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The comparative studies of ADI versus Hadfield cast steel wear resistance

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Summary

The results of comparative studies of wear resistance of ADI versus high manganese Hadfield cast steel are presented. For evaluation of wear resistance three type of ADI were chosen. Two of them were of moderate strength ADI with 800 and 1000MPa tensile strength while the third was 1400MPa tensile strength ADI. The specimens were cut from ADI test YII type casting poured and heat treated in Institute of Foundry in Krakow. The pin on disc method was used for wear resistance experiment. The specimens had a shape of 40mm long rod with diameter 6mm. The load and speed were 100N and 0,54m/s respectively. It was concluded that the wear resistance of ADI is comparable with high manganese cast steel and in case of low tensile grade ADI and is even better for high strength ADI than Hadfield steel.

Key words: High manganese cast steel, ADI, Mechanical properties, Structure

1. Introduction

Austempered ductile iron (ADI) is known as an engineering cast material with excellent combinations of strength, ductility and toughness [1]. The mechanical properties for given application are achieved by implementation proper austempering parameters. Selecting temperature and time of isothermal quenching different grades of ADI can be produced. One of most promising property of ADI is high hardness which is responsible for high wear resistance. However, as yet it is only few works on the exhibited wear properties. From literature it is clear that specific heat treatment (austempering) applied to conventional ductile iron improved wear resistance, but the role of austempering parameters on exhibited wear properties is still not fully disclosed. Both, Voigt end coworkers [2] and Prasnna et al. [3] agree that refining of ausferrite by austempering at or below 340^{o}C perform of significant increase of wear resistance. On the other hand Prado at al. [4] in dry sliding wear experiment found that wear resistance is independent of austempering temperature in the regime 270-370^{o}C. Schissler and collaborators [5] and Owahdi at al. [6] showed the beneficial role of untransformed austenite which if below 10% in ADI matrix is not carbon supersaturated and under mechanical stressing transforms into martensite according to the transformation – induced – plasticity (TRIP) mechanism. According to Hasseb and coworkers [7] TRIP mechanism is just responsible for exhibited high ADI wear resistance. They suggest that wear ADI resistance is improved with ferrite phase work hardening. On the basis of scanning electron microscopy (SEM) observations Pèrez et al. [8] found no evidence for TRIP mechanism operation.

In our paper [9] we presented the preliminary consideration concerning possibility of replacing high manganese cast steel used for military vehicle track pads with ADI. The starting point for these considerations was very high hardness of ADI being one of the most promising property of ADI and which is typically needed for high wear resistance elements. In this work we deliver results of wear resistance experiment carried out using three different grade ADI and high manganese Hadfield type cast steel.

2. Experiment

2.1. Material for testing

As mentioned above three grade of ADI were selected for the experiment. The material for study was cast and heat treated in Institute of Foundry in Krakow. The chemical composition of ADI is given in table 1 and the chemical composition of L120G13 cast steel in table 2

Table 1. The chemical composition of ductile iron used for austempering

Element concentration [weight %]								
C	Si	Mn	Ni	Cu	Mo	Mg	P	S
3.85	2.30	0,40	-	0.73	0.19	0.070	0.05	0.01
3.80	2.30	0,28	0.60	0.70	0.21	0.065	0.06	0.01
3.45	2.60	0,78	0.55	0.45	0.25	0.045	0.04	0.01

Table 2. The chemical composition of L120G13 cast steel [2]

Element concentration [weight %]						
C	Mn	Cr	Ni	Si	P	S
1 - 1.4	12 - 14	≤ 1.0	≤ 1.0	0.3 – 1.0	≤ 0.1	≤ 0.03

2.2. Experimental procedure

The tensile test experiment was performed for each ADI casting on fivefold specimens using Instron 1115 machine. To evaluate the average values of R_m, $R_{p,\,0.2}$ and A_5 three specimens were used. Except tensile strength, hardness measurement was carried out using Rockwell method. The specimens for microstructure investigations were first grinded and then polished with automatic Tenupol equipment. The microstructure was studied both with Olympus IX-70 light microscope and scanning electron microscope (SEM). The last one was applied also for fractography investigations. The wear resistance was carried out using so called "pin on disc" method where the specimens in shape of rods 6mm diameter and length 40mm were used. These specimens were under load 100N and held against the rotating wheel made from high speed steel hardness of 66HRC. The linear speed of specimens relative to rotating disc V = 0,54m/s.

