32/41

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DETERMINATION OF CONDITIONS FOR EFFECTIVE APPLICATION OF MAGNETIC FIELD IN CASTING PROCESSES

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Casting under the action of magnetic field means the performance of casts, which solidify at the forced movement of a liquid metal. The character of the movement produced in the liquid metal, described by a velocity field, volume and distribution of electrodynamic forces, pressure distribution etc. depends on the means and ways generating thereof in a solidifying metal.

The most often applied methods are so-called methods of an inductive mixing, due to their easiness in a practical use caused by the lack of the direct contact between the facility producing the field and the liquid metal.

The publications describe that, the forces of magnetic field affecting the liquid metal during a crystallisation phase cause an intensive mixing process therein, and the said process is the reason of the most often positive changes in the cast structure [1-7]. Those positive changes are first of all the reduction or the liquidation of a columnar crystals zone as well as a refinement of equiaxial crystals, diminishing of a segregation, elimination of axial porosity and the others.

At the background of the aforesaid results, the results of the detailed examinations carried out at the Foundry Department of Silesian Technical University concerning the effects of the magnetic field acting on the solidifying cast are a little different. It was stated namely, that a variable magnetic field does not cause the decrement of the columnar crystals zone in the cast in each case. The consequences of the magnetic field action depend on a metal purity first of all. They stated, that for so-called technically pure metals (Al99,99; Zn99,99) the magnetic field activity (forced convection) does not change the cast structure (fig. 1a). It means that, despite of the conditions of giving up the heat in the cast subject to changes in the result of the forced movement of metal, it is not a sufficient condition to achieve the changes in the crystallisation process. The elaboration proves the thesis that the necessary condition to achieve the decrement of the columnar crystals zone width in the casts solidifying at the forced convection is the content of contamination or an alloy addition above a minimal quantity in a pure metal or alloy.

Based on carried out examinations, it was stated that, e.g. for Zn99,99 the addition of Al. in the amount of 0,05% causes the visible effects of the magnetic field influence

onto the ingots structure (fig. 1c). Similar results were obtained for aluminium and other metals. The examinations of the conditions of a columnar crystals zone formation were carried out for the ingots of dimensions of ϕ 45 × 180 mm, cast from various metals and alloys to a graphite chill [10-16].

In sum, they achieved three-types' results. They determine the effects of magnetic field activity reduced only to the analysis of the columnar crystals zone width [10-16]:

- I-st case – at the alloy addition or contamination concentration in the pure metal below some minimal quantity ($C_o < C_{min}$) the changes in the cast structure are not observed,
- II-nd case – at the alloy addition or contamination concentration in metal above some minimal quantity ($C_o > C_{min}$) they observe the decrement of the columnar crystals zone width along with the increment of the equiaxial crystals zone dimensions,
- III-rd case - at the alloy addition or contamination concentration in metal as above ($C_o > C_{min}$) they observe the effect inverse to the second one, i.e.: the increment of the columnar crystals zone width along with the concurrent decrement of the equiaxial crystals zone dimensions.

Based on own examinations it was stated that, the columnar crystals zone width depends not only on a crystallisation velocity but also on – or even first of all – the crystallisation front stability during the solidification process [17,18]. Applying such criterion to a classic casting technology as well as under magnetic field action, one can anticipate the place of the stability loss of the crystallisation front, and the same one can determine – with some approximation – the width of the columnar crystals zone in the cast as well as the time of this zone formation.

Summary:

1. Effective application of the variable magnetic field is possible in metals and alloys, in which the contamination content or the alloy addition content is above some minimal quantity.
2. The decisive factors for the changes in the structure, including mainly the width of the columnar crystals zone in the casts made under the magnetic field action is not the crystallisation velocity but the process stability as well as the time of the said zone formation.
3. Magnetic field activity effects can be analysed and anticipated based on the criteria of the crystallisation front stability.
4. Changing the magnetic field activity conditions (induction, time of action) one changes the gradient and kinetic factors (gradient of temperature, crystallisation front displacement velocity) as well as the material conditions (distribution coefficient k) and the same, one can create to some extent the circumstances conducive to the cast structure change. The change of such great amount of factors requires the simulation calculations.