ARCHIVES OF METALLURGY AND MATERIALS
Volume 59 2014 Issue 3
DOI: 10.2478/amm-2014-0174

I. VASKOVÁ*, M. HRUBOVČÁKOVÁ*, J. MALIK*, Š. EPERJEŠI*

INFLUENCE OF TECHNOLOGICAL PARAMETERS OF FURANE MIXTURES ON SHRINKAGE CREATION IN DUCTILE CAST IRON CASTINGS

WPŁYW PARAMETRÓW TECHNOLOGICZNYCH NA TWORZENIE MIESZANEK FURANOWY SKURCZU W ŻELIWA ODLEWÓW Z ŻELIWA SZAREGO

Ductile cast iron (GS) has noticed great development in last decades and its boom has no analogue in history humankind. Ductile iron has broaden the use of castings from cast iron into areas, which where exclusively domains for steel castings. Mainly by castings, which weight is very high, is the propensity to shrinkage creation even higher. Shrinkage creation influences mainly material, construction of casting, gating system and mould. Therefore, the main realized experiment was to ascertain the influence of technological parameters of furane mixture on shrinkage creation in castings from ductile iron. Together was poured 12 testing items in 3 moulds forto determine and compare the impact of various technological parameters forms the propensity for shrinkage in the casting of LGG.

Keywords: graphitization, shrinkage, metalurgical quality, furan molding sands

W ostatnich latach obserwuje się intensywny wzrost produkcji odlewów z żeliwa sferoidalnego. Dotyczy to także zastępowania tym tworzywem odlewów staliwnych. W przypadku masywnych odlewów szczególnie duże znaczenie odgrywa przebieg skurczu tworzywa. Powstawanie skurczu wiąże się z materiałem odlewu, jego konstrukcją, układem wlewowym oraz materiałem formy. Celem badań zaprezentowanych w artykule jest ocena wpływu właściwości technologicznych formy na podstawie skurczu. Odlano 12 kształtek w 3 formach, aby ocenić wpływ jakości formy na skurcz odlewów z żeliwa sferoidalnego.

1. Introduction

During production of ductile iron castings comes to problems with usage of volume changes. Despite of technologies for economical and non-feeder pouring are known, theoretical groundings of volume changes during solidification of graphite alloys in mould cavity by defined metalurgical and technological conditions are not known [1] [2].

2. Theoretical part

As a result of shrinkage of the metal in the liquid state and the crystallization are formed in the casting shrinkage.Shrinkage and shrinkage porosity are formed during solidification, when total volume of shrinked metal in liquid state during solidification is higher than volume shrink of outer layers, which solidified in beginning stadium of crystallization process. Shrinkage is always formed in places of castings, which solidify last, where greatest amount of heat is concentrated. These are called thermic nodes. Volume decrease during solidification causes cavities creation inside of casting – shrinkage. Needed condition for creation of volume errors is decreasing of density with decreasing temperature. Total volume of shrinkage ΔV_{st} is result of three simultaneous going volume changes: Shrink of molten metal for value V_I, decrease of volume by phase change with value V_{II}, shrink of complete solidified crust with value V_{III}.

Therefore volume of shrinkage V_{st} will be given as[1] [2] [3]:

$$V_{st} = V_I + V_{II} - V_{I??I} \quad [cm^3] \qquad (1)$$

Is clear, that for mixtures with higher furane amount is the density of castings lower, which causes higher dimensional changes from original model due to burning-out of higher amount of furane binder. Total movement of the walls of the mould and casting during solidification is caused mainly by processess in mould wall, in later time depends only from own movement of molten metal caused by graphitization. Mould with increased toughness and thermal stability of volume enable to use economical feeding or non-feeding pouring and increase dimensional accuracy [4].

