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Structure Distribution in Precise Cast Iron Moulded on Meltable Model

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Abstract

Topic of this work is to compare metalurgy of cast irons poured into sand moulds and into shell molds at IEG Jihlava company and from it following differencies in structures of thin- and thick-walled castings. This work is dealing with investigation and experimental measurement on surfaces and sections suitable thin- and thick-walled investment castings at IEG Jihlava. Cast irons with flake graphite (grey cast iron) and cast irons with spheroidal graphite (ductile cast iron). Both mechanical and physical properties are determined using calculations from as measured values of wall thicknesses L and Lu, Vickers hardness and remanent magnetism. Measurement results are discussed, findings are formulated and methods for castings metallurgical quality improvement are recommended finally.

Keywords: Ultrasound structuroscopy, Cast irons, Metallurgical quality, Investment casting

1. Introduction

The aim of this work is take look into relation of structure and selected physical properties to flowability and wall thickness of investment cast iron castings. The determination of these relations favourable if we want to forecast structure of products or semiproducts without their destruction.

The relation of structure to flowability and wall thickness of cast iron castings poured into sand mol dis known. It is reflected in ČSN and EN standards generally. But the investment casting technology provides quite different cooling and solidification conditions. Application of abovementioned standards for prediction of investment casting useful properties could led to non allowed errrors.

The measurement of selected casting was made at least at two sites – on the wall at gate and at thinnest wall of castings from cast irons with spheroidal and flake graphite which were poured in IEG foundry shop.

The non-destructive structuroscopy was based on measurement of Vickers hardness, actual L and ultrasound thickness L_u and remanent magnetic field H_r using DOMENA B3. The limited resources for research in the frame of bachelor work [1] allowed use of castings from common commercial production. For this reason the results for description of given problem are not exhaustive but they indicate the way to further more detailed research of prediction of precious cast iron castings properties.

2. Investment casting technology

The investment casting i.e. “LOST WAX” method takes a key-position in the field of modern techniques of pouring of metals. It can be incorporated into techniques-products near to finished artefacts. The higher requirements at manufacturing are pressed for quality, surface quality, dimension accuracy, internal cleanness, higher functional parameters at strong pressure to production cost. This method belongs among progressive ones which enable at effective application significant savings of material and reduces using finishing operations. It is used mainly where the production of part by other technology is extraordinary expensive or even impossible with regard to complicated shape and difficultly machinable material.

Production process consists of :

- Manufacturing of molds for patterns.,
- m. of wax patterns,
- setting patterns to tree,
- m. of shells, soaking of wax patterns into ceramic slurry, pouring of wax patterns by refractory material,
- melting out of wax,
- burning of shells,
- melting and pouring,
- finishing operations (removing of ceramics, separation of castings from gating system, cutting, řezání, separation of gates from castings, shot blasting, grinding, inspection)

Single stages follow consecutively in this way and they can not be skipped or replaced.

The cracks of shells can remain after melting out of wax and they can be opened and they can cause cracks of casting after casting.

The molds are burnt off at 950 ˚C mostly to reach innertness and high stability. The application of ceramics on basis of silicates is limited by temperature 1550 ˚C which is close to melting point of silicate. The annealing of shells at IEG Jihlava is made in chamber furnace. The cast iron is poured into hot shells immediately after extraction from burning (annealing) furnace. The thermal shock at pouring is reduced by it and internal stress formation in shells is limited and dangerous cracking is lowered. Induction furnaces ISTOL and tyristor sources from Indukce Co, Ltd are use at IEG Jihlava Co. The unalloyed steels and cast irons with foliated and spheroidal graphite are melted in furnace with acid lining of EKW Co. The alloyed steels are melted in furnace with neutral lining of LUSIMA-LUNGMS Co. The sample of melt is taken for chemical analysis before casting. The final analysis is made after casting. The ceramic filters preheated to shell temperature are inserted usually into hot shells before casting.

Melting and pouring of cast irons in IEG:

Basic charge for production of cast irons with foliated and spheroidal graphite at IEG Co. Is pig iron PIG NOD with typical chemical composition C 4,2-4,6%, Mn less than 0,2%, Si 0,2-0,3%. Further part of charge is circulating steel scrap and circulating material from corresponding type of cast iron. The copper is used as a pearlite-forming element for cast irons with foliated an spheroidal graphite. The cast iron with spheroidal graphite is made by FLOTRET flow method with inoculation into stream of metal.

The metallurgical quality of pouring is checker by oxygen activity measurement, thermal analysis and sound speed c_L measurement which can be applied for finished casting mainly.

