EXPERIMENTAL MODEL FOR FLOWING ANALYSIS IN CASTING FERROUS ALLOY

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Modelul experimental conceput, în vederea analizării procesului de modelare la curgere a aliajelor feroase a urmărit punerea în evidenţă a corelaţiei dintre parametrii ce definesc ecuaţiile de curgere. Corelaţia dintre modelul experimental şi parametrii de proces se bazează pe sensibilitatea la temperatură care indică evoluţia nivelului de aliaj pe traseul curgerii.

The designed experimental model was intended to analyze the process of modeling the flow of ferrous alloys in order to highlight the correlation between parameters defining the flow equations. The correlation between the experimental model and process parameters was based on temperature sensitivity indicating the evolution of the alloy level on the flow path.

Keywords: experimental model; simulation; flowing; casting; ferrous alloy

1. Introduction

Mathematic models for testing flow, solidification and contraction of casting alloys involve using a geometric pattern. For this purpose a model was created (see fig. 1) to test the behavior of ferrous-alloy casting. The aim was to develop technologies for casting low consumption of materials [1].

Modeling is understood by many authors as a theoretical or practical method of operating on objects, phenomena or processes [2].

Process modeling is accepted many authors as a process of by understanding the interaction between the object with another object. The object studied is the original (A) and the object which is analyzed is the model (M) [3].

2. Characteristic of mathematical model

For computer simulations of the flow process in the mould cavity, an experimental model (EM) was used involving the following characteristics:

- Mathematical equation correlation between the critical flow section depending on time;

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- The generalization of the procedure for casting of different alloys has been considered the correlation time - characteristics of the alloy;
- Mathematical relations used.

The flow process analysis was performed within an interval marked by two boundaries (laminar flow and the maximum filling time of the mould) [4].

To establish measurable parameters of the process flow for the liquid alloy were used following mathematical equations:

$$Vm1_i = \mu_i \sqrt{2 \cdot g \cdot H} \tag{1}$$

$$Vm2_{i,j} = \mu_i \sqrt{2 \cdot g \cdot (H - h_j)} \tag{2}$$

$$V1 = \frac{V_p}{S \cdot \tau_{\lim}} \tag{3}$$

$$Sa_{\lim} = \frac{V_p}{\tau_{\lim} \cdot V_{\lim}} \tag{4}$$

$$Sp_{\lim} = \frac{2 \cdot Sa_{\lim}}{1{,}5} \tag{5}$$

$$VcrFc_i = \left(\frac{h_i}{\delta}\right)^{0{,}290 \ln\left(\frac{\sqrt{2 \cdot g \cdot h_i}}{100}\right)} \tag{6}$$

$Vm1_i$ – medium velocity of filling at ½ from height of EM, mm/s;
$Vm2_{i,j}$ – medium velocity of filling at ½ from height of EM, mm/s;
$V1$ – limit filling velocity, mm/s;
V_p – casting volume, mm^3;
S –feeder section, mm^2;
$\tau_{\lim}$ – limit time, s;
V_{lim} – flow velocity limit, mm/s;
$Sa_{\lim}$ – limit feeder section, mm^2;
Sp_{lim} – foot section limit, mm^2;
$VcrFc_i$ – critical velocity for ferrous alloy, mm/s;
δ – wall thickness, mm;
g – gravitational acceleration, mm/s^2;
μ_i – loss velocity coefficient;
H – piece height, mm;
h_j – variation index to calculate the medium velocity;
h_i – height variation at different values for H.

3. Results and discussion

Location of the experimental model in the form followed to eliminate disturbances in the process of experimentation, especially targeting the flow characteristics of cast alloys and the process of solidification and contraction.