3. Experimental part, results, discussion

The aim of realized experiments was to find out the influence of technological parameters of furane mixture on

---

[*] DEPARTMENT OF FERROUS METALLURGY AND FOUNDRY, FACULTY OF METALLURGY, TECHNICAL UNIVERSITY IN KOŠICE, SLOVAKIA

shrinkage creation in ductile iron castings. Together 12 testing elements were poured in three moulds. In each mould were 4 elements. Two elements were without chillers and two with chillers SiC with thickness 30 mm and 40 mm. First two moulds contained 1,05% and 1,25% of furane on the weight of opening material with same ingate thickness, third mould containe 1,05% of furane on weight of opening material with lower cross-section of ingates [1] [3].

As opening material quartz sand (SiO_2) – Šajdíkove Humence – d_{50} = 0,35 mm (middle granularity) was used. As hardening element, activator 100 T3 was used which is used in summer time, in winter time activator 500 T1 should be used. Optimal ratio of hardening element to the weight of binder is 0,5% - 0,7%. Moulding mixture was prepared in mixer FAT 15 with specific output 15 t of moulding mixture in hour.

Bending strength test is provided os testing elements with square cross-section 40 mm^2 with three-point bend on the length 150 mm [1].

From Fig. 1 is clear, that in case of resin mixtures on furane basis reaches the mixture No. 1 average value of 2,8 MPa of bending strength with 1,25% of binder and 0,55% of activator 24 hours after hardening. Higher values of bending strengths are reached by mixtures with higher amount of resin. Strength of mixture increases in first hours faster, but after some time the increase of strength slows down and at the end of hardening, it reaches its maximum[4].

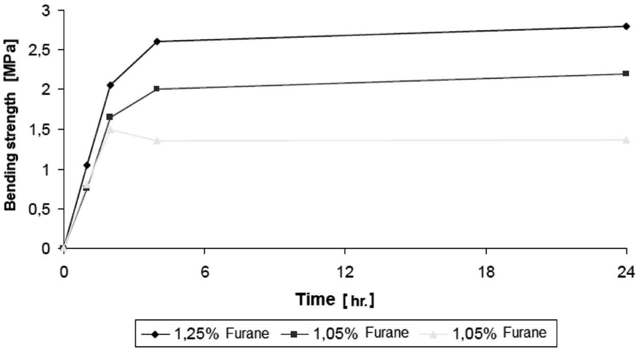

Fig. 1. Bending strength dependence on time

Elements for susceptibility to shrinkage tests were inspired with given explanation to Czikel. Test elements were moulded into metal moulds with dimensions 500×600×160/160. Dimensions of gating system were different in both melts. In first melt by pouring of the mould 1 and 2 were cut quarter ingates with dimensions cca 15×15 mm (see Fig. 2a) and in second melt, rectangle ingates with dimensions cca 17×5 mm (see Fig. 2b) were used [4].

After dissambeling of the mould, test elements were separated from ingates and gating system. They were cleared on surface from moulding mixture, so that the variances in dimensions and weight are as low as possible. Then, with direct and indirect methods were ascertained the volume of possible shrinkage. For every sample, i tis was measured cross – section, if it did not came to increase of sample due to graphitic expansion, or to decrease. Was also measured the height of the sample due to dimensional changes influenced with different strength properties of the mould, or increase in dividing plane. Next were the samples weighted and by sinking them into distilled water, volume of every sample had been measured. The density of samples was determined from measured weights and volumes. Then was compared it with table density for ductile iron, because feeding etalon had not been poured [5].

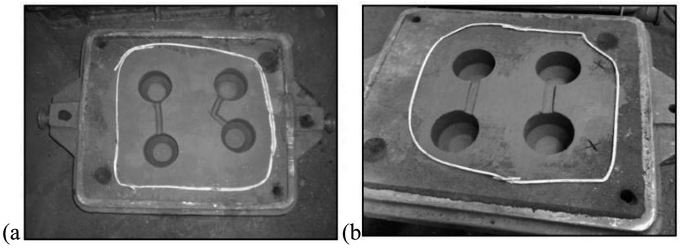

Fig. 2. Lower frame of the mould with a) triangle ingates, b) rectangle

Finally, every sample were cut in the half, so that with direct methods was set the volume of shrinkage. Not every sample had centered shrinkage. On some samples just small shrinkage occurred in thermal axis of castings, on som no shrinkage occurred. Volume of shrinkage had been measured with alcohol, when was filling the shrinkage with drops from pipete, which were blowed from other impurities. The presence of distributed shrinkage was determined with etching of cut surface with HCl.

