Simulation of the bimetal cast in the case of milling rolls

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Abstract. In the paper it is proposed, in main, to obtain of a model of numerical simulation, valid general and applicable the whole peculiars cases of bimetal casting, model with which help can be studied through the computer, the optimization possibility of flowing working condition of liquid alloy of the distribution of temperatures field, of the liquid phase and contraction during the solidification, with the minimum price (necessary reimbursement of the software and calculus equipment) in very short time etc.

1. Introduction

Bimetals cylinders rolling destination are make, in Romania, by casting of a two alloys types into a shape from making (for inferiors axels and maselote) combined with metallic one (for pane), this casting could be made static or dynamic (S.C. Fortus S.A. Iaşi).
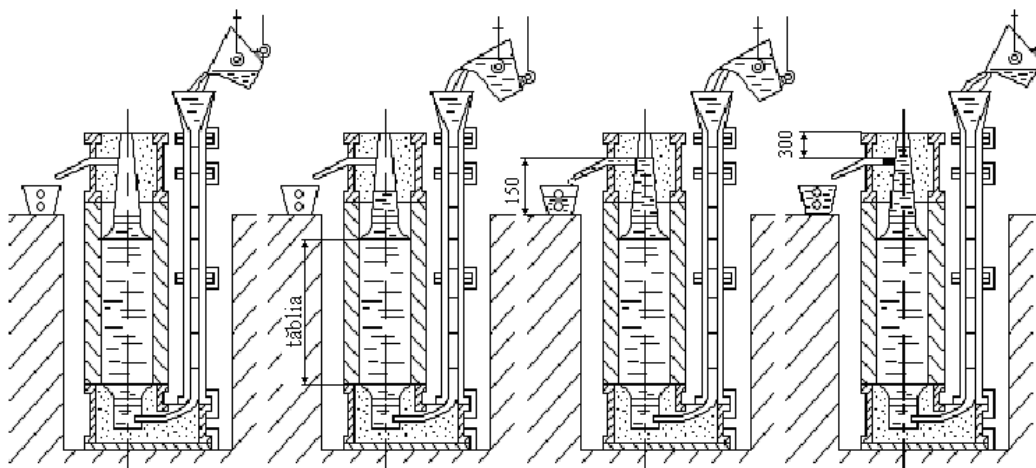

Figure 1. Casting duplex proceeding scheme of a rolling cylinders.

Static casting presume the casting of an alloy named "primary", alloy whit who it is wanted to obtain of an hard crust, and an alloy named "secondary", who is whicker alloyed and leads to the obtain of a middle and a inferiors axels with mechanical characteristics of an lower resistance, but tenacious. This variant of casting, like in Figure 1, presume more stage: primary alloy casting trough

the casting net, until the filling of a certain part of casting shape (over the chill mould level); after this operation, it is stay a time part to realization the hard crust solidification, from the chill mould thru the shape center, next moment a refer to beginning of gradually washing of the middle with secondary alloy, and then the finale stage – continuous washing, until the axels and middle obtaining [1].

In this paper has as purpose the technology optimization of bimetal casting, in static variant, as a result of economic technical analysis of the technology from S.C. Cilindrul S.A. Călan, on a 78 cylinders ϕ 750x1740 mm and ϕ 928x3300 mm lot, and also, by originals contributions bringed casting ansamble, by numerical modeled and simulation of the shape filling processes and alloys solidification. In sequel, under surname "communication vessels system", it is will be present the purposed bimetal casting technology [2].

2. Experiments

2.1. The establish of the bimetal casting technology (of a communication vessels), in porous metal consumption reduction and taking out index increasing
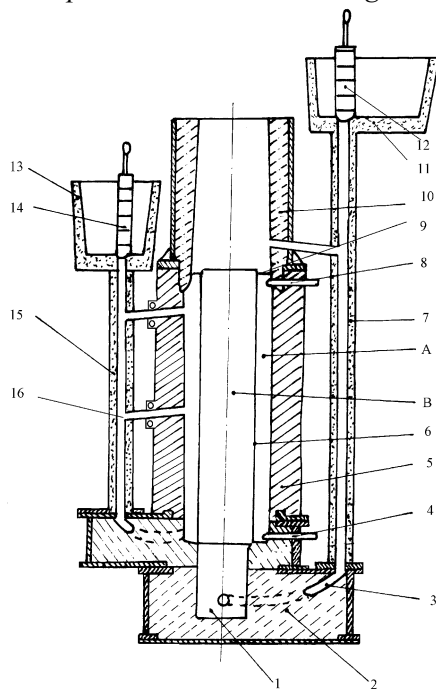

Figure 2. Proceeding and plant for casting of bimetals rolling cylinders, with the possibility of primary alloy casting on ranged net:

1 - inferior axle shape; 2 - inferior frame; 3 - alimentary channel; 4 and 8 - level signaling device; 5 - metallic shape (chill mould); 6 - dissolvable membrane; 7 and 15 the foot of casting net; 9 - membrane supports; 10 - superior frame (for making of superior axle); 11 and 13 - casting reservoir; 12 and 14 - stopper; 16 - the alimentary of ranged net.

