3-D MODELING AND COMPUTER SIMULATION OF ALUMINUM ALLOYS SOLIDIFICATION FOR A QUALITY ESTIMATION OF CASTING

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Abstract

3-D modeling and computer simulation is one of the most effective methods of studying of difficult problems in foundry and metallurgical manufacture. Computer models use for optimization of casting production, in many cases they are a unique possible technique for carrying out of the experiments which real statement is complicated. Formalizing and logicality of computer models allows defining the major factors for a quality estimation of cast alloys, to investigate "reaction" of solidified casting to changes of its parameters and initial conditions. Processes of solidification, cooling and heating for the majority of cast alloys are defining for a quality of the casting, and a problem of adequate modeling of foundry systems, firstly, depends on solution of heat equations. One of the most often-applied numerical methods for the decision of problems of modeling of cast and solidification processes is the method of final elements (MFE). Computer simulation software, such as ProCAST, is enough universal on alloys and casting conditions, widely use MFE for solidification modeling.

In this study, the comparative calculations were carried out for some variants of casting of aluminum alloy Al-10Si in the metal mould by the ProCAST for a quality estimation of real casting and liquidation of shrinkable defects in castings.

The solution of the thermal problem connected with the analysis of shrinkable defects, were carried out with use of real casting "Pump" of Minsk motor factory which has a significant amount of thermal sites. The problem consisted in working out of technological process of casting without shrinkable bowls. Technology included casting in metal mould of aluminum alloy AK9 with chemical compound, %: Si - 10; Mn - 0.4; Mg - 0.3; Fe - 0.8; Cu - 0.5; Zn - 0.2. Settlement temperature liquidus is 597 °C, solidus is 541 °C.

Results of computer simulation of solidification have shown that formation of shrinkable defects is possible in the top part of casting, that not completely corresponded to a real arrangement of shrinkable defects in castings after industrial conditions. The assumption as the possible reason of inadequate modeling of solidification of casting can be inexact data about temperatures of phase transitions and deviations of solid phase distribution as a function of temperature.

For definition of real temperatures of phase transformations of alloy was use a method of the thermal analysis (TA) on a curve of cooling of test probe melt. To investigate the influence of values of temperatures of phase transformations on results of modeling of solidification, the data of the thermal analysis of cast alloy AK9 were used. The thermal analysis set included the measuring block and a special support for fastening of the thermocouple. The measuring block is constructed on the basis of microcontroller, the signal from the thermocouple was transformed to a digital form and passed for processing in the

computer. Record of temperatures during crystallization process of melt was carried out through the time intervals: 0,48 msec. After solidification the phase transformation temperatures were calculated. As a result the data of thermal analysis has been established, that real temperature liquidus of cast alloy AK9 is 592 °C, solidus is 553 °C. Results of repeated computer simulation taking into account experimentally received data about phase transitions have shown, that character of solidification changes.

Results of modeling of solidification and distribution of shrinkable defects have shown the thermo-physical characteristics of alloy, solid phase distribution as a function of temperature is very important for simulation of solidification. The distinctions at computer modeling of cast aluminum alloys were causes by the non-adequate initial settlement data on temperatures of phase transformations.

TEXT OF THE CONTRIBUTION

3-D modeling and computer simulation is one of the most effective methods of studying of difficult problems in foundry and metallurgical manufacture. Computer models use for optimization of casting production, in many cases they are a unique possible technique for carrying out of the experiments which real statement is complicated. Formalizing and logicality of computer models allows defining the major factors for a quality estimation of cast alloys, to investigate "reaction" of solidified casting to changes of its parameters and initial conditions.

Processes of solidification, cooling and heating for the majority of cast alloys are defining for a quality of the casting, and a problem of adequate modeling of foundry systems, firstly, depends on solution of heat equations.

One of the most often-applied numerical methods for the decision of problems of modeling of cast and solidification processes is the method of final elements (MFE). Computer simulation software, such as ProCAST, is enough universal on alloys and casting conditions, widely use MFE for solidification modeling.

In this study, the comparative calculations were carried out for some variants of casting of aluminum alloy Al-10Si in the metal mould by the ProCAST for a quality estimation of real casting.