Molding mixture No. 1[6] [7] [8] [9]

In the Tables 1, 2 are results by using runner with dimensions 10×10. There are achieved results with 1,25% weight amount of furan resin in the Table 1.

TABLE 1

Values for melt 1 and 2

1,25% resin; 0,55% hardener 10×10 runner	Type of sample	Measure of sample [mm]		Weight [kg]	Volume [m^3]	Density [kg/m^3]
		height	ø			
	Without chill	102,8	100,4	4,7	7,6.10^{-4}	6198
	Without chill	102,6	101	4,7	7,2.10^{-4}	6575
	SiC30	104,3	100,9	4,7	7,1.10^{-4}	6704
	SiC40	102,7	101,3	4.7	7,5.10^{-4}	6293

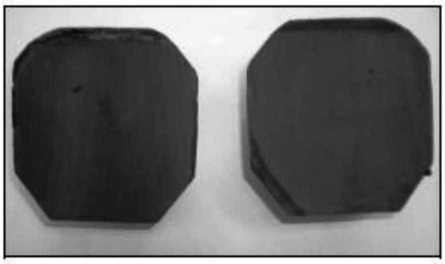

Fig. 3. Sample No. 1 (without chill)

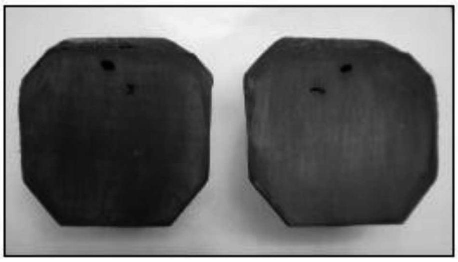

Fig. 4. Sample No. 2 (without chill)

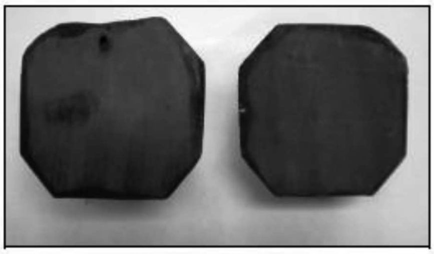

Fig. 5. Sample No. 3 (chill FeSi 30)

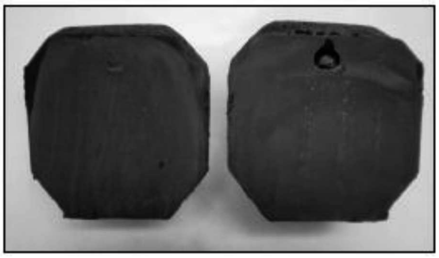

Fig. 6. Sample No. 4 (chill FeSi 30)

There are no centered shrinkage occurred on sample No. 1 (Fig. 3). On sample No. 2 came to formation of closed shrinkage, which volume after measurement with alcohol was 1,15 ml (Fig. 4). On sample No. 3 came to formation of inner shrinkage, which volume after measurement with alcohol was 0,65 ml(Fig. 5). Sample No.4 contained a pellet due to intake o fair through Williams core (Fig. 6) [4][7][10] [11].

Molding mixture No.2

There are achieved results by using of decrease weight amount of furan resin (1,05%) in the Table 2.

