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INFLUENCE OF RIB LENGTH ON THE SOLIDIFICATION OF CAST PARTS

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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 dimensions (length) 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 length of thin ribs ensuring the maximum cooling effect is determined.

KEYWORDS: rib lenght, solidification, cast part, 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 length 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 length on the solidification of cast parts

There has been studied the rib length influence on the solidification of cast parts.

The test piece thickness was of a = 20 mm and had ribs of thickness b_n=3 mm and b_n=5 mm, respectively. Figure 2 shows the geometry and dimensions of the cast parts and casting mould included by the study.

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.

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.

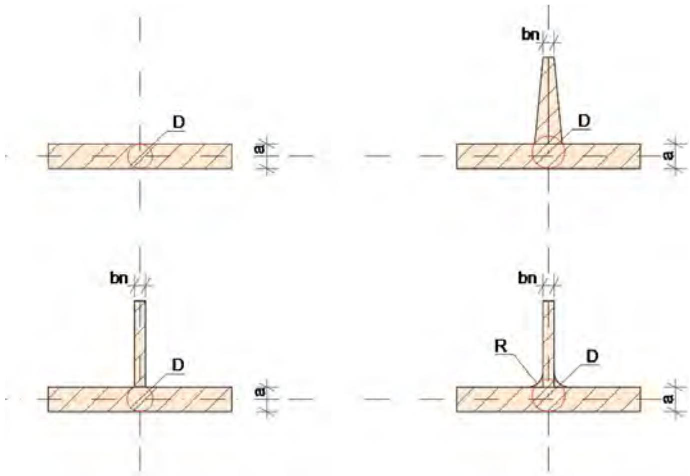

Fig. 1. *Influence of rib thickness, casting slopes and corner radii on the diameter of the circle inscribed in the contour of the cast parts.*

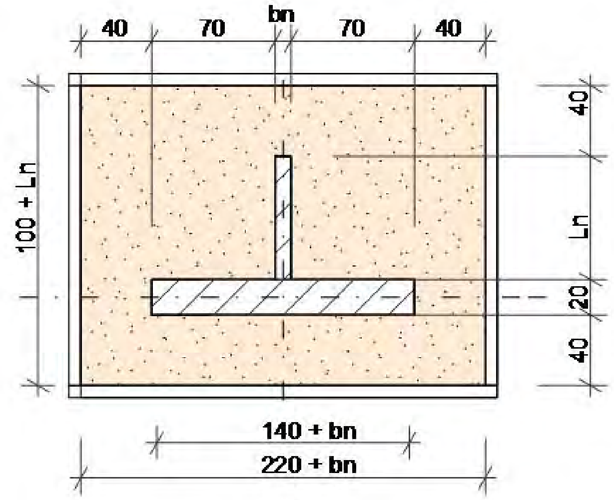

Fig. 2. *Geometry and dimensions of the part and mould.*

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 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

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Figures 3 ÷ 8 show for a number of the studied cases involving ribs of thickness bn = 3 mm the distribution of the isotherms in the cast part and the mould at the moment of solidification of the hotspots. Figures 9 ÷13 present the isotherms for ribs of thickness b_n = 5mm. Tables 2 and 3 show the coordinates of the hot spots and their respective solidification times. The hot spot coordinates relate to a frame of reference corresponding to the symmetry axes of the cast part walls, as shown in Figure 14. Figure 15 shows the influence of rib length on hot spot solidification time.

Figures 16 ÷ 19 feature the variation curves of temperature and of the solid fraction in the hot spots for some of the studied cases, in order to the reveal solidification kinetics in those points.

