RESEARCHES CONCERNING THE INGOTS DIRECTIONAL SOLIDIFICATION FOR THE RAILROAD MONOBLOCK WHEELS FABRICATION[1]

Ilie Butnariu[2]
Ioana Butnariu[3]
Nicolae Constantin[4]

Abstracts
In this paper is presented an evaluation of the technological causes generating flaws at the railway monoblock (monoingot) wheel as well as of the up-to-date casting technology of ingots. There a new casting technology of ingots for the making of the monoblock wheels achieving which take into view the elimination of defects which appear at the level of casting as well as at the level of solidification at solidification.
Key words: Ingots; Solidification; Railroad.

1 *Technical contibution to 62nd ABM - International Annual Congress, July 23rd to 27th, 2007, Vitória - ES – Brazil*
2 *Prof.Dr.Eng., University Politehnica of Bucharest*
3 *Dr., SOCESIT Bucharest*
4 *Prof.Dr.Eng., University Politehnica of Bucharest*

Introduction

Monoblock wheels, WTA type, are achieved at SC SMR SA Bals through stamping-rolling process on automatic line, starting from steel cylindrical ingots or conical ingots, having 4t weight, with high the diameter rate approximately between height-diameter 4,8 ap.
Hollow semi-manufactured acquiring process using deformation (stamping) process of big ingots (until 400 t) does not represent the best solution by neither from quality or from the productivity point of view and especially in the case of stainless steel usage.[1-3]
In Table 1, there are represented the final chemical composition of three steel charges which have been casting into conical ingots.

Table 1. Final chemical composition [%] of three casting charges and the medium composition of the mark.

Charge	C	Mn	Si	S max	P max	Cr	Ni	Cu	Mo
1	0,59	0,71	0,12	0,015	0,016	0,16	0,15	0,21	0,02
2	0,63	0,65	0,10	0,015	0,010	0,16	0,13	0,27	0,03
3	0,64	0,77	0,15	0,017	0,019	0,15	0,12	0,19	0,02
Mark medium composition	0,57	0,82	0,33	0,015	0,016	0,16	0,11	0,16	0,02

EXPERIMENTAL RESULTS

The uses of big hollow ingots which are achieved through casting determine a simplification of monoblock wheels acquiring and this reducing the cost. The proposed technology is based on the usage of cores obtained from granular materials dried and molded in a vacuum column. Granular material used to value of the vacuum core achieving can be: quartz sand, secondary carbon materials (electrode scraps), cast iron shots etc.[4]
In order to achieve the modeling we used the values in Table 2 and 3 for cast steel and cast iron ingots and the values in Table 4 for the core.

Table 2. Termophysical properties for ingot and steel, using values used at the modeling of the solidification process.

Material	Density ρ, [kg/m^3]	Thermal conductivity λ, [W/m˚C]	Particularly heat c, [J/kg˚C]	Latent heat [J/kg]
Steel (0,5%C)	7800	29,2	465	250000
Ingot (cast iron 3%C)	7570	49,8	470	-
Tamping material	1700	0,81	880	-

Table 3. Initially condition's.

Material	T_L, [˚C]	T_S, [˚C]	T_{init}, [˚C]
Steel (0,5%C)	1512	1480	1580
Ingot (cast iron 3%C)	-	-	150
Tamping material	-	-	150

Table 4. Termophysical properties for core, values used at the modeling of the solidification process (medium values).

Material	Density ρ, [kg/m³]	Thermal conductivity λ, [W/m˚C]	Particularly heat c, [J/kg˚C]
Cast iron shot	4500	15	470
Sand + 60% shot	2150	0,75	942
Dried quartz sand	1520	0,35	800

In equation (1) the critical condition of compensation of the liquid phase shrinkage is presented:

$$v_f \geq v_c \tag{1}$$

where: v_f is the filtering speed of the liquid phase in the biphasic zone; v_c – the velocity of transformation of the liquid phase into the solid phase.

