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Influence of Metallurgical Treatment on Properties of Ductile Cast Iron GJS 400-18 LT

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Abstract. Cast iron with spheroidal graphite is a very good constructional material. Production of castings from standard kinds of nodular cast irons is quite good managed, but manufacturing of mark GJS 400-18 LT with excellent strength and plastic properties by minus temperatures is complicated, because it reacts very sensitively on the changing of melting conditions and metallurgical treatment. The contribution is focused on an observation of changing of structure and mechanical properties by different ways of metallurgical treatment. In operating conditions of foundry three series of melts were made. From every melt the mould with testing pieces „Y“with dimensions 25 x 40 x 140 mm was poured. Tensile test, impact test and metallographic analyse were realized on the test samples.

Introduction

Ductile cast iron GJS 400-18LT is an iron with ferritic structure. Its strength and yielding properties respond to a shape, distribution and size of graphite and on the presence of perlite in its structure. Optimal structure and with it connected final properties bear relation to melting flow, ladle metallurgy and heat treatment [1, 2].

This contribution deals with influence of melting flow conditions and ladle metallurgy on final properties of ductile cast iron. Melt control is very important not only from the view of setting of optimal chemical composition, temperature but a timing course of melt is very important too. Ladle metallurgy by nodular cast iron production consist of modification and inoculation of initial melt. There are a lot of factors which influencing final properties by modification and inoculation as temperature of treated metal, kind and quantity of modifier and inoculant, way of addition of modifier and inoculant, subsiding effect of treatment etc.

Materials and experiments

Experiment consisted of 3 series of melts. It was realized in operating conditions of foundry. An initial molten metal was prepared in 2 tons middle frequency induction furnace with an acid lining. A charge consists of pig iron “Sorel” or “Kasagora” (30 %), steel scrap (50 %) and return cast iron (20 %), FeSi65 and carburizing agent Desulco were used for correction of chemical composition. The same kinds of modifier and inoculants were use for all series of melts. As the modifier “Elmag” 6039 (~ 1.35 % of weight of treated molten metal) and inoculant “VP 116” (~ 0.5 % of weight of treated molten metal) were used.

Particular series differed from each other by used kind of pig iron and by method of initial molten metal treatment. The first set contented of 3 melts (401, 402, 403), in that the pig iron Sorel was used in to the charge. A tapping of liquid metal was made in to the treatment ladle Tundisch cover. The modifier and 1/3 of inoculant were put on the bottom of reactive chamber. It was covered with small scrap with amount of 30 kg/1000 kg and then the metal was run through into a pouring ladle. By pouring the rest portion of graphitization inoculant was put into the stream of molten metal. In the second set of the melt the pig iron Sorelmetal was used again and 3 melts were realized (404, 405, 406). In contradistinction to the first set the initial molten metal was modified and inoculated in one step in the treatment ladle Tundisch cover. The third set of melts (407, 408, 409) has had the same method of treatment like the second melt, the different was only in the kind of used pig iron, instead of Sorel the Kasagora was used. Chemical composition of tested cast irons was in the range showed in Table 1.

Table 1 Chemical composition range of tested cast irons

C [wt. %]	Mn [wt. %]	Si [wt. %]	Cu [wt. %]	Cr [wt. %]	P [wt. %]	S [wt. %]	Mg [wt. %]
3.40-3.71	max. 0.21	1.89-2.10	max. 0.05	max. 0.03	max. 0.03	max. 0.01	0.028-0.065

There were poured 9 tested castings into moulds from furan sand mixture in 3 series of melts. At all evens the metal was inoculated in the mould secondary. Tested experimental castings contained two parts with Y – blocks, which were marked as part”0” and part “1”. The treated metal was poured via one gate and it passes into diverging gating system in which the inoculator “Germaloy P300” was placed in part ”0” and 3 inoculators “Germaloy P60” with weight 60 g were placed in part ”1”.
Table 2 shows the metallurgical treatment of particulate melts. From every tested pieces the samples for measurement of mechanical properties (tension test and impact test) and for metallographic analyse were taken. A shape of graphite, size and an amount of single structures (pearlite, ferrite or cementite) were evaluated.

Table 2 Description of melts treatment

Name of treatment	Melt-number	Kind of pig iron	Treatment in modification ladle	Inoculation in pouring ladle	Secondary inoculation (in mold)
1.	401 402 403	Sorel	Elmag + 1/3 VP 116	2/3 VP 116	Germaloy P300 - 0 Germaloy 3 x P60 - 1
2.	404 405 406	Sorel	Elmag + VP 116	-	Germaloy P300 - 0 Germaloy 3 x P60 - 1
3.	407 408 409	Kasagora	Elmag + VP 116	-	Germaloy P300 - 0 Germaloy 3 x P60 - 1

Achieved results and their analysis

By standard EN1563 the next values of mechanical properties are given for quality EN-GJS-400-18LT [3]:

- tensile strength $R_m = 400$ MPa,
- yield strength $R_e = 240$ MPa,
- elongation $A = 18$ %,
- impact strength $KV = 9$ J.