Positioning the experimental model in the form is shown in Fig. 1

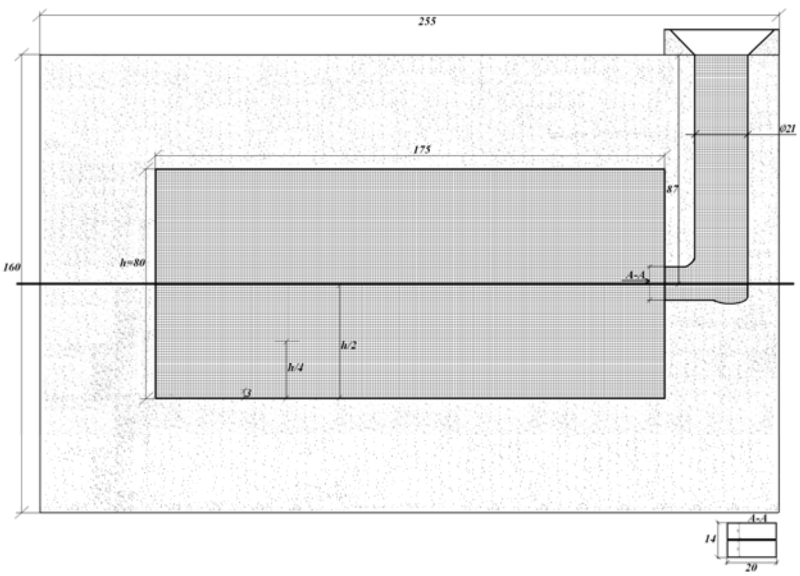
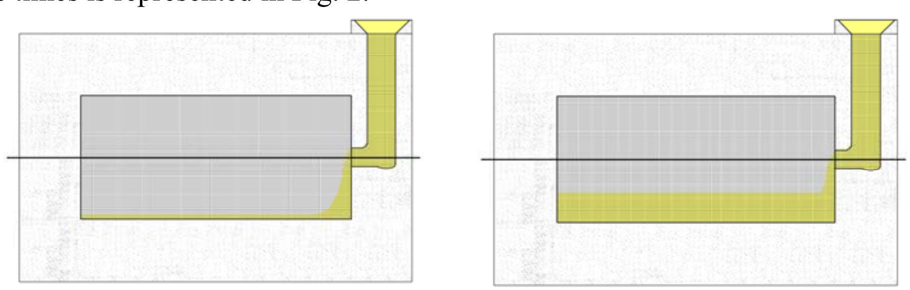


Fig. 1. Positioning of the experimental model in the mould and measurement points for casting parameters

2D Matlab program computer simulation of alloy flow to fill the mould at various times is represented in Fig. 2.



a) b)

Fig. 2. 2D image of the evolution process of filling the experimental model in the case of a ferrous alloy

a) initial moment ($\tau \sim 1\cdot10^{-1}$s); b) at filling moment for ¼ from h ($\tau \sim 1$s);

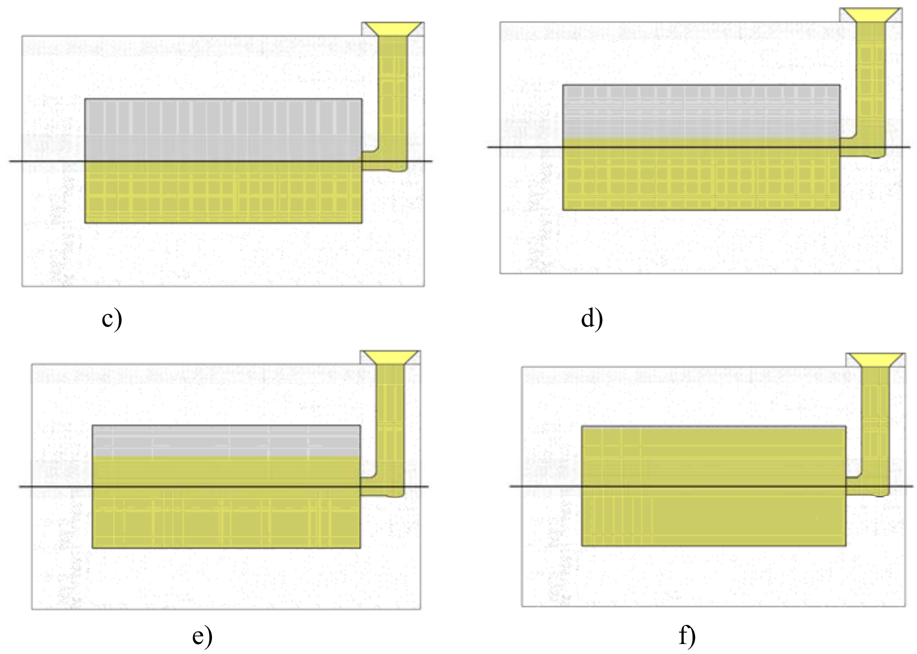


Fig. 2. 2D image of the evolution process of filling the experimental model in the case of a ferrous alloy:
c) in the filling moment for ½ from h (τ~2s); d) in the filling moment over ½ from h (τ~2,2s);
e) in the filling moment for ⅝ from h (τ~3s); f) nearly the end of filling process (τ~4s)