Transformation speed of the liquid phase in solid phase can be calculated with the relationship:

$$v_c = \beta \cdot (\psi_* - \psi_0)\overline{v} \tag{2}$$

where: v represents the advancing medium speed of the biphasic zone; β – the solidification shrinkage coefficient; $\psi_* = 0,8$ – flowing boundary; $\psi_0 = 0,3$ – feeding boundary.

Medium displacement speed of the biphasic zone or the medium speed of solidification is calculated with the following relationship:

$$\overline{v} = v_0 + \frac{v_* - v_0}{n+1} \tag{3}$$

where: v_0 represents the advancing speed of the following boundary; v_* - feeding boundary speed.

In the following was used n = 2,

$$\overline{v} = \frac{v_* + 2v_0}{3} \tag{3'}$$

By rearranging the terms of the (1)st and (2)nd relationships defines the filtering critical speed (4):

$$v_{cf} = k_p \cdot \frac{p_0 - p_*}{\beta \cdot \eta \cdot \Delta l(\psi_* - \psi_0)} \tag{4}$$

in which: k_p is the permeability coefficient of biphasic zone and varies in between the boundaries of $10^{-6}…10^{-10}$ cm² when solid phase quantity ψ = 0,6….0,9; η – dynamic viscosity coefficient of liquid phase; $p_0 = p_{atm} + \rho \cdot g \cdot h$ is the pressure put-on by the liquid alloy column; p_* - the cavity pressure due to the shrinkage and gases the form the alloys; Δl - wideness of the biphasic zone;

Based on the relationship (2), (3) and (4) relationship (1) becomes:

$$v_{cf} \geq \overline{v} \tag{5}$$

Because of the H/D ≈ 5 and of the interval of solidification of approximately 80 ˚C, it is necessary the analysis of the process of solidification on the ingot height, from the point of view of the shrinkage compensation with liquid phase.

Figure 1 represents the evolution in height of the biphasic zone for both ingots moulds. As one can notice the wideness of the biphasic zone increases very rapidly, occupying nearly all the height of the cylindrical ingot (height of ingot 2,48 m), while at the conical ingots this width reaches at maximum 2 m comparatively with 2,5 m which is its length without riser.

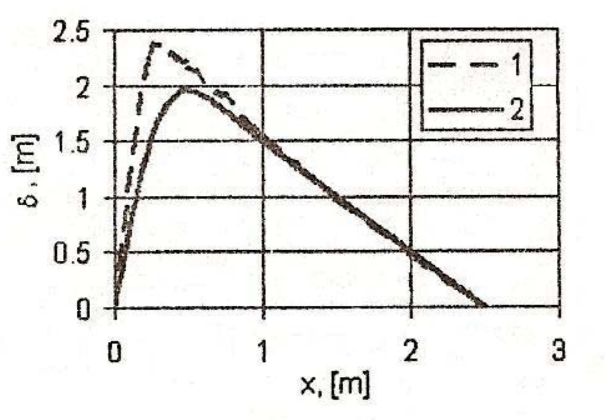
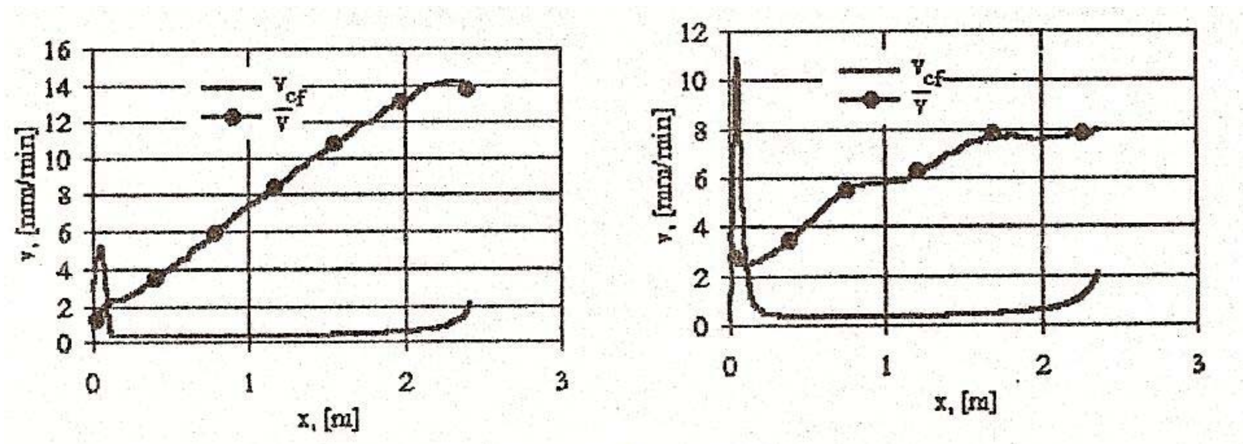