Measured results of mechanical properties are visible on Fig. 1 – 4. The values marked “0” were measured on samples that were inoculated secondary in the mould only with using of one piece of inoculator “Germaloy P300” (weight 300 g) and values marked “1” are from samples with smaller amount of inoculator (3 pieces “Germaloy P60” with weight 60 g).

By inoculation with higher amount of inoculator the values for minimal tensile strength by standard were not reached for half of all suspense melts.

Other suspense properties yield strength, Fig. 2, elongation, Fig. 3 and impact strength, Fig. 4 corresponded with the standard and only for melt 405 the lower elongation was measured. By using 3 smaller inoculative corpuscles with weight 60 g the values of mechanical properties given by standard were not achieved not only for one melt (Fig. 1 – 4). Elongation and impact strength did not achieve the values given by standard, inside out the values of tensile strength and yield strength achieved the values given by standard.

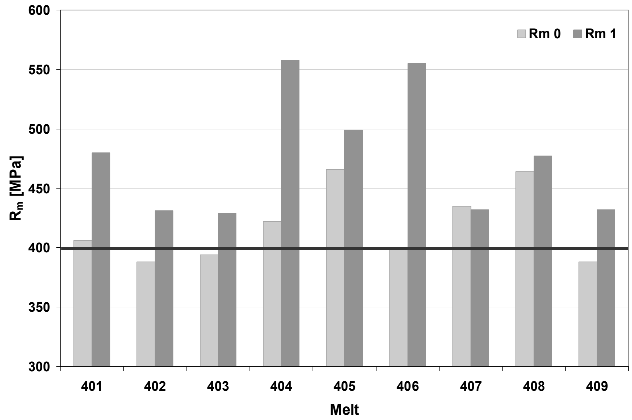


Fig. 1 Values of tensile strength R_m measured on the test bars from observed melts

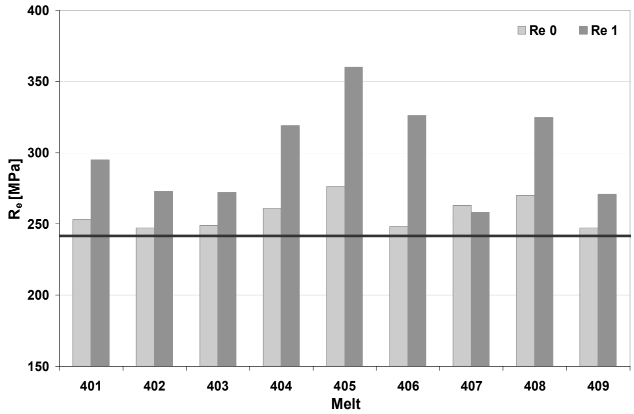


Fig. 2 Values of yield strength R_e measured on the test bars from observed melts

