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STUDY OF STAINLESS STEELS AT BOUNDARY LAYER FRICTION IN CORROSIVE ENVIRONMENTS

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Abstract: *Details of stainless steels GX12Cr12 (BDS EN 10283-1998) and GX30Cr13 (BDS EN 10088-1-1995) with different heat treatment were tested for wear resistance in terms of border friction in a corrosive environment (pH6). Results are available for the degree of wear in the said working medium, depending on the type of the heat treatment. The data were compared with those from experiments to determine the wear resistance of tribological couples between the studied steels and a reference sample.*

Keywords: *tribology, wear, friction, corrosive environment.*

1. INTRODUCTION

The article concerns the study of the corrosion resistant steels durability, used for the responsible details production in the pulp and paper industry, working in conditions of boundary layer friction in corrosive environments with pH6.

The object of the research are the steels of type GX12Cr12 (BDS EN 10283) and GX30Cr13 (BDS EN 10088).

The boundary layer friction of machine parts in corrosive environments causes corrosion – mechanical wear that is observed at the chemical interaction of the contacting metal surfaces with environment elements.

Basic parameters characterizing the wear process in these conditions are:

- absolute mass wear: $m = m_0 - m_1$ – the mass difference of the sample before and after the test at a certain path of friction;
- absolute wear resistance: $I_n = \rho \cdot A_a \cdot L/m$, where: n – 1 to 6 (number of the test sample); m – absolute mass wear; ρ – density of the test material; A_a – nominal contact area of the interacting parts; L – path length of friction;
- relative wear resistance: $\varepsilon = I_n/I_0$ – relation between the absolute wear resistance of the test sample and that of a reference model (as a contra-body).

The aim of the work is to be evaluated the wear resistance of different heat – treated samples of GX12Cr12 and GX30Cr13 steels details at boundary layer friction in corrosive environments (pH6) in regard to reference model and in a joint contact system (tribocouple).

2. MATERIALS, DEVICES AND PROCEDURE

For the purpose of the experiment cylindrical samples (Ø8 mm and h = 25 mm) were made.

They were taken from different heat treated details of the steels mentioned above – Table 1. The chemical compositions of the investigated steels are shown in Table 2, average value, wt. %.

Table 1. Heat treatment modes of the samples

№ of the sample	Signa-ture	Heat treatment mode
1	R_o	Sample of GX12Cr12 steel without heat treatment
2	RT1	Sample of GX12Cr12 steel, heat treatment T1 mode
3	RT2	Sample of GX12Cr12 steel, heat treatment T2 mode
4	B_o	Sample of GX30Cr13 steel without heat treatment
5	BT1	Sample of GX30Cr13 steel, heat treatment T1 mode
6	BT2	Sample of GX30Cr13 steel, heat treatment T2 mode

Table 2. The chemical compositions of the investigated steels

Type of steel	C	Si	Mr	Cr	Ni	Mo	V
Gx12Cr12	0.155	0.36	0.66	12.92	1.6	0.55	0.06
Gx30Cr13	0.29	0.41	0.65	13.10	1.6	0.6	0.05

The heat treatment T1 is an initial stress-relief annealing of the cast parts to reduce their high energy and to remove their structural and chemical inhomogeneity.

The heat treatment T2 consists of homogenization (for GX12Cr12 steel), respectively hardening (for GX30Cr13 steel), with subsequent final annealing to obtain the most favourable structure of the steel product, which ensures the required mechanical properties.

On Figure 1, the functional scheme of the experimental device for study of the wear resistance of metal materials of boundary layer friction of corrosive environments is shown.

As a corrosive environment a buffer solution was prepared, containing sodium hydroxide (NaOH) and citric acid ($C_6H_8O_7$) in a certain ratio to achieve a pH6 of the medium.

