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RESEARCH CONCERNING THE STRUCTURE IMPROUVEMENT OF STEEL INGOTS

Ana SOCALICI, Ioan ILCA, Teodor HEPUŢ

UNIVERSITY POLITEHNICA TIMISOARA
FACULTY OF ENGINEERING HUNEDOARA, ROMANIA

ABSTRACT

The paper present the experiment made with the purpose of improving the structure of steel ingots undergoing smiting by adding microcoolers in the central part of the liquid ingot, to create a new crystallization and solidifying front. Application of this technology allowed the substantial increase in the homogeneity and spreading degree of the dendrite structure, the decrease in the stretch and width of the chemical in homogenates development area and that of the air holes placed at the edge of the primary grains, the reduction of segregation and gas content. It has also been ascertained the increase in the plasticity characteristics of the metallic material (at the same resistance) with 15-30%.

KEYWORDS:

improuvmenent, steel ingots, experiments, structures îmbunătăţire, lingouri de oţel, experimentări, structură

1. Introduction

The solidifying of steel ingots is associated with important contractions, independent of the purity degree, fact that leads to a certain deterioration of the structure and the appearance of chemical and structural in homogeneity. The mechanism of the solidifying process in these ingots is determined a great degree by thermal phenomena that occur while transmitting the heat from the liquid steel to the environment [1]. These phenomena depend especially on the ratio between the ingot volume and surface, ratio that adjust the speed of heat evacuation from the liquid steel.

The problem that has to be saved to attenuate the deficiencies of classic solidifying is the adaptation of the efficient method of heat evacuation from the solidifying steel. An efficient influent technology upon the solidifying process consists of introduction in the liquid ally of the microcollers [2].

2. Experimental results

The experiments were made for a carbon steel, grade OLC 45, from which it were cast ingots having the mass 9 tones, with micro-coolers addition in specific quantities of 1kg/t, 1.5 kg/t, 2 kg/t, 3kg/t and 4 kg/t, having the dimensions ranging between 2 - 6 mm. The granules have been introduced in the chill moulds at 30%, 60%, respectively 90% filling of the chill mould. From every ingot it have been taken samples for establishing physical-mechanical properties.

By processing the obtained data from the experiments using SIDHD5 and MATLAB computer programs we obtained a series of equations with multiple correlations of second order between the dependent parameters: tensile strength (R_m, [N/mm^2]), seeming yielding limit ($R_{p0,2}$, [N/mm^2]), percentage elongation after failure (A_5, [%]) and necking coefficient (Z, [%]) and three independent parameters: the micro-coolers dimensions (d, [mm]), micro-coolers quantity (m, [kg/t]) and casting temperature (t, [°C]). For each equation it were determined the average values of the fallowed parameters, dispersion, standard deviation, stationary point values, correlation coefficient value and standard error value.

The multiple correlations (with three parameters) allowed the establishing of some equations between a qualitative parameter (dependent parameter) and three independent parameters. For graphical representation need to consider one of three parameters to be constant, therefore it were given alternatively values to these parameters, namely they have been considered equal to average value after which it were made graphical representations.

The equation of the regressing hyper-surface for seeming yielding limit ($R_{po,2}$) is:

$$R_{p0,2} = -3{,}997 \cdot m^2 + 0{,}9814 \cdot d^2 + 0{,}0001533 \cdot t^2 - 0{,}4112 \cdot m \cdot d - 0{,}005089 \cdot d \cdot t + 0{,}02484 \cdot t \cdot m - 0{,}002547 \cdot m + 0{,}006111 \cdot d - 0{,}00003174 \cdot t + 0{,}00003806; \quad R^2 = 0{,}9726 \qquad (1)$$

The equations with multiple correlations of third order for regress surface (figure 1) is:

$$R_{p0,2} = 3{,}578 \cdot m^3 + 0{,}231 \cdot d^3 + 0{,}908 \cdot m^2 d - 0{,}541 \cdot md^2 - 25{,}903 \cdot m^2 - 8{,}868 \cdot d^2 + 5{,}806 \cdot md + 85{,}360 \cdot m - 22{,}75 \cdot d + 391{,}137 \qquad (2)$$

