

## **EXPERIMENTAL RESEARCHES REGARDING THE POSSIBILITY TO INCREASE THE DURABILITY OF A CRMO ALLOYED STEEL SUBJECTED TO SOME NON-CONVENTIONAL TREATMENTS APPLIED IN MAGNETIC FIELD**

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### **Abstract**

In the last 20 years, the technical progress made it possible the use of very hard materials in several fields like manufacturing parts for the car industry, the railroad coaches, the nuclear power, the aeronautics and the mechanical industries.

In this paper, it was studied the evolution of the superficial layer subjected to a non-conventional treated steel, during the wear tests. The material was subjected to the thermo-chemical treatment (nitro-carburized treatment in plasma, or ion nitriding, or laser nitriding treatment) applied after thermo-magnetic treatment regimes.

The structural 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.

**Keywords:** Durability, thermo-magnetic treatments, thermo-chemical treatment, wear process.

### **1. INTRODUCTION**

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

Introducing a surface treatment as ion nitro-carburizing process or ion nitriding, or laser nitriding process, the wear resistance increases and the resistance of corrosion increases too.

For example, 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. The process of Ion nitriding or nitro-carburizing modify the grain limit and the resistance of materials treated.

For instance, the mechanical properties of the steel -as the wear process- can be significantly improved and the hardness of the tool steels can be double on the surface [1, 2, 3, 5, 14,15].

Before applying a superficial treatment, it is necessary to subject the steel grade to a basic treatment. During this basic treatment (the improved treatment) it is necessary to apply a magnetic field (A.C. or D.C.). Finally, results a thermo-magnetic treatment (different regimes) applied before thermo-chemical treatments.

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

If a magnetic field overlapping on the heat treatment, determine the modify of the structure because the energy of the magnetic field interferes in the global energy balance of the solid stage transformation. This magnetic field changes the transformation mechanisms and kinetics, resulting the thermo-magnetic treatment. In the end, it can obtained the change of mechanical properties and the change of the structure for this material. Adding a surface treatment (for example, a thermo-chemical treatment), determine the increase of the wear resistance and the corrosion resistance. [1].



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

In this paper, it was made the balance-sheet looking at the advantages/disadvantages between the classic improvement treatment and non-conventional treatment regimes. We considered the results obtained applying the thermo-magnetic treatment regimes, considering the different regimes of the magnetic field (d.c. and a.c.)

## 2. EXPERIMENTAL RESEARCHES

For the experimental program were considered the samples from AISI (SAE) 4038 steel grade. The chemical composition of this material was presented in table1.

The material was subjected to the plasma nitro-carburizing treatment process, or ion nitriding, or laser nitriding process, after thermo-magnetic treatment regimes.

It was necessary to be applied the classic treatment regimes because it is important to make the balance-sheet between the classic treatment regimes and the non-conventional treatment regimes.

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

Steel grade	C (%)	Mn (%)	Si (%)	P (%)	S (%)	Cr (%)	Cu (%)	Mo (%)	Al (%)
AISI(SAE)4038	0.38	0.50	0.25	0.026	0.020	1.38	0.058	0.17	1.18

The tests of wear process are designed to estimate the material resistance. It was used an Amsler type machine, taking two degrees of sliding, at different contact pressures and testing in time (see Figure 2).

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)

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

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

Steel grade	R <sub>p0.2</sub>	R <sub>m</sub>	A <sub>5</sub>	Z	KCU <sub>300/2</sub>	KCU <sub>300/5</sub>	HB (State of annealing)
	[daN/mm <sup>2</sup> ]		[%]		[daJ/cm <sup>2</sup> ]		[daN/mm <sup>2</sup> ]
AISI(SAE) 4038	85	100	15	50	9	6	229

It 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, 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;

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, or ion nitriding, or laser nitriding.

It were noted:

T1= t1+ ion nitriding (530°C); T2= t3+ ion nitriding (530°C); T3= t4+ ion nitriding (530°C);;

T12= T1' = t1 + ion nitro-carburizing (plasma nitro-carburizing) at 530°C.

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

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

T5' = t1+ laser nitriding; T7' = t3+ laser nitriding; T8' = t4+ laser nitriding.

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).

