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Cast Iron Reinforced with Foaming Ceramic Insert

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Abstract

This paper presents matters related to production of ceramic and cast iron composite. The composite was made with the use of a foam structured ceramic insert. The tests included measuring of hardness, impact strength and resistance to abrasive wear of the composite produced. On the basis of obtaining results was stated that the use of foamed ceramic filters provides good conditions of filling a ceramic framework with molten grey or chromium cast iron. The growth of hardness of the ceramic- grey cast iron composite is ca. 60% as compared to the grey cast iron hardness. The growth of hardness of the ceramic- chromium cast iron composite is slight and does not exceed 5 % in comparison to the chromium cast iron. Introduction of the ceramic inserts deteriorates the cast iron impact strength by ca. 20 - 30 %. The use of ceramic inserts increases the resistance to abrasive wear in case of grey cast iron by ca. 13% and in case of the chromium cast iron by ca. 10 %.

Keywords: Ceramics, Composite, Cast iron

1. Introduction

Abrasive wear of materials is a common phenomenon in the world surrounding us and it is immensely significant in terms of technology and economy. It causes huge material losses. On the global scale the friction resistance consumes up to 10% of annual power production [1-4]. Therefore, various solutions of the said issues have been sought for. One of them is the use of materials with better anti-abrasive properties [5]. However, the use of such materials brings about high expenses and therefore, it is not always feasible. Accordingly, an attempt to improve the performance of those materials through thermal processing, application of protective coatings or hardfacing of the elements forms another solution. Such methods are good, but not always effective enough. Integration of materials with different properties has become very popular throughout the recent years. Thus, a very good material of diverse properties and low production costs can be obtained. The combination can be made using the mold method [5-7]. The use of such molds for machinery parts enables their operation under the conditions of e.g. high abrasive wear. In molding sector such molds are called layer molds or in case of two different materials - bimetallic layer molds [8-10]. The composites are more and more diverse, the tests and experiments show that not only various metals, but also metals and ceramics can be combined [11]. This paper includes description and presentation of an attempt to produce a beneficial composite by filling a foam-structured ceramic insert with molten metal.

2. The authors' own tests

The purpose of the tests was to produce a cast-iron mold reinforced with a foam-structured ceramic insert and to test the selected mechanical properties and abrasive wear.

In search for metal materials with high resistance to abrasive wear, more and more attention is paid to such ceramic particles as: SiC, Al_2O_3 [11], diamond powder submerged in metal plating to create a composite structure of high abrasion resistance. Out of the particles mentioned above silicon carbide, SiC is the most cost effective and simultaneously very hard one (70%Si, 30%C, 9,5 hardness in Mohs scale), confirming its high abrasion resistance in pressed products. Unfortunately, SiC is dissolved in cast irons of very high temperature, decomposing into carbon and silicon, therefore it has been applied as the carrier of carbon and silicon and, in the form of electrocubes – as a modifier. Upon such SiC products as ceramic metal filters [12], foam structured and insoluble in molten metal, appeared, the idea occurred to use them as elements reinforcing cast iron mold surface. Therefore, an attempt was made to implement SiC as a finished porous insert and pour it over with cast iron. The foam-structured filters known for a long time and easily available, of dimensions 75x75x20 mm and 10ppi and 30ppi (pores per linear inch) porosity were selected as the insert to be tested.
The view of the mold and its cross-section was presented in figures 1 and 2.

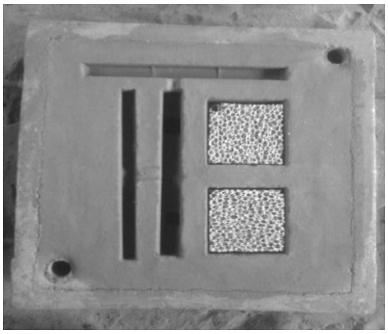

Fig. 1. Mold with ceramic inserts

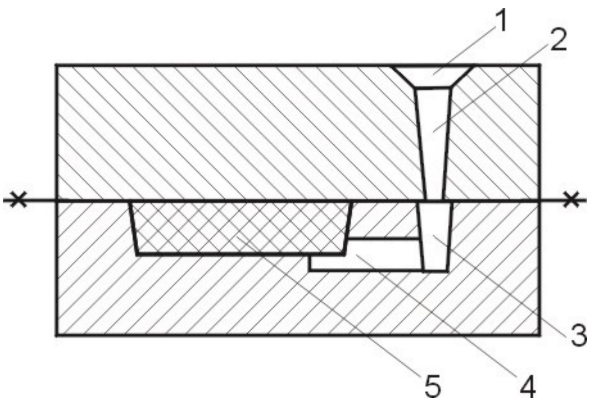

Fig. 2. Cross-section of mold of cast reinforced with ceramic insert: 1 – tank filler, 2 – main filler, 3 – cross-gate, 4 – feed intake, 5 – ceramic insert

Grey cast iron and medium chromium cast iron were used for production of the reinforced molds. The chemical compositions of the types of cast iron used have been presented in table 1.
The pouring temperatures were 1550 °C and 1600 °C, respectively. After the mold had been produced samples were taken for tests and measuring of hardness, impact strength and resistance to abrasive wear.