TABLE 2

Values for melt 1 and 2

1,05% resin; 0,55% hardener 10×10 runner	Type of sample	Measure of sample [mm]		Weight [kg]	Volume [m^3]	Density [kg/m^3]
		height	ø			
	without chill	103	101,2	4,756	$7{,}45.10^{-4}$	6383
	without chill	103,4	101,2	4,764	$6{,}7.10^{-4}$	7110
	SiC30	103,1	101,4	4,716	$7{,}1.10^{-4}$	6642
	SiC40	103,6	101,1	4.756	$7{,}3.10^{-4}$	6515

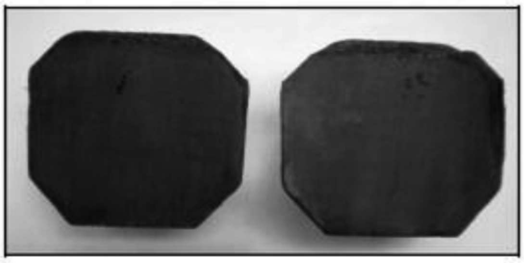

Fig. 7. Sample No.5 (without chill)

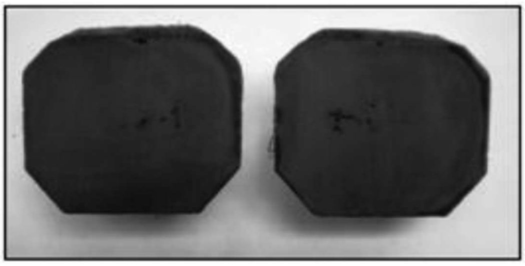

Fig. 8. Sample No. 6 (without chill)

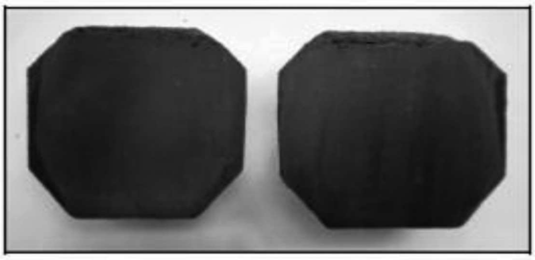

Fig. 9. Sample No.7 (chill FeSi 30)

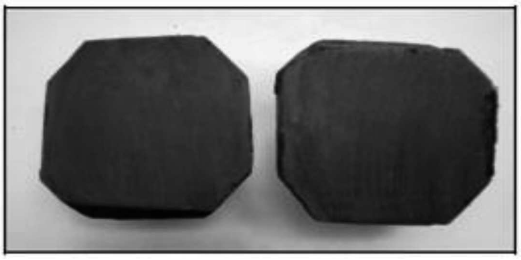

Fig. 10. Sample No.8 (chill FeSi 30)

For samples No. 5 and 6, local cumulations of small shrinkages occurred after etching with HCl, which were clearly showed as loose places in cross-section (Fig. 7, 8). For samples No. 7 and 8, no shrinkage was observed, the main reason could be used chillers(Fig. 9, 10).

Molding mixture No. 3

In the Tables 3,4 are results by using runner with dimensions 20×7 while maintaining the amount of resin 1,05%.

For samples No. 9-12, which were poured from second melt, no evidence for shrinkage or other errors could be seen after cutting. Possible reason could be pouring temperature,

TABLE 3

Values for melt 1 and 2

	Type of sample	Measure of sample [mm]		Weight [kg]	Volume [m^3]	Density [kg/m^3]
		height	ø			
1,05% resin; 0,55% hardener 20×7 runner	**without chill**	**101,3**	**100,8**	**4,625**	**6,4.10^{-4}**	**7226**
	without chill	**102**	**100,5**	**4,65**	**5,9.10^{-4}**	**7881**
	SiC30	**101,2**	**100,6**	**4,675**	**6,0.10^{-4}**	**7791**
	SiC40	**101,1**	**101,1**	**4.67**	**6,55.10^{-4}**	**7129**

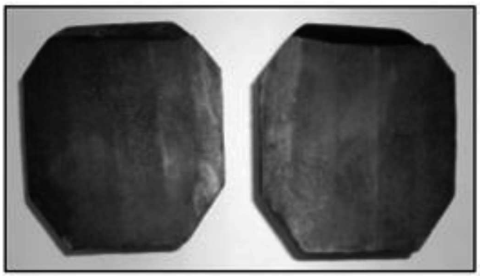

Fig. 11. Sample No.9 (without chill)