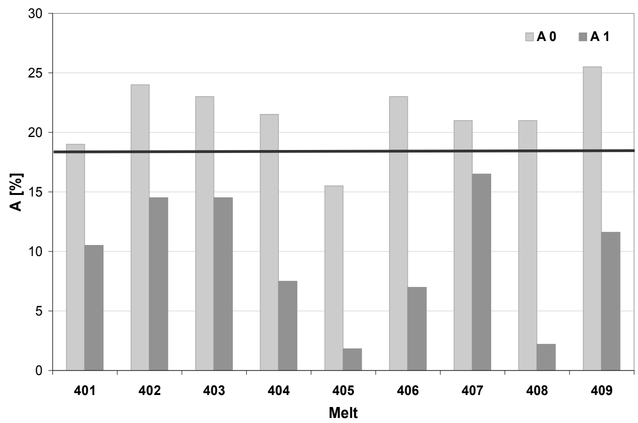


Fig. 3 Values of elongation A measured on the test bars from observed melts

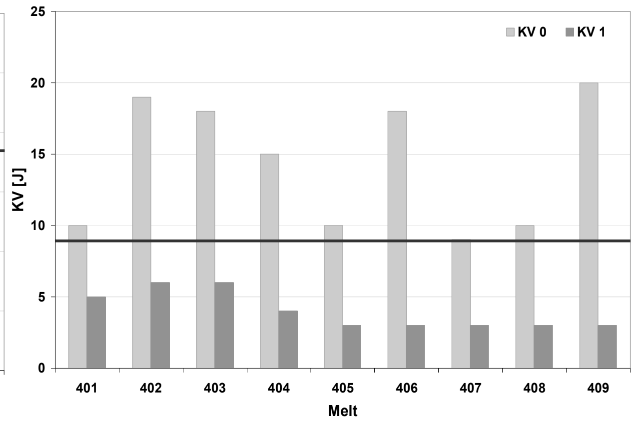
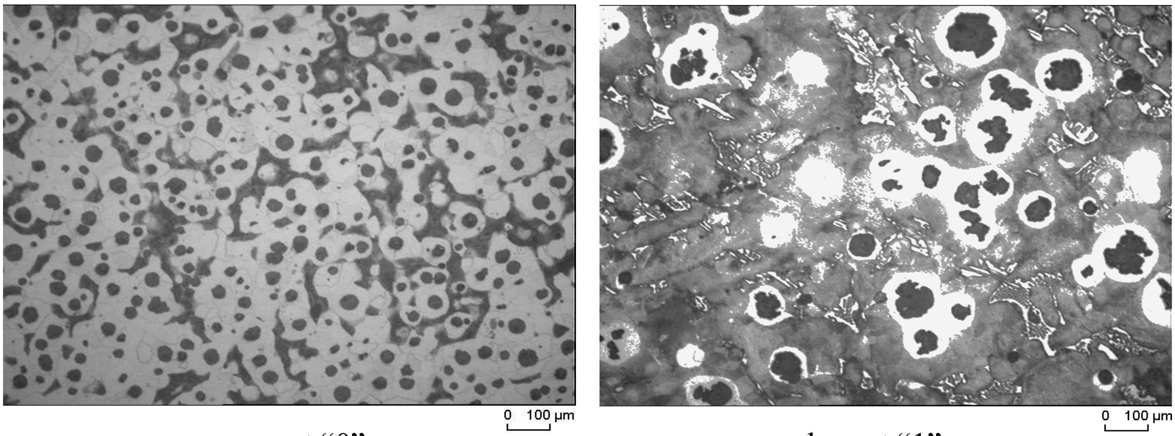


Fig. 4 Values of impact strength KV measured on the test bars from observed melts

Different quantity of inoculator had the most marked influence on the values of measured elongation and impact strength. The lowest values were measured by melt 405 which metallographic analyze is given on Fig. 5.

It is possible to see a big defference between size of graphite, shape of graphite, amount pearlite/ferrite, and presence of cementite on the displayed samples. Results of metallographic analysis (softwar CastIron G, EN ISO 945) of samples from individual melts are given in Table 3.



a. part “0” b. part “1”

Fig. 5 Metallographic analysis of melt 405, etched specimen

a. part 0 – secondary inoculation with higher amount of inoculant P300

b. part 1 – secondary inoculation with lower amount of inoculant 3 x P60

Table 3 Results of metallographic analysis of observed samples

Melt-number	Ferrite [wt. %]		Size of graphite* [µm]		Nodularity** [wt. %]		Cementite [wt. %]	
	0	1	0	1	0	1	0	1
401	94.05	69.41	60-120	60-120	54.74	56.12	0	8.13
402	97.77	87.98	30-60	60-120	78.48	59.17	0	0
404	88.58	-	30-60	-	64.47	-	0	-
405	81.31	24.55	30-60	60-120	80.46	14.69	0	11.25
406	91.86	37.80	30-60	60-120	74.23	49.17	0	7.90
407	85.71	-	30-60	-	73.89	-	0	-
408	74.45	28.00	30-60	60-120	65.30	25.46	0	8.00

*predominant size of graphite

** nodularity – percentage of fully spheroidal graphite

Comparing the different methods of treatments it is possible to say that resuls from the second method of treatment are slightly different from the results of first and third method. From the view of standard the best results were achieved in the second method of melt treatment, but only in the case of using bigger amount of inoculator in the mould. Bigger quantity of inoculator didn´t provides the necessary elongation for melt 405. The results of metallographic analyse show the highest nodularity and lower content of ferrite (melt 405) in comparison with other samples, Table 3. As a contrast is result of the lowest nodularity and the highest amount of cementite and lowest amount of ferrite in samples with lower quantity of inoculator in the same melt.

From the several references [4-7] is known that final mechanical properties are influenced by microstructure which is dependent on chemical composition, rate of cooling and melt treatment. Fig. 6 shows the dependence of elongation and impact strength on the ratio of ferrite in the structure.