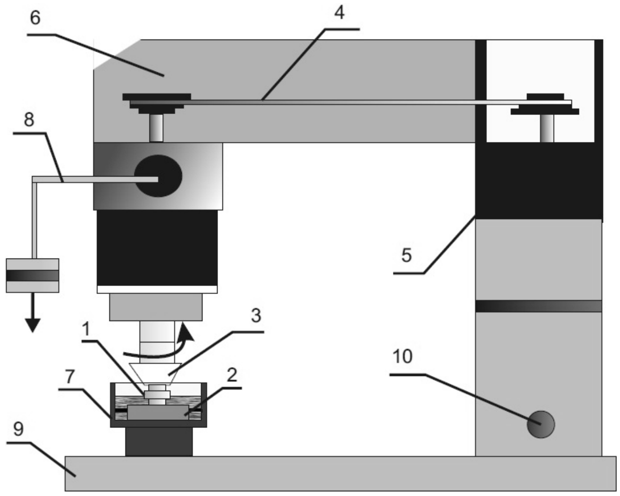

Figure 1. Functional scheme of the experimental device: 1 – studied sample; 2 – contra-body; 3 – holder; 4 – belt drive; 5 – electromotor; 6 – mount; 7 – corrosive bath; 8 – arm; 9 – frame

The experimental parameters are shown in Table 3.

Table 3. The experimental parameters

Parameters	Values
Nominal contact pressure, p_a [$N \cdot cm^{-2}$]	39.24
Nominal contact area, A_a [m^2]	$50.24 \cdot 10^{-6}$
Contra-body – reference model, C22 steel (BDS EN 10083-2)	R_a = 0.05 µm 63 HRC
Normal charge, P [N]	19.62
Testing time at 560 RPM [min]	30
Acidity of the medium at working temperature of 35 °C	pH6

3. EXPERIMENTAL

The results of the experiments are shown on Tables 4, 5 and 6.

Table 4. Results of the experiments

№ of the sample	Signature	Wear resistance, $I_n \cdot 10^{-8}$	ε
1	R_o	0.70	0.78
2	RT1	0.69	0.77
3	RT2	1.64	1.82
4	B_o	3.70	4.11
5	BT1	0.10	0.11
6	BT2	3.74	4.15
0	Refer. model	0.90	1.0

Table 5. Results of the experiments

№ of the sample	Signature	Wear resistance, $I_n \cdot 10^{-8}$	ε
3 sample	RT2	0.082	0.69
6 contra-body	BT2	0.120	0.69

Table 6. Results of the experiments

№ of the sample	Signature	Wear resistance, $I_n \cdot 10^{-8}$	ε
6 sample	BT2	2.2	1.89
6 contra-body	BT2	1.2	1.89

Figure 2 is an illustration of the heat treatment influence of the investigated steels details on their absolute wear resistance, in regard to a reference model as a contra-body.

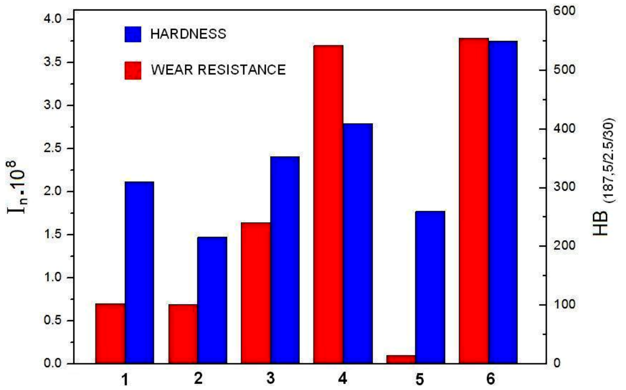

Figure 2. Absolute wear resistance and hardness of different heat treated samples of GX12Cr12 steel (1, 2, 3) and GX30Cr13 steel (4, 5, 6)

It is evident, that the samples which were not passed through the heat treatment – 1 (R_O) and 4 (B_O), as well as those, subjected to a stress-relief annealing (T1) only – 2 (RT1) and 5 (BT1), exhibit significantly lower absolute wear resistance.

According to the data, the highest wear resistant sample is 3 (RT2), as well as the sample 6 (BT2), that completed the full heat treatment (T2) – normalization or hardening respectively, with subsequent final annealing.

Also shown is the relationship between the absolute wear resistance and hardness of the samples 1- 6.

There is an obvious dependence on absolute wear resistance of all tested samples of their hardness, conditioned by the heat treatment applied.