Technical parameters: Mas sof castings 10-1000g, after agreement upto 3000g, wall thickness from 1mm, dimensions 10-150 mm, max. 220 mm. Permissible deviations of dimensions after ČSN 01 4470

2.1. Experimental

The subject of experiments were commercially cast castings.

Each sample is marked by serial number with name of casting and casting material. The measurement with non-destructive method was made for each sample in site A (gate of melt) and in sites B, eventually C (thin and thick wall of casting). Single pictures of samples with measurement sites (A,B,C) are incorporated in Appendix of work [1]. The speed of sound vL was measured (it characterizes the morphology of graphite, elasticity modulus, ultrasound thicknessmeter DIO 570 with probe 4MHz) [2], hardness HV (hardnessmeter Brinell-Vickers HECKER-WPM Leipzig type:HPO-250) and remanent magnetic field intenzity H_r [3]. Mean values of as-measured and calculated data are written-down for each sample and measurement sites to overview Table 3-5. The structure, ie. graphite distribution and its shape, pearlite and skin of casting were determined from sections of selected samples at laboratory of TU of Liberec.

Sound speed

$$\mathbf{v_L = v_L o \times L/L_u} \quad [m/s] \qquad (1)$$

Initial elasticity modulus

$$\mathbf{E_o = (K \,.\, L/L_u)^2} \quad [\,MPa] \qquad (2)$$

The constant K comprises density and Poisson number. It is determined by measuring of standard testing bars [2]. As-measured and calculated value of K for cast iron with flake graphite is K = 452,2, for cast iron with spheroidal graphite is K = 432,6 [5].

Different formulas created in the frame of work [4] are valid for calculation of R_m of cast irons with flake and spheroidal graphite .

The checking of graphite share was made using relation for melting test of nodularity at IEG foundry shop [6]

$$\mathbf{GVI = 3014 \,.\, L/L_u - 2783} \quad [\%] \qquad (3)$$

Table 1.
Values of E_o for quality classes cast iron with spheroidal graphite in wall L 15mm

ČSN quality	42 2410	42 2415	42 24 20	42 24 25
E_o (GPa)	85	97	110	125

Table 2.
Classification of graphite cast irons after shape of graphite and E_o

Type of cast iron	Initial eleasticity modulus E_o (GPa)	Abbreviation
with flake graphite	87-144	FGI
with vermicular(or compacted) graphite	145-160	CGI
with spheroidal graphite	165-175	SGI

2.2. Results

Due the limited extent of contribution only some results are introduced.
Typical samples – Fig. 1 and 2.

Fig. 1. Sample 1 with measurement positions


Fig. 2. Aresting member = sample 24.
Wall sites A =10mm, B = 2mm

Table 3.
Close correlation of HV hardness and remanent magnetism M of sample 24.

Sample no. 24	M [A/m]	HV
I	188	232
II	191	232
III	183	224
IV	132	209
V	233	270
diameter	185,4	233,4
standard deviation	32,12849	20,13554
correlation cofficient	0,94483969	

Table 4.
Eo values in walls of samples of cast iron with foliated graphite

sample no.	name of casting	material after ČSN	measurement site	actual thickness L /mm/	ultrasound thickness L_u /mm/	sound speed v_L (m/s)	E_o (MPa) calculated	Corresp. ČSN	dE_o
4	Fork	42 2425	A /Gate/	101,7	134,2	4484	117 435	ČSN 42 2425	
			B	4,6	5,4	5043	148 385	ČSN 42 2425	31
7	Cock	42 2420	A /Gate/	33,85	43,5	4606	123 823	ČSN 42 2420	
			B	7	8,7	4763	132 379	ČSN 42 2420	9
14	Lifter body	42 2420	A /Gate/	21,67	30	4276	106 693	ČSN 42 2415	
			B	1,6	1,9	4985	145 009	carbides	38
21	Cock	42 2420	A /Gate/	34	43,3	4648	126 079	ČSN 42 2420	
			B	1,5	5,1	5074	150 234	Carbides	24

