THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N^{0}. 3 – 2014, ISSN 1453 – 083X

THE EVOLUTION OF THE CHARACTERISTICS OF MECHANICAL RESISTANCE FOR THE NITRO-CARBURIZED TREATED STEEL, AFTER THERMO-MAGNETIC TREATMENT

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ABSTRACT

The aim of the research was to study the evolution of the characteristics of mechanical resistance for one type of steel. The material was subjected to the thermo-chemical (nitro-carburized treatment in plasma) treatment applied after thermo-magnetic treatments. The structural and diffractometric aspects of the superficial layers of the steel are studied after the wear process, using an Amsler type machine, taking two sliding degrees at different contact pressures and testing in time. The tests were done to detect the sustainability to the material, the evolution of the superficial layer characteristics through different tests and to establish the influence of these thermo-magnetic treatments regimes.

The magnetic field modifies the grain size in the material structure. It was obtained a small grain size in the middle of the sample and the orientation of these grains is in the same direction with the lines of the magnetic field.

It was made a balance sheet between classic treatment and unconventional (thermo-magnetic) treatment.

KEYWORDS: durability, characteristics of mechanical resistance, thermo-magnetic treatments, thermo-chemical treatment, hardness, wear process

1. Introduction

The study of the contact aspects between machine elements is essential due to the fact that more than 60% of provided energy is lost by friction resulting from the relative movements between the elements.

The conventional machining methods such as turning and milling leave inherent irregularities on the surface and it becomes necessary to very often resort to a series of finish operations with high costs.

In last 20 years, the technical progress made it possible to develop the use of very hard materials in several fields like manufacturing parts for the car industry, the railroad coaches, the nuclear power, for the aeronautics and for the mechanical industries. In this paper, it was study the evolution of the superficial layer for an un-conventional treated steel, during the wear tests.

The superficial layer is defined according to the type of interaction between the external action and materials.

In figure 1 was presented one of the first model of the superficial layer [2, 4, 5, 15].

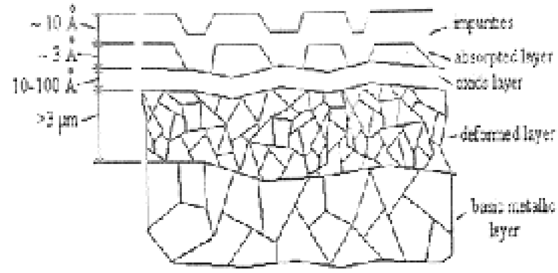

***Fig. 1**. One model for the superficial layer (J. Caubet)*

Introducing a surface treatment as nitro-carburized process with plasma (ionic) nitro-carburized, the wear resistance increases and the resistance of corrosion increase too.

The diffusion process and the interaction of the nitrogen and carbon with the basic material lead to structural constituents whose nature determines a major hardness of the nitro-carburized layer.

Plasma nitriding/nitro-carburizing modify the strain limit, and the fatigue strength of the metals being treated.

For instance, mechanical properties of austenitic stainless steel like wear process can be significantly reduced and the hardness of tool steels can be double on the surface [1-3, 5, 14, 15].

2. Experimental researches

For experiments it was used 38MoCrAl09 steel grade samples. The material considered in this study is a steel of standard quality known as SAE 4038.

The material was subjected to the plasma nitro-carburizing treatment regime, after thermo-magnetic treatment regimes. The classic treatment, without magnetic field applied, was considered too. It was necessary to consider the classic treatment regimes to make the balance-sheet between the classic regimes and the un-conventional regimes.

Wear tests are designed to estimate the material resistance. It was used an Amsler type machine, taking two sliding degrees at different contact pressures and testing time (see figure 3).

The tests were done to detect the evolution of the superficial layer through different tests. It was established the influence of the tribological factors (operating parameters) on the superficial layers.

The chemical analysis obtained by atomic absorption primarily revealed a basic composition presented in Table 1. The steel analyzed reach a max score 4.5 from inclusions and a fine grain (score 8-9).

Table 2 presents the standard mechanical characteristics of the steel 38MoCrAl09 (SAE 4038) [2, 4], corresponding to The Society of Automotive Engineers (SAE) and The American Iron and Steel Institute (AISI).

Table 1. *Chemical composition of the materials* [6, 8]

Steel grade	C	Mn	Si	P	S	Cr	Cu	Mo	Al
	[%]								
38MoCrAl09	0.38	0.50	0.25	0.026	0.020	1.38	0.058	0.17	1.18

Table 2. *Mechanical characteristics of the steel* [6, 8]

Steel grade	$Rp_{0,2}$	R_m	A_5	Z	$KCU_{300/2}$	$KCU_{300/5}$	HB (State of annealing)
	[daN/mm^2]		[%]		[daJ/cm^2]		[daN/mm^2]
38MoCrAl09 AISI(SAE) 4038	85	100	15	50	9	6	229

Were applied the following treatment regimes:

a) t1 = martensitic hardening process at 920 °C and high recovery at 620 °C → classic treatment (Magnetic field intensity is H =0 A/m);

b) t3 = quenching (hardening) (920 °C) and high tempering (620 °C) applied to steel 38MoCrAl09, cooling being performed in alternative current (a.c.) magnetic field (H = 1300 A/m);

c) t4 = quenching (920 °C) and high tempering (620 °C), cooling being performed in d.c. (direct current) magnetic field (H = 1300 A/m).