The equation of the regressing hyper-surface for tensile strength (R_m) is:

$$R_m = -3{,}745 \cdot m^2 + 0{,}03494 \cdot d^2 + 0{,}0002385 \cdot t^2 - 0{,}7767 \cdot m \cdot d - 0{,}004689 \cdot d \cdot t + 0{,}02739 \cdot t \cdot m - 0{,}004822 \cdot m + 0{,}0002206 \cdot d - 0{,}00002927 \cdot t + 1{,}393 \cdot 10^{-6}; \quad R^2 = 0{,}9920 \qquad (3)$$

The equations with multiple correlations of third order for regress surface (figure 2) is:

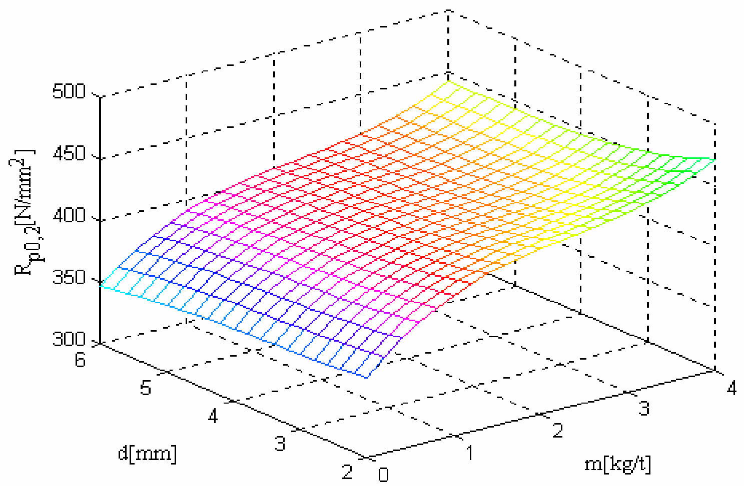
$$R_m = -0{,}407 \cdot m^3 + 0{,}998 \cdot d^3 + 0{,}336 \cdot m^2d - 0{,}055 \cdot md^2 - 5{,}351 \cdot m^2 - 7{,}8 \cdot d^2 + 0{,}033 \cdot md + 61{,}6 \cdot m + 4{,}97 \cdot d + 599{,}10 \quad (4)$$

The equation of the regressing hyper-surface for percentage elongation after failure (A_5) is:

$$A_5 = -0{,}5567 \cdot m^2 + 0{,}06035 \cdot d^2 + 9{,}121 \cdot 10^{-6} \cdot t^2 - 0{,}5331 \cdot m \cdot d - 0{,}0001736 \cdot d \cdot t + 0{,}004736 \cdot t \cdot m - 0{,}003318 \cdot m + 0{,}0003761 \cdot d - 1{,}069 \cdot 10^{-6} \cdot t + 2{,}344 \cdot 10^{-6};\ R^2 = 0{,}9812 \quad (5)$$

The equations with multiple correlations of third order for regress surface (figure 3) is:

$$A_5 = 0{,}230 \cdot m^3 + 0{,}220 \cdot d^3 - 0{,}032 \cdot m^2d + 0{,}041 \cdot md^2 - 2{,}789 \cdot m^2 - 1{,}22 \cdot d^2 - 0{,}379 \cdot md + 12{,}650 \cdot m + 1{,}88 \cdot d + 19{,}828 \quad (6)$$