Table 5.
Sound speed and shape of graphite of sample no. 24. arresting member

sample no.	name of casting	material after ČSN	measurement site	actual thickness L /mm/	ultrasound thickness L_u /mm/	sound speed v_L (m/s)	GVI%	dGVI thin-thick wall (gate)
24	Arresting member I	42 2305	A / Gate /	15,25	16,47	5481	7,74	
			B	3,2	3,4	5571	53,7	46
	Arresting member II	42 2305	A / Gate /	15,23	16,69	5402	GIII	
			B	3,22	3,41	5590	63,06	63
	Arresting member III	42 2305	A / Gate /	15,23	16,47	5474	4,08	
			B	3,22	3,4	5606	71,43	67
	Arresting member IV	42 2305	A / Gate /	15,27	16,29	5549	42,27	
			B	3,22	3,41	5590	63,06	20
	Arresting member V	42 2305	A / Gate /	15,27	16,29	5542	38,57	
			B	3,23	3,4	5624	80,3	41

Table 6.
Elasticity modulus E_o and strength limit R_m for castings from cast iron with spheroidal graphite

sample no.	name of casting	material after ČSN	measurement site	actual thickness L /mm/	HV hardness	E_o (MPa) calculated	R_m (MPa) calculated
1	Nipple	42 2304	A / Gate /	6,9	250 HV	169 628	761
			B	4,2	240 HV	169 706	702
			C	1,98	221 HV	166 366	651
2	Lever	42 2306	A / Gate /	18	248 HV	167 962	737
			B	10,1	309 HV	176 502	1014
3	Holder	42 2304	A / Gate /	4,38	272 HV	155 826	655
			B	13,2	193 HV	164 015	558
5	Guiding head	42 2304	A / Gate /	15	275 HV	168 671	814
			B	5	242 HV	173 024	780
6	Lever	42 2304	A / Gate /	12,1	195 HV	164 651	568
			B	7,4	201 HV	164 441	619
8	Splice plate	42 2304	A / Gate /	7,1	270 HV	172 277	847
			B	6,3	242 HV	170 516	750
9	Pin	42 2304	A / Gate /	10	348 HV	146 560	689
			B	4,6	252 HV	179 264	886
11	Inserting ring	42 2304	A / Gate /	12	252 HV	161 941	678
			B	22,2	198 HV	165 598	585
			C	12	270 HV	175 264	886
12	Pad	42 2306	A / Gate /	14,3	227 HV	167 838	681
			B	14,3	272 HV	174 712	885
13	Lever	42 2304	A / Gate /	19,8	255 HV	161 713	683
			B	15,5	234 HV	161 214	629
15	Key	42 2304	A / Gate /	5,6	165 HV	152 674	404
			B	Not measured	223 HV	Not calculated	Not calculated
16	Holder	42 2304	A / Gate /	29,4	198 HV	157 967	517
			B	8	198 HV	158 239	513
17	Needle bar holder	42 2304	A / Gate /	11,6	263 HV	169 188	790
			B	7,7	232 HV	182 375	864
18	Pestie	42 2304	A / Gate /	25,3	235 HV	169 298	1051
			B	25,3	239 HV	173 182	1116
			C	6,5	228 HV	181 515	1262
19	Plunger	42 2304	A / Gate /	23,7	252 HV	172 296	799
			B	10	252 HV	169 744	768
20	Termination	42 2304	A / Gate /	21	160 HV	164 481	478
			B	22,2	233 HV	169 890	973
22	Stand	42 2304E	A / Gate /	8,4	315 HV	178 540	1062
			B	10	315 HV	179 876	1083
23	Wing	42 2304	A / Gate /	4,8	301 HV	165 774	841
			B	26	242 HV	167 284	714

3. Conclusions

This contribution is dealing with selected knowledge from experiments on 24 castings of various types of cast iron manufactured in frames of common production of foundry shop of precission casting. FGI castings (cast iron with flake graphite) contain ledeburitic carbides in walls upto 5 mm tickness except of gate. Their presence is indicated reliably by ultrasound measurement (enhanced value of sound speed). On the contrary the dangerous carbides can not be discovered by hardness values – high hardness of carbides is eleiminated by enhanced share of ferrite in cast iron matrix of as –investigated parts of castings. Austenitic GJL (NIREZIST) solidified with carbon bound in carbides without graphite.

The upper limit of allowed hardnes is practically allways exceeded at ferritic cast iron with spheroidal graphite (200 HB for quality after ČSN 42 2304) at gate and in thick wall as well. Upper hardness value in thin wall against the gate of casting is not natural for GJS. GJS rigidity is least at gate always. Collective mathematic models for magnetic hardness measurement and ultrasound rigidity measurement of E_o (or %GVIcan not be used. It is necessary to create mathematic models for calculations of HB hardness, E_o %GVI rigidity and R_m tailored for certain types of castings.

The subjec of further research will be taking account of effect of position on pouring tree on mechanical properties.

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