For industrial alloys, the latent solidification heat and its dependence of temperature on a share of a solid phase is the alloy characteristic. In this case, the latent solidification heat and character of its distribution is assumed constants. It is fair in a case when there is a steady unequivocal dependence of a thermal emission on quantity of a solid phase in a wide interval of rates of cooling. In this case, the adequate account of non-uniformity of a thermal emission in the range of solidification temperatures is most important. Application for this purpose the various functional dependences connecting quantity of a solid phase with diagrams of a states of alloys more often ineffectively and extremely inadequately reflects the valid character of a thermal emission for real non-equilibrium conditions. Therefore, the account of dependence of percentage quantity of the solid phase from temperature is important. The most adequate data on phase transition can be defined by methods of the thermal analysis of alloys.

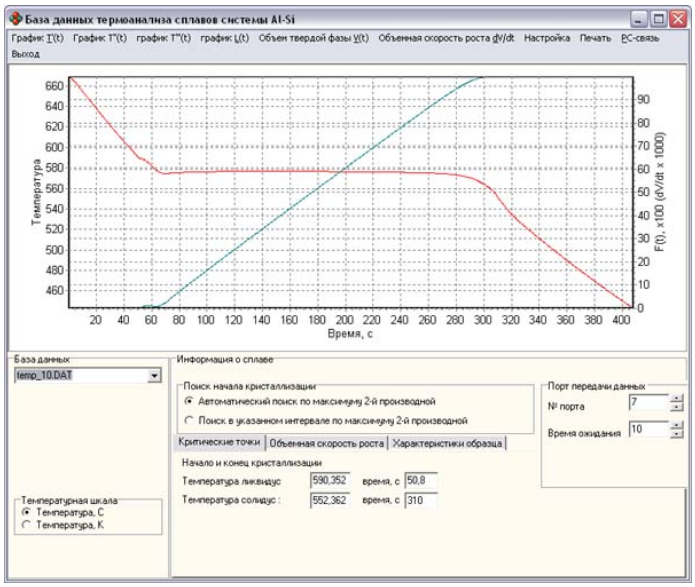

Fig. 1. *The cooling curve of test of alloy Al-10%Si*

The greatest reliability is provided with an experimental spectrum of a thermal emission. The technique of its definition consists in recalculation on a thermal emission of cooling curve for special test probe. It is possible to show, what even for the elementary binary alloys calculation of a spectrum of a thermal emission under the state diagram causes to additional errors, which it is easy to avoid if use an experimental spectrum.

The deviation in the set spectrum accordingly causes deviations at the numerical decision of a thermal problem. On fig. 2 the settlement curve of dependence of allocation of a solid phase in the range of solidification in casting "Pump MMZ" from cast alloy AK9 in metal mould is resulted.

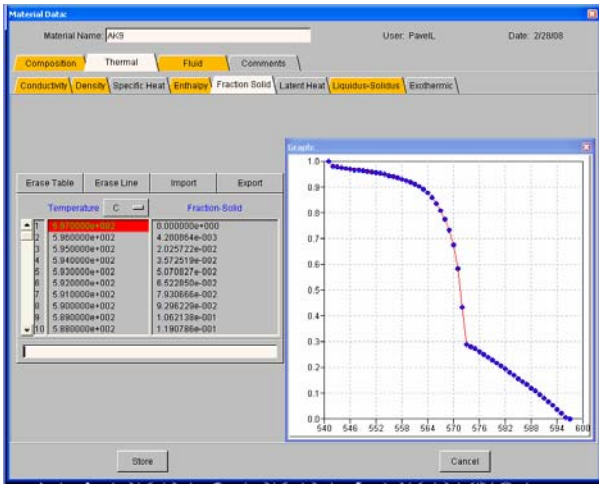

Fig. 2. *Solid phase distribution as a function of temperature, calculated for Al-10Si alloy*

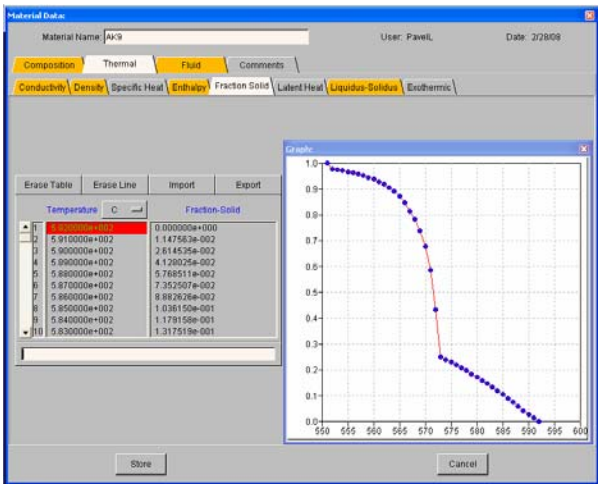

Fig. 2. *Solid phase distribution as a function of temperature, measured by the thermal analysis method for Al-10Si alloy*