Test results of samples of GX12Cr12 steel – 3 (RT2) and of GX30Cr13 steel – 6 (BT2) as a tribocouple are shown on Figures 3 and 4. It can be seen that in the contact system composed of the sample 3 (RT2) and sample 6 (BT2), higher absolute wear resistance indicates the sample 6 (BT2) as the contra-body.

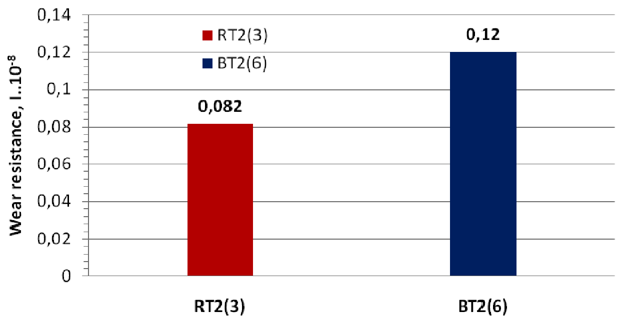

Figure 3. Wear resistance of samples 3 (RT2) and 6 (BT2) as a trbocouple, where the sample 6 (BT2) is the contra-body

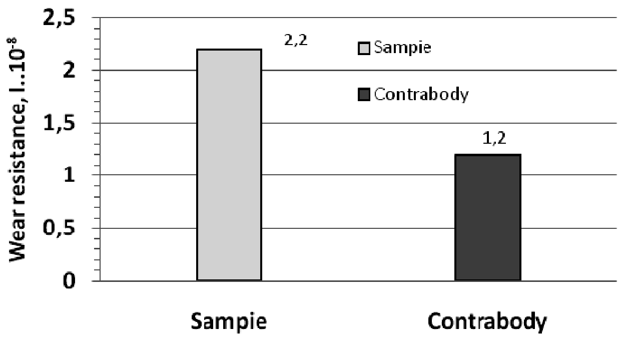

Figure 4. Wear resistance of one and the same samples 6 (BT2) as a tribocouple

At contact system consisting of two identical samples 6 (BT2), significantly wear that, which is acting as the contra-body.

Figure 5 shows the relative wear resistance of different heat treated samples of both types of steels with respect to a reference model as a contra-body. Highest relative wear resistance is characteristic for the sample 3 (RT2) and for the sample 6 (BT2).

On Figures 6 and 7 the macrophotographies of the sample 3 (RT2) and the sample 6 (BT2) as a tribocouple after testing at boundary layer friction in corrosive pH6 environment are shown.

On Figures 8 to 13 the microphotographies of all samples investigated are shown.

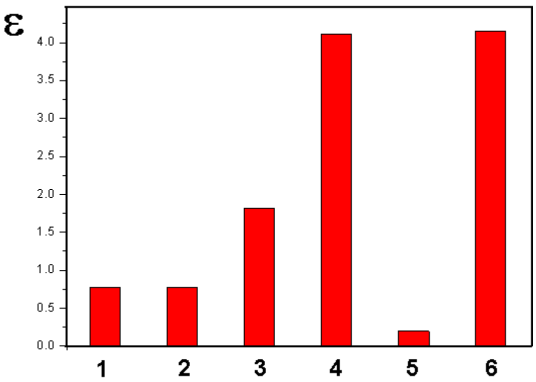

Figure 5. Relative wear resistance of different heat treated samples of GX12Cr12 steel (1, 2, 3) and GX30Cr13 steel (4, 5, 6)

Figure 6. Macrophotography of the wear surface of sample 3 (RT2) after testing

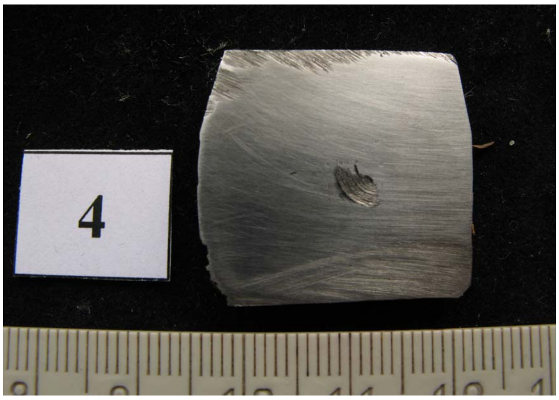

Figure 7. Macrophotography of the wear surface of sample 6 (BT2 – contra-body) after testing