The samples of the steel suffered a Martensitic hardening process at 920 °C and high recovery at 620°C (classic improvement treatment which was noted with "t1") followed by nitro-carburizing process at 530 °C. It was noted T12=T1' = t1 + ionic nitro-carburizing (plasma nitro-carburizing) at 530°C.

T13 = T3' = t3 + ionic nitro-carburizing (plasma nitro-carburizing) at 530 °C.

T14 = T4' = t4 + ionic nitro-carburizing (plasma nitro-carburizing) at 530 °C.

The treated samples were used for wear tests on Amsler machine (see figure 3) and the diffractometric analysis were performed by means of a Dron 3. It were determined the durability of the rollers and the surface structure evolution for different parameters of testing regimes.

The other factors which influence the wearing process are: the contact geometry of the friction couple (roller on roller, roller on ring etc.), the technological parameters (surface quality, heat treatments etc.) and the exploitation conditions (the thermal solicitation, for example).

Wear tests were carried out on an Amsler machine (see figure 3), using several couples of rollers (see figure 2), each couple corresponding to different sliding degrees ξ, defined as:

$$\xi = [(\nu_1-\nu_2) / \nu_1] \, 100 \, [\%] \quad (1)$$

where v_1 and v_2 are the peripheral velocities of the rollers in contact, each one having their specific peripheral velocity due to a particular combination of angular speeds (n_1, n_2) and diameter sizes (d_1, d_2).

Index 1 or 2 are added for the roller 1 or 2, respectively, both of the same tested friction couple. For instance, ξ = *10%* is obtained for a pair of tested rollers having d_1 = 40 mm, n_1 = 180 rpm and d_2 = 40 mm, n_2 = 162 rpm; ξ = *18%* is obtained for a pair of tested rollers having d_1 = 44 mm, n_1 = 180 rpm and d_2 = 40 mm, n_2 = 162 rpm; the level of the stress is corresponding to a specific load of 150 daN (as normal load is Q = 1.500 N) and the contact between roller is b = 10 mm [2, 4, 6, 8].

Magnetostriction may cause local plastic deformations, thus determining a cold hardening of the residual austenite. Furthermore, this implies higher material hardness and for many applications good endurance characteristics (see Figure 4).

Introducing a thermo-chemical treatment as nitro-carburizing process with plasma (ionic nitro-carburizing), the wear resistance increase and the resistance of corrosion, increase too.

Fig. 2. *Couples of rollers corresponding to different sliding degrees* ξ [6, 8]

In figure 3 was presented the Amsler machine for wear tests.

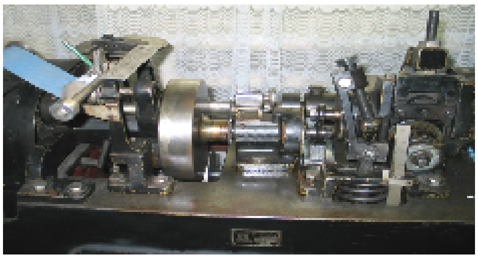

Fig. 3. *Wear tests were carried out on an Amsler machine* [6, 8]

3. Experimental results

In figure 4, was presented the evolution of the hardness number function by the magnetic field regimes applied. The specific regime for optimal hardness was considered the un-conventional treatment.

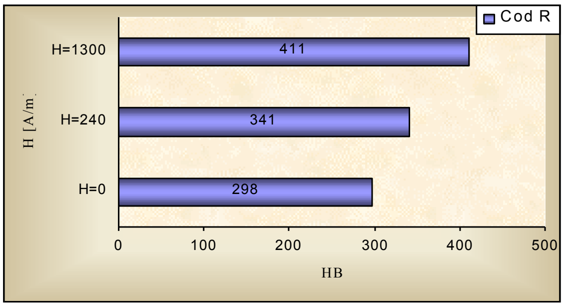

Fig. 4. *The influence of the magnetic field regimes on the hardness value, for code R samples (38MoCrAl09)* [6, 8]

Plasma nitro-carburized layers had a different evolution during wear process.

In table 3 are presented: characteristics, symbols, mathematical relations, which were used during the study of the superficial layers. It were tested the tribological evolution corresponding to wear process (damp wear case).

