



ARCHIVES
of
FOUNDRY ENGINEERING

DOI: 10.1515/afe-2017-0056

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (2299-2944)
Volume 17
Issue 1/2017

85 – 88

Effect of Different Inoculants on Impact Toughness in High Chromium Cast Iron

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Received 06.03.2017; accepted in revised form 07.05.2017

Abstract

The present work, presented the study of effect of different inoculants on impact toughness in High Chromium Cast Iron. The molds were pouring in industrial conditions and samples were tested in laboratory in Faculty of Foundry Engineering at AGH. Seven samples were tested - one reference sample, three with different addition of Fe-Ti, and three with different addition of Al. The samples were subjected to impact toughness on Charpy hammer and the hardness test. The presented investigations indicate that for the each inoculant there is an optimal addition at which the sample obtained the highest value of impact toughness. For the Fe-Ti it is 0.66% and for Al is 0.17%. Of all the examined inoculants best results were obtained at a dose of 0.66% Fe-Ti. Titanium is a well-known as a good modifier but very interesting results gives the aluminum. Comparing the results obtained for the Fe-Ti and Al can be seen that in the case of aluminum hardness is more stable. The hardness of all samples is around 40-45 HRC, which is not high for this type of cast iron. Therefore, in future studies it is planned to carry out the heat treatment procedure that may improves hardness.

Keywords: Mechanical properties, High chromium cast iron, Inoculation, Impact toughness, Hardness

1. Introduction

The High Chromium Cast Iron (HCCI) is an effective material with a wide range of applications in aggressive environments, where resistances to abrasion, erosion and erosion-corrosion are required. The applications of that material include slurry pumps, brick dies, several pieces of mine drilling equipment, rock machining equipment, and similar ones. In the wet wear applications, such as the desulfurization slurry pump, the HCCI must have a stable austenite. For this purpose elements such as nickel, molybdenum, copper and so on, are added [1-10]. Nevertheless, there are some limitations and problems to be resolved in order to HCCI had more applications. One of the biggest issues is the low impact toughness of HCCI; an average value is 4 – 7 J/cm². One of the reasons is the carbon content. The relationship

between the impact strength and the content of carbon in the HCCI content of 15% Cr, present Zhou in work [3]. With increasing carbon content, the hardness and wear resistance of a white cast iron are increased. The same impact carbon has on the brittleness. However, it has an opposite effect on impact toughness - the higher the carbon content, the lower the impact toughness, as present Fig. 1.

In order to increase impact toughness of HCCI while maintain the abrasive and erosive properties a lot of researchers have conducted an improvement of HCCI properties by alloying methods. Yezhe Lv et al. in [4] tested the influence of tungsten addition to impact toughness of HCCI (3% C, 24% Cr). The results are shown in Fig. 2.

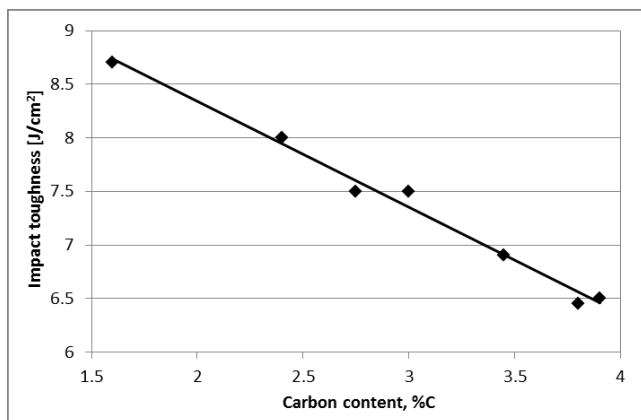


Fig. 1. Relationship between the impact toughness and the content of carbon in the HCCI content of 15% Cr [3]

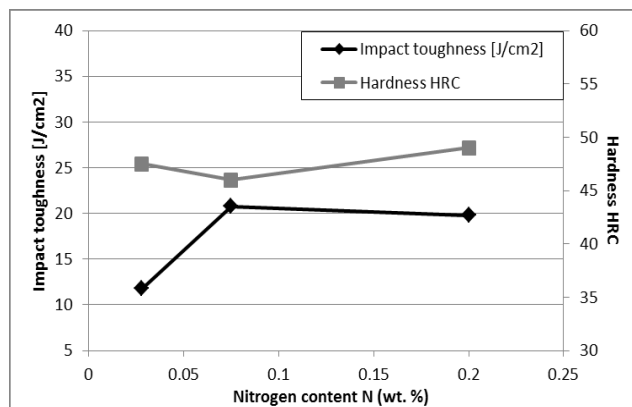


Fig. 3. Impact toughness and hardness as a function of the nitrogen content in HCCI [5]

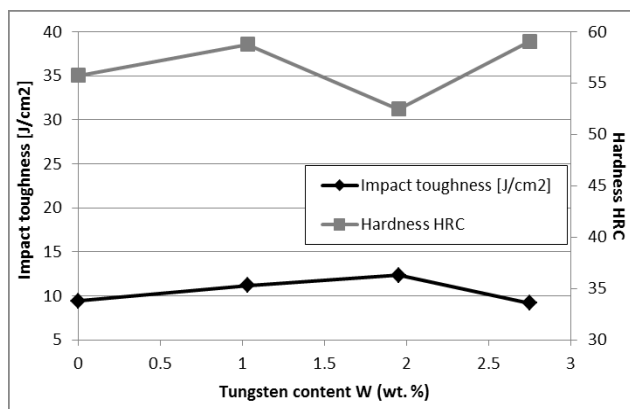


Fig. 2. Impact toughness and hardness as a function of the tungsten content in HCCI [4]

Excellent results achieved Hongsheng Ding et al. [5] adding nitrogen to HCCI (2.3% C, 24.5% Cr, 0.45-0.5% Ti). Fig. 3 presents results.