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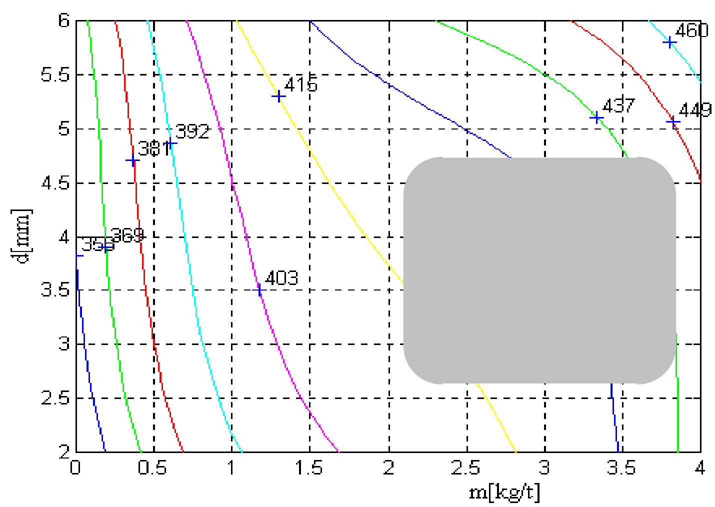


b.

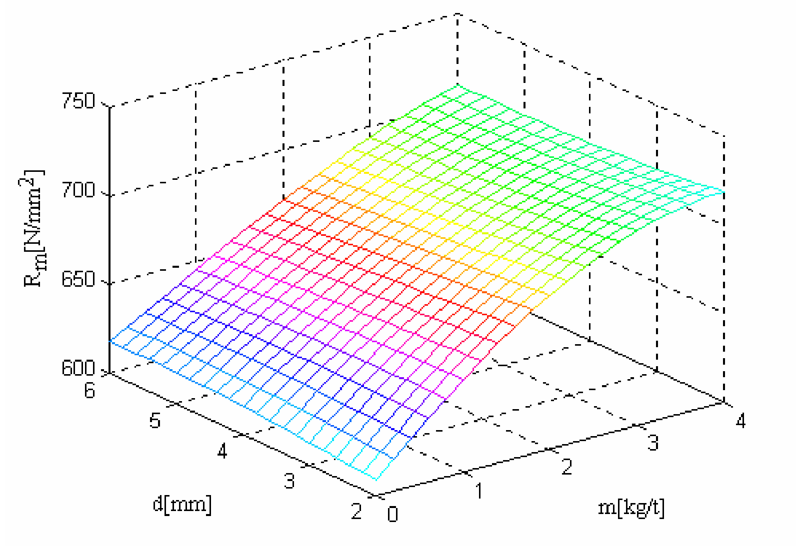
FIGURE1. REGRESSION SURFACE (a) AND CONTOUR LINES (b) FOR $R_{p0,2}$.

The equation of the regressing hyper-surface for necking coefficient (Z) is:

$$Z = -0{,}548 \cdot m^2 - 0{,}03047 \cdot d^2 + 0{,}00002312 \cdot t^2 - 0{,}02422 \cdot m \cdot d - 0{,}00004905 \cdot d \cdot t + 0{,}00344 \cdot t \cdot m - 0{,}0001488 \cdot m - 0{,}0001898 \cdot d - 7{,}688 \cdot 10^{-8} \cdot t - 1{,}183 \cdot 10^{-6}; \; R^2 = 0{,}9974 \quad (7)$$

The equations with multiple correlations of third order for regress surface (figure 4) is:

$$Z = 0{,}602 \cdot m^3 + 0{,}415 \cdot d^3 - 0{,}029 \cdot m^2 d - 0{,}013 \cdot md^2 - 6{,}822 \cdot m^2 - 2{,}06 \cdot d^2 + 0{,}0198 \cdot md + 24{,}720 \cdot m + 0{,}757 \cdot d + 43{,}709 \quad (8)$$



