INFLUENCE OF HEAT TREATMENTS WITH CONCETRATED ENERGY SOURCES ON THE ALLOY STEELS MECHANICAL PROPERTIES

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ABSTRACT: The results presented in this paper are part of a larger project that includes the study of the heat treatment influence with concentrated sources on the microstructure and mechanical properties, when this are applied to the alloyed steels X210Cr10 and HS 18-0-1. The numerous tests made, show that independently of the studied properties: microstructure, hardness and wear resistance, the heat treatments application with concentrated sources, lead to higher values of the studied properties in comparison with those obtained with the conventional treatments. For some properties, the values can increase up to 245% when are applied the heat treatment with concentrated sources, versus the classical heat treatment. The difference between the properties values obtained by heat treatment with laser and cathode beam not are very high, especially that for some properties the laser heat treatment provides better values but for other properties, those with cathode beam. The study shows that depending on the material, tools destination and of the property whose value is desired to be maximized, will be applied the adequate heat treatment with concentrated sources, more exactly with laser or cathode beam.
KEYWORDS: alloy steels, concentrated energy sources, heat treatment, mechanical properties

1. INTRODUCTION

The mechanical properties improving of the alloys by heat treatments is the changing results of the nature, shape, size and distribution of the structural metallographic constituents, because of phase transformations produced by the thermal action of the concentrated sources. Today, in the heat treatments domain are many trials to be obtained the better properties for materials. For the long tools with small diameters, a good work piece surface roughness can be achieved, provided the tooth passing frequency used in the milling process [1]. For the tool wear not only the hardness of the processed material has a vital role, but also the microstructure and thermal characteristics of the tool material (metallurgical powder) [2]. Under the action of the vibrations applied during welding, the material behaviour is better: the density of the material deposited increases, tensions and friction of the basic material go down [3]. The non conventional treatment demonstrated more improvement in the wear resistance and hardness compared with conventional heat treatment [4]. An example is as the transition zone between the substrate and the coating should possess enough ductility and toughness [5]. The quenching and partitioning novel treatment can be used to generate microstructure with martensite/austenite combination for giving attractive properties [6]. An advantage of induction-plasma hardening is the possibility of regulating over a wide range, the depth of the total hardened layer, as a result of high frequency quenching [7]. In the worldwide there are many attempts to improve the tools performance, using the unconventional processes. In the case of HSS, through cryogenic treatment the tool performances can be increased with 44%, in certain cutting conditions [8, 9]. The schematic diagram of the laser surface heating is shown in figure 1.

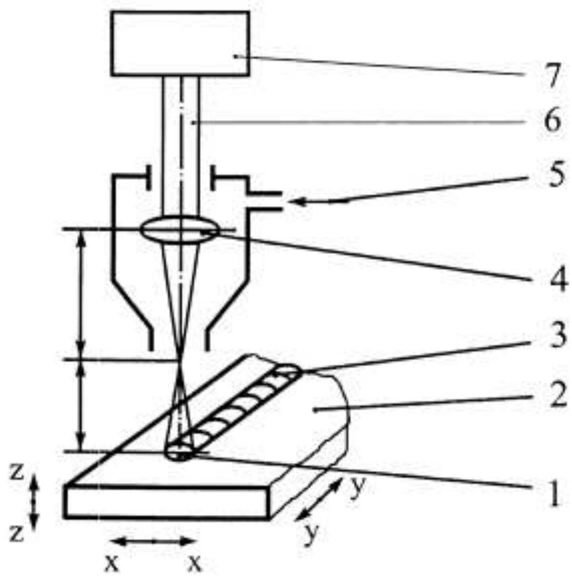

Figure 1. Scheme of laser heat treatment: 1 – spot laser, 2 – surface, 3 – treated zone, 4 – focusing system, 5 – inert gas, 6 – laser beam, 7 – laser generator

The heat treatments made with the help of concentrated sources of energy are based on phenomena of thermal origin. Each of these sources after it is produced must be transferred in a concentrated form (high energy on small surfaces) on surface that must heat. The using of the concentrated thermal energy sources in the surface heat treatments impose special restrictions, concerning the right selection of these, for as it do not produce the undesirable phase changes in the materials structure, in the affected areas. When applying the laser heat treatment, the heating temperature of the piece surface and the material penetration depth, can be modified by the beam power adjusting (focusing) and the piece speed adjusting, or the laser pulse duration. The heat-treated layer thickness is influenced by the thermal conductivity of the piece material. For heat treatments, usually is used the laser equipments with continuous emission, with CO, He and N_2 gases, but it can use the laser with impulses emission.

