The 73rd World Foundry Congress
„Creative Foundry"
23 - 27 September 2018, Krakow, Poland

USE OF A MATHEMATICAL TREATMENT FOR THE PREDICTION OF STRUCTURAL ZONES LOCALIZATION IN THE CONTINUOUSLY CAST BRASS INGOTS

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Key words: heat transfer model, continuous casting, brass ingots, structural zones, CET transition

The heat transfer model used in the current predictions is shown schematically in Fig. 1.

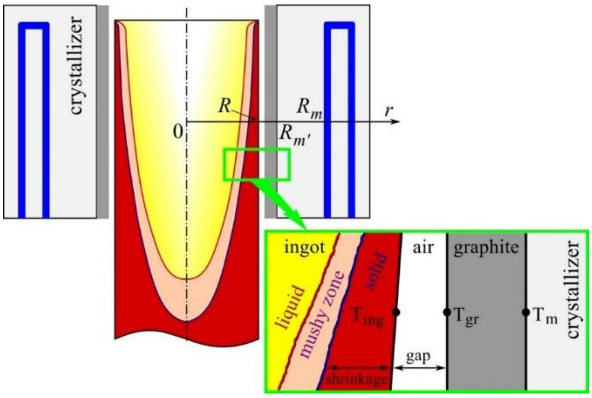

Fig. 1. ***Outline of the system for the continuous casting of brass ingots as shown in the*** x, r ***- coo coordinates, [1]***

The governing equation for heat transfer is as follows:

$$c_{ef}(T)\cdot\rho(T)\cdot\frac{\partial T}{\partial t}=\frac{\partial}{\partial r}\left[\lambda(T)\cdot\frac{\partial T}{\partial r}\right]+\frac{\lambda(T)}{r}\cdot\frac{\partial T}{\partial r} \qquad (1)$$

$$T=T(t,r), \qquad r\in[0,R_m]$$

$$c_{ef}(T)=\begin{cases} c_b(T), & T<T_S \\ c_b(T)+\dfrac{L}{T_L-T_S}, & T_S\le T\le T_L \\ c_b(T), & T>T_L \end{cases}$$

where, L is the latent heat, and T - temperature.

The above equations together with the adequate boundary conditions, [2], were applied to the prediction of the structural zones in the continuously solidifying brass ingot. The prediction follows the mathematical method of these zones modelling worked out for the steel static ingot, [3]. Particularly, the columnar into equiaxed structure transformation (CET) was the subject of this mathematical modelling.

The mentioned method, [3], takes into account the extreme points (minima and maxima) and also points of inflection of some considered / simulated functions.

In the current model, the functions are the result of the use of Eq. (1) with regard to the current outline, Fig. 1.

Mainly, the brass ingots contain the columnar and equiaxed structures, (thus, CET – transition), Fig. 2.

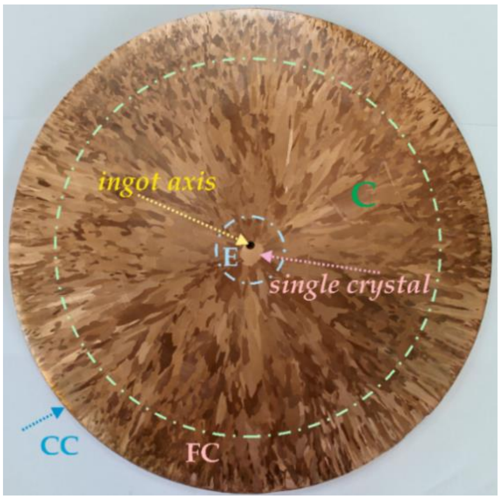

Fig. 2. ***Morphology of the continuously cast ingot: CC – chilled columnar, FC – fine columnar, C – columnar, E – equiaxed structures and a single crystal situated axially***

The obtained / simulated Space – Time – Structure Map (STSM) allows to suggest the localization of the CET for a given brass ingot solidifying with an imposed velocity of its translation across the crystallizer, Fig. 3.

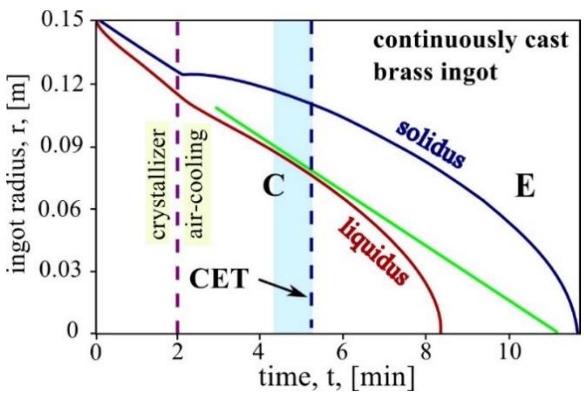

Fig. 3. ***Prediction of the CET in a brass ingot solidifying with the velocity of translation equal to 0.4 mm/min; localization is in the agreement with the local maximum***

Next, the numerically obtained temperature field was transformed into the thermal gradient field. The thermal gradient field and particularly the resultant function, G(t), confirms the formerly predicted CET - localization, Fig. 4.

