THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI.
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N^{0}. 4 – 2010, ISSN 1453 – 083X

INFLUENCE OF RIB THICKNESS ON THE SOLIDIFICATION OF CAST PARTS

Ioan CIOBANU, Diana ŢUŢUIANU, Tibor BEDŐ, Aurel CRIŞAN
Faculty of Materials Science and Engineering
„Transilvania" University of Braşov,
email: ciobanu_i_bv@yahoo.com

ABSTRACT

The ribs applied to the walls of cast parts are designed for enhancing both stiffness and aesthetics. The presence of ribs modifies the conditions of heat transmission and implicitly the solidification of the alloy in the joining area of the rib to the part wall. This is highlighted by the modified radius of the circles inscribed in the rib – wall joining area. The diameter of the circles inscribed in this area is greater than of those in the rest of the part wall. This leads to the assumption that the solidification of the alloy in this area is slowed. The paper presents the results of a study concerning the influence of rib thickness on the duration of cast part solidification and on the position of the hot spots. The study was conducted by computer simulation of solidification. The results have revealed that in certain situations (thin ribs compared to wall thickness) the ribs cause an acceleration of the solidification of cast parts. The thickness of ribs ensuring the maximum cooling effect is determined.

KEYWORDS: rib thickness, cast parts solidification, computer simulation

1. Introduction

While representing the technological elements required by the designer or manufacturing engineer, ribs, casting slopes and corner radii of the cast parts also have an aesthetic function. Generally ribs have the role of stiffening the walls of the cast parts. These technological elements (ribs, slopes, corner radii) influence the solidification of cast parts. Ribs determine a local thickening of parts in the rib – part wall joining area, as highlighted by the local increase of the circle radii inscribed in the part perimeter, as shown in Figure 1.

Consequently it is to be expected that these technological elements determine a local increase of solidification time and hence the generation of hot spots, causing on their turn solidification-specific defects (porosity, shrinkholes, cracks, etc.).

The paper presents the results of a study on the influence of rib thickness on the solidification of cast parts, and thus on the tendency of defect generation caused by solidification. The aim is to establish the magnitude of this influence and the opportunity of prevention measures.

Research was conducted by computer aided simulation of the solidification process, by means of the dedicated „Sim-3D" software, developed at the Faculty of Materials Science and Engineering of the Transilvania University of Braşov.

2. Influence of rib thickness on the solidification of cast parts

The rib thickness influence on the solidification of cast parts has been studied.

The test piece thickness was of a = 20 mm. Figure 2 shows the geometry and dimensions of the cast parts and casting mould included in the study. The ribs length was of L_n = 50 mm. The rib thickness was between b_n = 0 mm and b_n = 23 mm.

The study was conducted on eutectic cast iron parts cast in silica sand moulds. Table 1 features the thermo-physical characteristics of the alloy and the mould used for simulation.

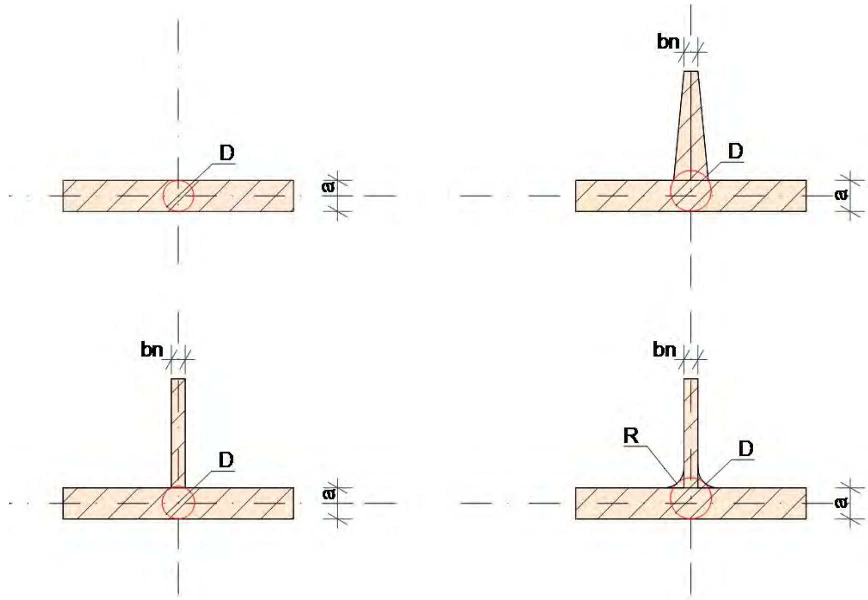

Fig. 1. *Influence of rib thickness, casting slopes and corner radii on the diameter of the circle inscribed in the contour of the cast parts.*