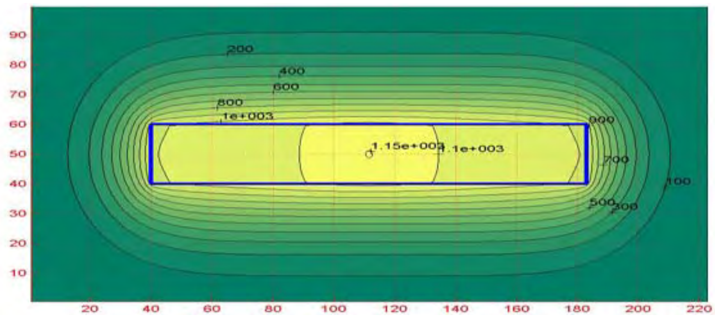

Fig. 3. *Isotherm outline for the ribless part (thickness a = 20 mm, width L = 140 mm) at the moment of solidification t = 302.70 s.*

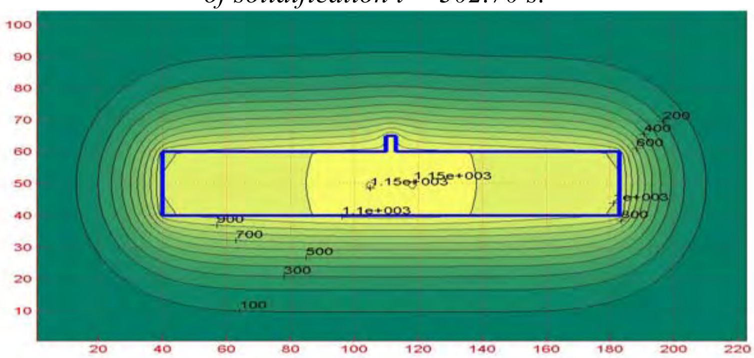

Fig. 4. *Isotherm outline for the part with a rib of thickness b_n = 3 mm and length L_n = 5 mm (at the time of solidification t_{sol} = 294.34 s).*

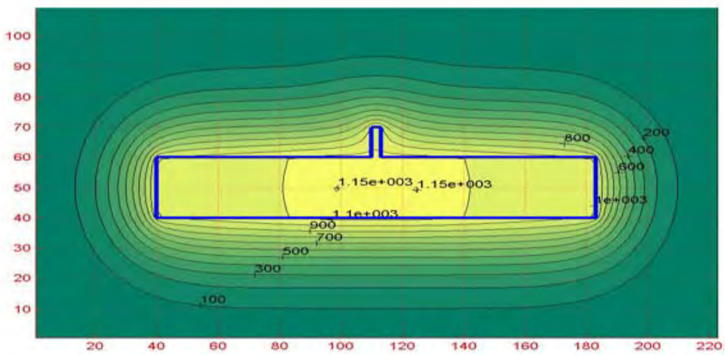

Fig. 5. *Isotherm outline for the part with a rib of thickness b_n = 3 mm and length L_n = 10mm (at the time of solidification t_{sol} = 283.02 s).*

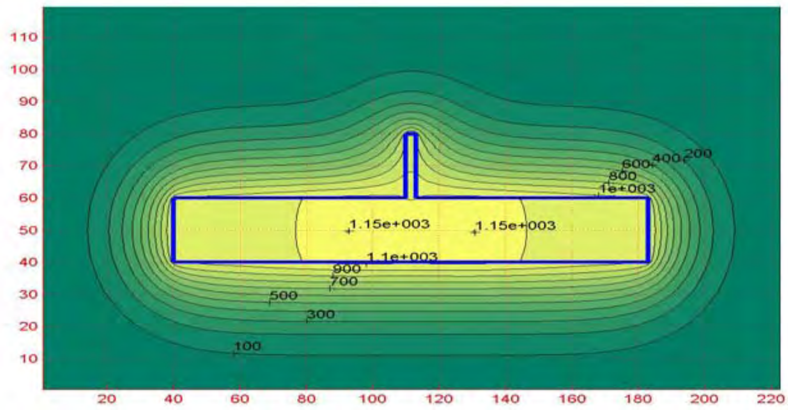

Fig. 6. *Isotherm outline for the part with a rib of thickness b_n = 3 mm and length L_n = 20mm (at the time of solidification t_{sol} = 268.06 s).*

