Wear resistance of heat treatable steels, surface hardened with concentrated energy sources

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Carbon and alloyed heat treatable steels have been subjected to some surface treatments using the laser radiation; the surface treatment was preceded by the improvement one. The attempts to wear effectuated on special samples have revealed the different behavior depending on the steel quality and the applied heat treatment.

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1. General considerations

The wear, among the fatigue and corrosion are three problems most common found in industry. Representing the destruction process of the surface parts, in the industrial and private activity, wear even if it isn't always severe, it may slow down efficaciousness [1].This process occurs in the mechanical interaction of the considered part with another solid or a fluid medium with solid particles in suspension. The area of real contact is very important in terms of influence on wear. Thus, at the mechanical interaction between two smooth surfaces there is a maximum contact pressure which is lower than in the case of two rough surfaces [2]. If the interaction takes place as a force of friction, the wear is defined as "wear by friction" [3,10,11]. The wear size can be expressed using several sizes as :

- Linear wear when determining the worn layer thickness;
- The volumetric wear when determining the amount of material removed by friction;
- The gravimetric wear which is expressed through the mass of material lost by friction.

The wear process can be characterized also by other indicators, such as:

- Wear speed

$$u = \frac{v}{l}$$

where:
V - worn material volume; l - wear length.

The wear speed is proportional to the normal pressing force:

$$u = f(F_n)$$

- The linear wear intensity is given by the following relation:

$$I_{lu} = \frac{\Delta H}{L_f} = \frac{\Delta H}{n \cdot L_1} \left[\frac{\mu m}{km}\right] \text{ or } [-], \quad \text{dimensionless}$$

Where : ΔH – total thickness of worn layer;
L_1 – friction length at one cycle;
n – number of cycles.

The inverted linear wear intensity is called "wear resistance":

$$R_u = \frac{1}{I_{lu}} = \frac{L}{\Delta H}[-]$$

The gravimetric wear resistance

$$I_g = \frac{\Delta m}{L_f}\left[\frac{g}{km}\right]$$

In which Δm – the mass of material removed by wear.

The gravimetric wear intensity can be expressed as well by the ratio of the mass of material lost by wear and the test time:

$$' I_g^1 = \frac{\Delta m}{\tau}\left[\frac{g}{\min}\right]$$

Wear sensitivity:

$$\gamma = \frac{\Delta v}{F_f L_f}\left[\frac{mm^2}{N \cdot m}\right]$$

Wear resistance can be measured to a variety of test methods. [4][8]. Wear tests are made to determine certain types of relative movement, which can frequently lead to distinct mechanisms of wear in dissimilar materials, or at varied loads or speeds [9,12]. Pin on disc is characterized by continuous contact between the two samples in tribological contact. Furthermore, in case of abrasion test a specimen is pressed under o certain normal loads against a rotating abrasive wheel [5,6].

2. Experimental attempts

The tribometric experimental tests were performed on some specimens made of four heat treatable steels, two unallied EN 1.0503 and EN 1.0601 and respectively two allied EN 1.7035 and EN 1.6582. The special shaped specimens (fig. 1) were subjected to the heat treatment, namely improvement (hardening + high tempering) and followed by superficial hardening with laser. (H + HT + L)

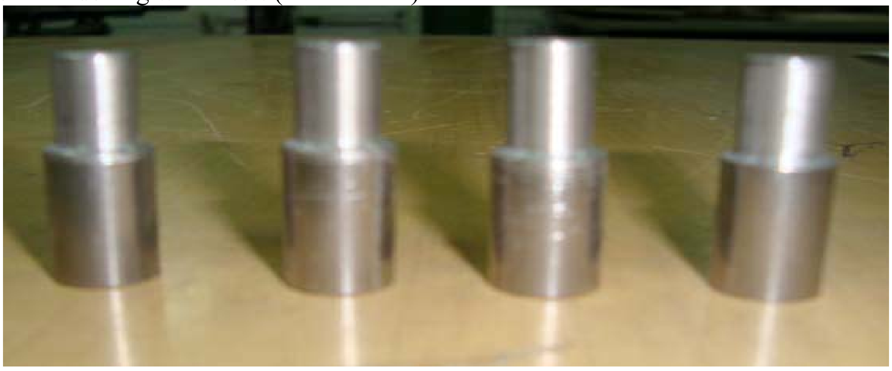
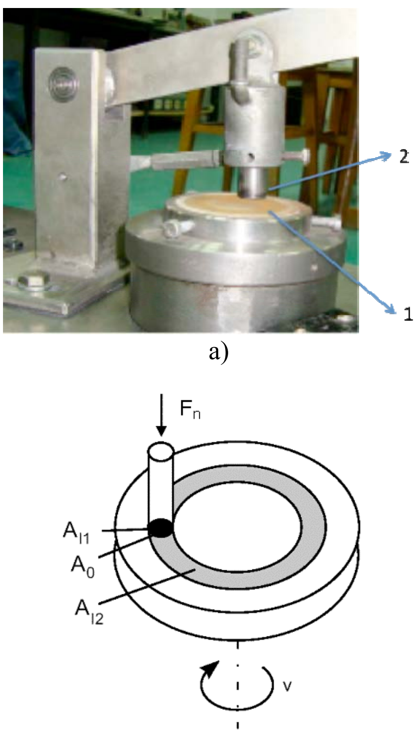