The presented proceeding in Figure 2 remove the classical method short comings, anterior remembered, by using of un exact quantity of an secondary and primary alloys, realization an hard crust and passing stratum dimension well checked, removing of cracks appearance to warm or/and to could and the cylinder relating, on base internal tension decreasing.

The installation for the proceeding realization it is composes from an inferior frame 2, provided with an alimentary channel 3 whitch is in relation with an alimentary net 7 (in cascade, with two alimentary). This from behind distribute secondary liquid alloy from casting reservoir 11, assured with an stopper 12, which role is to begin and interrupt the shape supply and, also, retain the slag in reservoir 11.

Over inferior axle shape 2 it is set the metallic shape 5, having vertical separation surface to allowed the making out and extract casted raw cylinder. In her interior is dispose cooling membrane dissolvable of cylinder shape 6, which symmetrical axe correspond to with the child mould one, her role being the one of a separate this space in two compartments: exterior compartment **A** destinated

primary alloy casting, for making hard crust of the pane, and interior compartment **B** is destinated secondary alloy casting, which will make the cylinder middle. Separating membrane is centered at superior part of the chill mould by three supports 9 (manufactured from the same material as the membrane) fixed in shape wall, which have also the role to stop membrane raising during shape alimentation with the two alloy. Separating membrane and fixing supports it is realized from alloys with thermo-physical characteristics of well-determinated material, will alled the dissolved during the solidification of two types of pig iron (with which comes in contact), having measured thickness from the condition of thermic balance.

To the inferior part of the chill mould it is dispose a second casting net (in cascade, with three supply, vertically set) mint to the primary alloy casting, adequate dimensioned, from the shape filling condition, in compartments **A** and **B** of the chill mould 5, with the same speed:

$$s_{alloyI} \cong s_{alloyII}, \tag{1}$$

in which s_{alloyI} and $s_{alloyII}$ are increasing speeds in the shape of the two alloys, primary and secondary. Casting reservoir 13, with who are connected the net 15, is assured with stopper 14, having the same role as the one in the position 12.

Presented proceeding allowed concomitant casting of the liquid alloys, by different ways, for the liquid alloy, which will make the axles and the cylinder middle, to rise in shape at the same level, with the alloy which will make hard crust or active part of the cylinder [3].

After the both casting reservoirs are supplied with adequate alloys, at the optimum temperatures of casting, it is rise de stopper 12, beginning filling sequence of the supply net 7 with secondary alloy, followed by the inferior shape filling 1. When liquid alloy touched the inferior level of the cylinder pane, begin also the casting sequence of the primary alloy, by the second net of casting 15. This sequence it is initiated by rising de stopper 14, in the moment of touching realization between the secondary liquid alloy and level signaling device 4. This signaling device may by a immersion thermocouple tide to an indicator device of temperature (SPEDOMAX), placed on the inferior shape at the adequate quote of the inferior level of the pane.

Departing membrane it is dimensiong in such way the not dissolve herself, on her height, before the chill mould filling with the both liquid alloys. Because of the alloys themperature, still in liquid phase, with which comes in contact, the membrane it is dissolve, taking place a miscibilitate a tho two alloys, realizing the passing zone between the hard crust and the tenacious middle of the cylinder, on a thickness not bigger than 20 … 40 mm, because of the solidification, in species by meeting of the two crystallization fronts (from the chill mould 5 to the cylinder axe and from the cylinder axe to the cavity periphery **A**).

Next sequence of the proceeding it is refer to the stopping of the primary alloy casting, when this level is in the right of the second signaling device 8, identical from building point of view with the signaling device 4, established in the superior frame, at the superior quote of the cylinder pane. The casting stopping it is realizes by obturating supplies net 15, by descending of the stopper 14. In this time, the secondary alloy casting continues, until the filling of the superior shape, when it is descending also the stopper 12, and the supply net 7 are so obdurate.