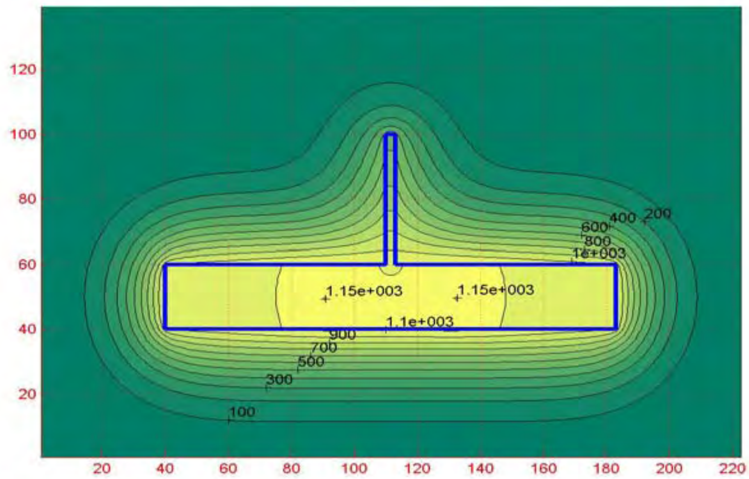

Fig. 7. *Isotherm outline for the part with a rib of thickness b_n = 3 mm and length L_n = 40mm (at the time of solidification t_{sol} = 262.24 s).*

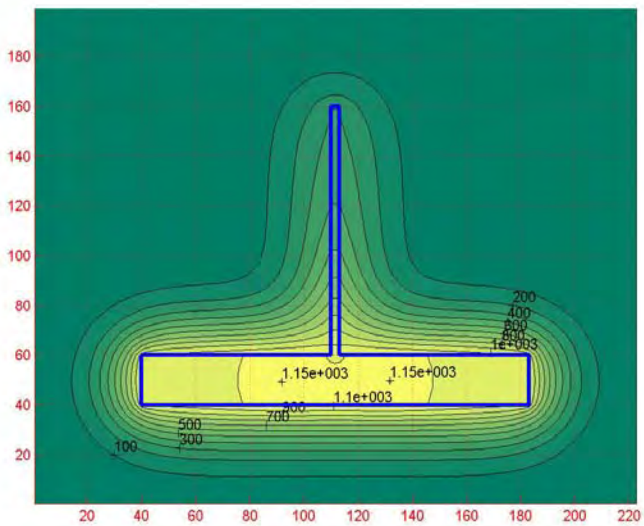

Fig. 8. *Isotherm outline for the part with a rib of thickness b_n = 3 mm and length L_n = 100mm (at the time of solidification t_{sol} = 264.08 s).*

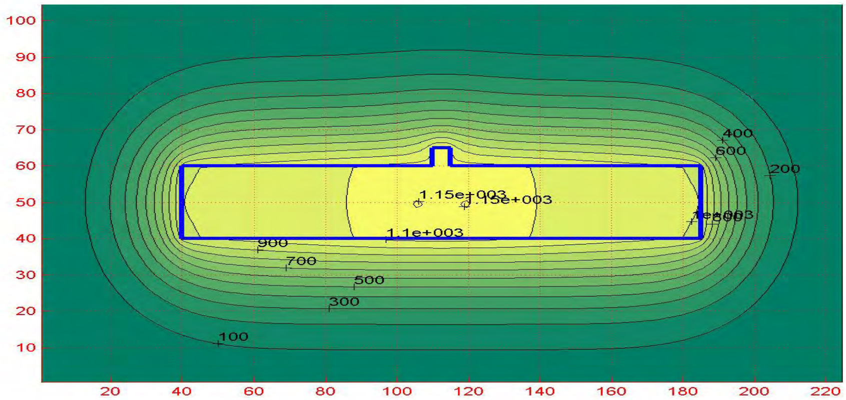

Fig. 9. *Isotherm outline for the part with a rib of thickness b_n = 5 mm and length L_n = 5 mm (at the time of solidification t_{sol} = 298.48 s).*