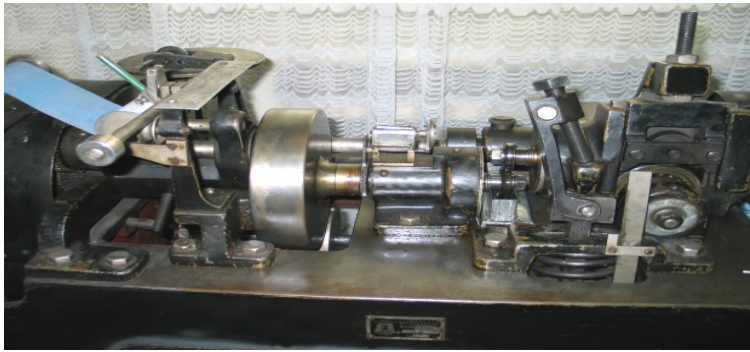
Wear tests were carried out on an Amsler machine (see figure 2), using several couples of rollers (see figure 3), each couple corresponding to different sliding degrees  $\xi$ , defined as:

$$\xi = [ (v_1 - v_2) / v_1 ] 100 [\%], \quad (1)$$

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,  $\xi = 10\%$  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;  $\xi = 18\%$  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 oscillations and local plastic deformations. Thus, magnetostriction determine a cold hardening of the residual austenite. Furthermore, this implies higher material hardness and for many applications -good endurance characteristics (see figure 4).



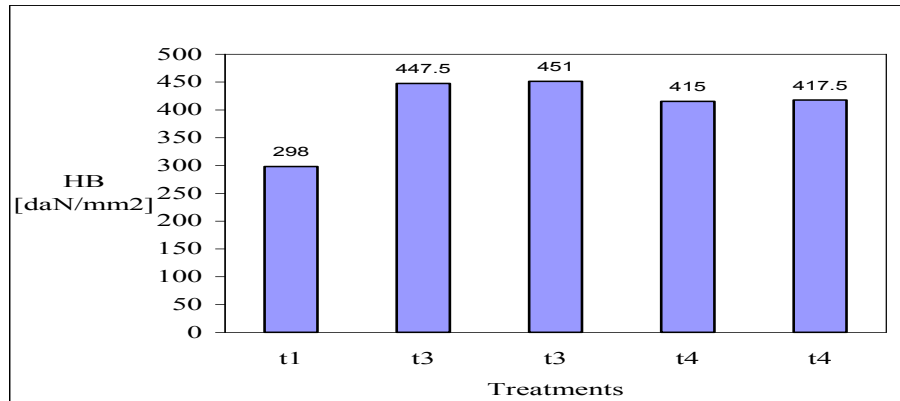
**Fig.2.** Wear tests were carried out on an Amsler machine [6,8/



**Fig.3.** Couples of rollers corresponding to different sliding degrees  $\xi$  [6,8]

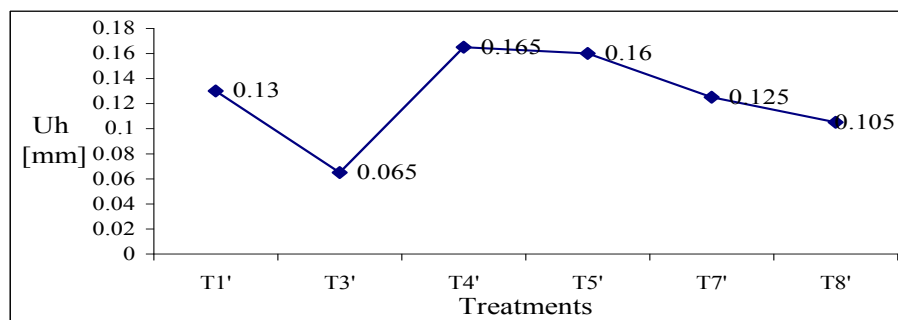
### 3. EXPERIMENTAL RESULTS

In figure 4, was represented the variation of the hardness corresponding with each treatment applied. The magnetic field applied influences the hardness of the steel.



