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# Thermal gradient analysis of solidifying casting

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#### Abstract

For description of casting solidification and crystallization process the thermal derivative analysis (TDA) is commonly used. Besides the process kinetics considered in TDA method to describe the solidification process, the thermal gradient analysis can be also used for this purpose [1, 2]. In conducted studies analysis of thermal gradient distribution inside the solidifying wedge casting was shown which enabled determination of heat flow intensity on casting section.

Keywords: Solidification, Thermal derivative analysis (TDA), Gradient analysis

#### 1. Introduction

Aim of this work was the studies of heat flow direction inside the wedge casting. During the studies some numerical simulations



Fig. 1. Wedge-shape casting dimensions and virtual thermocouples position (a), method of thermal gradients determination (b)

were calculated with use of NovaFlow&Solid®<sup>™</sup> software. Modelled object was a wedge-shape casting inside some virtual thermocouples were assumed. Its dimensions and thermocouples placement are shown in Fig. 1. Thermocouples 1 - 7 were placed on wedge symmetry axis with 17 mm spacing from wedge tip. Thermocouples 8 - 13 were placed on angle bisector between symmetry axis and wedge wall. These points were selected in way, that pairs 1 i 8, 2 i 9, 3 i 10 etc. were placed on normal to wedge wall. Such placement enabled thermal gradient determination along wedge axis GPi and in direction to wedge wall GNi. The method of thermal gradients determination was shown in equation (1) and (2).

$$GP_i = \frac{T_{i+1} - T_i}{x_{(i \div i+1)}} \quad \left[\frac{\mathbf{K}}{\mathbf{cm}}\right] \tag{1}$$

$$GN_i = \frac{T_{i+7} - T_i}{x_{(i+i+7)}} \quad \left[\frac{K}{cm}\right]$$
(2)

where:

 $\begin{array}{l} GP-vertical \ gradient,\\ GN-normal \ gradient,\\ i-thermocouple number,\\ T_i-temperature \ in \ point \ i,\\ x-distance \ between \ thermocouples. \end{array}$ 

As a base material AlSi eutectic alloy was assumed from NovaFlow&Solid database, and for mould material the moulding sand for shell moulds.

### 2. Results analysis

The first stage of the analysis of collected results was the setting-up the thermal gradients in diagrams to compare solidification and crystallization process in following points of the studied region. The preliminary analysis of obtained diagrams showed some similarities (fig. 2 and 3).



Fig. 3. Thermal gradients distribution along the normal to wedge surface

In the firs stage, that is in first seconds one can observe significant oscillation of gradient along both considered directions, with intensive value changes and direction of the heat flow. As the process continues the changes are less dynamic and characteristic points are shifted in time. For more accurate analysis distribution of thermal gradients in both direction were set-up and resultant gradient were determined. These results were shown together with thermal –derivative analysis diagrams (fig. 4).





g. 4. Thermal gradients distribution and TDA curves for points on wedge casting cross-section a) – f) gradients distribution in points 1 – 6; g) – h) TDA curves in points 1 – 6

Presented diagrams show clearly, that thermal gradient changes significantly on casting cross-section and in time of casting solidification and cooling. According to prediction the highest values of thermal gradient are observed for regions with the shortest solidification times. Some other regularities have been observed.

For analyzed system dominant is the heat flow upwards (values of GP are significantly higher than of GN).

Comparing thermal gradient curve with TDA curve it can be seen, that characteristic points on both curves are registered in the same time. This can be used for determination of solidification beginning and end. It must be pointed out, that both phenomena are visualized on curves representing gradients with different intensity. The beginning of solidification is readily observed on GP curve and it is the first local maximum; on GN curve it is visible as the inflexion point. The end of solidification is better visible on GN curve, in form of distinct leap, which is visible on GP curve as a small refraction. Both curves are characterized by another feature. GN curve after refraction interpreted as the end of solidification heads toward value of 0. The GP curve before the end of solidification increases, reaching its maximum after the end of solidification, then decreases with readily visible point of inflexion indicating the end of crystallization (it can be concluded after analysis of TDA curves). Based on determined values of GP and GN gradients for all analyzed points the resultant gradient GW was calculated. Analysis of this gradient did not contribute to the studies on this stage.

#### **3.** Conclusions

Conducted studies enabled formulation of following conclusions:

- 1. Curves of thermal gradients in function of time can be used for solidification description.
- 2. The beginning of solidification is readily visible on vertical gradient curve (the first local maximum in GP curve).
- 3. For determination of solidification end the normal gradient curve can be used (leap in GN curve).
- 4. Calculation of resultant gradient did not contribute to the studies on solidification process at this stage.

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