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Investigation of Wear Resistant of Low-Alloyed and Chromium Cast Steel

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Abstract

Results of investigations of wear resistant of two species of cast steel were introduced in the article (low-alloyed and chromium cast steel) on the background of the standard material which was low alloy wear resistant steel about the trade name CREUSABRO ®8000. The investigations were executed with two methods: abrasive wears in the stream of loose particles (the stream of quartz sand) and abrasive wears particles fixed (abrasive paper with the silicon carbide). Comparing the results of investigations in the experiments was based about the counted wear index which characterizes the wears of the studied material in the relation to the standard material.

Keywords: Low-Alloyed Cast Steel, Chromium Cast Steel, Wear, Wear Index

1. Introduction

The abrasive and corrosive wears of materials applied in the constructions of machines and devices is the very unfavourable effect, causes large economic losses, is the cause of the loss of the durability of the construction, and can sometimes be the cause of the damage. The safety considerations should decide about the final choice of materials on constructional elements subject during exploitation on the working of abrasive and corrosive factors. Cast steels belong to casting materials from which one waits high mechanical properties, in this particularly plastic, which they determine the use of material on responsible elements for the safety of the construction. Resistance on the abrasive wear of cast steels is very differential and it depends often on present in the practice tribological arrangements in the considered construction. The authors of works [1-3] return the special attention on the proper selection of these alloys in dependence from the environment of the work. Low-alloyed cast steel is applied on constructional castings because of quite high strenght parameters near comparatively low costs of the production and the simple technologies of mechanical processing and joining e.g. by welding. Chromium cast steel finds the basic use on elements subject during the work on the working of corrosion and abrasion e.g. the slide bearing and different kinematic pairs. The considerable part of chromium and different alloy elements in this cast steel assures them the high corrosive-erosive resistance, which one can improve still suitable metallurgical treatments and the heat treatments.

Results of investigations of two cast steels belonging to the group of the low-alloyed and alloy cast steels which can find the wider use in the building of massive working machines because of high mechanical properties near the good resistance on abrasive and corrosive wear were introduced in the presented work. New low-alloyed cast steel being approximate to standardized cast steel L20HGSNM and chromium cast steel belonging to cast steel on the corrosive-erosive wear subject according to two methods to the investigations of the abrasive wear in which abrasive grains (quartz sand or the silicon carbide) are materials causing the wear. In the method I (the device tribotester 9-Bitter) quartz sand attacks the creator abrasive stream the surface of specimens. In method II (the device tribotester 3-POD) the specimens of the studied material move after the fixed grains of the silicon carbide (abrasive paper). Standard materials are applied in both methods.

As the standard material for every method was chosen wear resistance low-alloyed steel about the trade name CREUSABRO®8000 [4].
The qualification of the resistance was the aim of investigations on the abrasive wear studied cast steels in the conditions of the strong influence of particles abrading in various tribological arrangements on the background of the standard material.

2. Material and method wear abrasive investigations

Two species of cast steels (low-alloyed and chromium cast steel) were chosen to the investigations of the abrasive wear with mainly the destination on the elements of the working massive machines which during the work have the direct contact with the abrading material e.g. in mining industry and processing industry. The standard material (reference) was also chosen among the iron alloys and it was low alloy resistant steel about the trade name CREUSABRO®8000. Studied cast steels were subjected toughening and standard steel was in the condition of delivering that is after the special thermal processing with the controlled process of the cooling [4]. Materials applied in realized investigations are presented in Table 1. The metallographic structures of studied materials are shown on Figure 1. The structure of low alloy cast steel K2a after the executed heat treatment consists of sorbite and non-metallic inclusions. One can notice sorbite from the chromium carbides in chromium cast steel T2a. Standard steel CREUSABRO®8000 (C8) in the structure observe annealed martensite with retained austenite and small carbides.