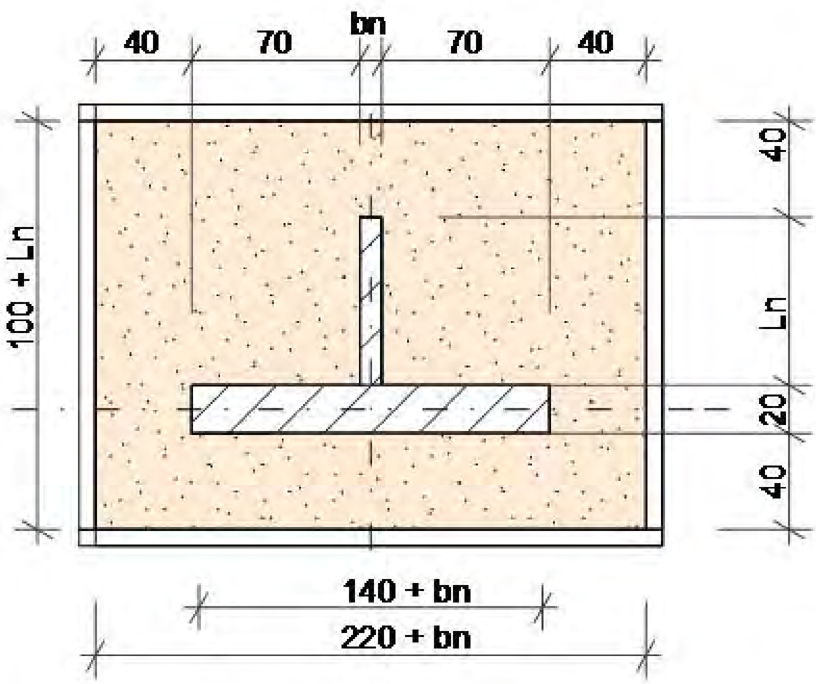

Fig. 2. *Geometry and dimensions of the part and mould.*

The study concerned the influence of rib length on the position of hot spots, on the solidification time, on temperature variation and on the solidified fraction in the hot spots. Figures 3 ÷ 9 show for a number of the studied cases the distribution of the isotherms in the cast part and the mould at the moment of solidification of the hotspots.

Table 2 shows the coordinates of the hot spots and their respective solidification times

Table 1. *Values of the quantities used for simulation of solidification*

No.	Parameter	Physical symbol	Measure unit	Value
1	Mesh width of mould dividing	Δ	m	0,001
2	Time interval	τ	s	0,02
3	Environment temperature for the exterior of the mould	T_{ex}	^0C	20
4	Thermal exchange coefficient of the mould-exterior environment	α_{ex}	$W\cdot m^{-2}\cdot K^{-1}$	10,0
5	Solidus temperature of the cast alloy	T_{sme}	^0C	1150
6	Thermal conductibility coefficient of the mould	λ_{sfo}	$W\cdot m^{-1}\cdot K^{-1}$	0,85
7	Thermal conductibility coefficient of the solidified alloy	λ_{sme}	$W\cdot m^{-1}\cdot K^{-1}$	40
8	Thermal conductibility coefficient of the liquid alloy	λ_{lme}	$W\cdot m^{-1}\cdot K^{-1}$	30
9	Specific heat of the mould	C_{sfo}	$J\cdot kg^{-1}\cdot K^{-1}$	1170
10	Specific heat of the liquid cast iron	C_{lme}	$J\cdot kg^{-1}\cdot K^{-1}$	850
11	Specific heat of the solid cast iron	C_{sme}	$J\cdot kg^{-1}\cdot K^{-1}$	750
12	Mould density	ρ_{fo}	$kg\cdot m^{-3}$	1550
13	Alloy density	ρ_{me}	$kg\cdot m^{-3}$	6700
14	Specific latent heat of the cast alloy	L_{me}	$J\cdot kg^{-1}$	250000
15	Initial temperature of the mould	T_{0fo}	^0C	20
16	Initial temperature of the cast alloy	T_{0me}	^0C	1350