Using an Amsler machine, it were obtained the following results:

Table 3. *Characteristics, symbols, mathematical relations used during the study of superficial layers tribological evolution [2, 13]*

Characteristics	Symbol	u.m.	Relations
The diameters of the rollers	d_1, d_2	*Mm*	-
The width of the rollers (dimension of the contact)	*B*	*Mm*	-
Longitudinal Elasticity Module (the equivalent size)	*E*	*MPa (N/mm^2)*	$E = 2E_1E_2 / (E_1 + E_2)$
Speed of the rollers	n_1, n_2	*Rot./min.*	-
Specific glide	ξ	*%*	$\xi = 2 (1 - k\, d_2 / d_1) / (1 + k\, d_2/d_1)\ 100\%$
Task loading (the force applied)	Q_i	*N (daN)*	-
The radius of curvature equivalent	*P*	-	$\rho = d_1 d_2 \ / 2(d_1+d_2)$
Hertsiana maximum pressure	p_m	-	$P_m = 0.418\ (QE / b\rho)^{-2}$
Testing time	*T*	*s*	-
Moment of friction	M_f	*N mm*	*Will be measured*
Coefficient of friction	*M*	-	$\mu = 2M_f / d_1 Q$
Length of friction	L_f	*mm*	$L_f = \pi d_1 n_1 t /60$
The used layer depth	U_h	*mm*	*Will be measured*
The wear strenght (intensity of the wear)	I_u	-	$I_u = U_h / L_f$
Wear class		-	*See table 4*

In Figure 5, was presented the influence of the thermo-magnetic treatment regimes applied before of the plasma nitro-carburizing on the used layer depth evolution (Uh), during wear tests, for task loading Q = 150 daN. In Figure 6 was presented the influence of thermo-magnetic treatment regimes applied before of the plasma nitro-carburizing on the mass loss evolution, during wear tests, for task loading Q=150 daN (ξ = 10%) (conducting roller).

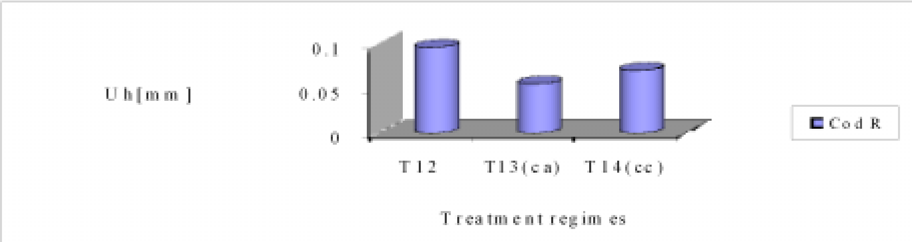

Fig. 5. *The influence of the un-conventional treatment on the used layer depth (Uh), during the wear tests (Q= 150 daN)*

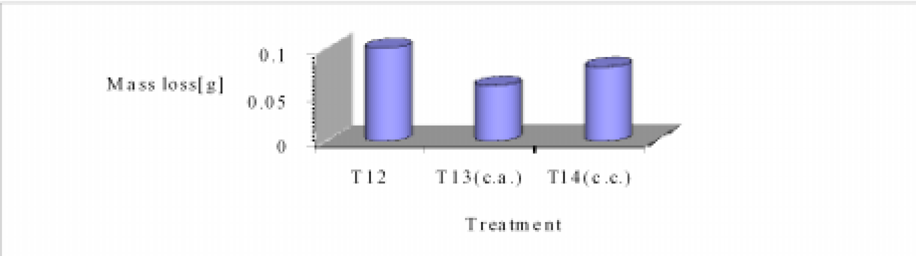

Fig. 6. *The influence of the un-conventional treatment on the Mass loss [Δm] evolution, during the wear process*

The cumulated metal weight loss represented by the value of *Δm* was evaluated using the following expression:

$$\Delta mi = (mi - 1 - mi) + \Delta mi - 1 \qquad (2)$$

where *Δmi* characterizes the wear which results from the contact between the rollers in contact. Wear tests are carried out on a basis of 60 min. duration, three times.

In Figures 7, 8, 9 are presented the superficial layers un-conventional treated, before the wear tests [6, 8, 12].

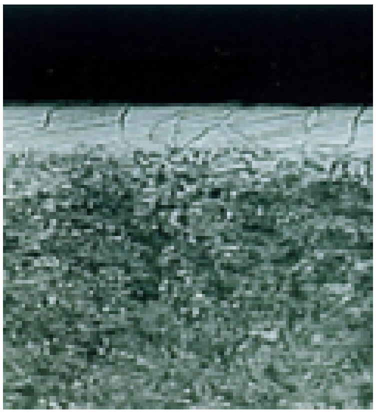

Fig. *7. Superficial layer thickness before wear tests, in the case of T12 treatment regime (x100). Nital attack 2%*

Fig. 8*. Superficial layer thickness before wear tests, for of T13' treatment regime (x100) (with a.c. magnetic field regime)*

Fig. 9. *Superficial layer thickness before wear tests, for T14 treatment regime (x100) (with d.c. magnetic field regime)*

4. Conclusions

The positive influence of the thermo-magnetic treatment on the surface layer treated thermo-chemically resulted in a higher hardness [4].

The wear resistance increase and the depth of the used layer decrease [5, 7] by approx. 50%. In the case of alternative current (a.c.) or direct continuous (d.c.) magnetic field applied to the steels (T13, T14), it were observed a higher initial quantity of martensite and a higher quantity of carbo-nitrurs, comparing with the classic treatment.

During the wear process, the martensite quantity increase and the carburs quantity decrease very rapidly. Mass loss (*Δmi)* had a maximum value in the classic treatment case and it had a minimum value in the case of a.c. magnetic field applied.

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