The investigations of the wear abrasive were conducted according to two methods which differ the type of the tribological arrangement. In first method (the position Tribotester 9-Bitter) wear results in the stream the loose particles of the abrasive attacking the surface of the studied specimen under the various angles of the attack. Second method (the position Tribotester 3-POD) is numbered to methods pin-on-disc, where studied material in the pin form is held down to the abrasive material (abrasive paper) during the mutual move.

Table 1.
Chemical composition (in % weights), heat treatment and hardness of studied materials

no	marks	C	Mn	Si	P	S	Cr	Ni	Mo	V	Cu	Al	Ti	hardness HRC
1	C8*	0.224	1.09	0.751	0.014	0.002	0.65	0.296	0.251	0.006	0.453	0.065	0.032	45
2	K2a**	0.209	0.619	0.833	0.014	0.002	0.925	0.301	0.251	0.057	0.449	0.003	0.018	35
3	T2a***	0.50	0.49	0.70	0.017	0.009	18.10	0.53	1.22	0.29	0.17	0.004	0.21	42

* C8 – *wear resistance low-alloyed steel about trade name CREUSABRO®8000 in delivering state*
** K2a – *low-alloyed cast steel after heat treatment (hardening 920°C/0,5h/water, tempering 600°C/2h/air)*
*** T2a – *chromium cast steel after heat treatment (hardening 950°C/0,5h/air, tempering 600°C/2h/air)*

a) b) c)

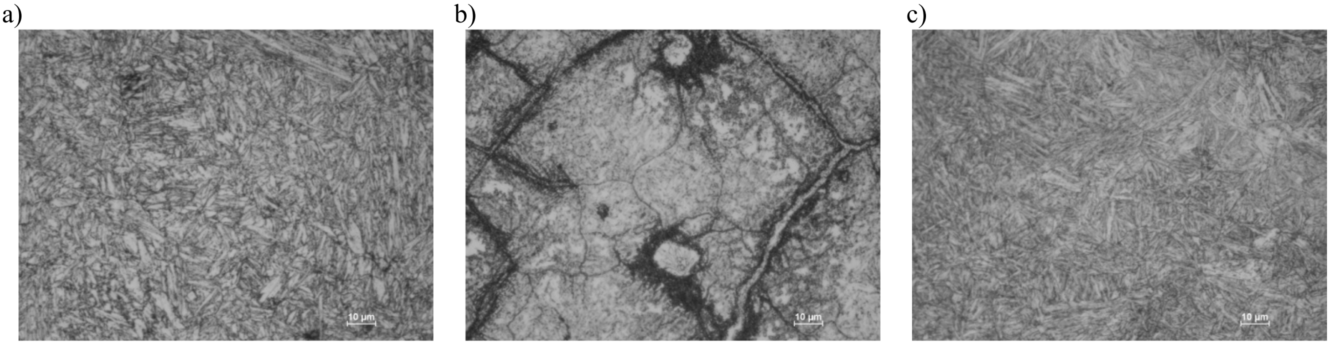

Fig. 1. The metallographic structures of studied cast steels and standard steel: a) low alloy cast steel - K2a; b) chromium cast steel - T2a; c) low alloy steel CREUSABRO®8000 - C8

2.1. Tribotester 9-Bitter stand

This stand makes possible the investigation of abrasive wear of materials to the Bitters theory according to [5,6], which mechanism of wear of the material attacked loose particles described. Bitter distinguished two basic processes causing the destruction of the material in his theory such as cutting off and crumbling up. The part of basic processes became addicted from material and energetic parameters the material rubs off and rubbing off and from kinetics and the angle of the attack of particles rubbing off. Tribotester 9-Bitter became constructed and made in Department of Foundry Silesian University of Technology [7]. The simultaneous investigation of abrasive wear makes possible through stream of particles attacking the surface of the studied material under 9 angles of the attack with fixed speed. On Figure 2 are presented scheme of principle of operation. The general view of the device was shown the Figure 3.