According to Hongsheng Ding et al. the main reason why nitrogen can improve the impact toughness of HCCIs is that it can refine M_7C_3 carbides, and make them distributing more structured and homogeneously. Nevertheless nitrogen is known as a questionable alloying element. It is generally considered to be a disadvantageous element, due to it reduces the ductility and toughness of certain steels. Although, nitrogen is a strong austenite stabilizing alloying element, and is usually added in the austenitic stainless steel instead of nickel due to the reduction of production costs.

As can be noticed an increase of impact toughness is an important topic on improving the properties of HCCI.

2. Methodology

The aim of this work was to examine the effect of different modifiers on impact toughness of High Chromium Cast Iron. Experiments were carried out on Charpy hammer.

The melts were carried out in industrial conditions. Liquid metal overheated to 1600°C in induction furnace. The liquid metal poured from furnace to ladle. The inoculation was carried out on the stream of liquid metal.

The following inoculants have been used:

- 0.25% Fe-Ti;
- 0.66% Fe-Ti;
- 1.0% Fe-Ti;
- 0.17% Al;
- 0.33% Al;
- 0.5% Al.

The standard impact toughness samples were cut from the cast as shown at the Fig. 4.

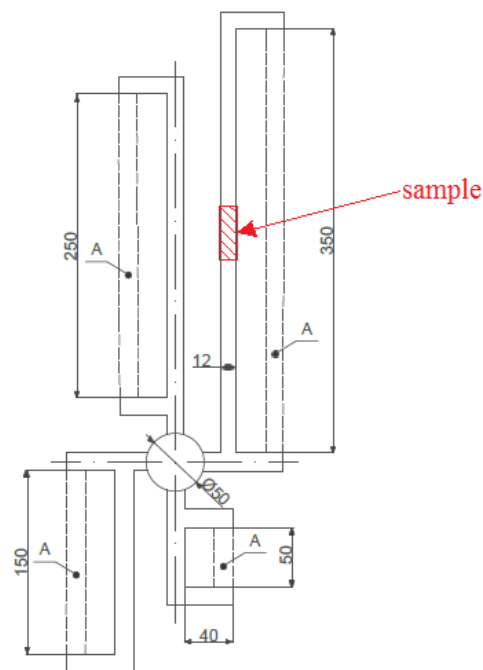


Fig. 4. Scheme of the cast with marked place of sample cut-out

The chemical analysis was performed on a spectrometer and the

results are shown in Table 1.

Table 1.
Chemical composition

	Chemical composition, % mass								
	C	Si	Mn	P	S	Cr	Ni	Ti	Al
reference sample	1.842	0.656	0.527	0.022	0.014	22.516	0.188	0.016	0.003
0.25% Fe-Ti	1.962	0.535	0.362	0.019	0.012	21.632	0.161	0.129	0.010
0.66% Fe-Ti	1.672	0.770	0.427	0.017	0.010	21.058	0.183	0.204	0.016
1.0% Fe-Ti	1.878	0.596	0.429	0.015	0.020	22.707	0.187	0.600	0.042
0.17% Al	1.865	0.604	0.364	0.019	0.012	22.864	0.191	0.007	0.079
0.33% Al	1.864	0.590	0.405	0.018	0.010	22.656	0.192	0.009	0.192
0.5% Al	1.768	0.593	0.416	0.018	0.011	22.833	0.194	0.010	0.239

3. Results and discussion

The samples were tested in laboratory in Faculty of Foundry Engineering at AGH. Seven samples were tested - one reference sample, three with different addition of Fe-Ti, and three with different addition of Al. The results of impact toughness test and hardness of samples modify by Fe-Ti are shown in the Fig. 6, and the results for samples modify by Al are presented on Fig. 7. Fig. 8 shown photos of samples after impact toughness test.