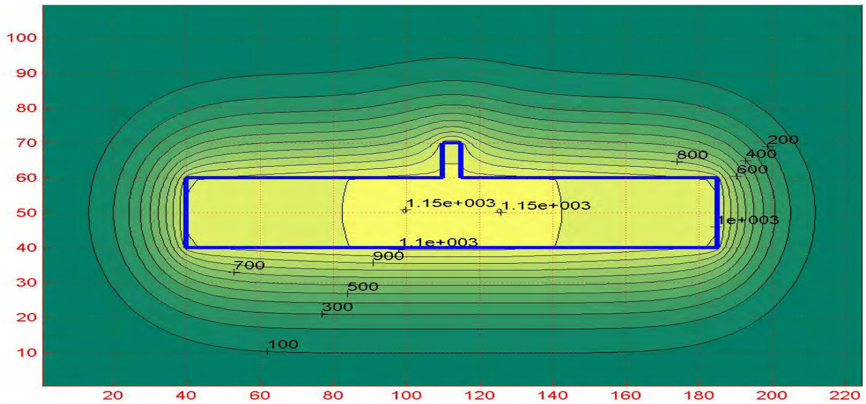

Fig. 10. *Isotherm outline for the part with a rib of thickness b_n = 5 mm and length L_n = 10mm (at the time of solidification t_{sol} = 289.00 s).*

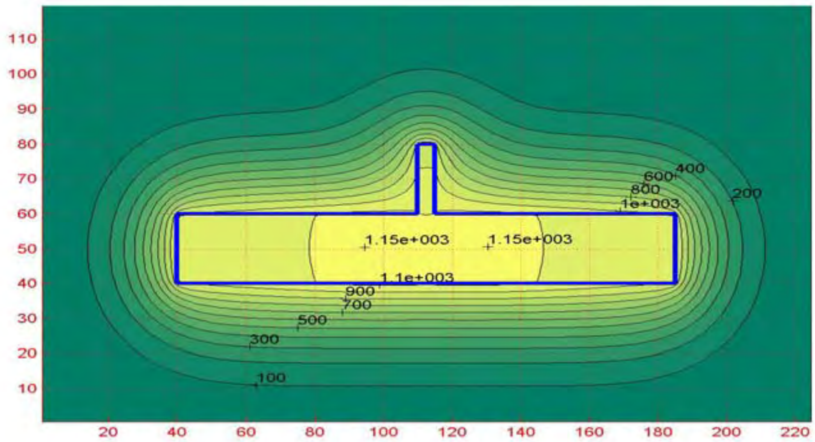

Fig. 11. *Isotherm outline for the part with a rib of thickness b_n = 5 mm and length L_n = 20mm (at the time of solidification t_{sol} = 275.30 s).*

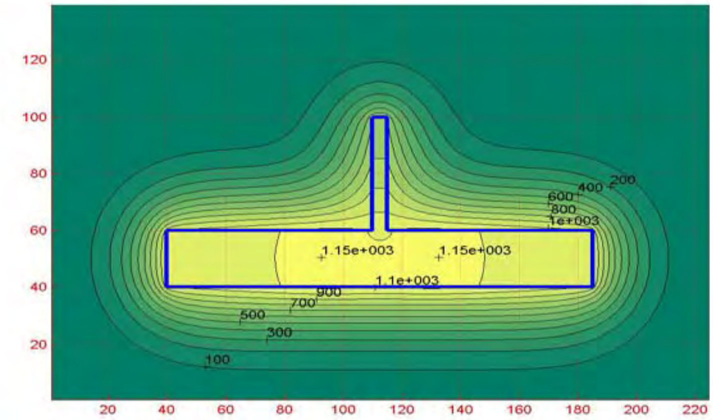

Fig. 12. *Isotherm outline for the part with a rib of thickness b_n = 5 mm and length L_n = 40mm (at the time of solidification t_{sol} = 269.62 s).*