The standard material which is placed in the set of specimens each time was also applied in the device. This gives the possibility of the direct comparison of the studied material with the standard material and comparing results in next experiments makes easier. It was introduced in this aim i.e. the wear index being the undimensional relation of loss mass the studied specimen to loss mass of the standard specimen. The whole set of measuring specimens subjected the investigation in tribotester 9-Bitter counts 18 specimens (9 studied, 9 standard). Apply additionally shore specimens, the protection of the edge of measuring specimens is whose task, so the stream wearing off attacked only the front surface of every one from them. The set of all specimens fixed in one hold was showed on Figure 3. One can apply various particles (materials) rubbing off in investigations on tribotester, however it is used from practical regards the most often quartz sand, which this is the material the frequent participant of destroying the elements of machines.

a)

b)

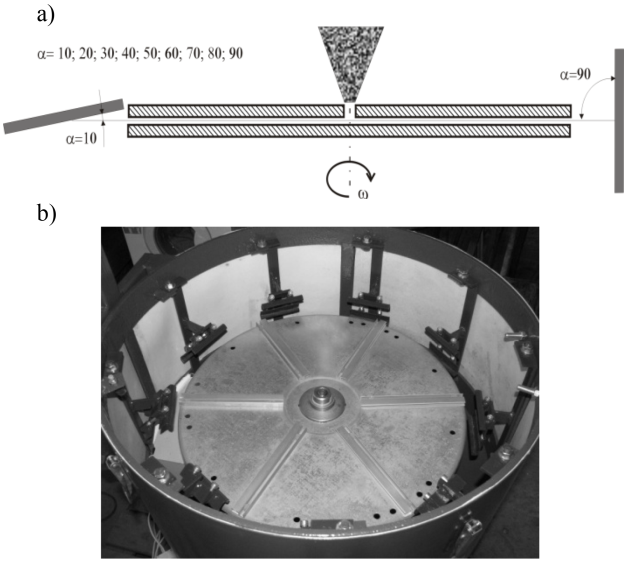

Fig. 2. Scheme of principle of operation (a) and the view of the chamber measuring Tribotester 9-Bitter (b) [7]

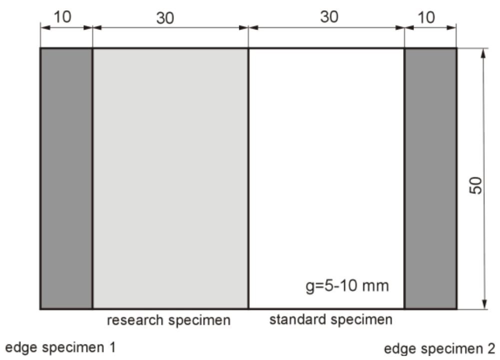

Fig. 3. Set of specimens fixed in the holder

Fig. 4. General view of tribotester 9-Bitter [7]

2.2. Tribotester 9-POD stand

The stand is in the large part similar on solutions stands numbers to methods investigative pin-on-disc in which the specimen is studied in the shape of the pin held down to the whirling disc causing abrasive wear. In tribotester 3-POD 3 specimen which also whirl in the special hold are tightened to the whirling disc simultaneously. The scheme of principle of operation is presented on Figure 5.