By comparison with the classical proceeding of the bimetals cylinders casting, the major advantage of this method consist in the fact that it is realizing the alimentation with liquid alloy at the constant themperature on shape height, eliminating so the nondisolving risk of the separation membrane at the superior part of the pane, where it is usually registred lost themperature of secondary alloy to approximately 100 ^{o}C, face to the themperature which enter in ahape.

If the alimentation net with primary alloy would have the alimentary disposed ranged, differenced, no in the same vertical plane, the rotation move imparted to the liquid alloy will be accelerated, then eventual impurity attracted in the time of casting processes will be decanted in the exterior stratum of the pane and in the superior part of the cylinder maselot, parts which, anyway, are removed by mechanical processing (of the ulterior unthichen).

The method disadvantage it is refers, in first place, to manufacture necessity of the casting equipment (chill mould), with more orifices mint to the alimentation, in this case appearing locals

overheats in the alimentary zones (considered cushion for cracks to heat). Although, exist the possibility of lowering the number of the casting cylinders be described aparature and frequetility replacement of the chill mould 5 [3].

2.2. Bidimensional numerical model (with finished differences) of bimetal cylinder solidification
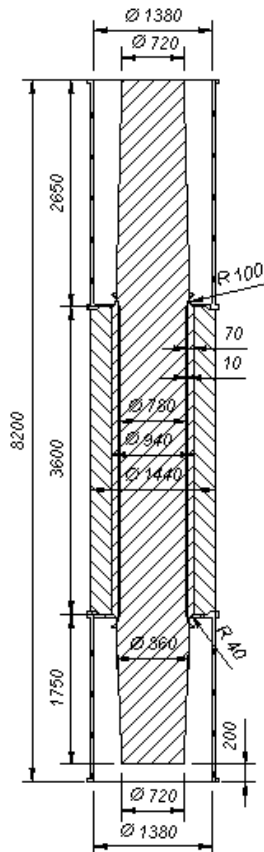

Figure 3. The dimensions casted raw cylinder and the casting ansamble.
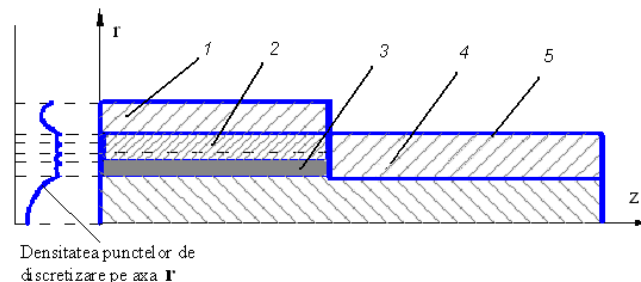

Figure 4. Quality schem of thermic system used in simulation:
1 – chill mould; 2 – hard crust; 3- cooling membrane;
4 – middle and cylinder axle; 5 – axle shape.

It is purpose a model of numerical simulation using the method of finished differences, of the solidification phenomenon of the bimetal cylinders rolling [4]. In this purpose, the analysis field, represented by a continuous medium (Figure 3) is transformed in a discontinuous medium (discreet), formed by a points net (discretionary net), of which density is given by the choosen steps for each coordinates axe (Figure 4). The themperature in each knot represents the medium themperature of the knot adjacent surface. In those knots it is written the differential equations of the transforming heat transmition in equations with finished differences.

Differential equation of the heat transmition after the three axes has the form [4]:

$$\frac{\partial t}{\partial \tau} = a \cdot \nabla^2 t \tag{2}$$

where: t - themperature, [$^{\circ}$C]; τ - time, [s]; a - thermic difuzivity, [m^2/s]; ∇^2 - Laplace operator.

The realization of numerical model imposes the establishment of the simplifications ipotesis:

1. It is considering that the system has perfect axial symmetry (after z axe). As a result would not be transmitted heat only radial and vertical.

2. Because the cylinder has a complex shape, this will be simplified, removing the conics and connection rays.

3. It is neglecting the density variation, so of volume of the materials which form the system.

4. The heat transmition to the chill mould surface and the frames to the ambient medium take place by convection and radium.

5. It is neglecting the heat release by the superior surface of the maselot and the inferior one of the inferior axle frame of the cylinder.