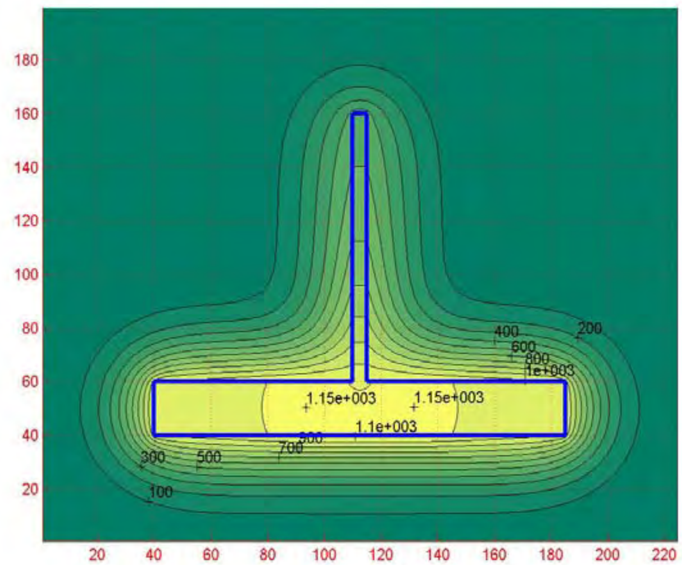

Fig. 13. *Isotherm outline for the part with a rib of thickness b_n = 5 mm and length L_n = 100mm (at the time of solidification t_{sol} = 273.98 s).*

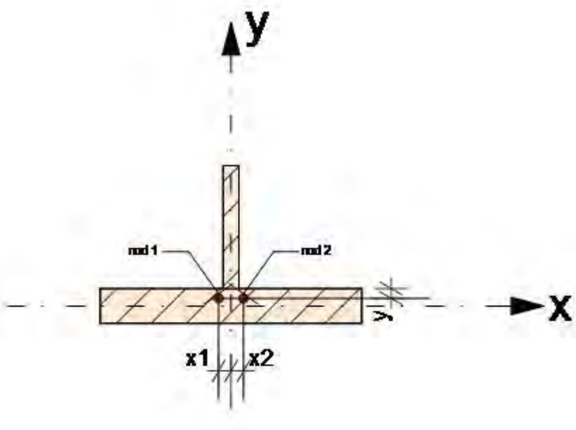

Fig. 14. *Coordinates of the hot spots.*

Table 2. *Coordinates of the hot spots and solidification time for ribs of thickness b_n = 3mm*

No.	**Rib lenght**	**No. of hot spots**	**Coordinates of hot spots**	**Solidification time**
Symbol	l_n	N_n	(x,y)	t_{sol}
u.m.	mm	-	(mm,mm)	s
1	0	1	(0;0)	302.70
2	5	2	(-7.0; -0.5) and (+7.0; -0.5)	294.34
3	10	2	(-13.0; -0.5) and (+13.0; -0.5)	283.02
4	20	2	(-19.0; -0.5) and (+19.0; -0.5)	268.06
5	30	2	(-20; -0.5) and (+20; -0.5)	263.00
6	40	2	(-21; -0.5) and (+21; -0.5)	262.24
7	50	2	(-21; -0.5) and (+21; -0.5)	262.58
8	60	2	(-20; -0.5) and (+20; -0.5)	263.08
9	70	2	(-20; -0.5) and (+20; -0.5)	263.52
10	100	2	(-20; -0.5) and (+20; -0.5)	264.08

Table 3. *Coordinates of the hot spots and solidification time for ribs of thickness b_n = 5mm*

No.	**Rib lenght**	**No. of hot spots**	**Coordinates of hot spots**	**Solidification time**
Symbol	l_n	N_n	(x,y)	t sol
u.m.	mm	-	(mm,mm)	s
1	0	1	(0;0)	304.12
2	5	2	(-7.0; -0.5) and (+7.0; -0.5)	298.48
3	10	2	(-13.0; +0.5) and (+13.0; +0.5)	289.00
4	20	2	(-18.0; +0.5) and (+18.0; +0.5)	275.30
5	30	2	(-20; +0.5) and (+20; +0.5)	270.14
6	40	2	(-20; +0.5) and (+20; +0.5)	269.62
7	50	2	(-20; +0.5) and (+20; +0.5)	270.50
8	60	2	(-19; +0.5) and (+19; +0.5)	271.58
9	70	2	(-19; +0.5) and (+19; +0.5)	272.58
10	100	2	(-19; +0.5) and (+19; +0.5)	273.98