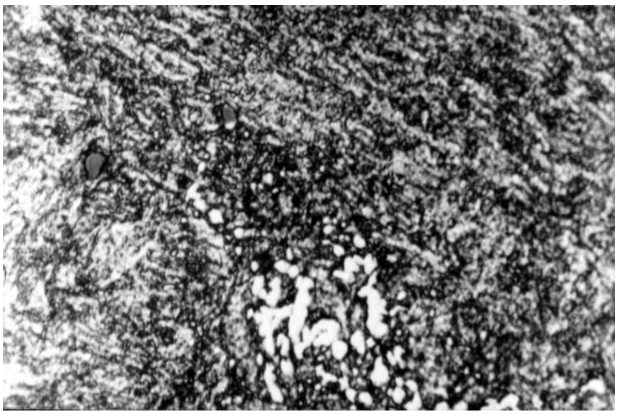

Figure 8. Microphotography of sample 1 (R_o), 800 × [3]

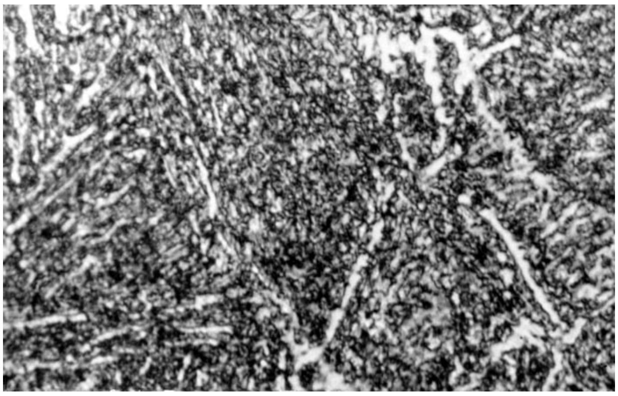

Figure 9. Microphotography of sample 2 (RT1), 800 × [3]

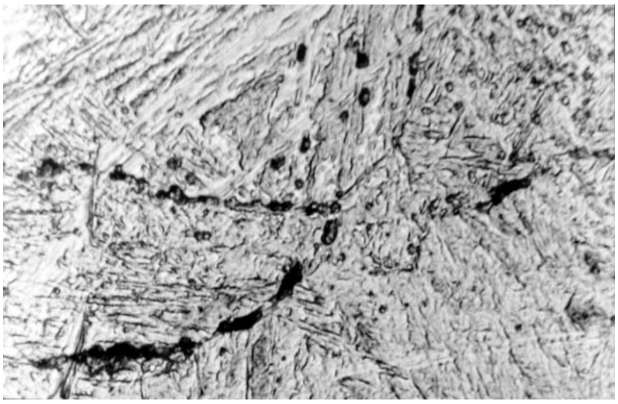

Figure 10. Microphotography of sample 3 (RT2), 800 × [3]

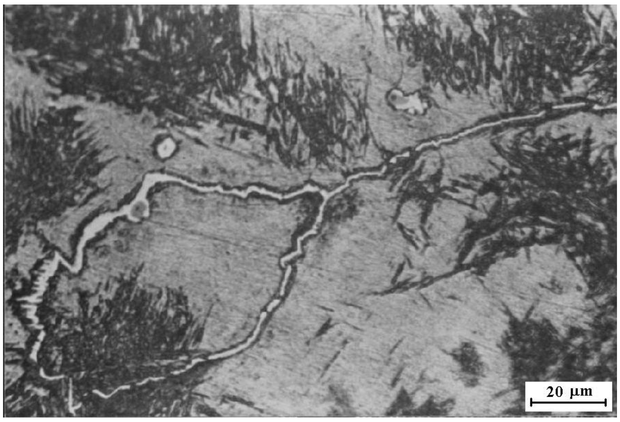

Figure 11. Microphotography of sample 4 (B_o) [4]