Fig.1. Samples for wear attempts

Table 1. The hardness values for samples used for tribological tests.

Steel type	alphanumeric symbolization	1C45	1C60	41Cr4	34CrNiMo6
	numerical symbolization	1.0503	1.0601	1.7305	1.6582
Hardness [HRC]	H+HT [HRC]	33,8	38,1	37,6	41,8
	H+HT+L [$HV_{0,3}$]	676	118	739	723

The tribometer used in trials allows the rotation around a vertical axis of a cylindrical hardened speed steel plaque (which represents the standard piece), on which is perpendicularly pressed with a constant force, the specimen tested. Fig. 2 illustrates the operation of the device.



b)

Fig. 2. Tribometer a) Photo image, b) Functional scheme: 1. Speed steel plaque, 2. Sample;

In all the performed tests were kept the same working conditions, namely: F_n = 48N; n = 600 rot/min; $\frac{D_m}{2}$=5mm.

The work methodology for wear determining was the following:

- Fixing the friction half coupling type plaque on the rotative plaque of the machine, this was realized using screws;
- Setting the friction half coupling type pivot (sample) into the place and ensuring with a fixing screw, the sample was previously weighed;
- Adjusting the two half coupling so as to ensure the parallelism between the plaque and the pivot axis and respectively between the two friction surfaces;
- Fixing the lever in a position to provide the wanted value of the $\frac{D}{2}$ parameter;
- Positioning the thaler on the lever and chosing the weights in order to obtain the normal pressing force *Fn*;
- Adjusting the plaque speed using a potentiometer it is measured the effective plaque speed with a tachometer;
- It is measured the operating time $\Delta\tau$;
- The device is stoped; the sample is weighed using an analytical balance;

It repeats determinations for the next time interval $\Delta\tau$.

3. Experimental results

The measurements were effectuated on samples which were subjected to wear attempts and treated by different methods showed the results presented in the tables below.

Table 2.The mass loss during the wear tests by friction (H+HT)

Steel type	m_i-m_1 [mg]	m_i-m_2 [mg]	m_i-m_3 [mg]	m_i-m_4 [mg]	m_i-m_5 [mg]
1.0503	3,2	5,9	7,9	9,5	11,4
1.0601	3,6	5,5	7,6	10,0	11,2
1.7305	2,2	4,5	6,0	7,3	8,4
1.6582	3,4	6,3	8,6	10,4	12,5

Table 3. The mass loss during the wear tests by friction (H+HT+L)

Steel type	m_i-m_1 [mg]	m_i-m_2 [mg]	m_i-m_3 [mg]	m_i-m_4 [mg]	m_i-m_5 [mg]
1.0503	2,1	3,8	4,3	4,6	4,8
1.0601	1,2	2,6	3,2	3,6	3,9
1.7305	1,8	2,3	2,6	3,3	3,5
1.6582	1,4	2,2	2,7	3,6	3,8

The graphical representation of the wear evolution during the tribological attempts is shown in the figures below:

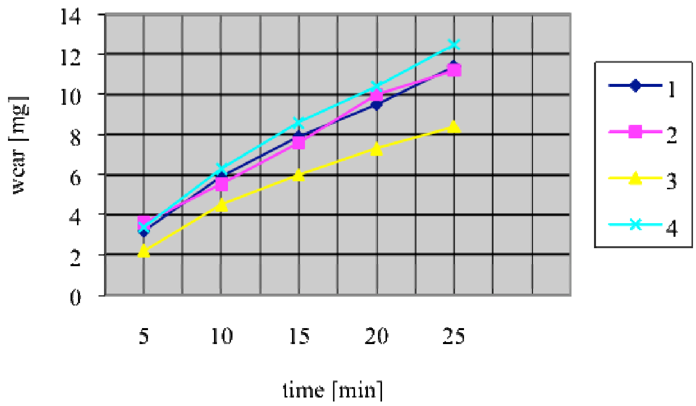


Fig3. The evolution of mass loss at the wear attempt to steels in an improved condition (H + HT): 1 - 1.0503 steel, 2 - 1.0601 steel, 3 - 1.7305 steel, 4 - 1.6582 steel.

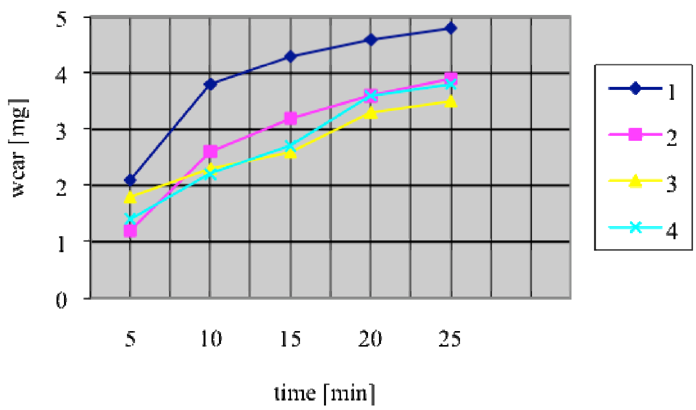


Fig. 4.The evolution of mass loss at the wear attempt to steels improved and superficial hardened with laser (H + HT + L): 1 -1.0503 steel, 2 - 1.0601 steel, 3 - 1.7305 steel, 4 -1.6582 steel.

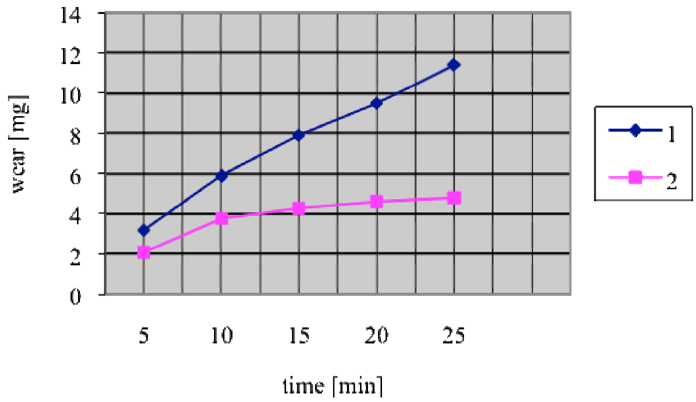


Fig. 5.The evolution of mass loss at the wear attempt to the 1.0503 steel: 1 - H+ HT, 2 - H + HT + L.

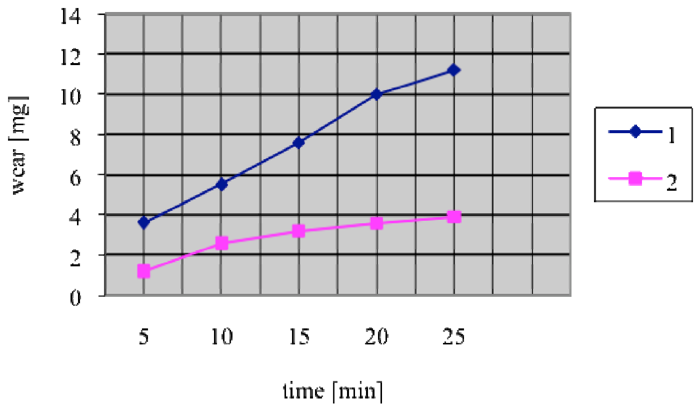


Fig. 6. The evolution of mass loss at the wear attempt to the 1.0601 steel: 1 - H + HT; 2 -H +HT + L.