Liquidation of shrinkable defects in castings is rather difficult process at modeling of thermal problems. The solution of the thermal problem connected with the analysis of shrinkable defects, were carried out with use of real casting "Pump" of Minsk motor factory which has a significant amount of thermal sites (Fig. 4). The problem consisted in working

out of technological process of casting without shrinkable bowls. Technology included casting in metal mould of aluminum alloy AK9 with chemical compound, %: Si - 10; Mn - 0.4; Mg - 0.3; Fe - 0.8; Cu - 0.5; Zn - 0.2. Settlement temperature liquidus is 597 °C, solidus is 541 °C.

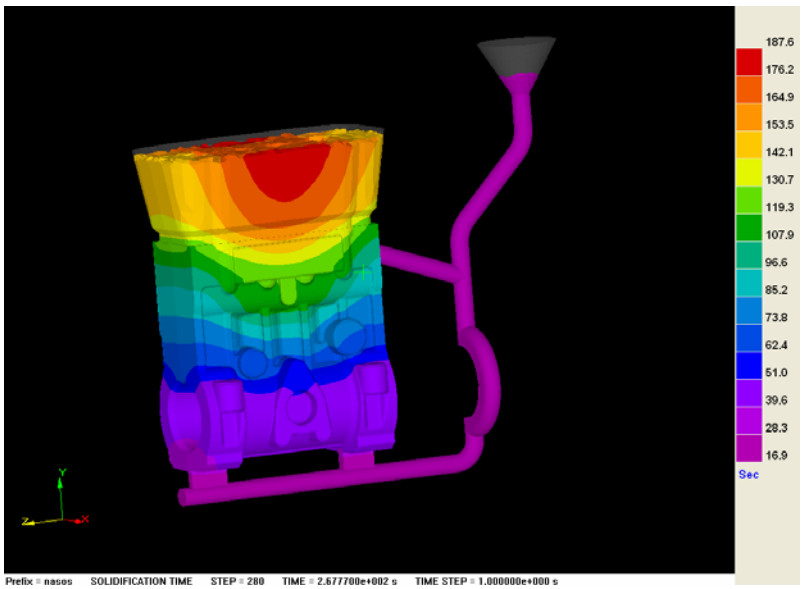

Fig. 4. *Dynamics of time of solidification of casting "Pump"*

Results of computer simulation of solidification have shown that formation of shrinkable defects is possible in the top part of casting (fig. 5), that not completely corresponded to a real arrangement of shrinkable defects in castings after industrial conditions. Therefore, the assumption as the possible reason of inadequate modeling of solidification of casting can be inexact data about temperatures of phase transitions and deviations of solid phase distribution as a function of temperature.

Fig. 5. *Probability of formation of shrinkable defects (porosity) in casting alloy AK9 with simulation data of ProCAST*

For definition of real temperatures of phase transformations of alloy was use a method of the thermal analysis (TA) on a curve of cooling of test probe melt.

To investigate the influence of values of temperatures of phase transformations on results of modeling of solidification, the data of the thermal analysis of cast alloy AK9 were used. The thermal analysis set included the measuring block and a special support for fastening of the thermocouple. The measuring block is constructed on the basis of microcontroller, the signal from the thermocouple was transformed to a digital form and passed for processing in the computer. Record of temperatures during crystallization process of melt was carried out through the time intervals: 0,48 msec. After solidification the phase transformation temperatures were calculated. As a result the data of thermal analysis has been established, that real temperature liquidus of cast alloy AK9 is 592 °C, solidus is 553 °C. Results of repeated computer simulation taking into account experimentally received data about phase transitions have shown, that character of solidification changes (fig. 6).

Fig. 6. *Probability of formation of shrinkable defects (porosity) in casting with use of experimental data about phase transitions of alloy AK9*

Therefore, as shown from fig. 5-6, results of modeling of solidification and distribution of shrinkable defects essentially differ. Thermo-physical characteristics of alloy, solid phase distribution as a function of temperature is important for simulation of solidification. The distinctions at computer modeling of cast aluminum alloys were causes by the non-adequate initial settlement data on temperatures of phase transformations.