Table 2. *Coordinates of the hot spots and solidification time versus rib thickness (Rib length of L_n=50mm).*

No.	Rib thickness	No. of hot spots	Coordinates of hot spots	Solidification time
Symbol	b_n	N_n	(x,y)	t_{sol}
u.m.	mm	-	(mm,mm)	s
1	0	1	(0;0)	300,38
2	3	2	(-21,0; -0,5) and (+21,0; -0,5)	262,58
3	5	2	(-20,0; +0,5) and (+20,0; +0,5)	270,50
4	9	2	(-15,0; +0,5) and (+15,0; +0,5)	299,94
5	13	2	(-9; +0,5) and (+9; +0,5)	333,32
6	15	1	(0; +0,5)	355,44
7	19	1	(0; +3,5)	401,42
8	23	1	(0; +6,5)	446,16

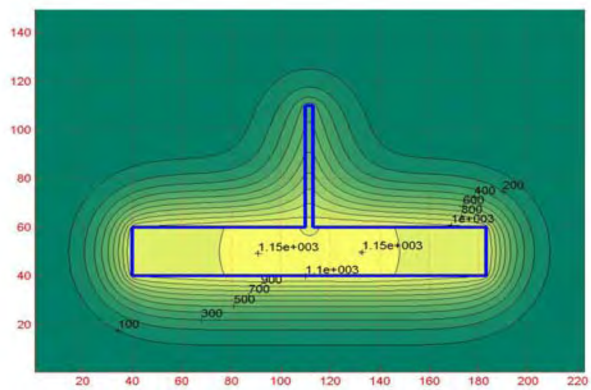

Fig. 3. *Outline of isotherms in the case of the part with a rib of thickness b_n = 3 mm. (at the moment of solidification t_{sol} = 262.58 s).*

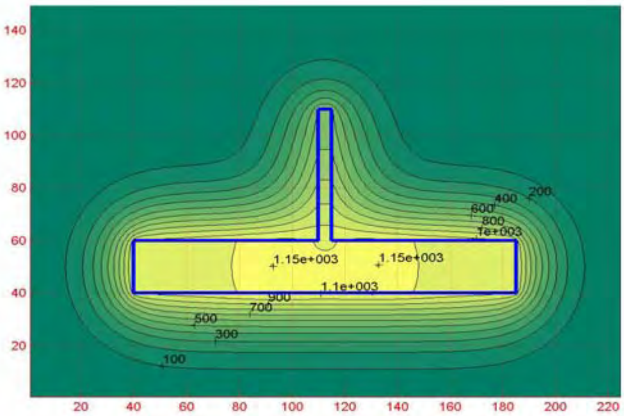

Fig. 4. *Outline of isotherms in the case of the part with a rib of thickness* $b_n = 5$ *mm (at the moment of solidification* $t_{sol} = 270.50$ *s).*

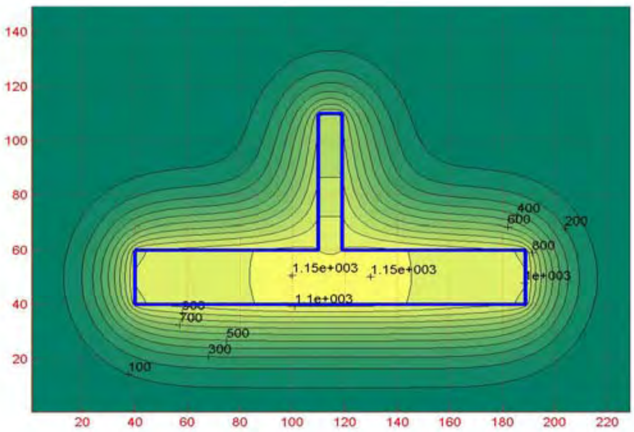

Fig. 5. *Outline of isotherms in the case of the part with a rib of thickness* $b_n = 9$ *mm (at the moment of solidification* $t_{sol} = 299.94$ *s).*