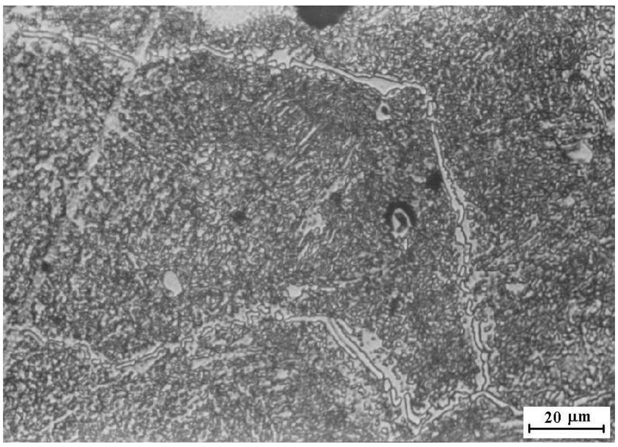

Figure 12. Microphotography of sample 5 (BT1) [4]

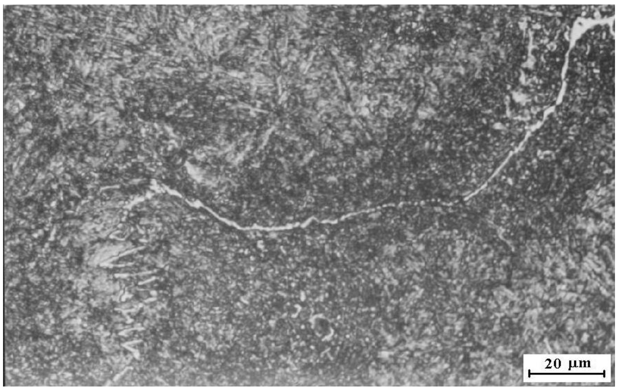

Figure 13. Microphotography of sample 6 (BT2) [4]

4. EXPERIMENTAL DATA ANALYSIS

The low absolute wear resistance of samples 2 (RT1) and 5 (BT1), subjected to an initial stress-relief annealing only (for both types of steels), is mainly due to the lower hardness, determined by the heat treatment mode.

A slide fractional carbide network around separate grains on the background of lower bainite was observed at microstructural analysis of these samples.

The highest absolute wear resistance of the samples 3 (RT2) and 6 (BT2) passed through the full heat treatment at T2 mode, may be explained by their favourable microstructure due to the redistribution of the alloying elements in the based matrix, increasing the amount of strengthening phases (structure free carbides) and a coalescence, eliminating the unstable condition.

As the result of the final annealing, the sample 3 (RT2) and the sample 6 (BT2) remain high hardness, especially distinctive for vanadium alloyed steels, high impact strength and excellent anticorrosive and antifriction properties.

The behaviour of the samples without heat treatment of the both types of steels is determined by their wilfully hardening propensity on air immediately after casting. Steels with carbon content to about 0.25 wt. % (GX12Cr12) are not prone to hardening and therefore their hardness remains lower, compared to that for steels with carbon content above 0.25 wt. % (GX30Cr13).

The steels structure immediately after casting is coarse, inhomogeneous, with single primary carbides.

Castings are characterized by high internal energy, causing inner tensions, and as a consequence, lower mechanical parameters and inferior anticorrosive and antifriction properties as a whole (Figs. 8 and 11).

5. CONCLUSIONS

The obtained results show that the heat treatment mode T2 (normalization and subsequent final annealing for GX12Cr12 steel, respectively hardening and subsequent final annealing for GX30Cr13 steel) provides the most favourable microstructure of the said steel details, that on the other hand determines good mechanical properties, in particular hardness, which is essential for the wear resistance of the materials to different types of friction.

Studied steels heat treated by mode T2 show good absolute and relative wear resistance, compared to the reference model.

It has been shown that the wear resistance in weakly acidic medium with pH6 was fully satisfactory for the production purposes in the pulp and paper industry and the steels, which are chosen as a tribocouple are quiet suitable for these purposes.

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