Table 1.
The chemical composition of the cast produced

	Chemical constitution %			
	C	Si	Mn	Cr
Grey cast iron	3,8	2,1	0,55	0,12
Chromium cast iron	2,8	1,0	0,8	7,2

Figure 3 presents average values obtained on Brinell hardness test. The method also enabled measuring including the reinforcement.

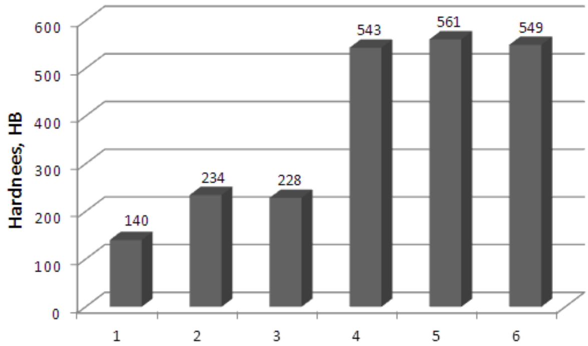

Fig. 3. Brinell hardness test results: 1 – grey cast iron without insert, 2 – grey cast iron, insert (30ppi insert), 3 - grey cast iron, (10ppi insert), 4 – chromium cast iron without insert, 5 – chromium cast iron, (30ppi insert), 6 – chromium cast iron, (10ppi insert)

The impact strength tests were carried out using Charpy's hammer of maximum energy of 50 J. Reinforced and unreinforced samples with dimensions 15x15x55 [mm] were tested.

The average of three measurements was assumed as the final value and the results were presented in figure 4.

The tests on the machine type Skoda – Savine [13] were carried out to determine the abrasive wear value of the reinforced molds.
Abrasion process parameters:

- circle (counter sample) of sintered carbide 30mm,
- relative motion velocity v=1,5m/s,
- sample load - 100 N,
- test duration 5 min,
- cooling liquid: 0,05% K_2CrO_4 solution (potassium chromate) in distilled water.

The volumetric wear of samples was read in virtue of the wear length [13]. The measuring results were presented in table 2 and figure 5.

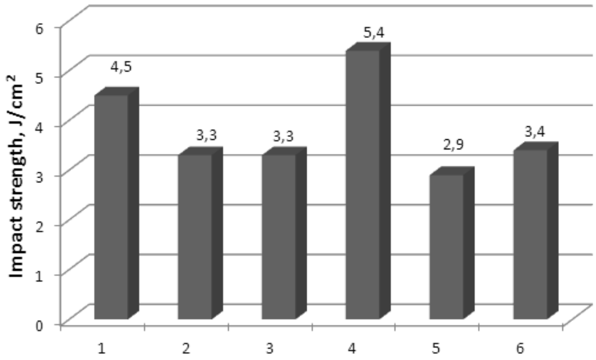

Fig. 4. Impact strength measuring results: 1 – grey cast iron without insert, 2 – grey cast iron, insert (30ppi insert), 3 – grey cast iron, (10ppi insert), 4 – chromium cast iron without insert, 5 – chromium cast iron, (30ppi insert), 6 – chromium cast iron, (10ppi insert)

Table 2.
Abrasive wear results on the Skoda – Savine machine

Sample	Length of worn dent L [µm]			$L_{Śr}$	$V_{Śr}$ [1/1000mm^3]
1 – grey cast iron without insert	500	550	466	505	387,5
2 – grey cast iron, insert (30ppi insert)	500	466	483	483	339,0
3 - grey cast iron, (10ppi insert),	479	470	488	479	330,6
4 – chromium cast iron without insert	432	434	428	432	242,4
5 – chromium cast iron, (30ppi insert),	416	400	433	416	216,4
6 - chromium cast iron, (10ppi insert)	466	416	400	427	234,1

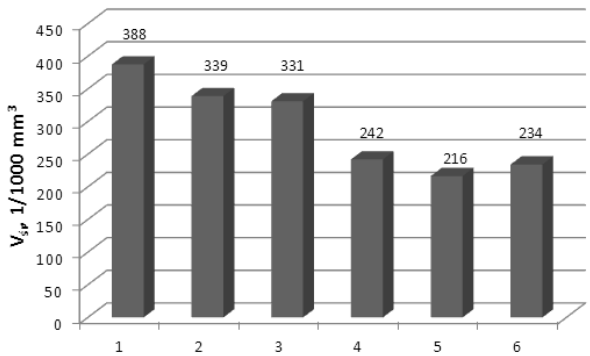

Fig. 5. Abrasive wear resistance measuring results ($V_{Śr}$): 1 – grey cast iron without insert, 2 – grey cast iron, insert (30ppi insert), 3 – grey cast iron, (10ppi insert), 4 – chromium cast iron without insert, 5 – chromium cast iron, (30ppi insert), 6 – chromium cast iron, (10ppi insert)

The macrostructure was observed on optical microscope with 50x magnification value of the eyepiece and presented in fig. 6.