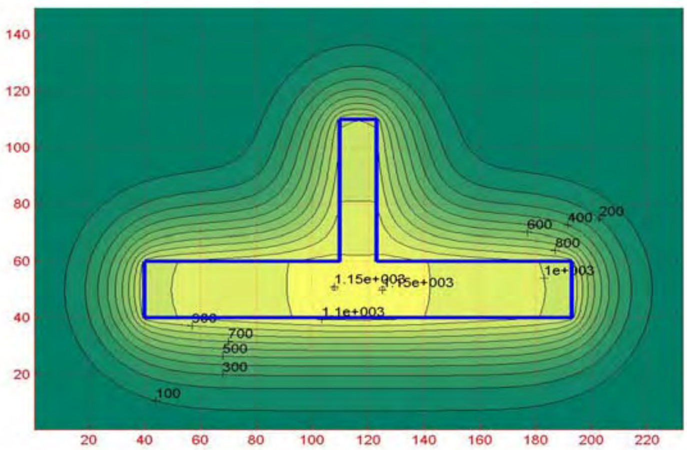

Fig. 6. *Outline of isotherms in the case of the part with a rib of thickness* $b_n = 13$ *mm (at the moment of solidification* $t_{sol} = 333.32$ *s).*

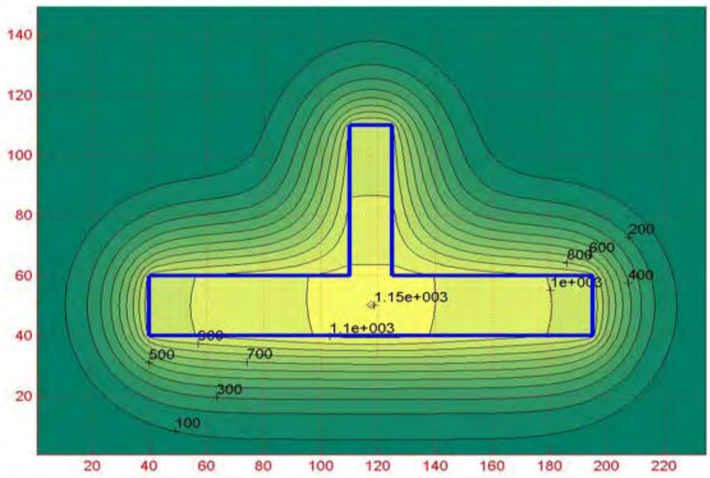

Fig. 7. *Outline of isotherms in the case of the part with a rib of thickness b_n = 15 mm (at the moment of solidification t_{sol} = 355.44 s).*

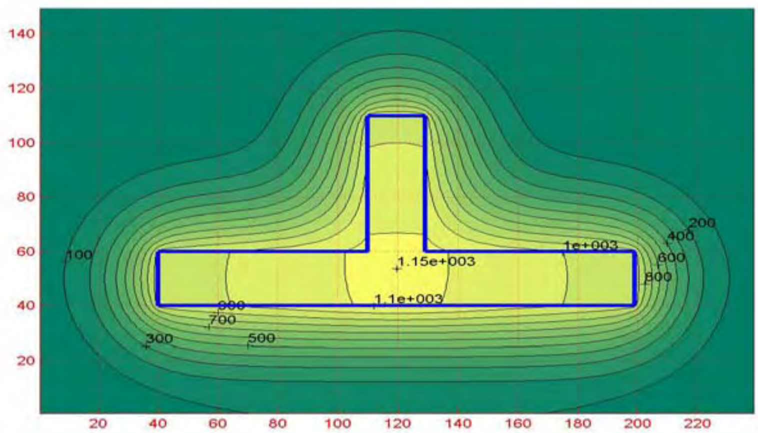

Fig. 8. *Outline of isotherms in the case of the part with a rib of thickness b_n = 19 mm (at the moment of solidification t_{sol} = 401.42 s).*