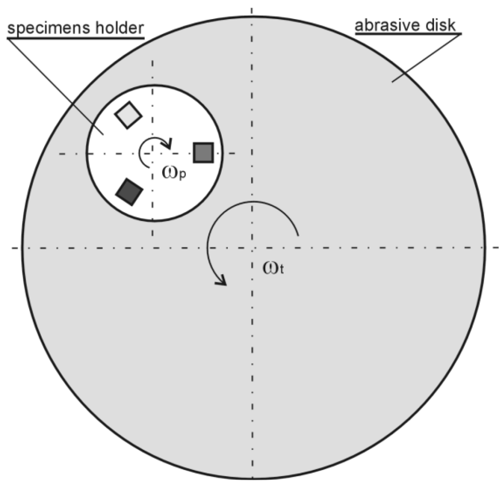

Fig. 5. Scheme of principle of operation of tribotester 3-POD

Tribotester 9-POD became constructed and made in Department of Foundry Silesian University of Technology [7]. They are studied on the device simultaneously three specimens from which one is always the standard specimen (reference). Every one the specimen is fixed in the special whirling hold which the individual pressure of every specimen makes possible to the abrasive disc. The abrasive disc makes up the abrasive paper disc about definite gradation and the kind of the abrasive grain most often. The direction of the rotations of the abrasive disc is opposite to the rotations of the holder with specimens. The regulated parameters of the work of the device are: the rotations of the abrasive disc, the rotations of the holder of specimens, force pressure of specimens, the kind of the abrasive disc, the time of the experiment.
The general view tribotester 3-POD and the construction of the specimen was shown on Figure 6.

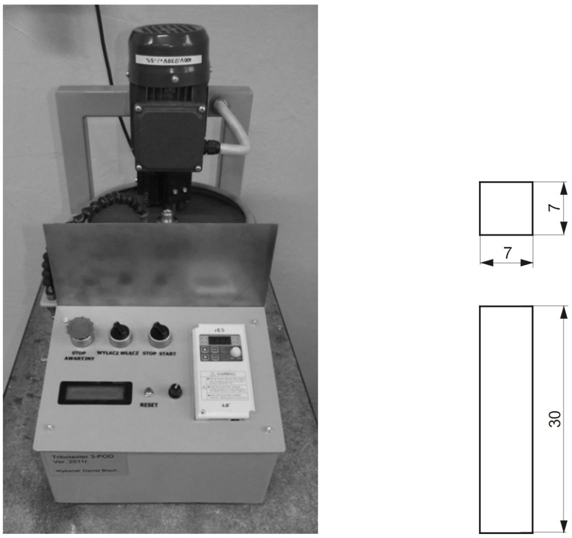

Fig. 6. View of tribotester-3 POD,dimensions of the specimen [7]

In conducted investigations the parameters of tribotester 3-POD work is following:

- abrasive disc: abrasive paper 120, silicon carbide,
- rotatory speed of the abrasive disc: 60 $^{obr}/_{min}$,
- rotatory speed of the holder of samples: 500 $^{obr}/_{min}$,
- burden of the single sample: 370 G,
- total time of the test of the abrasion: 50 min.,
- abrasive action on dry.

3. Results of investigations and their analysis

3.1. Wear of cast steels in the set sample-stream abrasive

On the stand tribotester 9-Bitter it was conducted two experiments appointed as A and B.

In the experiment A was studied low-alloyed cast steel (K2a) with standard material (wear resistance low alloy cast steel CREUSABRO®8000 (C8)). The wear graphs of these materials in the function of glancing angle of quartz sand on the surface of measuring specimens were shown on Figure 7. The low wears of both materials was observed for small angles. Just after crossing 40^o the clear growth of wears follows near what standard steel has always larger wears than low alloy cast steel.
It was materials studied in the experiment B chromium cast steel (T2a) and this alone standard steel (C8) what in the experiment A. Obtained results demonstrated the similar course curve wears (Fig. 8) how in the experiment A. The stream of quartz sand near the small angles of fall on the surfaces of specimens caused the low wears of both materials, and well can not affirm which material is better. The answer are already simpler near the angles of the fall of the abrasive material above 40^o. More decidedly resistant in this range of angles is chromium cast steel. However it does not exclude the use of both materials in the case of the perpendicular working of the abrasive stream on studied materials. Different regards should weigh on their use in this case.