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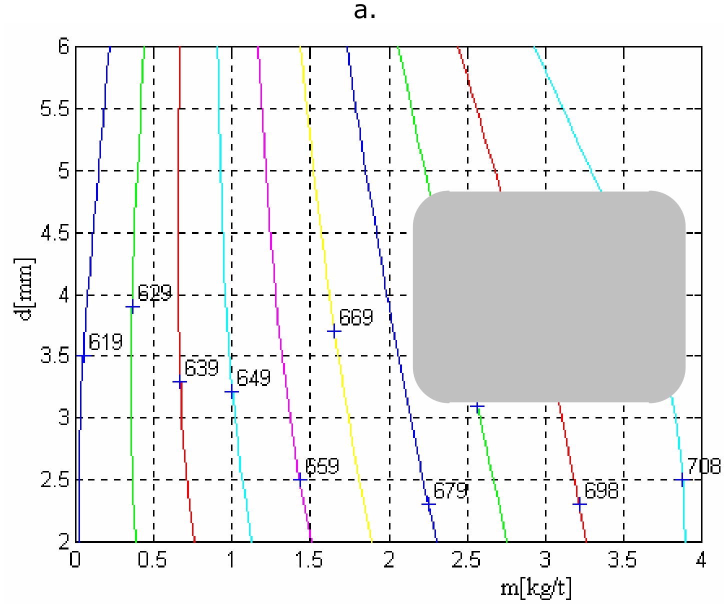
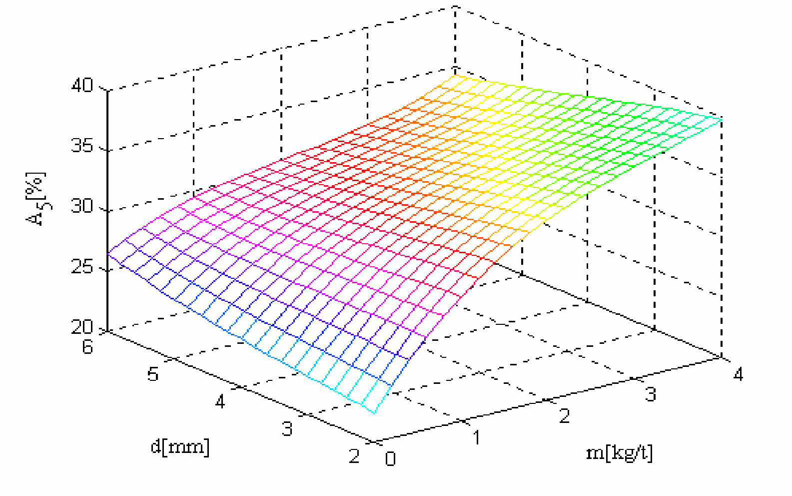


b.

FIGURE 2. REGRESSION SURFACE (a) AND CONTOUR LINES (b) FOR R_m.

These graphical representations allow the establishing of variations sub-domains for independent parameters so that to obtain the desired values for dependent parameters. In cases when regress surfaces have a stationary point it exist two sub-domains, and it is obvious that in practice it is chosen the most convenient from technological point of view.



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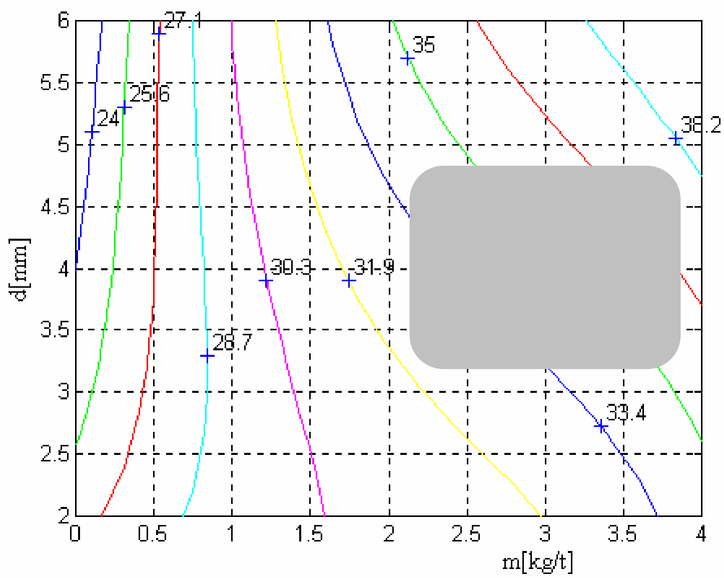