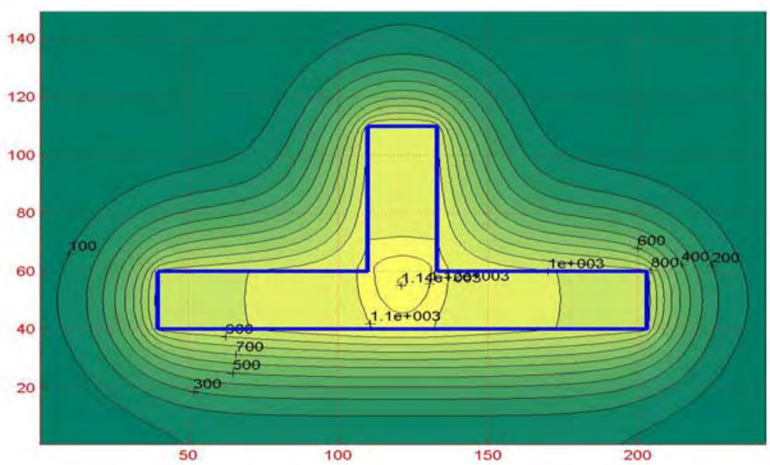

Fig. 9. *Outline of isotherms in the case of the part with a rib of thickness b_n = 23 mm (at the moment of solidification t_{sol} = 446.16 s).*

The hot spot coordinates relate to a frame of reference corresponding to the symmetry axes of the cast part walls, as shown in Figure 10. Figure 11 shows the influence of rib thickness on hot spot solidification time. Figures 12 ÷ 14 feature the distribution of temperatures in the mould, at a moment close to the end of the solidification time, along the AB line corresponding to the axis of 20 mm thickness wall in the case of a rib. Figures 15 ÷ 18 feature the variation curves of temperature and of the solid fraction in the hot spots for two of the studied cases.

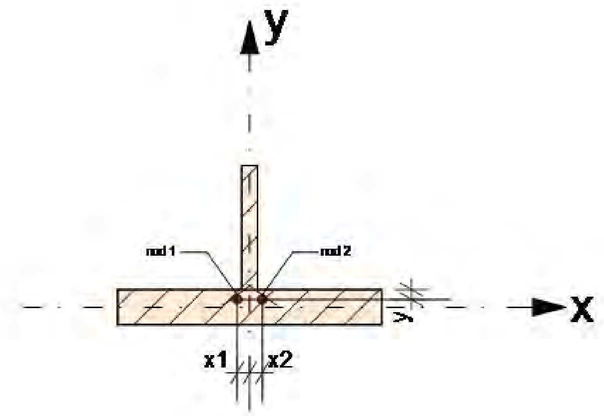

Fig. 10. *Coordinates of the hot spots.*

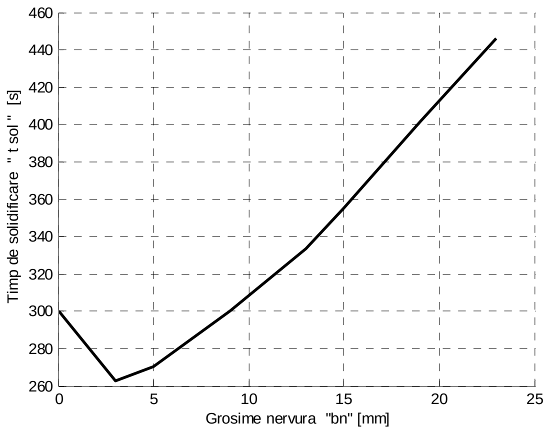

Fig. 11. *Influence of rib thickness on the solidification of a part (plate of thickness a = 20 mm and rib of L_n = 50 mm length) (T_{sol} = Solidification time, b_n = Rib thickness).*

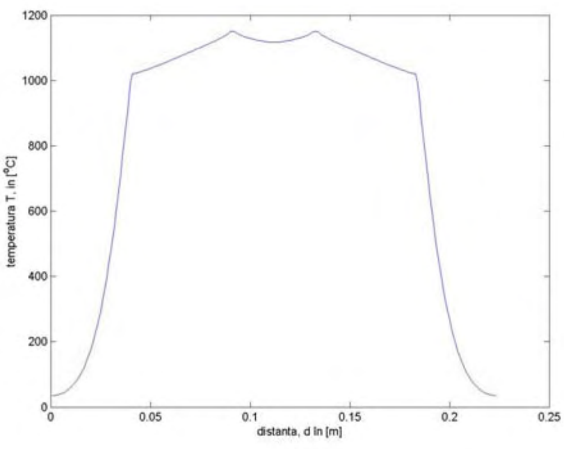

Fig. 12. *Distribution of temperatures line AB (axis of wall of thickness 20 mm) in the case of a rib of thickness b_n = 3 mm, at moment t = 260s. (T = temperature d = distance).*