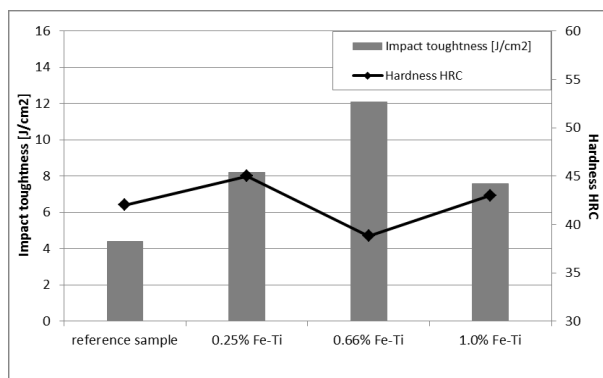


Fig. 6. Impact toughness and hardness the modified samples of Fe-Ti

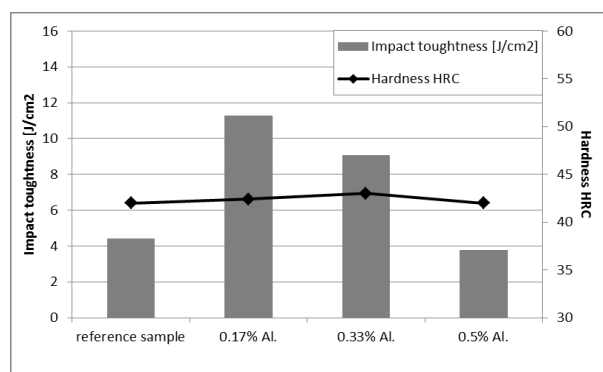


Fig. 7. Impact toughness and hardness the modified samples of Al

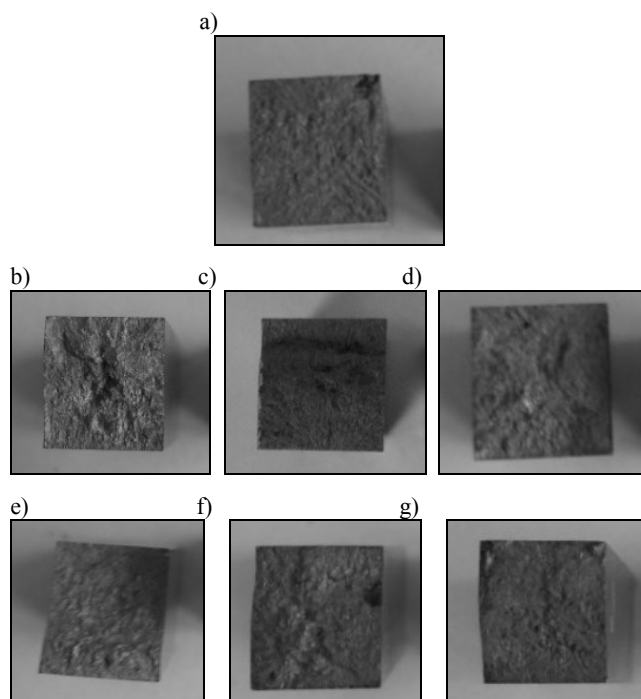


Fig. 8. Pictures of the samples after impact toughness test:
a) references sample; b) 0.25% Fe-Ti; c) 0.66% Fe-Ti;
d) 1.0% Fe-Ti; e) 0.17% Al; f) 0.33% Al; g) 0.5% Al

The experimental results indicate that for the each inoculant there is an optimal addition at which the sample obtained the highest value of impact toughness. For the Fe-Ti it is 0.66% and for Al it is 0.17%. Of all the examined inoculants best results were obtained at a dose of 0.66% Fe-Ti. From the literature [4, 5] and the research can be seen that the impact toughness is closely related to hardness - with increasing impact toughness, hardness decreases. Titanium is a well-known as a good modifier [1, 2] but very interesting results gives the aluminum. Comparing the results obtained for the Fe-Ti and Al can be seen that in the case of aluminum hardness is more stable.

Samples with low impact toughness have brittle fracture. With the increasing the impact toughness the fracture is more plastic. Observed in Fig. 8 photos show that for the samples with the

highest impact toughness - thus the samples c) and e) - the fracture is plastic. For the samples with low impact toughness - a) and d) - the fracture is brittle. The interesting result shows the sample modified by 0.5% Al which has the plastic fracture (Fig. 8g), but the impact toughness is low - 3.75 J/cm². This could be due to the aluminum is an element that increases the ductility, so that the breakthrough of the sample may be a plastic, however the large amount of aluminum added to alloy (0.5%) may reduce the impact toughness.

4. Conclusions

The present work, aimed at studying the effect of different inoculants on impact toughness in High Chromium Cast Iron led to the following conclusions.

The greatest value of the impact obtained for a sample of the modified 0.66% Fe-Ti, it reached 12 J/cm².

Aluminium is an element that is rarely used as an inoculants chromium cast iron, but thanks to his property improves the plasticity of castings. The best additive amount of aluminium was 0.17%, which was reached at 11 J/cm² of impact toughness.

Interesting result gives with addition of 0.5% Al which has the plastic fracture, but the impact toughness is low - 3.75 J/cm². This could be due to the aluminum is an element that increases the ductility, so that the breakthrough of the sample may be a plastic, however the large amount of aluminum added to alloy (0.5%) may reduce the impact toughness.

The hardness of samples is around 40-45 HRC, which is not high for this type of cast iron. Therefore, in future studies it is planned to carry out the heat treatment procedure that may improves hardness.

Acknowledgements

The study was co-financed by NCBiR as a targeted project No. PBS/B5/44/2015 and as a part of the PhD thesis MSc. Doroty Siekaniec.

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