Figure 1. Biphasic zone width (δ) on ingot high (x): 1 – cylindrical; 2 – conical.

In order to making in evidence the shrinkage at solidification, in Figure 2 (a,b) presents, comparatively, the advancing medium speed of solidification faults (v, value obtained through the modeling of solidification process) and the critical value (v_{cf}), calculated with the relationship (4).



a b

Figure 2. Filtering critical speed (v_{cf}) and medium value ($\overline{v}$): a – cylindrical ingot; b –conical ingot.

In order not to negatively influence the feeding conditions by using vacuum cores, which are disadvantageous, there are attempts at analyzing the influence of the core on a transversal section, the analyzed section being situated at the half of the ingot height.

Figures 3, 4, 5 and 6 represent solidification conditions for the three types of material used at core achieving under vacuum column.

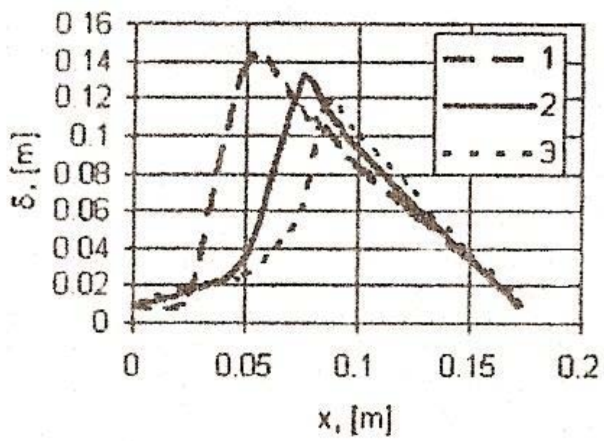


Figure 3. Biphasic zone width variation (δ) on ingot section with vacuum core from: 1- cast iron shot; 2- dried quartz sand + cast iron shots; 3- dried sand.

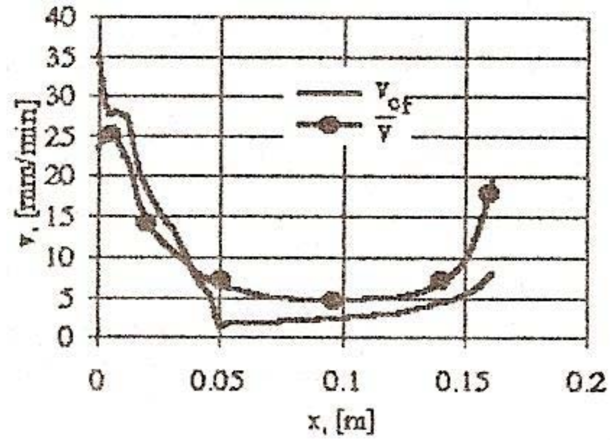


Figure 4. Filtering critical speed variation (v_{cf}) and advancing medium speed of solidification front ($\overline{v}$), on ingot section with vacuum core from cast iron shots.