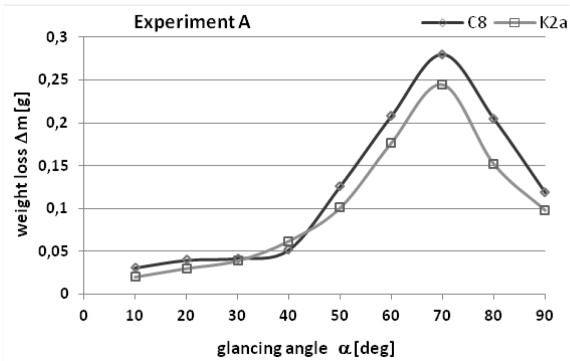

Fig. 7. Wear abrasive of low-alloyed cast steel (K2a) and steel (C8) in the function of the angle of incidence of quartz sand on the surface of measuring specimens

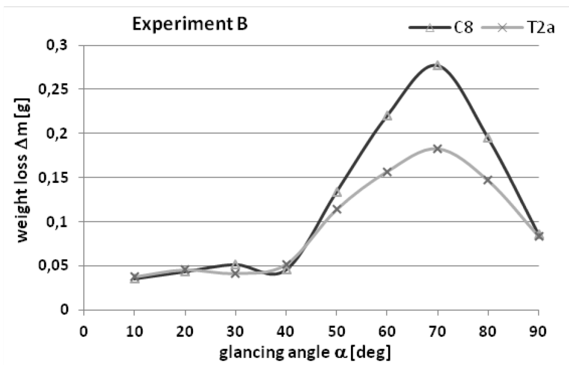

Fig. 8. Wear abrasive of chromium cast steel (T2a) and steel (C8) in the function of the angle of incidence of quartz sand on the surface of measuring specimens

3.2. Wear of cast steels in the set sample-abrasive disc

On the stand tribotester 3-POD conduct the experiment in which specimens were studied made from cast steel K2a and T2a and standard specimen from steel C8. The test of the abrasion conducted by 50 minutes, making the measurement of the mass loss of specimens every 10 minutes. Results obtained during this test were shown on Figure 9.

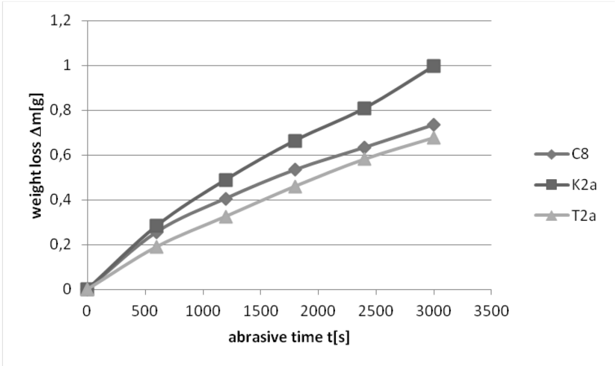

Fig. 9. Wear abrasive of cast steels K2a and T2a and steel C8

Low-alloyed cast steel (K2a) the worst material turned out in this experiment. One is the lowest hardness of this material probably the reason of quick wear in this tribological arrangement.
Harder materials such as chromium cast steel (T2a) and steel CREUSABRO®8000 have the similar character of wear with the light superiority of the resistance on the wear of chromium cast steel what it probably can be caused the presence in this cast steel of hard carbide phase.

3.3. Wear Index in the experimental investigations of the abrasive wear of materials

The comparability of investigation results of wear is very essential. Transfer of arbitrary measurements (the mass loss of the specimen) from separate experiments one cannot uncritically analyse. The repeatability of all parameters of the work of the investigative device simulating the tribological configuration is controversial. Introduction in the measuring devices of the specimen of the reference called the standard specimen makes possible credible comparing results. Specimens executed from low-alloyed steel resistant on wear abrasive CREUSABRO®8000 were standard specimens in the present work.

The possibility of comparing the results of the investigations of wear gives wear index (equation 1) which was defined as the relation the mass loss of specimen studied to the mass loss of standard specimen, not only within the one method.

$$\mathbf{W = \Delta m_b/\Delta m_w} \qquad (1)$$

where: Δm_b – mass loss of specimen studied in g;
Δm_w – mass loss of specimen standard in g.