Using the experimental model previously designed and running the MatCad software for various conditions of the program it was possible to determine an optimal cast technology and to monitor the process of the flowing alloy bz drawing graphical views of domain change and of the basic parameters required for alloy flow characterization.

Fig. 3 shows a notable velocity decrease versus increasing the height of casting for different values of μ.

The decrease filling rate of the part depending on the height of Vm2 (see relation 2) leads to different viscosity (see Fig. 4 and 6).

Increased viscosity values to increase height part are shown in Fig. 5.

Critical speed (see relation 6) and calculated values (see relation 7) depending on height of piece is shown in Fig. 7.

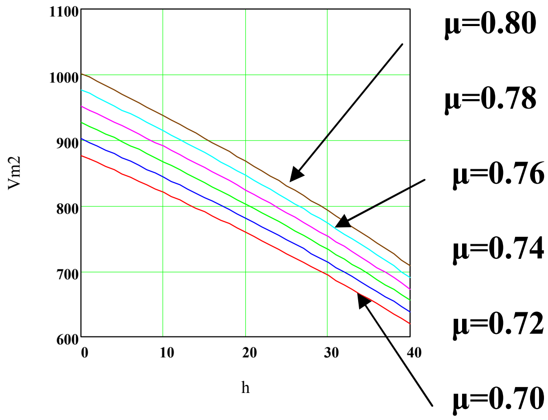


Fig. 3. Filling variation depending on piece height "h"(mm) for various values of the coefficient of loosing velocity μ

The input data for the relations (1), (2), and (6) are the following:

H:=80; j:=1-41; g:=980'; i:=1-6;

The result calculus is in relation 7.

$VcrFc_i$ =

0.614
1
1.55
1.752
1.957
2.137
2.667
2.763

(7)

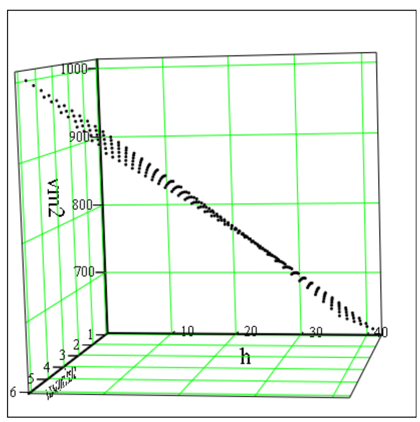


Fig. 4. Distribution of velocity field at second level of filling

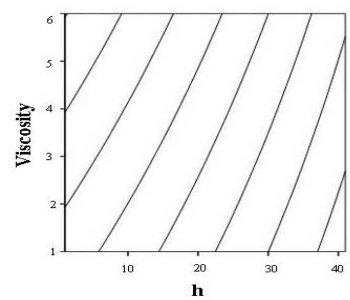


Fig. 5. Alloy viscosity (P) variation on height “h” (mm) of piece function of velocity field