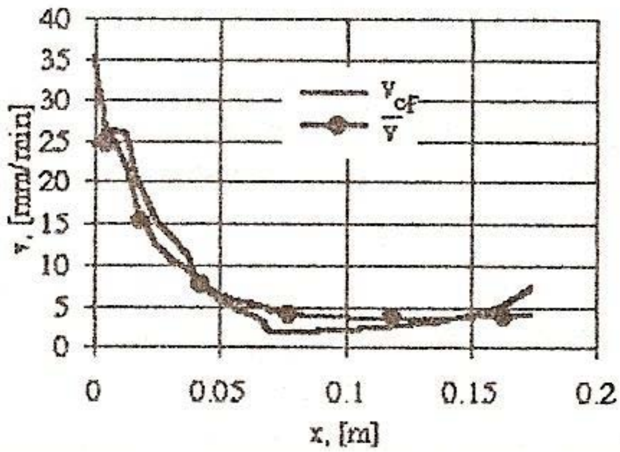


Figure 5. Filtering critical speed variation (v_{cf}) and advancing medium speed of solidification front ($\overline{v}$), on ingots section with vacuum core from dried sand + cast iron shot.

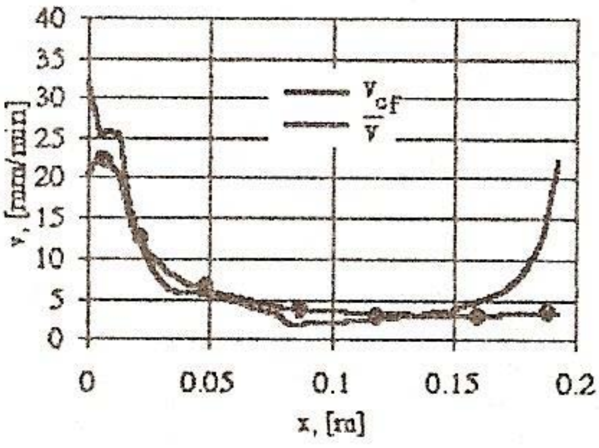


Figure 6. Filtering critical speed variation (v_{cf}) and advancing medium speed of solidification front ($\bar{v}$), on ingot section with vacuum core from dried sand.

INTERPRETATION AND CONCLUSIONS

As one can notice in Figure 2, the shrinkage compensation conditions at solidification, because of H/D rate and of great solidification boundary, is not fulfilled on most of the ingots height. The difference between mean speed and critical speed is greater the shrinkage cavities (micro shrinkage) will have one high weight. From Figure 2b is observable that the slope of the curve v is smallest comparative to Figure 2a, thus feeding conditions for conical ingots are better comparatively with cylindrical ingots.

In Figure 4, one can observe that the mean solidification speed outruns the critical speed at a 0,04 m distance approximately, from the ingot wall and difference between these remains positive on the rest of the section. Thus, shrinkage compensation with liquid phases is presented (stopped). Talking into account the fact that the analyzed section is situated at the half of the ingot height, it follows that these feeding conditions on height are very much.

Thus, as one can notice when analyzing Figure 3, the maximum width of the biphasic zone is closer to the core as the heat accumulation coefficient of the core is smaller.

From the same graphic (Figure 3), on can draw the conclusion that the core made from sand under the shape of vacuum column satisfy the highest degree the feeding conditions.

REFERENCES

1 Victoria Pasarica, Dascalu Gh., Pitigoi V., Cercetari privind forma si dimensiunile frontului de solidificare in lingourile cilindrice netede cu masa de 2,6 tone si H/D = 5, destinate fabricatiei rotilor monobloc pentru vagoane de cale ferata, Metalurgia nr. 10, Bucuresti, 1988, p. 433-438.

2 Pop Gh., Experimentari industriale privind turnarea lingourilor cave din otel, Metalurgia nr. 9, Bucuresti, 1989, p. 417-420.

3 Pop Gh., Cercetari industriale privind turnarea lingourilor cave din otel, Constructia de masini nr. 2/3, Bucuresti, 1989, p. 114-117.

4 Samoilovici I. A., Formirovanie slitka, Moskova, 1997.