The heat treatment with cathode beam has some similitude with laser heat treatment, because it is used likewise a concentrated source, that provides both ultra fast heating and rapid cooling, without additional measures of the heated material volume. The application of the heat treatment with concentrated energy sources on cast irons, it established the properties improvement of these. The wear resistance in lubricant environment is maxim for heat treatment with cathode beam (cast iron with 220 MPa the fracture strength). For the cast iron with fracture strength of 400 MPa, the best results regarding wear resistance in lubricant environment are offered by heat treatments with laser [10]. The application of the heat treatment with concentrated sources of energy, on alloy steels is an area less explored by the researchers. The alloy steels are widely used reason for that exist many possibilities of their processing. The analysed steels are used mainly in the domain of plastic deformation tools (X210Cr12) or chip removing (cutting) process (HS 18-0-1). These applications often require more special properties such as surface high hardness and in some time high toughness, all these of many times on small surfaces as area. For these reasons, the behaviour study of the analysed steels when are applied the heat treatments with concentrated sources, may be a response to the previous presented requirements.

2. THEORETICAL CONSIDERATIONS

The pieces and tools making with high wear and thermal shock resistance has a more and more importance, as a result of continuous mechanization and automation of all industries, which permanent requires the products with high mechanical and technological characteristics. The tools wear resistance is provided by a high hardness of the surface, which can be obtained using high carbon steels. The study of the heat treatment influence with concentrated sources on the mechanical and technological properties was made on the X210Cr12 and HS 18-0-1 steel types. Table 1 shows chemical composition of studied steels.

Table 1. Chemical composition of the studied steels

Steel type	Chemical composition (average values in %)									
	C	Mn	Si	Cr	Ni	Mo	W	V	P	S
X210Cr12	1.97	0.37	0.30	12.3	0.33	-	-	-	-	-
HS 18-0-1	0.75	0.4	0.38	3.85	0.30	0.28	17.9	0.9	0.02	0.02

X210Cr12 steel makes part of the stainless steel category, having high toughness, reason for that is used in industry for making dies (moulds). The high alloy steels HS 18-0-1 for cutting tools are known as high-speed steels name, because this can work with high cutting speeds. The alloying of steel with tungsten increases the quenching (hardening) capacity. The wolfram-molybdenum high-speed steels can use for tools made by plastic deformation [11]. High temperature thermo-mechanical treatment (HTTMT) can be used for parting-off tools and other high-speed steel for simple geometrical shapes [12]. Figure 2 shows the correlation between the laser radiations power level, piece speed and depth of quenching [10].

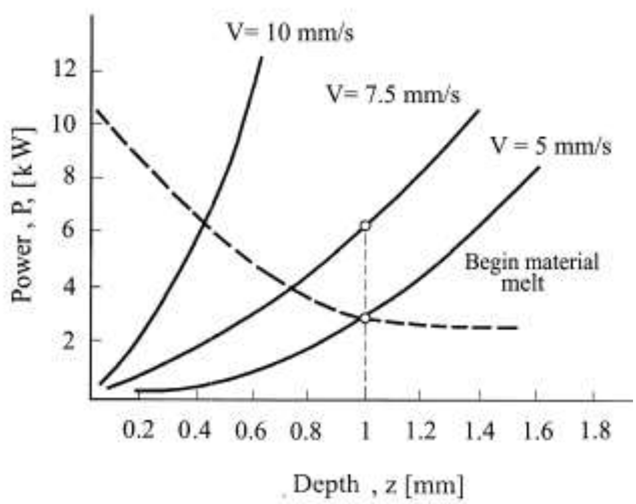

Figure 2. Influence of the laser radiation power and piece speed on the depth of quenching

The graph shows that for the obtaining great depths of heating are necessary a low laser power and a small piece speed. For the small depth of quenching, both the power and the piece speed must be great. As concerns the concentrated sources, have made more trials to establish the necessary parameters for the realization of the proposed heat treatments.