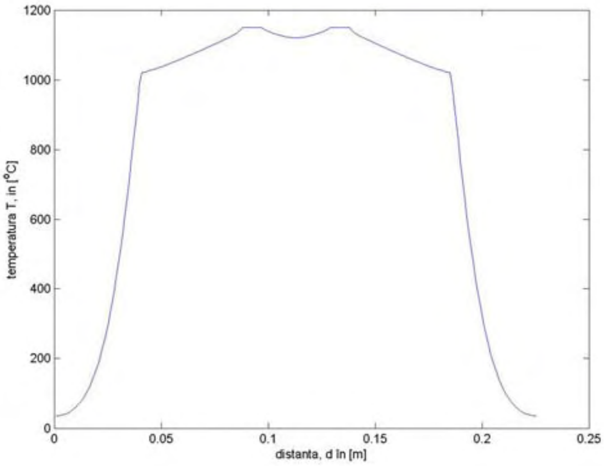

Fig. 13. *Distribution of temperatures line AB (axis of wall of thickness 20 mm) in the case of a rib of thickness b_n = 5 mm, at moment t = 260s. (T = temperature d = distance).*

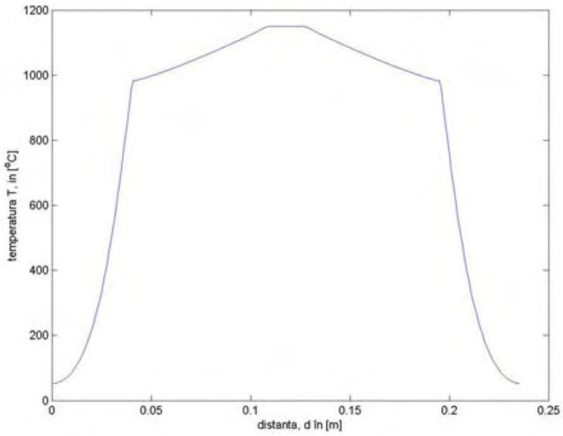

Fig. 14. *Distribution of temperatures line AB (axis of wall of thickness 20 mm) in the case of a rib of thickness b_n = 15 mm, at moment t = 340s. (T = temperature d = distance).*

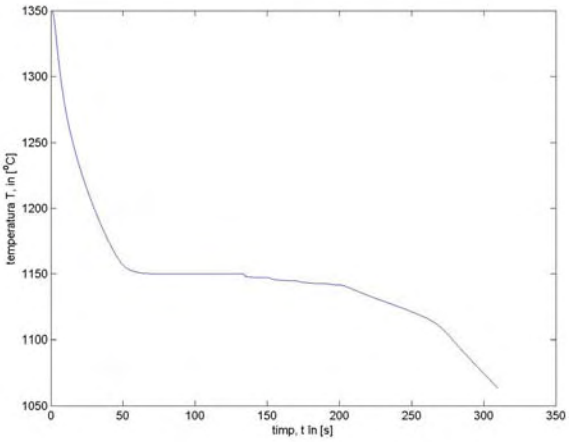

Fig. 15. *Variation of temperature in the point of coordinates (x,y) = (0; 0.5), rib of b_n = 3 mm thickness and L_n = 50 mm in length (T = temperature; t – time).*