3. Results

3.1. Mechanical properties

The results of mechanical testing of ADI and high manganese Hadfield type cast steel are given in table 3 and table 4.

Table 3. The average measured mechanical properties of ADI

ADI type	$R_{p,0.2}$	R_m	A_5	Hardness
	[MPa]	[MPa]	[%]	HRC
A	602	820	5,0	31
B	794	1077	7,1	39
C	1049	1454	4,4	49

Table 4. The average measured mechanical properties of L120G13

$R_{p,0.2}$	R_m	A_5	Hardness		KC	KCV
MPa	MPa	[%]	HB	HRB	[J]	[J/cm^2]
432	706	12,3	174,1±3.2	89,1±0.5	69,50	1.73

It should be noted that the values of A_5, KC and KCV for Hadfield cast steel given in table 4 showed high dispersion of the measurement results.

3.2. Structure investigations

The aim of structure investigations was mainly to characterize ADI material used for the studies. These included both conventional metallography and SEM observations. The results of metallography observations are given in fig.1. In all cases the matrix consists of mixture of needle like ferrite and carbon supersaturated austenite. Some amount of martensite can be identified in fig.1c, presenting C type ADI with average tensile strength higher then 1450MPa. It is very easy to see the differences between the matrix microstructure each of ADI type. First of all is relative proportion between austenite and ferrite and the second is morphology of matrix constituents. In first two micrographs (fig.1a and b) ferrite is much thicker than in the third one (fig.1c)

In fig.2 results of SEM investigations are given. The aim of these observations was to see the differences in morphology of fracture surface which exhibits ductility of ADI used in our studies. Although no enormous differences were discovered nevertheless more deep observations shoved secondary microcracks in C type ADI (fig.2c)

Another information following from SEM observations concerns the geometry of graphite precipitates. It is clear that these precipitates are not ideally spheroidal but a little deformed. This confirms the metallography observation, although never graphite precipitates in shape of flakes were identified.