6. The hit transmitions by removing surfaces (middle – membrane – hard crust – chill mould) take place by conduction.

7. The latent heat release of melting. It is make during liquidus – solidus, proportional with the themperature.

3. Results and discussions

The simulation was realized for the casting ansamble from Figure 3 (the casting shape and casting raw cylinder), which geometrical dimensions are $\phi 1440 \times 8200$ mm. As the number of discretisation knots are bigger (for the casting shapes, as for the bimetal cylinder), respective enthalpy variation maximum in a smaller iteration, so as the real time of simulation is bigger. In the case of presented data, de simulation time was of 20 minutes for a real time of flowing process, solidification and cooling of 500 minutes [3].

The program could be enterupted (time step), with the mention that can't be turn on from the same time step, but must be rolled the program from the beginning. For a better illustration of the program functions, we effectuated captures of the computer screen, at the differentious time steps, and the figures such as resulted are presented next, from them obtaining regarding information to themperatures from diverses knots of the discretionary net and the real time (of calculation) covered of the simulated process. At the stopping of simulation process, the program presents the bill sticking option of simulated parameters variation in time.

Table 1. The coordinates of sections planes and points in discretionary net.

Quote on z axe	Mesuring points from cylinder inside	Mesuring plan from discretonary net inside of cylinder
$z_1 = 1750$	1 ($r_1 = 0$; $z_2/2 = 2675$), placed in cylinder axe	
$z_2 = 5350$	2 ($r_2 = 455$; $z_2/2 = 2675$), placed in cylinder crust	
$z_3 = 8000$	3 ($r_3 = 415$; $z_2/2 = 2675$), placed in membrane	
	4 ($r_4 = 500$; $z_2/2 = 2675$), placed to the interface of chill mould - crust	
	5 ($r_5 = 700$; $z_2/2 = 2675$), placed to the interface ambient field – chill mould	

The realized program allows the quality seeing of the thermic field, for differentious time moments, in planes section of the cylinders ϕ928x3300 mm, perpendiculars on z axe of the choosen reference system (in cylindrical coordinates). z axe is identical with symmetry axe of the bimetal cylinder, and the section are situated at the differentious heights face to the base plan, with whom those are parallels (for example z = 0, the plan is situated at the inferior axle base of the rolling cylinder).

In Table 1 are presented the planes quotes of the discretionary net section from numerical model field with finished differentious, those having correspondent with de planes from real field (casting ansamble ϕ1440x8200 mm, for bimetal rolling cylinder).
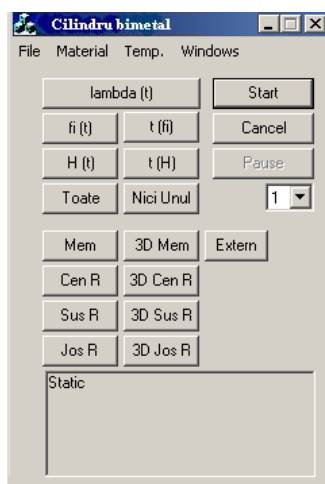

Figure 5. The principal dialog window.

In Figure 5 is presented the dialog window which is open with the initialization moment of the program "Bimetal cylinder" it is realizes pushing the button "Start/Stop". In the very next moment, the obtained image allowd the seeing of the discretionary net (Figure 6), of the simulation time and of the themperatures from diferentious zones of bimetal cylinder, as also the level to which are arrived the alloys in shape. The themperatures are showed trough color gradient, with the values: red for casting themperature, blue for ambient thermic themperature and green for their mediate. Any intermediate themperature is a combination of those.

In Figure 6, the 5 color gradient allowds an quality analysis of the solidification in time. So, the coloured zones in red are liquidus, tore in blue are solids, and the zone in greed shades show the distribution of biphasic zones (liquid and solid), with other words liquidus – solidus interval.

From Figure 6 it is could be observe that at the 4848 iteration (mining 156,458 seconds simulated time) secondary alloy, arrived to the table level. Next step, to 158,08 seconds from the simulation beginning, mentions the beginning of 2 crust alimentation with primary alloy, to the themperatur of t_4 = 1370°C (in figure 6, indication t_4 = 0 show that still it is not begin the primary alloy casting).

The membrane themperature is introduced in simulation with initial value t_3 = 250°C, so as the one of the chill mould t_5 = 250°C. The themperature t_1 is measured to the superior part of the cylinder superior axle, and the indication t_1 = 0, from Figure 6, is refers to the fact that, at this moment of simulation, the liquid alloy have not arrived to the respective level.

Notes j = 34 respective lev = 1738,42, from Figure 6, show the level (z and r coordinates) to which has arrived the fusion, meaning in 34 point of the discretionary net at the 1738,42 quote.