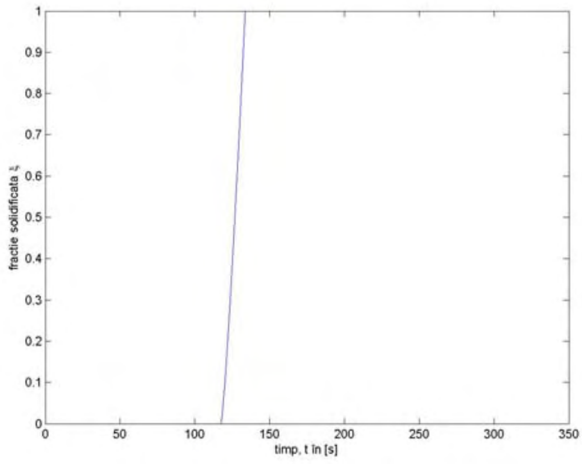

Fig. 16. *Variation of the solid fraction in the point of coordinates (x, y) = (0; 0.5), rib of b_n = 3 mm thickness and L_n = 50 mm in length (Solidified fraction; t = time).*

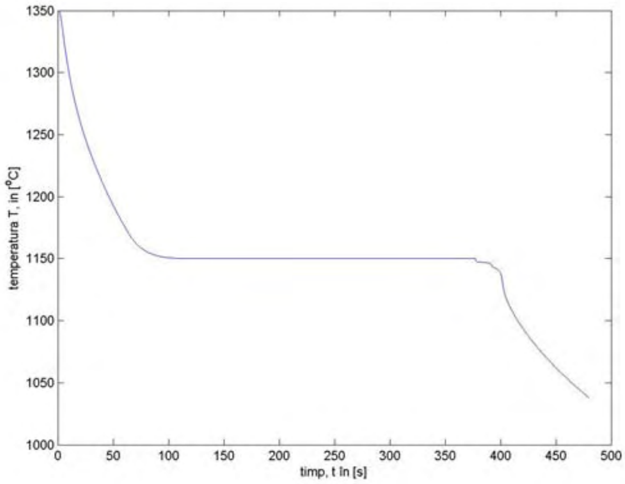

Fig. 17. *Variation of temperature in the point of coordinates (x, y) = (0; 0.5), rib of b_n = 19 mm thickness and L_n = 50 mm in length (T = temperature; t – time)*

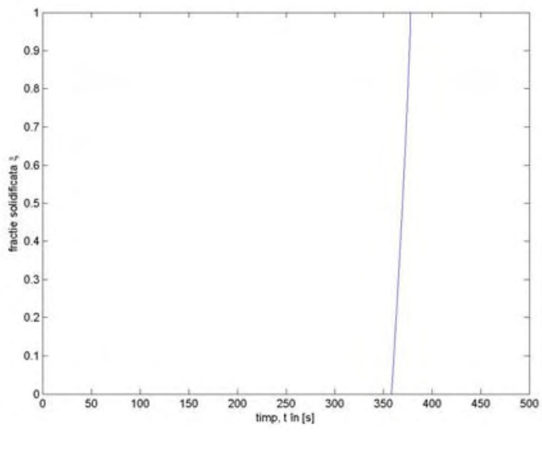

Fig. 18. *Variation of the solid fraction in the point of coordinates (x, y) = (0; 0.5), rib of b_n = 19 mm thickness and L_n = 50 mm in length (Solidified fraction; t = time).*

3. Conclusion concerning the influence of rib thickness on solidification

The following conclusions are yielded by the results of this study:

- ribs significantly thinner than the wall of the cast parts have a cooling effect, causing the decrease of solidification time compared to that of a ribless part;

- the cooling effect (or wing effect) is observed in the case of ribs thinner than 0.5a (half the wall thickness) and is clearly visible in Figures 12 and 13;

- the maximum effect of the cooling caused by the ribs is observed (in the case of the studied parts, part of thickness a = 20mm) for the rib of thickness b_n = 3mm);

- for rib thickness exceeding b_n = 9mm the cooling effect of the ribs disappears (Figure 14); thickness exceeding this value causes an increase of the cast part solidification time;

- in the part of thickness a = 20mm and thin ribs, $b_n \leq 13$mm, two hot spots are generated, positioned symmetrically in relation to the rib axis;

- in the case of ribs with thickness $b_n \geq 15$ mm a single hot spot is generated in the part, placed on the rib axis;

- the greatest decrease of solidification time (compared to the ribless part) is observed for the 3 mm thick rib, namely from 300.38s to 262.58s, representing 12.5%;

- Figures 15 ÷ 18 reveal the significant influence of rib thickness on temperature variation and solidification kinetics in the points of the rib – part wall joining area.

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