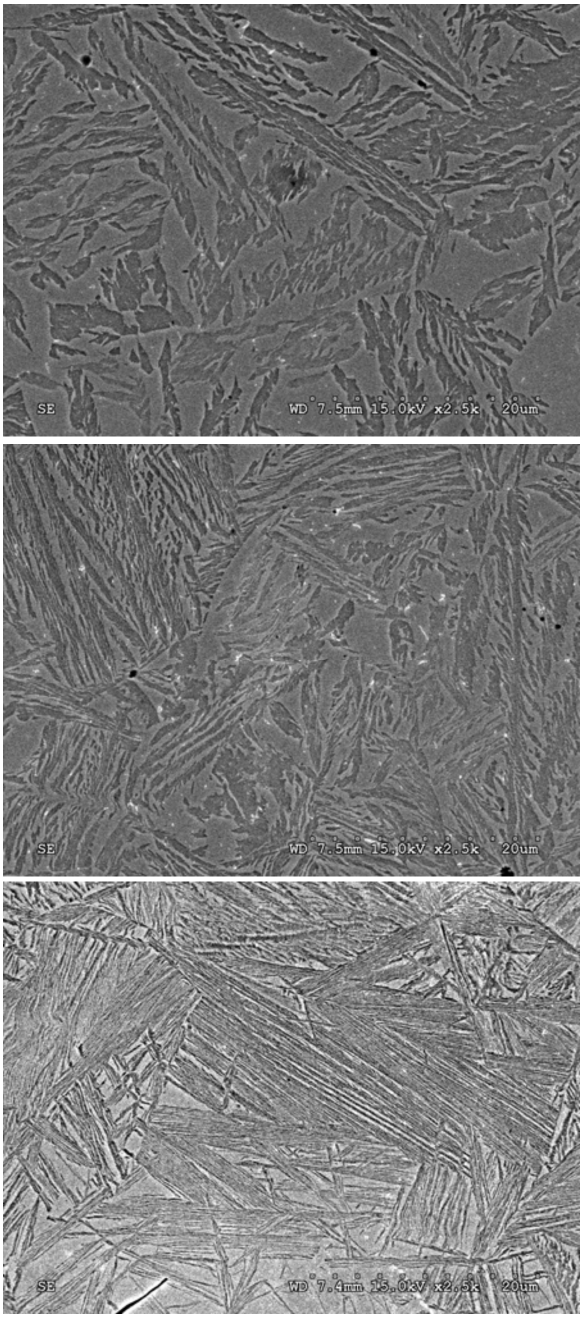

Fig. 1. The microstructure of different ADI specimens: a – A type, b – B type and c – C type

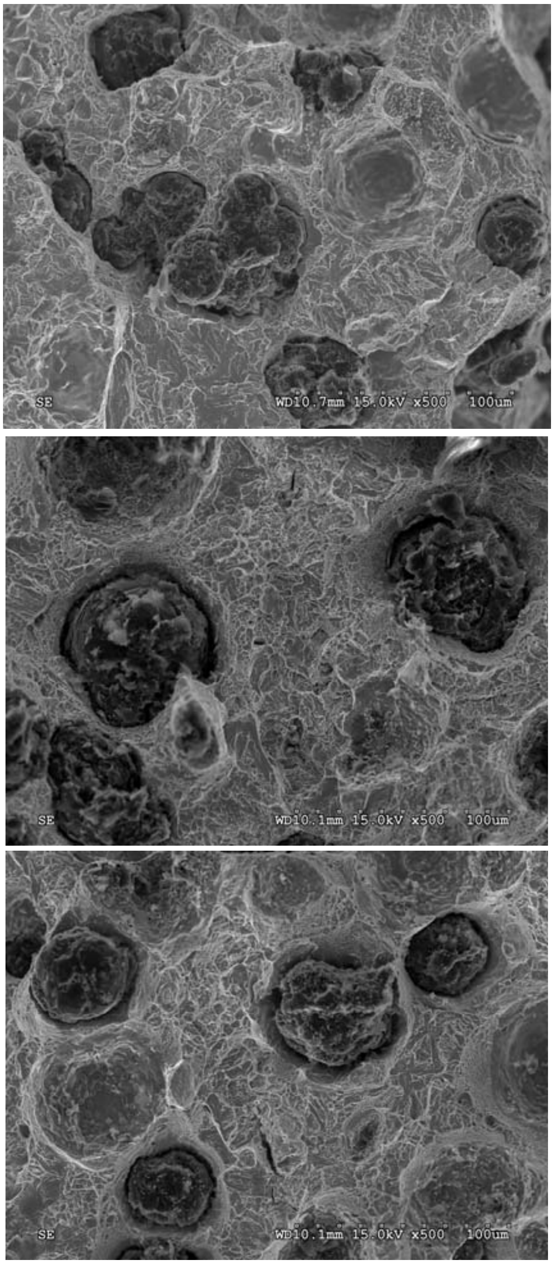

Fig. 2. The morphology of fracture surface of ADI specimens: a – A type, b – B type and c – C type

3.3. Wear resistance

The results of wear resistance obtained for the wear distance equal L_{1} = 1000m an L_{2} = 2000m are given in table 1 and in fig.3. As follows from table 5, the wear resistance of ADI is not only concurrent but even better than high manganese Hadfield cast steel.