For a correct analysis, as a quality point of view but also quantitatively, in 7. a, b, c, d, e and f figures are presented the liquids alloys evolutions (primary and secondary) during the shape filling and in solidification time.

Is observe from Figures 7.a and b the filling of two cavity of chill mould (2 crust and 4 middle) with the same speed and, also, moving forward of the solidification from to the cylinder axe (Figure 7,

c, d, e and f). The program cannot establish, so, the place of contraction defaults and either their measure.

From the tridimensional representations of the thermic field it is could be made the conexions between the level (z quote) to which had increase the alloys in shape, the themperatures and the simulated time (fig. 8). This imagines tipes are obtained by activating the dialog window **Metal3DGraph**, or of the butons from main window (3D Cem R etc) [3].
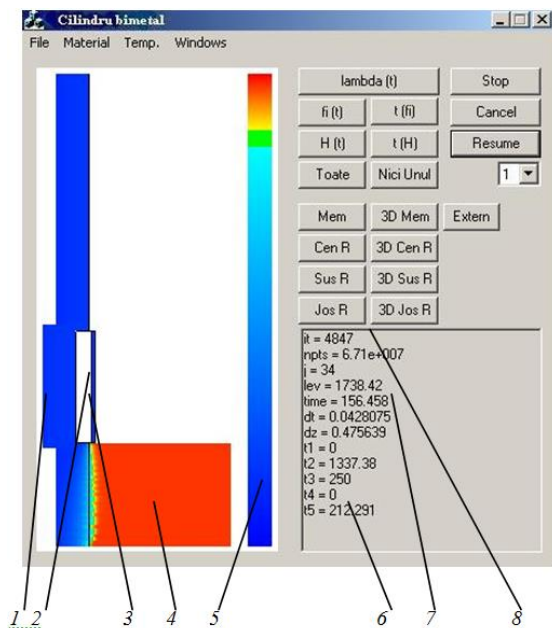

Figure 6. Seeing the simulation steps of the solidification and filling processes of bimetal cylinder: 1–chill mould; 2- hard crust; 3– disolvable cooling membrane; 4– inferior axle; 6–touche temperatures in differentious zones of the casting ansamble; 7–simulated time; 8–iteration.
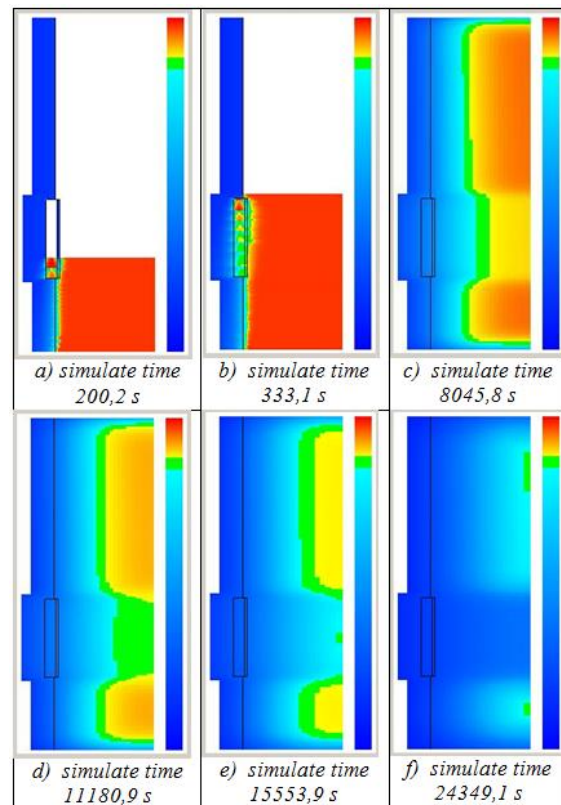

a) simulate time 200,2 s   b) simulate time 333,1 s   c) simulate time 8045,8 s

d) simulate time 11180,9 s   e) simulate time 15553,9 s   f) simulate time 24349,1 s

Figure 7. The liquid phase distribution on filling up way of the shape and during the solidification of bimetal casted cylinders.

Observation: The variation graphics of the time, temperature, at the differentious planes of the section in long axes r and z, use the procentual expression of the coordinates.

The evolution in time of the 1, 2, 3, 4 and 5 points themperature (Table 1) may be fallowed by activating the window **MetalGraph**, or directly, pushing the main window buttons (Cen R, Sus R etc), presented in Figure 9.