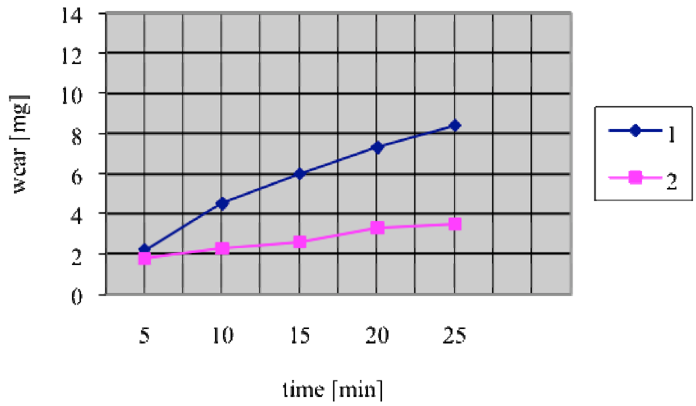


Fig. 7. The evolution of mass loss at the wear attempt to the 1.7305 steel: 1 - H + HT; 2 - H + HT + L..

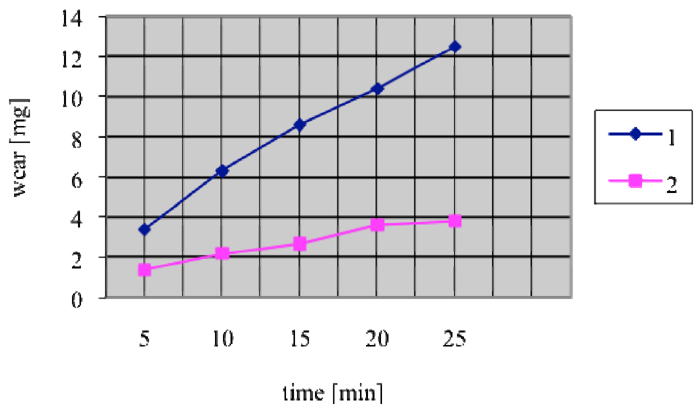


Fig. 8. The evolution of mass loss at the wear attempt to the 1.6582 steel: 1 - H + HT, 2 - H + HT + L.

4. Discussion

Hardness values after each heat treatment studied, there are presented in table 1. There were four heat treatable steels, two unallied 1.0503 steel and 1.0601 steel and respectively two allied 1.7035 steel and 1.6582 steel, of which were done specimens subjected to experimental attempts [7]. Thus, there can be seen that hardness values increased after heat treatment with laser radiation (H+HT+L) regardless of the steel studied. In tables 2 and 3 there are observed the mass loss during the wear test by friction of specimens subject to different types of heat treatment. The values obtained for the mass loss during the wear test specimens subjected to heat treatment to improvement, respectively hardening that high tempering (H+HT) are shown in Table 2. Following results it can be observed a very good behavior of 17305 steel compared to the other steel studied. In table 3 are revealed values for mass loss during the wear test specimens subjected to laser surface hardening that were previously subjected to heat treatment to improvement (H+HT+L). In the analysis results it can be seen a considerable increase in wear resistance of steels tested for wear.

Graphical representation of the evolution of wear during tribological tests in figure 3 indicates the answer given by the studied steels that were initially treated with hardened and tempered high (H+HT), namely heat thermal improvement . It can be observed a high degree of wear at 1.6582 steel . After heat treatment of laser surface hardening of specimens subjected to wear, which previously have been improved (H+HT+L), as shown in Fig. 4, we could notice a diminished wear evolution. To emphasize the wear resistance of 1.0503 steel subjected to surface hardening with laser radiation, in Fig. 5 is shown the graphically evolution of mass loss. Also for 1.0601 steel the evolution of mass loss are reprezented in Fig. 6. In the graphical representation of mass loss from Fig. 7 regarding1.7305 steel, it has been noted with (H + HT) heat treatment to improvement, and (H + HT + L) is in addition with heat treatment of laser radiation. Fig. 8 presented graphically the evolution of mass loss of 1.6582 steel. Experimental tests highlight the influence of heat treatment with laser radiation on the wear resistance of steels studied.

5. Conclusions

From the above the following conclusions are highlighted:

- The steels wear resistance is influenced by many factors, most important being the chemical composition and the applied thermic treatment;

- The wear behavior considerably improves by the superficial heat treatments; they increase the exterior layers strength and cause the formation of internal compressive tensions, with are favorable to the process.

It is recommended using concentrated energy sources because of the economic efficiency and obtained technical performances.

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