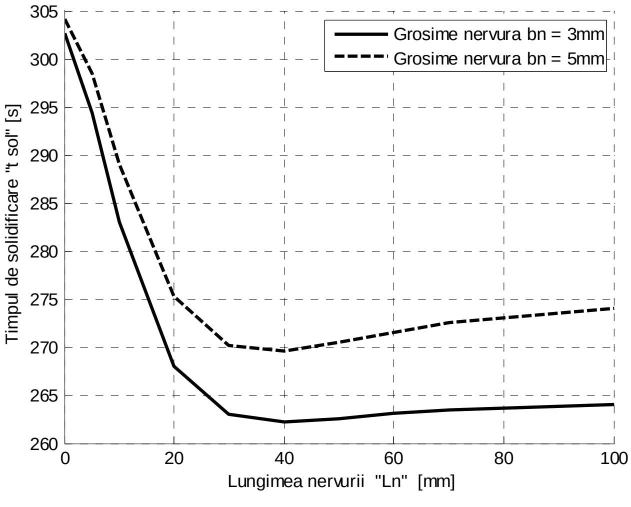

Fig. 15. *Influence of rib length "L_n" on the solidification time for a cast iron plate of thickness a = 20 mm (b_n = rib thickness; L_n = rib length).*

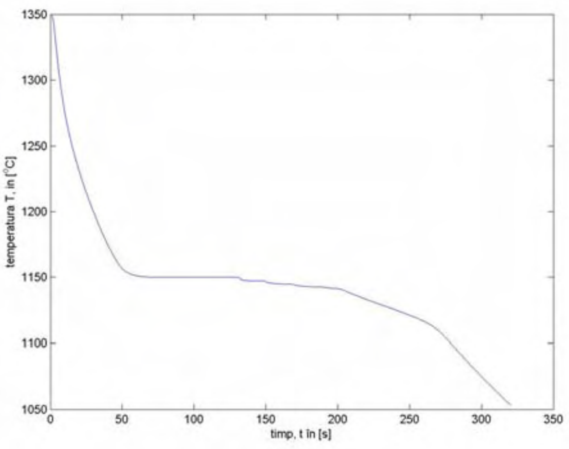

Fig. 16. *Temperature variation in the intersection of axes of symmetry of the walls part point of coordinates (x,y) = (0; 0.5), rib of thickness b_n = 3 mm and length L_n = 40 mm.*

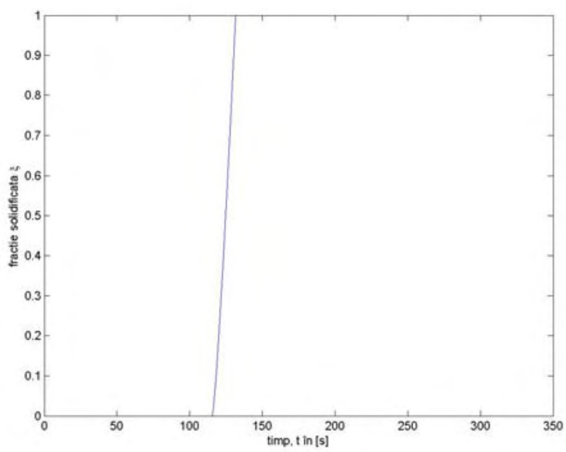

Fig. 17. *Variation of the solid fraction in the intersection of axes of symmetry of the walls part point of coordinates (x,y) = (0; 0.5), rib of thickness b_n = 3 mm and length L_n= 40 mm.*

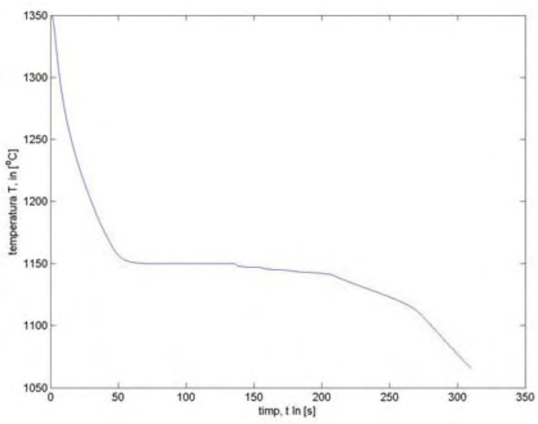

Fig. 18. *Temperature variation in the intersection of axes of symmetry of the walls part point of coordinates (x, y) = (0; 0.5), rib of thickness b_n = 3 mm and length L_n = 100 mm.*