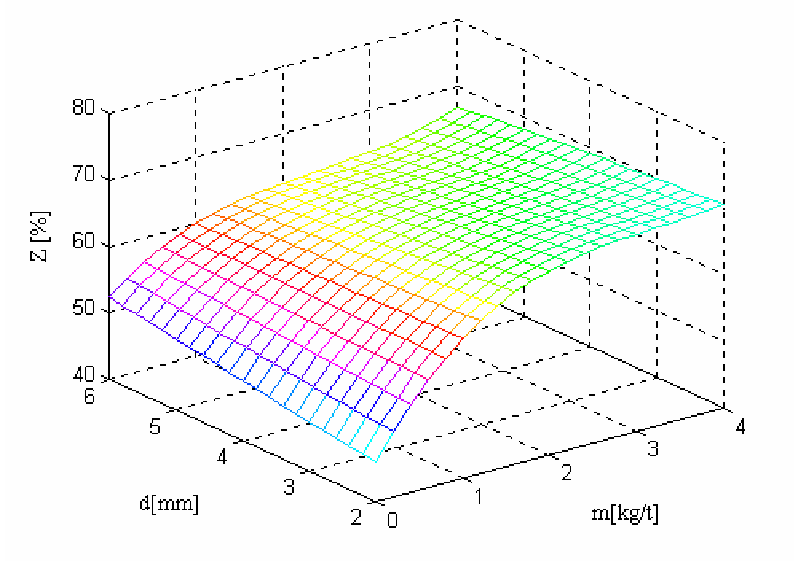
b.

FIGURE 3. REGRESSION SURFACE (a) AND CONTOUR LINES (b) FOR A_5.

3. Conclusions

Analyzing the equations with multiple correlations and the obtained regress surfaces it is observed increasing and a significant homogeneity of mechanical characteristics.

The optimum variation field for independent parameters: casting temperature it is between 1560-1580°C, specific micro-coolers consumptions used for directing of solidification is between 2-4 kg/t, and micro-coolers diameter vary between 3-5 mm.



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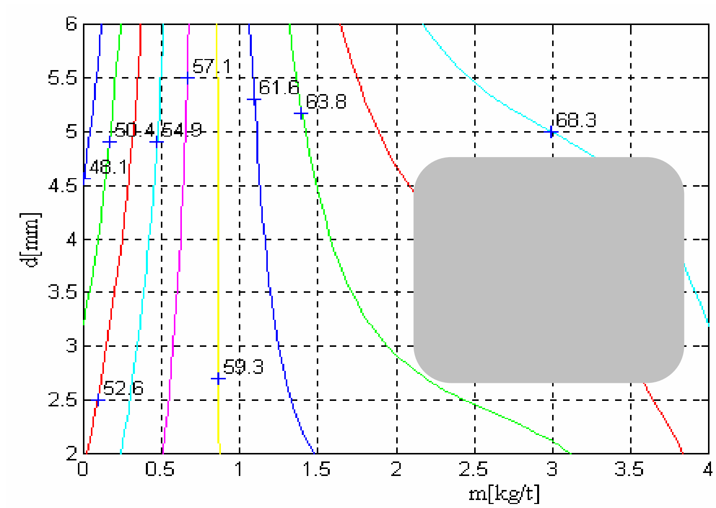

b.

FIGURE 4. REGRESSION SURFACE (a) AND CONTOUR LINES (b) FOR Z.

The applying of this technology allow the substantial increasing of homogeneity and spreading degree of pine-tree structure, decreasing of length and width of developing zone of chemical non-uniformity as well as of sulfide placed at the boundary of primary grains, reduction of segregation and gases content. It is find a increasing of mechanical characteristics, especially of plasticity with 15-30%.

REFERENCES

[1.] EFIMOV, V.A. – Steel casting and cristalisation, Ed.Tehnică, Bucureşti, 1976.

[2.] BRATU, C., SOFRONI, L. – Researches concerning leading steel proces of cristalisation using microcoolers, Metalurgia, Nr.6, 1981, pag.281.