Following the effected tests, the heat treatments applied to the X210Cr12 steel samples (specimens), are made with the next parameters:

- alternative 1 (variant) – heating temperature was 960^{o} C, cooling was effected in oil, 10 minutes; quenching was fallowed by a tempering (annealing) at 480^{o} C, keeping for 2 hours and cooling in oil; the applied heat treatment determined the increase of the hardness because of the separation of the chromium carbide fine particles, of martensite and residual austenite;
- alternative 2 – heating with laser concentrated sources, with power density q=50 W/cm^2 for 6.5 10^{-3} s, with defocusing value Δf=4 m, sample speed 7 mm/s, the depth of quenching 0.3 mm and laser power 10kW;
- alternative 3 – heating with cathode beam, that have the acceleration voltage 10 kV, the action time of the concentrated source on surface 10^{-2} s, the depth of quenching 0.4 mm, the sample speed 7 mm/s, intensity 0.2 A, superficial flux q=40 W/cm^2 and source power 7 kW.

For the HS 18-0-1 steel, the applied heat treatment parameters were:

- alternative 1 – pre heating in two stages at 550^{o}C keeping 2 hours and to 860^{o} C respectively keeping 0.5 hour, followed by heating up to 1260^{o}C four 3 hours and oil cooling; the tempering was done in two stages at 560^{o} C four 2 hours, continued with nitrogen cooling;
- alternative 2 and 3 – have same parameters as the heat treatments applied to X210Cr12 steel.

It is noted that the parameters of the heat treatments applied to the two types of steels were identical. All the tests were made on the samples with cylindrical shape, having the 50 x 30 mm dimensions.

3. EXPERIMENTAL RESULTS

For the X210Cr12 steel after the applying of the 3 heat treatment alternatives was measured the obtained micro hardness. By the results processing, the micro hardness evolutions for the X210Cr12 steel are shown in figure 3. Following the evolution of X210Cr12 steel micro hardness, it is found that the curve profile is similar, but the higher values were obtained for the heat treatment with laser (alternative 2). For the sample, heat-treated with concentrated sources, micro hardness higher values are obtained for greater depth than of the samples treated by classical (conventional) method.