Summary

There are three methods of metallurgical treatment of nodular cast iron evaluated in the contribution. The testing piece consisted of two parts which were inoculated in the mould with different amount of inoculator. It follows from the achieved results:

1. Nodular cast iron GJS-400-18LT is material with required values of R_m, R_e together with A and KV. It is very difficult to achieved the values of these properties in different wall thickness of casting where except a lot of parameters a very important role plays the cooling rate.
2. By evaluation of mentioned three ways of metal treatment it was observed that the best results from the view of standard were achieved for the second way of treatment – modificator and inoculator were added together in to tundisch ladle and pig iron Sorel was used in the charge. The standard was hold only in case of higher amount of inoculator.

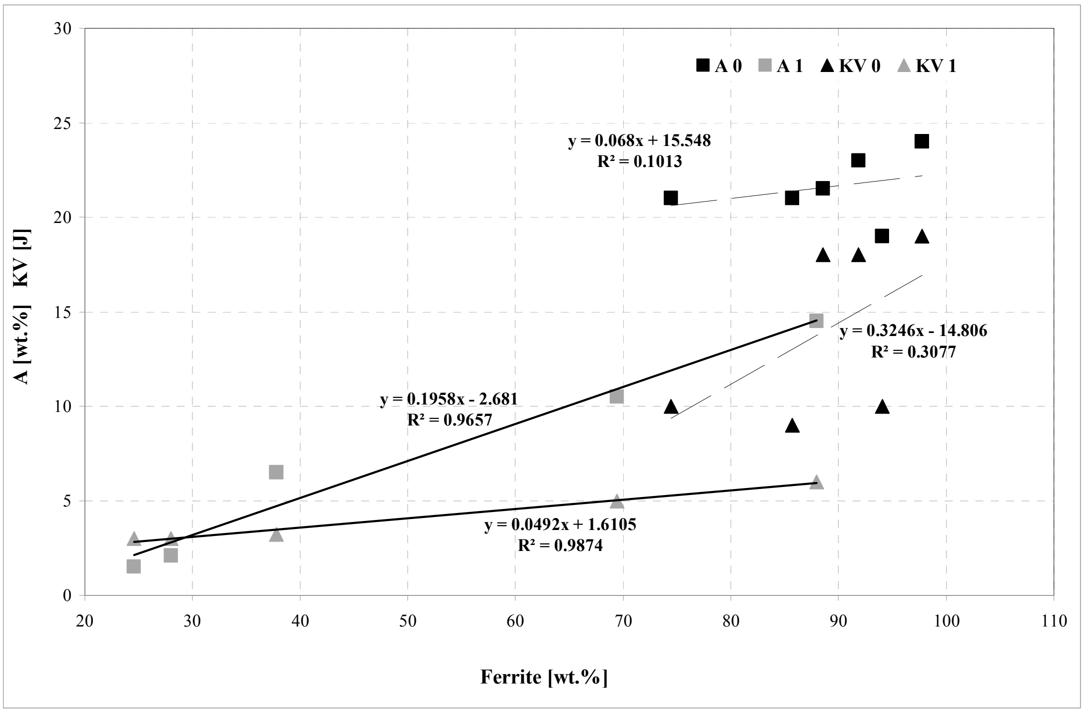


Fig. 6 Dependence of elongation and impact strength on ration of ferrite in the structure

3. Different amount of inoculant in mould had the highest impact on elongation and impact strength. On the other side the yield strength responds on the different quantity of inoculant and metal treatment least of all.
4. In order to ensure the stability of the production of nodular cast iron GJS 400-18LT it is very important to evaluate the full production process complex. It is suitable to choose the bigger amount of inoculant, of course with regard to the casting construction.

Acknowledgments

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References

[1] Qit-Fer et Titane Inc., Ductile iron, Rio Tinto Iron & Titanium, Montréal, (2000).

[2] Z. Gedeonová, I. Jelč, Metalurgia liatin, Hutnícka fakulta TU v Košiciach, Košice, (2000).

[3] DIN EN 1563:2005, Gieβereiwesen-Gusseisen mit Kugelgraphit

[4] A. Alhussein, M. Risbet, A. Bastien, J. P. Chobaut, D. Balloy, J. Favergeon, Influence of silicon and addition elements on the mechanical behavior of ferritic ductile cast iron, Materials Science and Engineering A. 605 (2014) 222-228.

[5] S. Hasse, Duktiles Gusseisen, Handbuch für Gusserzeuger und Gussverwender, Schiele & Schön, Berlin, (1996).

[6] P. Skočovský, I. Šiman, Štruktúrna analýza liatin, ALFA, Bratislava, (1989).

[7] Information on http://www.sorelmetal.com/de/publi/PDF/087_DE.pdf