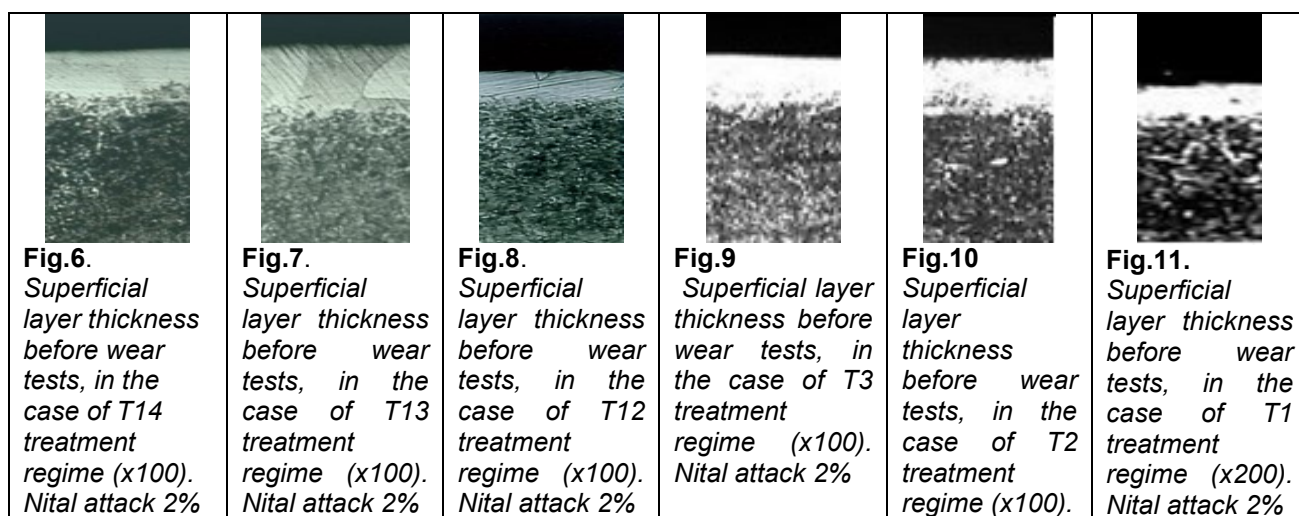
**Fig.4.** The influence of the magnetic field applied on the hardness value [6,8]

In figure 6, was presented the influence of the thermo-magnetic treatment on the worn-out layer depth, after 3 hours of wear tests,  $\xi=20\%$  and  $Q=150$  daN. The thermo-magnetic treatment regimes were applied before thermo-chemical treatment regimes.

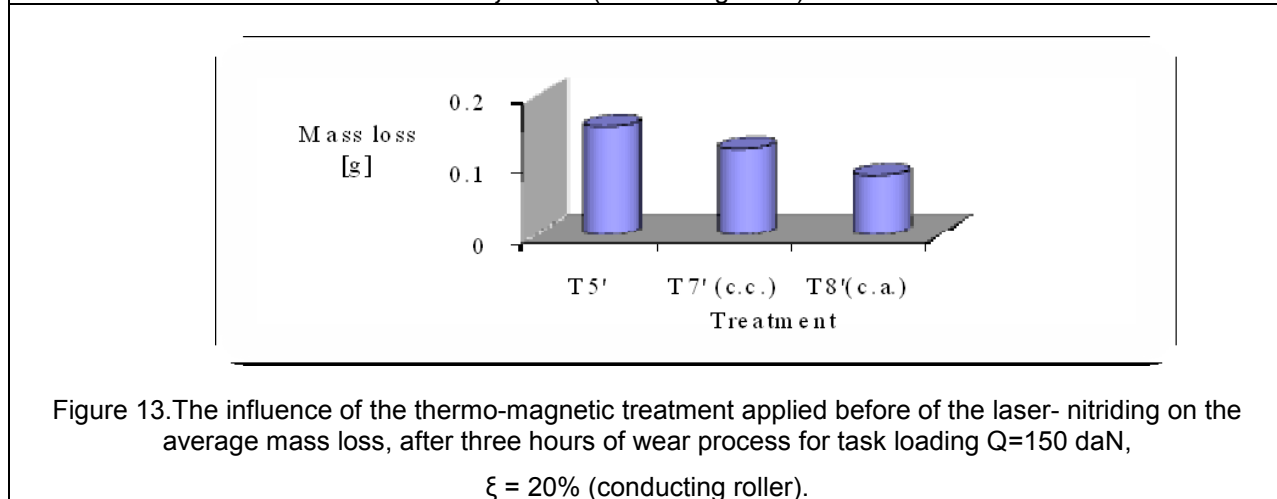
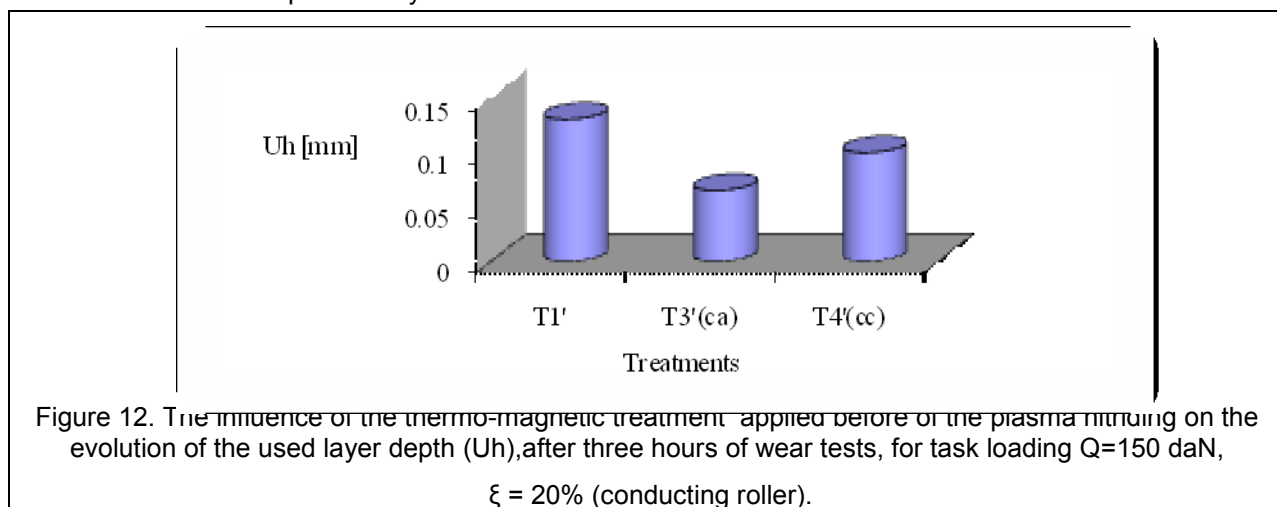