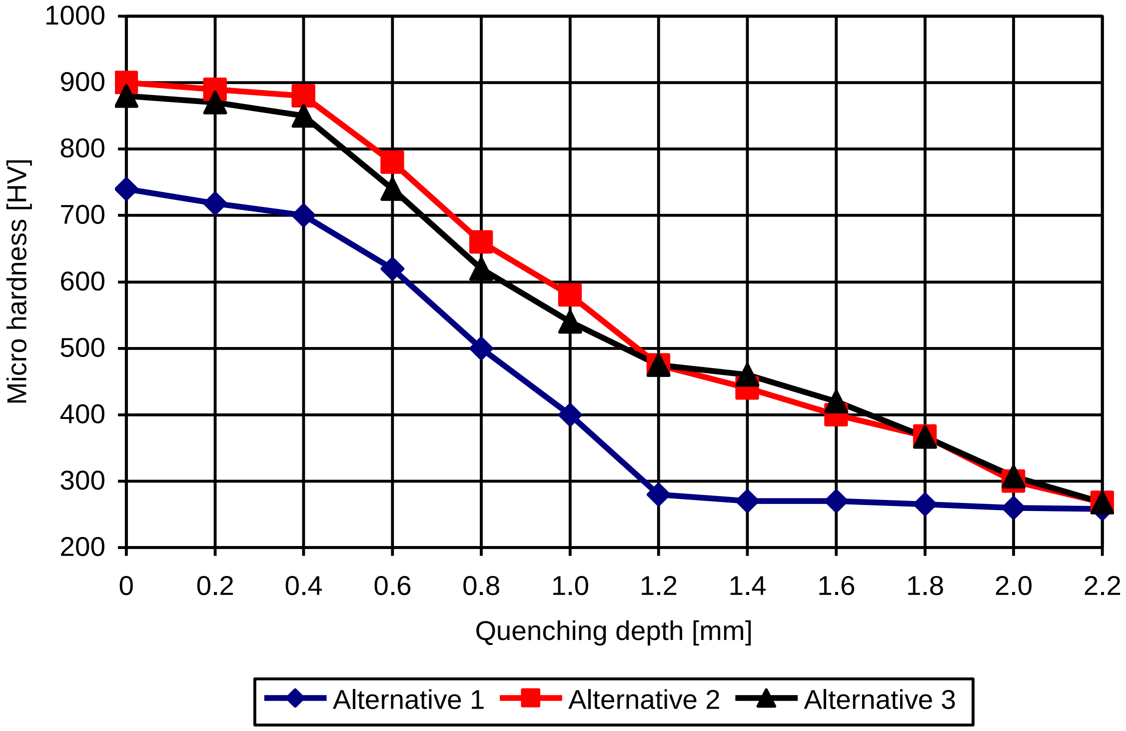

Figure 3. Influence of heat treatment alternatives on the X210Cr12 steel micro hardness

For the HS 18-0-1, the micro hardness values obtained by applying of the 3 heat treatment alternatives are shown in figure 4. For the high speed steel, the curves profile that shows the micro hardness evolution are similar for the 3 alternatives of the applied heat treatment, with the higher values for the heat treatment realized with cathode beam. For the heat treatment with concentrated sources are obtained micro hardness high values for greater depths than in the classical heat treatment case.

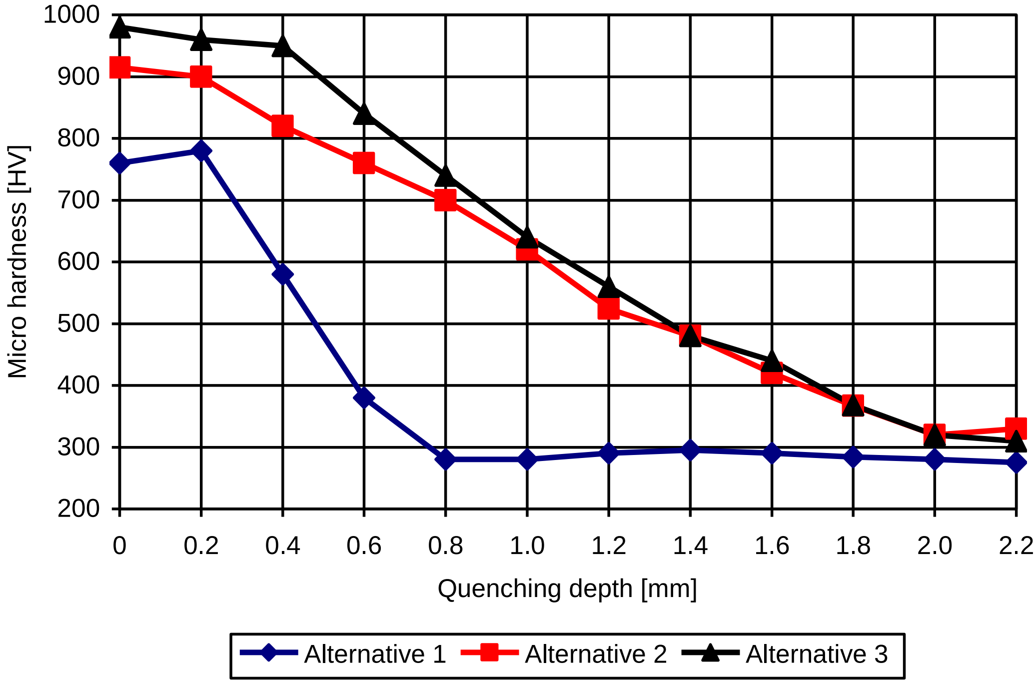

Figure 4. Influence of heat treatment alternatives on the HS 18-0-1 steel micro hardness

Figure 5 shows the evolution of the weight loss for the X210Cr12 steel when the trial has place in lubricant medium. The tribology emphasizes, that the friction process has large implications both in the energy consumption reducing and of the raw materials consumption. The wear is the process, but the abrasive wear its product (surfaces degradation, particles pulling out).