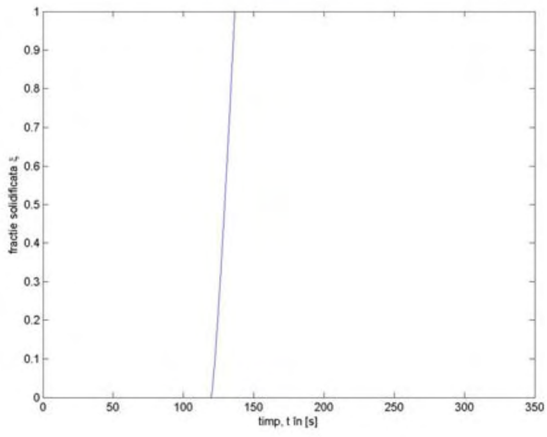

Fig. 19. *Variation of the solid fraction in the intersection of axes of symmetry of the walls part point of coordinates (x, y) = (0; 0.5), rib of thickness b_n = 3 mm and length L_n= 100 mm.*

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3. Conclusions concerning the influence of rib length 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 stronger in the case of thinner ribs;
- the maximum effect of the cooling caused by the ribs is observed (in the case of the studied parts, part of thickness a = 20 mm, rib of thickness b_n = 3mm and 5mm) for a rib length of L_n = 40 mm (L_n = 2a), that is the double of the cast part wall thickness);
- the cooling effect of the ribs intensifies significantly with the increase of their length from 0 mm to 40 mm;
- the increase of rib length over L_n = 40 mm determines a small increase of the cast part solidification time, revealing a slight damping of the cooling effect;
- in the studied cases (part of thickness a =20 mm and ribs of thickness b_n = 3 mm and 5 mm) the maximum decrease of solidification time (compared to the ribless part) is of times 1.13 - 1.15, illustrating the small influence of rib length on part solidification;
- in the case of the b_n = 3 mm rib, the solidification time of the part decreases from 302.70 s in the case of the ribless part to 262.24 s for the part with a rib of length L_n = 40 mm. In the case of a rib of thickness b_n = 5 mm the solidification time decreases from 304.12s to 269.62 s (for a rib of length L_n = 40 mm);
- figures 16 ÷ 19 show that in the case of very thin ribs, the length has no visible influence on the temperature variation curves and on solidification kinetics in the rib-wall joining area.

References

[1]. Ciobanu I., Monescu V., Munteanu S. I., Crişan A. – *Simularea 3D a solidificării pieselor turnate*, Editura Universităţii "Transilvania" din Braşov, Braşov, Ro, 2010, ISBN 978-973-598-678-0.

[2]. Ciobanu I., Ţuţuianu Diana – *Estetica, element valoric al pieselor turnate*, Metalurgia, no. 1, pag. 3-8, ISSN 0461/9579.

[3]. Ciobanu, I., Maşniţă, M., Monescu, V. *Cercetări privind solidificarea pieselor cu secţiune "T"*, Metalurgia, nr.13, 2006.

[4]. Maşniţă M. – *Cercetări privind influenţa unor factori tehnologici şi constructivi asupra solidificării pieselor turnate*, Teză de doctorat, Universitatea Transilvania din Braşov, 2007**.**

[5]. Ţuţuianu Diana, Ciobanu I. – *Consideraţii privind implicaţiile tehnologice şi estetice ale înclinaţiilor de turnare şi ale razelor de racordare în cazul pieselor turnate*, Sesiunea de comunicări stiinţifice cu participare internaţională Terra Dacică - România mileniului trei. Acad. Forţelor aeriene Henri Coandă Brasov, 5-6 mai 2006, An VII, nr.1, CD - ISSN 1453 – 0139.

[6]. Zirbo G., Ciobanu I. – *Tehnologia turnării*, vol 1 & 2, Institutul Politehnic Cluj – Napoca, 1989.