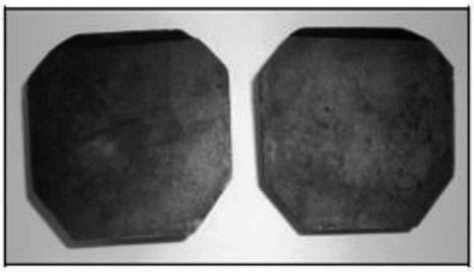

Fig. 12. Sample No.10 (without chill)

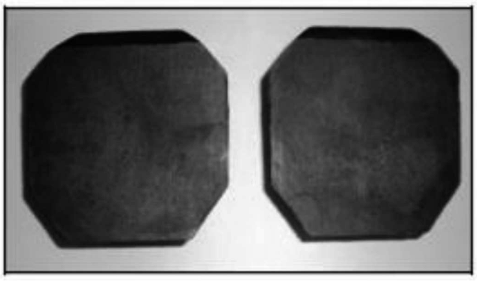

Fig. 13. Sample No.11 (chill FeSi 30)

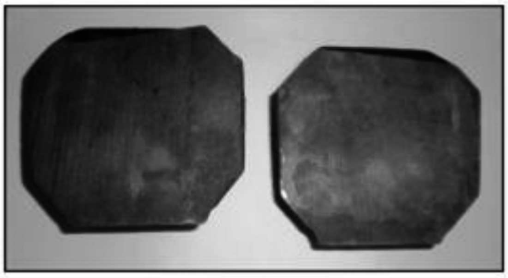

Fig. 14. Sample No.12 (chill FeSi 30)

which was lower as pouring temperature used for first moulding mixture, and so it did not came to such volume changes during solidification.

4. Conclusion

The main aim of experiments was to check and set the influence of technological parameters of furane mixture on shrinkage formation in ductile iron castings in real production conditions. From experiments and their results can be stated:

- With use of 1,25% furane, presence of shrinkage and gas defects was proved.
- Influence of pouring temperature was proved. In case of first melt was the shrinkage creation more significant as in second melt, which pouring temperature was lower.
- Eutectic degree calculated from chemical composition of first and second melt confirmed higher susceptibility to shrinkage formation in first melt.
- From production technology point of view, no significant influence of chills and different cross-sections of ingates was not confirmed.

Realized production explanation to Czikel did not show significant influence of moulding mixture quality to susceptibility of shrinkage creation. This shows in real production conditions only on heavy thick-walled castings with different thickness of casting walls, which probably corresponds with degradation of furane on mould surface during its overheat over 400°C.

Acknowledgements

This work was supported by the Slovak Research and Development agency under the contract no. VEGA 1/0498/11.

REFERENCES

[1] Z. Gedeonová, I. Jelč, Metallurgy of Cast Irons. Technical university at Košice, Faculty of Metallurgy, 2000.
[2] J. Vilčko, S. Slovák. Foundry Technologies. ALFA, Bratislava, 1987.
[3] Ductile Iron and its using, p. 2, Slévárenství, 8/199.
[4] T. Smekal, Effect of technological parameters on the formation of furan mold shrinkage in LGG casts. PhD thesis Košice, 2009.
[5] Z. Gedeonová, H. Pacyna, Metallurgical and technological influences to impacts onthe need fora poweredmetalduring solidificationof spheroidal graphitecast iron, Slévárenství, 2003.
[6] J. Rous, Shrinkage in castings. P.273 Slévárenství 7/1997.
[7] Z. Gedeonová, Theory of foundry processes. Technical university at Košice, 1990.
[8] I. Fürbacher, K. Macek, J. Steidl, Lexicon of technical materials. VerlagDashöfer.CES EduPack 2006, Granta Design Ltd., Cambridge, UK.
[9] R. Hummer, Giesserei – Praxis, Nr.17/18, 241-245 (1985).
[10] S. Karsay, QIT comp: DUCTILE IRON III.
[11] L. Bechný, P. Masarik, Cast Iron Modern .1, 49 (1989).

Received: 20 March 2014.