The obtained data can be exported in purpose of their comparison with the obtained values by casuals experimental measures, realized with the help of immersion thermocouples (plased in points of real field corresponding to the points of definite measure in discretionary net, simulated with the help of finished differentious method [3].
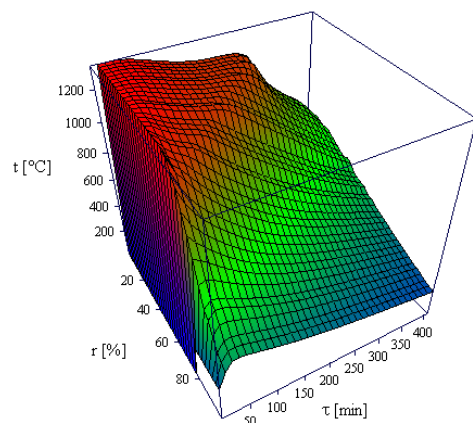
Figure 8. The temperature variation in time, determinated at the quotation $z_2/2 = 2675$, after 400 minutes from the simulation beginning
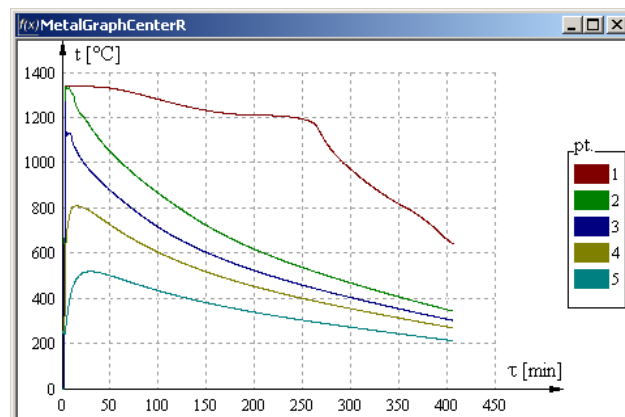
Figure 9. The graphic presentation of temperature evolution at the chill mould middle ($z_2/2 = 2675$), after 400 minutes from the simulation beginning

4. Conclusions

As a result of critical analysis of actual technology of bimetal casting, in static regime, of the big diameters cylinders, destinated pane rolling, it were proposed three variants (author own conception) of technology improving, final, establishing as optimum the vessels communication, which use a dissolvable micro-cooler membrane and of ranged casting nets.

Beginning from filling up principle of the two cavity of chill mould (A – destinated to the tenacious middle obtaining of the cylinder pane and B – destinated the hard crust realization, of equal thickness on pane generatrix) at the same level, on filling up whole way, it was dimensioned casting system, compose from the independent alimentary two nets.

Taking account of micro-cooler effect played by the dissolvable membrane, introduced in chill mould, was effectuated a moulding study of solidification process of bimetals cylinders (casting from A and B fusions), in this hypothesis.

The numerical and analytic moulding of the flowing processes solidification and cooling constitue a base instrument, useful as in conception phase such as in the analysis one of the metallurgical processes, which, combined with computers use, allowds the establish of the optimums regims of those development.

The results and the obtained conclusions after numerical moulding with the help of finite differences method can be extrapolated with a high veracity at the industrial processes which take place at the solidification conduction of bimetal cylinders of big diameters, in porous of their quality improving in exploitation.

In the presented context, one of the main objectives (the quality improving of big diameters bimetal cylinders) was realized by solidification research and the links establishment regarding to technologic parameters various (casting temperature, specific consume of micro-coolers and those dimensions) depending on operational variables specific of solidification processes, to determinate the influence modalities of those in view of obtaining of some pieces (bimetals rolling cylinders) of superior quality, reproducibility conditions and maximum economic – technical efficiency.

References

[1]   Mihuţ G, Prejban I and Maksay S 2003 *The influence of the elements C, Cr and Mo upon the hardness of the bimetallic casted iron pig milling rolls*, 7th International Symposium Interdisciplinary Regional Research, Hunedoara, Romania, pp 634-639

[2]   Mihuț G 2000 Studyes and researches on the replacing of carbide rolls for wire rolling with bimettalics rolls, *Universitaria ROPET 2000* 165-170
[3]   Mihuț G 2005 *Optimization of bimetal casting technology for large diameter cylinders destined rolling*, Politehnica University of Timisoara, Romania, Doctoral Thesis
[4]   Minkowycs W J 1996 *Advances in Numerical Heat Transfer*, Volume I, Taylor & Francis, Washington, USA