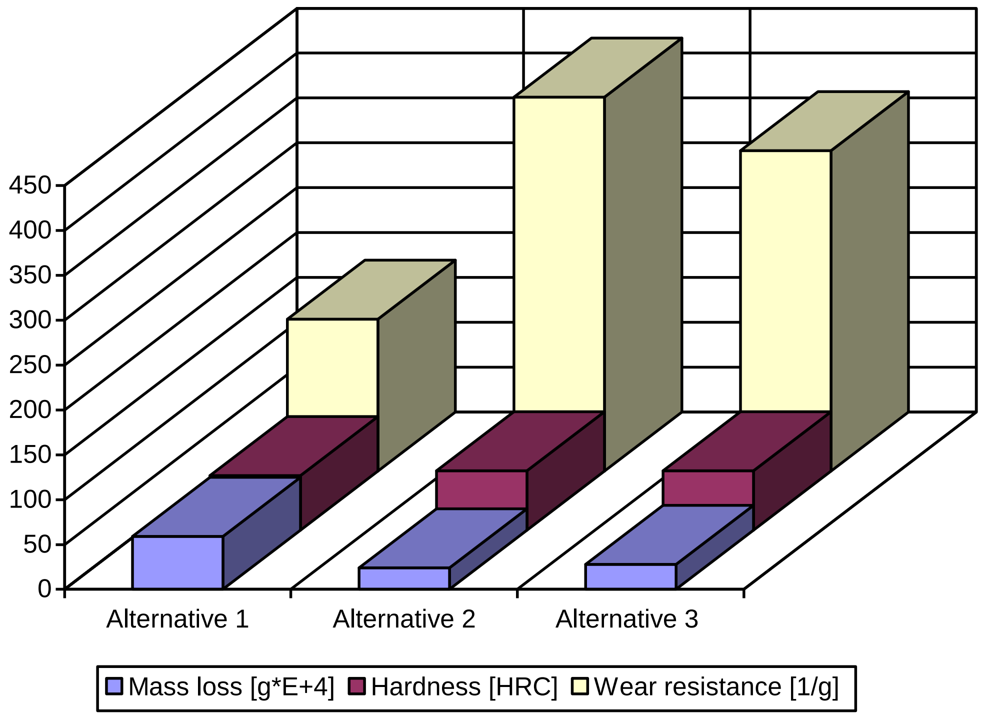

Figure 5. Heat treatment influence on X210Cr12 steel mechanical properties

The making of parts or tools with high wear resistance has determined as by applying the heat treatment with energy concentrated sources, to be analysed the wear behaviour of the respectively samples. After each test, for a better accuracy of the results, all the samples were cleaned in an ultrasonic bath of alcohol before weighing [13]. The wear behaviour was done by the gravimetric method, for this purpose, using a Sartorius analytical balance type. The samples for this test were of block type and for the best accuracy each sample was degreased with ultrasound, in carbon tetrachloride. The test speed was of 1750 rpm, but test force of 100 daN. The chemical composition of the tested materials and the heat treatment process parameters were previously presented and maintained during the wear behaviour tests. Figure 5 shows the evolution of the weight loss for the X210Cr12 steel when the trial has place in lubricant medium. Also figure shows that the wear resistance in the lubricant medium is different for those proposed 3 heat treatments alternatives. The maximum wear resistance are registered for laser heating source and the minimum value for the classical heat treatment. For the samples heat treated with cathode beam, the wear resistance is similar with that of laser heat treatment. Also the hardness evolution is in concordance with the wear resistance. In figure 6 is presented the friction coefficient evolution for analysed heat treatment alternatives.

