The effect of a magnetic field on the kinetics of phase transformations

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The kinetics of phase transformations at the cooling of molten iron in the magnetic field has been investigated by DTA measurements. The magnetic field effect acting during the cooling of samples from the liquid state was presented with a narrowing of the temperature intervals of phase transformations, a shift of temperatures and a total change in the kinetics of phase transformations.

The results of investigation of influencing the primary crystallization of metallic melt by using of Lorentz forces, published in [1] and [2] have shown that the resultant effect of the influence cannot be explained by only a mechanical acting of the electromagnetic forces in the crystallization front zone. Since the affected volume is exposed to the acting of the magnetic field during generation of Lorentz forces some predictions have indicated a probable magnetic field effect on the kinetics of phase transformations. A serious reason for this assumption has also been the knowledge of theory and practice of heat treatment in the magnetic field utilizing its acting on the kinetics of phase transformations and the diffusion processes in solid [3].

In view of the fact that the character of the primary crystallization determines the cast metallic product properties in a decisive way, the attention has been mainly paid to the investigation of the magnetic field effect on the kinetics of phase transformations in the temperature interval between liquidus and solidus.

Procedure

The DTA method was selected as a suitable one, since it is characterized by the high sensitivity in the temperature interval of liquidus and it does not introduce any unfavourable factor in the process during cooling.

The experiments were made by DTA equipment NETZSCH which operates with samples of dimensions 5 mm × 9 mm at a heating and cooling rate ranging from 0.1 to 100 K min^{-1} and in the temperature interval of 293—1873 K with a reading precision of temperature ± 1 K. The magnetic field was generated by electromagnet that was situated on a working chamber so that the crucibles with samples were in a geometric centre of air gap. The cross-section of pole tips was 80 mm × 120 mm and the distance between them was 160 mm. With regard to small crucible dimensions (0.3 cm^3 each) with samples, the magnetic field could be considered homogeneous on their spots. The DTA equipment has operated on the principle that the cooling curves of two objects are plotted, when one of them is referred to the tested material and the other to corundum that has no phase transformations in the observed temperature interval. The results have been evaluated from plotted records of three curves, the first one determines the etalon temperature course, the second one presents the temperature difference between the etalon and the investigated sample, and the third one is a record of the first derivation of the second one in order to determine its local extremes easier.

In the first experiments of searching character the magnetic field effect during the cooling of samples was verified on a technical pure iron. In this stage of research altogether twelve experiments were carried out, for each value of magnetic induction of 0.06 and 0.12 T with four samples and the last four ones cooling without magnetic field effect. Arithmetic means from four measurements were used for graphical evaluation. The cooling rate was fixed on 100 K min^{-1} and the heating rate on 50 K min^{-1} The shift rate of record paper was 4 mm min^{-1}

Results

In Fig. 1 are shown three curves of the temperature differences of the powder iron samples without and with the effect of magnetic field with two magnetic induction values, namely 0.06 and 0.12 T. In order to enable mutual comparison of changes, only the segments of records from a temperature interval of the studied primary crystallization are given. The minimum dispersion of the values not increasing ± 4 K for the given level of the affecting was shown by the individual plotted records of the series of twelve powder iron experiments and in this way the records in Fig. 1 present the representative results. The heating rate, the level of superheat, and the dwell time at the maximum temperature of melt had no influence upon the studied kinetics of phase transformations and the shift in their temperatures.

A clear separation of the areas of the l—δ and δ—γ phase transformations has been the most marked change due to the magnetic field that appeared on the curve of the temperature differences as a clear interval without the deviation which would indicate the temperature balance changes. This interval increased with the increasing of magnetic induction; it was in the range from 18 to 23 K at 0.06 T and increased to 37—43 K at 0.12 T. In the case of all samples cooling without the magnetic field effect both transformations immediately followed.

The magnetic field effect with induction of 0.06 T was further presented by the shift of both phase transformation starts towards the lower temperatures, in the case of the l—δ transformation by 7—9 K and of the δ—γ one by 16—22 K.

At the induction of 0.12 T the shift sizes were increased by 9—12 K (l—δ) and 28—32 K (δ—γ). There was observed the change in the course of both transformations which have obtained the avalanche character. The curves of the temperature differences of the δ—γ transformation have immediately shown after this transformation start that their maximum shifted against the start by 5 K equally in all cases, while the transformation maximum of samples cooling

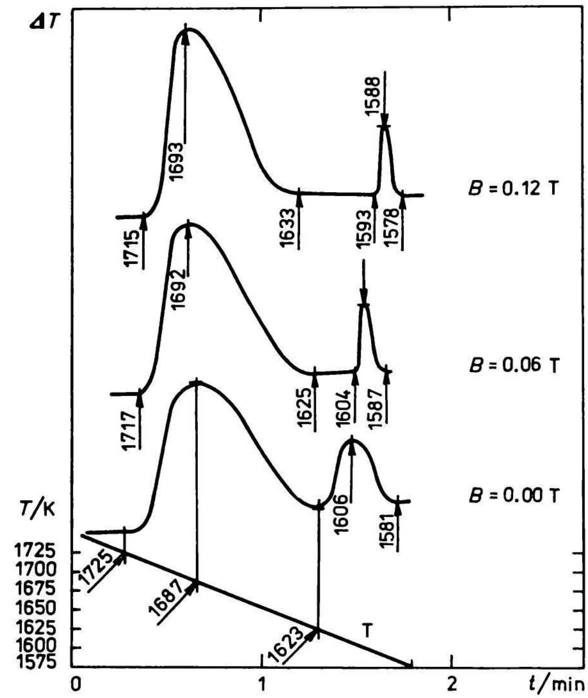

Fig. 1. The DTA records for powder iron without and with the magnetic field effect with the induction of 0.06 and 0.12 T.

without the magnetic field effect was observed from the third to the half of the transformation temperature interval, *i.e.* about 18 K below the temperature of the start of transformation. The avalanche course of phase transformations has also manifested itself as seen in Fig. 1, by the reducing of the temperature intervals, in which the transformations occurred and this course gives evidence that there have been the changes in the energy balance of transformations, mainly in the case of the δ—γ one. The samples cooling under the influence of magnetic field with the induction of 0.06 T had the l—δ phase transformation temperature interval reduced by 5—12 K and the δ—γ one by 15—30 K. At the induction of 0.12 T the interval of l—δ phase transformation temperature was narrowed down by 15—22 K and the interval of δ—γ one by 20—28 K.

Besides the experiments with the powder iron also the effect of magnetic field on the kinetics of phase transformations of the powder high-speed steel of M2 type has been investigated. The proved effect on the phase transformation of the recrystallization could be confronted with the high-speed steel heat treatment knowledge of this type in the magnetic field [3]. The results of the investigation of the low-temperature transformations and the changes in the kinetics of the phase transformation of the primary crystallization caused by the magnetic field were analogical to the changes observed in the iron.

At present a preparatory work proceeds on a construction of a single-purpose equipment for the study of cooling curves in magnetic field. The results will be analyzed by the computer method that would enable to verify the magnetic field effect faster and within broader parameter range.

References

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