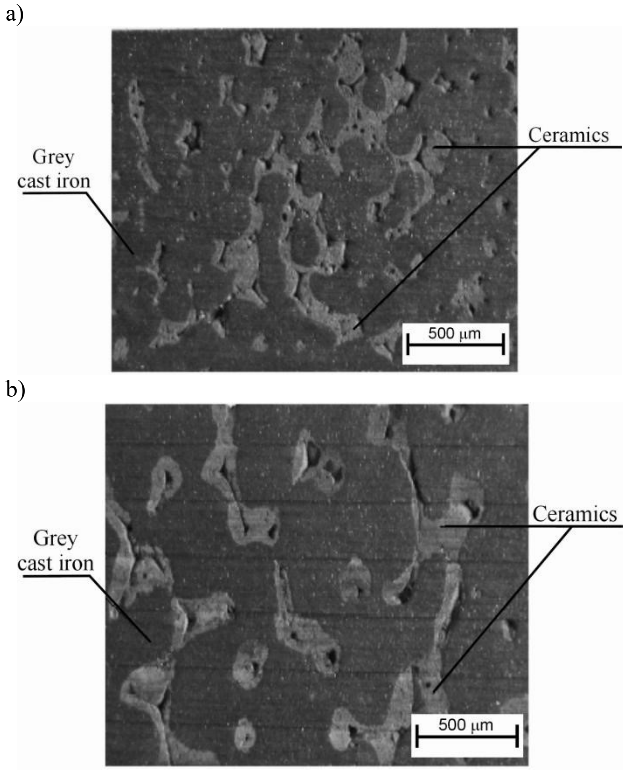

Fig. 6. Macrostructure on cross-section of cast iron mold reinforced with ceramic insert: a) 30 ppi, b) 10 ppi; 50x magnification value

Based on the observation of obtained composite, it has been noticed that the molten metal poured into the mould well penetrated between the insert free spaces (Fig. 7). A sharply boundary can be observed between the ceramic insert (reinforcement) and gray cast iron (matrix).

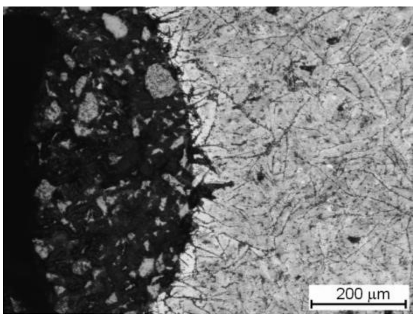

Fig. 7. Microstructure of a cast iron reinforced with ceramic insert. magnification 100x

3. Summary and conclusions

According to the hardness test results, both the samples from grey cast iron and chromium cast iron reinforced with ceramic insert appeared to be harder than the non-reinforced samples. The grey cast iron hardness differences are substantial, reaching ca.

60% in Brinell test in favour of reinforcement, while in case of chromium cast iron the reinforced samples hardness growth is scarce. Probably, the significant difference of hardness in case of grey cast iron results from the insert's function as the internal cooler causing partial whitening of the cast iron. The chromium cast iron in this case is less sensitive to the insert's effect. Testing the impact strength showed that the reinforced samples impact strength was by 20-30% lower than that of the non-reinforced samples, disregarding the type of insert (e.g. 30, 10 ppi) and type of cast iron (grey or chromium cast iron). The impact reduction results from high fragility of the ceramic inserts alone, which is also transferred onto the molds. The abrasive wear tests, in turn, showed that the reinforced samples are characterised with lower wear than the non-reinforced ones. The difference appears in particular in grey cast iron tests for 30ppi with abrasion wear of ca. 30% lower than for cast iron types with 10 ppi inserts. In case of chromium cast iron no such significant differences were observed, although the use of such inserts slightly reduced the wear. Comparing the hardness and wear we may say that the higher hardness was the lower abrasive wear is. Unfortunately, too low impact of the types of cast iron with inserts excludes the production of reinforcement in the entire mold, therefore, considering the good filling of the porous insert with cast iron, some opportunities appear to reinforce a fragment or part of the mold, with particular consideration to the points most exposed to wear.

Based on the tests and analysis carried out, the following conclusions may be drawn:

1. The use of foamed ceramic filters provides good conditions of filling a ceramic framework with molten grey or chromium cast iron.
2. The growth of hardness of the ceramic- grey cast iron composite is ca. 60% as compared to the grey cast iron hardness.
3. The growth of hardness of the ceramic- chromium cast iron composite is slight and does not exceed 5 % in comparison to the chromium cast iron.
4. Introduction of the ceramic inserts deteriorates the cast iron impact strength by ca. 20 - 30 %.
5. The use of ceramic inserts increases the resistance to abrasive wear in case of grey cast iron by ca. 13% and in case of the chromium cast iron by ca. 10 %.
6. It seems to be purposeful to carry out tests of abrasive wear under different wear conditions, e.g. metal – mineral.

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