**Fig.5.** The influence of the magnetic field on the worn-out layer depth, after 3 hours of wear tests,  $\xi=20\%$  and  $Q=150$  daN, for AISI 4038 steel grade (ion nitrided:  $T1'$ ,  $T3'$ ,  $T4'$  or, laser nitrided:  $T5'$ ,  $T7'$ ,  $T8'$ , treatments) [3,11]

The microstructures (figures:7,8,9,...,11) achieved with thermo-magnetic treatment and plasma nitro-carburizing treatment show that the thickness of the thermo-chemical treated surface layer is higher when applying the thermo-magnetic treatment [6,8,14].



It was obtained a higher diffusion for thermo-chemical treatments applied after thermo-magnetic treatments regimes [6,8,14]. Analyzing the microstructures before the wear tests, it can be observed that the influence of the magnetic field applied modify the depth (thickness) of the white superficial layers. The thickness increases if we apply a thermo-magnetic treatment. Every stage of the heat treatment in magnetic field (AC current or DC current in magnetic field) influences the hardness, the durability of the superficial layers and the thickness of the superficial layers obtained after thermo-chemical treatments.



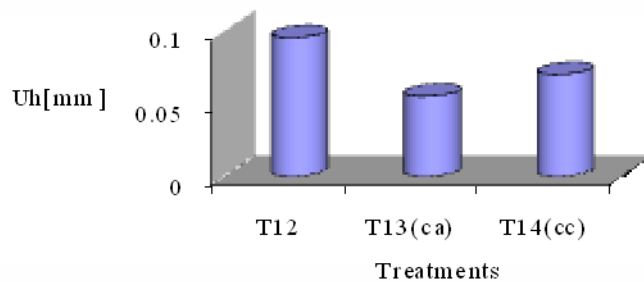


Figure 14. The influence of thermo-magnetic treatment applied before of the ion nitro-carburizing on the evolution of the used layer depth (Uh), after three hours of wear process for task loading

Q=150 daN,  $\xi = 10\%$

The cumulated metal weight loss represented by the value of  $\Delta m$  was evaluated using the following expression:

$$\Delta m_i = (m_{i-1} - m_i) + \Delta m_{i-1}, \quad (2)$$

where  $\Delta m_i$  characterizes the wear which results from the contact between the rollers in contact. Wear tests are carried out on a basis of 60 minutes duration, three times.

## CONCLUSION

The positive influence of the thermo-magnetic treatment on the surface layer thermo-chemically treated resulted in a higher hardness of the layer [4]. The used layer depth (Uh) during the wear process decrease if we apply a thermo-magnetic treatment (A.C. current in magnetic field) before the thermo-chemical treatment.

The microstructures (figures:7,8,9,...,11) achieved with thermo-magnetic treatment and thermo-chemical treatments show that the thickness of the thermo-chemical treated surface layer is higher when we apply the thermo-magnetic treatment (for example, A.C. current in magnetic field), vs. the conventional treatment case [6,14].

In conclusion, if will be applied a thermo-magnetic treatment (A.C. current in magnetic field) the wear resistance increases, the mass loss decreases and the depth of the wear in layer [5,7] decreases by approx. 40%. In a first stage, the samples were analyzed after applying the thermo-magnetic treatment and, in the second stage, the samples were analyzed after the thermo-chemical treatment regimes applied.

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