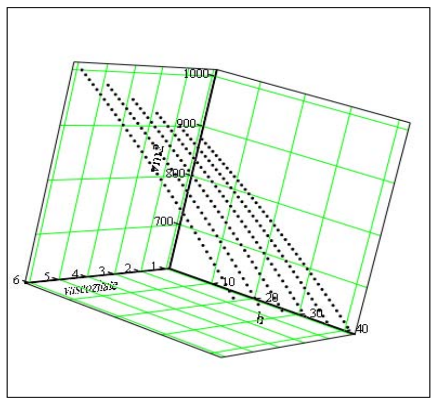


Fig. 6. Medium velocity distribution at filling the mould with alloy

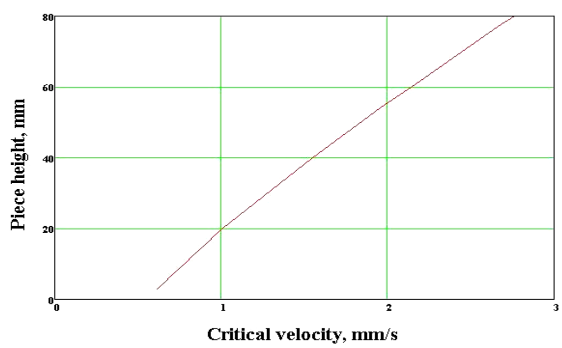


Fig. 7. Critical velocity variation on piece height calculated for avoiding casting defects

Both ME and used program allows choosing optimal solutions for the parameters characterizing the flow makes possible to design a ME for mathematical modeling of the processes occurring during casting.

Input data for relation (4) and (5) are the following:

$$L := 175(mm); \delta := 20(mm); \tau_{\lim} := 5(s); i := 1-8; \lim := 1-6; h := 80(mm);$$

$$V1 := 200(mm/s); S := 14 \cdot 20(mm^2); Vp = L \cdot l \cdot h = 2.8 \times 10^5 (mm^3)$$

The results from equation (4) and (5) are shown in the next table :

$Sa_{lim} =$	$Sp_{lim} =$	$V_{lim} :=$
560	746.667	100
280	373.333	200
186.667	248.889	300
140	186.667	400
112	149.333	500
93.333	124.444	600

(8)

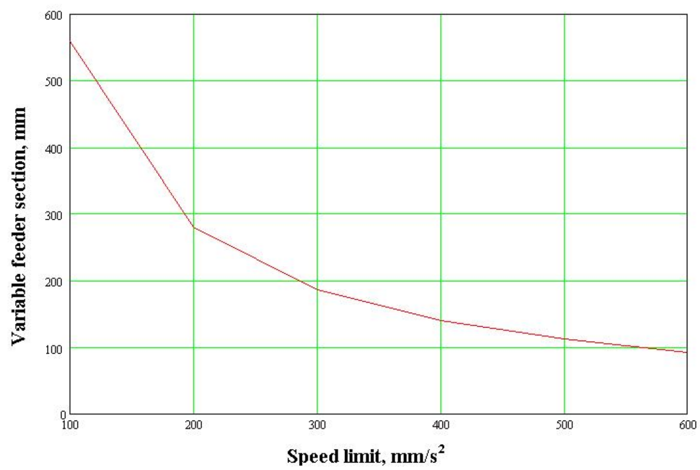


Fig. 8. Velocity limit distribution function of feeder section

Analyzing the variation of the speed limit (see relation (8)) according to the section feeder variable, one can notice a sudden drop to V_{lim} = 100-300 mm/s^2 and a slower decrease for V_{lim} = 301-600 mm/s^2.

4. Conclusions

- The current technical conditions (in terms of hardware and software) make possible the casting design in order to ensure a computer simulation of flow close to the real flow of the liquid alloy.

- One of the major problems facing designers of casting technology is the problem of the thermal nodes and the possibility of their removal from inside castings. Simulation programs offer the possibility to govern the process of flow and solidification in order to completely eliminate casting thermal nodes.

- Phenomena that occur in these conditions are very difficult to simulate because of the multitude of factors influencing the flow process and make the mathematical models describing these processes to be complicated and with high errors.

- Commercial programs currently used worldwide refer to flow modeling and heat transfer with phase transformation encompassing removal of latent heat of solidification, but less attention is paid to the phenomena related to the contraction during solidification of alloys and formation of shrinkage in solidified casting [4].

- One can say that the program and ME used here allow choosing the optimal solutions for the flow parameters characterizing, making possible to design a ME for mathematical modeling of the processes occurring in ferrous and non ferrous alloy casting, with application to the establishment of casting technologies with low materials and energy consumption.

- Establishing the optimal size for the feeder section and the flow rule in gate runner and mold cavity allows maximum use of the liquid alloy, reducing energy and material consumption, and reducing labor costs by shortening specific manufacturing cycle.

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