Table 5. The results of wear resistance measurements

Material	Loss in weight [g]	
	L_{1} = 1000m	L_{2} = 2000m
Hadfield cast steel	0.0035	0.0099
ADI – type A	0.0044	0.0109
ADI – type B	0.0026	0.0045
ADI – type C	0.0028	0.0055

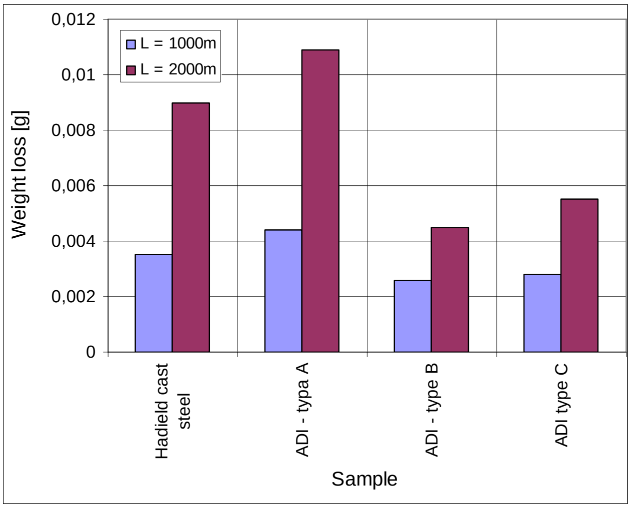

Fig. 3. The weight loss of specimens made from Hadfield cast steel morphology and three type of ADI

Comparing the weight loss of specimens from Hadfield cast steel with that in specimens made from three type of ADI it can be seen that the best material from wear resistance point of view is type B – ADI. This material is intermediate between the relative "soft" A type and "hard" C type of ADI.

4. Discussion and conclusions

As was stated above, the specimens made from different type austempered ductile iron are concurrent and even better from wear resistance point o view. The best of all materials being subject of these studies is B – type ADI which posses the strength intermediate compare to A and C type ADI. This result looks a little surprising because the wear resistance depends strongly on hardness. Typically, the higher the hardness the better wear resistance. It must not be the truth and the best proof is Hadfield steel which hardness is not comparable with the hardness of ADI see the tables 3 and 4). On the other hand it is known that for high Hadfield steel wear resistance is responsible the austenite → martensitic phase transformation caused by shear stress. In this moment the question arise: was the load of the specimens during wear resistance experiment high enough to initiate martensitic transformation in Hadfield specimen? If not than it would be understandable why the specimens from this material are not as good as B or C type ADI.

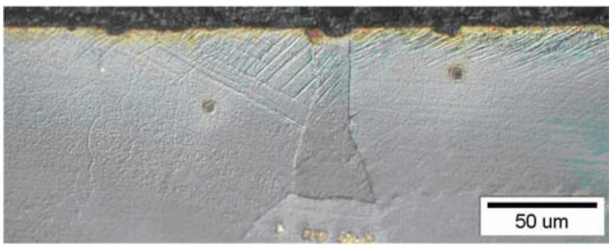

Fig. 4. The microstructure of surface of Hadfield cast steel specimen after wear experiment

Fig. 4 shows the microstructure of the specimen from Hadfield cast steel after wear resistance test where straight lines with specific orientation each to other are clear visible. Although these are more fine compare to that presented in our earlier paper [9] but convincing enough to be the proof that the load of the specimen applied in the wear experiment was sufficient to cause austenite → martensite phase transformation.

Taking into account the considerations given above lead the authors to the final conclusion that ADI can be considered as a good substitute for L120G13 austenitic cast steel used now for track pad. The reasons pushing us to such conclusion are:

1. The wear resistance of three type of ADI is comparable with these for high manganese Hadfield cast steel behavior in service.
2. The B and C type of ADI show the wear resistance even better then Hadfield cast steel in dry wear experiment.
3. Taking into account good toughness requirement B – type ADI looks to be the best substitute for Hadfield cast steel used now for track pad.

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