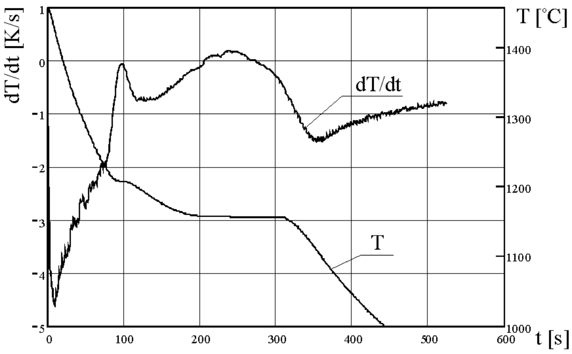

Fig. 2. Cooling curve and time derivative at the sensor 1 (experiment)

The thermal and derivative analysis (TDA) have been done in order to determine the characteristic temperatures associated with the change transition [1]. The heat transfer processes proceeding in the solidifying metal connected with the latent heat emission of successive phases have been registered taking into account the cooling curve $T_d(t) = T(x_d, t)$ and its time derivative $\partial T_d(t)/\partial t$ (Fig. 2).

Using the diagrams of the thermal and derivative analysis the values of temperature-dependent latent heat have been registered (Fig. 3). Next, the substitute thermal capacity distribution for mushy zone containing the information about the austenite and eutectic phases has been described - Figure 4.

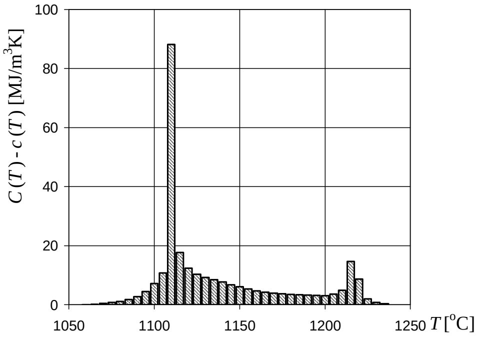

Fig. 3. Distribution of cast iron latent heat

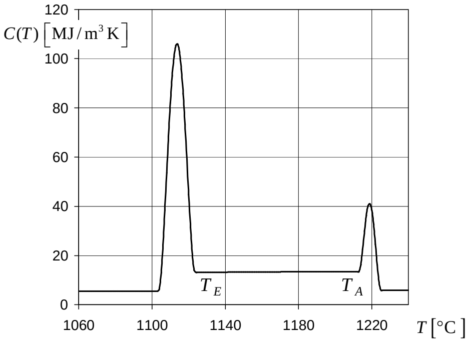

Fig. 4. Substitute thermal capacity of cast iron

2. Numerical modelling of temperature field

The energy equation describing the casting solidification has the following form [2, 3]

$$C(T)\frac{\partial T(x,t)}{\partial t} = \nabla\left[\lambda(T)\nabla T(x,t)\right] \tag{1}$$

where $C(T)$ is the substitute thermal capacity [2, 4] - Figure 4, $\lambda(T)$ is the thermal conductivity, T, x, t denote the temperature, geometrical co-ordinates and time.

The considered equation is supplemented by the equation concerning a mould sub-domain

$$c_m\frac{\partial T_m(x,t)}{\partial t} = \lambda_m \nabla^2 T_m(x,t) \tag{2}$$

where $c_m(T)$ is the mould volumetric specific heat, $\lambda_m(T)$ is the mould thermal conductivity.

In the case of typical sand moulds on the contact surface between casting and mould the continuity condition in the form

$$\begin{cases} -\lambda\, \mathbf{n}\cdot\nabla T(x,t) = -\lambda_m\, \mathbf{n}\cdot\nabla T_m(x,t) \\ T(x,t) = T_m(x,t) \end{cases} \tag{3}$$

can be accepted. On the external surface of the system the Robin condition

$$-\lambda_m\, \mathbf{n}\cdot\nabla T_m(x,t) = \alpha\left[T_m(x,t) - T_a\right] \tag{4}$$

is given (α is the heat transfer coefficient, T_a is the ambient temperature).

For time $t = 0$ the initial condition

$$t=0:\;\; T(x,0)=T_0(x)\;,\;\; T_m(x,0)=T_{m0}(x) \tag{5}$$

is also known.

The problem has been solved using explicit scheme of finite difference method [2-6]. The input data have been taken from [3].

The cooling curve and its time derivative found (using the mean differential quotients) at the node corresponding to sensor 1 are shown in Figure 5. Figure 6 illustrates the experimental and calculated cooling curves at the central point of the sample casting.

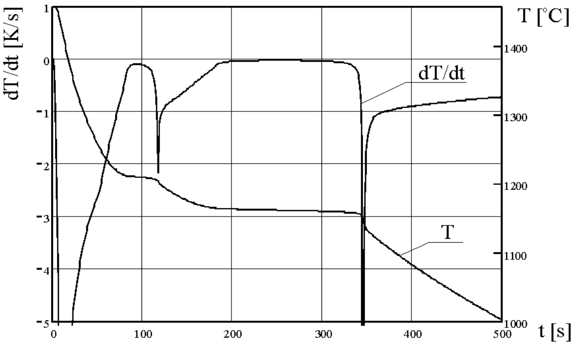

Fig. 5. Cooling curve and differential derivative at the sensor 1 (simulation)

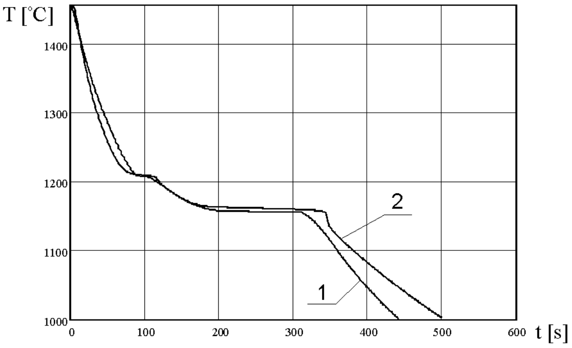

Fig. 6. Cooling curves (1 - real experiment, 2 - simulation)

Conclusions

The typical verification of numerical model of transient heat transfer bases on the comparison of calculated and measured temperature histories. Application of TDA technique allows one to obtain the information concerning not only the non-steady temperature field but the courses of cooling rates at the set of points selected from casting domain are also known. So, it gives the possibilities of more precise analysis of numerical simulation quality and a such problem is here considered.

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