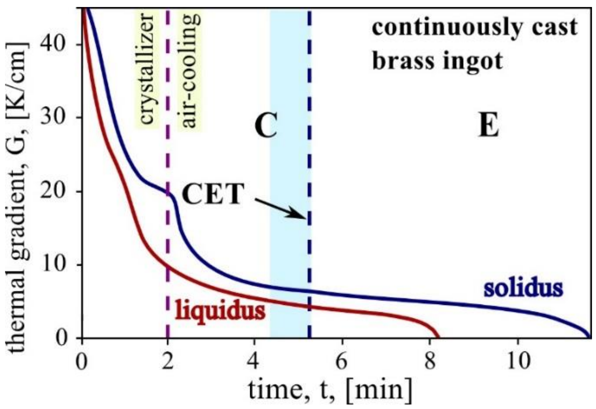

Fig. 4. Localization of the CET as it results from the thermal gradient field; localization is in the agreement with the points of inflection of the analyzed function

A localization of the FCCT is also possible to be distinguished due to the more detailed analysis of the simulated functions, Fig. 5a.

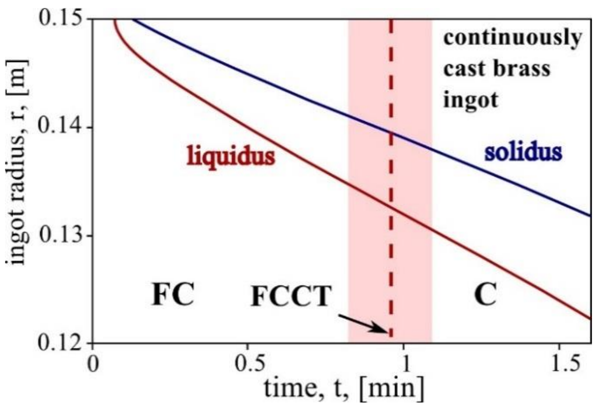

Fig. 5a. Localization of the FCCT being in the accordance with the points of inflection of the simulated STSM

The above FCCT - localization, Fig. 5a, is confirmed by the other simulations, Fig. 5b (local minimum), and Fig. 5c (points of inflection).

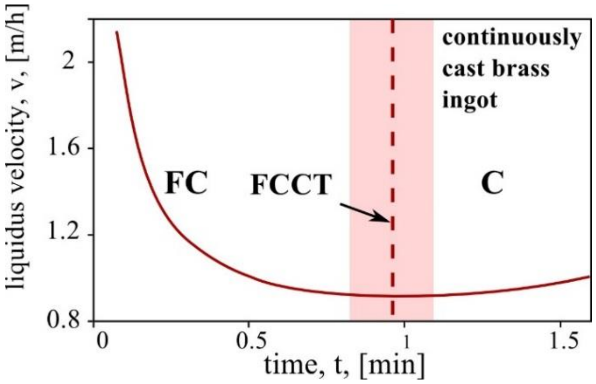

Fig. 5b. Localization of the FCCT being in the accordance with the situation of the local function minimum

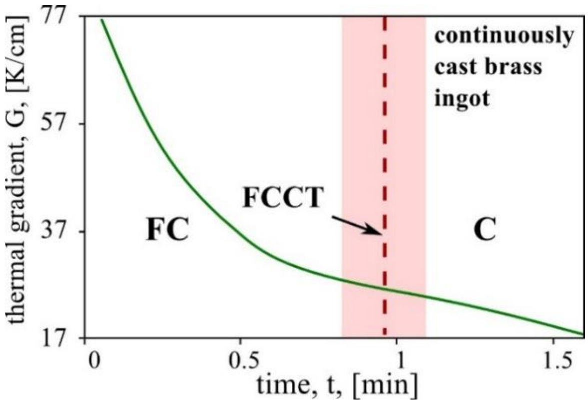

Fig. 5c. Localization of the FCCT being in the accordance with the points of inflection of the simulated G(t) - function

Finally, the current model was used for the prediction of the course of the *liquidus* velocity movement. This function, Fig. 6., shows all the structural zones visible / distinguished within the brass ingot morphology, Fig. 2.

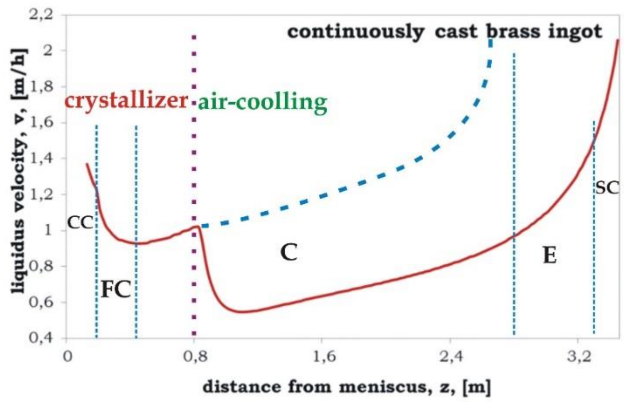

Fig. 6. Localization of the CCFCT, FCCT, CET, and ESCT structural transitions possible in the brass ingot subjected to continuous casting with the crystallizer height equal to 0.8 m

The structural zones of the investigated brass ingot are contained between adequate vertical dashed lines. The crystallizer height is marked by the vertical dotted line.

Acknowledgments
The support was provided by the National Center for Research and Development, Grant No. PBS3/A5/52/2015. The assistance of Mr. P. Kwapisiński with the "KGHM - Polish Copper" is greatly appreciated.

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