The wear index is the undimensional number and the reference of the studied material passes to the standard material. The change of the abrasive wear index of studied cast steel was shown on Figure 10 in the function of the angle of incidence of the quartz sand stream. Can notice that the influence of the medium abrading is changing and should know about this choosing materials.

Results investigations on the stand tribotester 3-POD it was also introduced using the abrasive wear index. It was counted for the full cycle of investigations. The comparison of studied materials was showed on figure 11 using the this index.

Chromium cast steel the best material presents again on this form of wears. The meaning again has probably the part of carbide phase in this cast steel. Low-alloyed cast steel the worst material presents but low-alloyed steel exposes in these conditions its advantages advertised by the manufacturer.

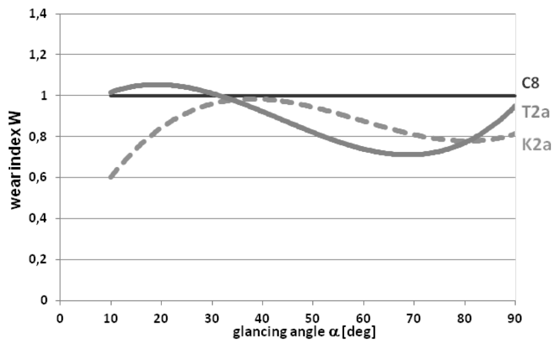

Fig. 10. Abrasive wear index **W** in the function of the angle of incidence of quartz sand stream on the surface of specimens

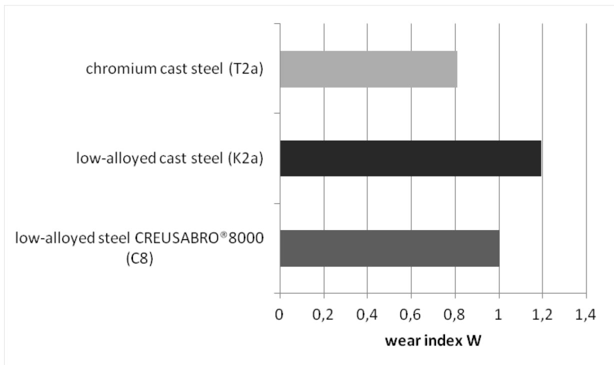

Fig. 11. Abrasive wear index W of studied materials in the tribological arrangement pin-abrasive disc

4. Summary

The executed investigations of the abrasive wears of low-alloyed cast steel and chromium cast steel two methods showed the validity of this type of the actions for the study of the completer profile of abrasive wear resistance of casting materials which should help constructors and the exploiters of machines works. Considered tribological arrangements are present in the practice often and abrasive materials, in this quartz sand particularly are essential factors causing destroying the elements of working machines. Among others, the corps of machines mining mineral materials are washed through the stream of particles crumbled materials often. The wear graphs in the function of angle of incidence of abrasive material characterize the quantity resistance of material on the abrasion but they also show the constructor e.g. what setting of the working surface of the element in relation to the stream abrading will be the most profitable.

The dangerous range of the angles of the attack of the abrasive stream is contains in the compartment 60-80^o for studied cast steel.

The abrasive wear index graphs worked out for various materials make possible the choice of the optimum material in dependence from the tribological arrangement. On easier and exact seems their selection on the working elements of machines and devices to the basis of the analysis of the abrasive wear index graphs for the group of given an examination low-alloyed cast steel and chromium cast steel.

Affirming about the superiority of the material about the casts structure (low-alloyed cast steel K2a) in the relation to the material reworked plastically (steel CREUSABRO®8000) is the interesting conclusion after analysing present investigations working in the tribological arrangement stream rubbing off – the working surface. Both materials have the approximate chemical composition.

Acknowledgements

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