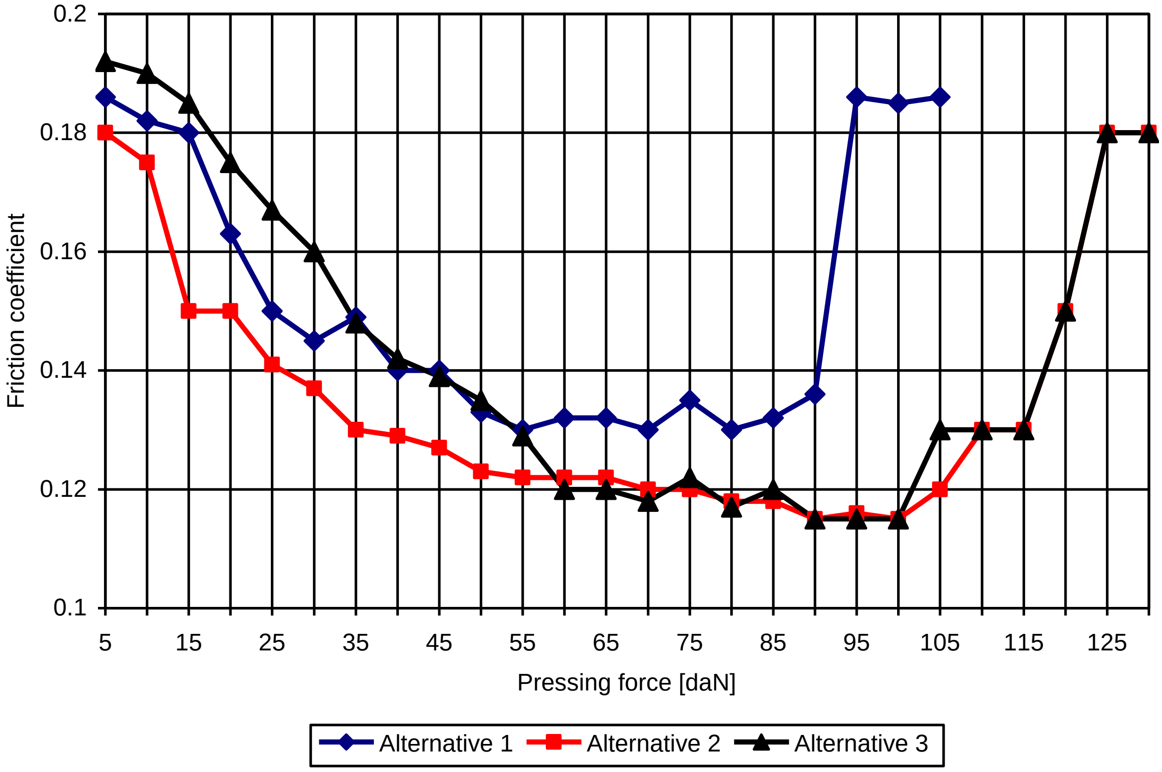

Figure 6. Friction coefficient evolution for X210Cr12 steel, function of applied heat treatment

Figure 6 reveals that the gripping for the classical heat treatment alternative is produced for the pressing force values of 90 daN, for the alternative 2, the value is of 115 daN, same with the alternative 3.

Figure 7 shows dependence in function of the trial duration for the all X210Cr12 heat treatment alternatives. The figure permits to deduct that the long time period of wear is installed (appeared) faster in the case of heat treatment with concentrated sources, comparative with the classical heat treatment. In same time, the mass loss is more reduced for the heat treatment with concentrated sources.

Also, the figure reveals that stable wear appears after 4.5 hours for the classical heat treatment, while at the alternative with concentrated sources after 3 hours, but the mass loss is more reduced for these alternatives. The mass loss when the stable wear appeared, in the case of classical heat treatment for the X210Cr12 steel is with 300% greater than alternatives of the heat treatment with concentrated sources.

The same types of tests were effectuated for the HS 18-0-1 steel. The tests permitted the establishment of the friction coefficient evolution for the analysed heat treatment alternatives. The test shows that gripping appears for the classical heat treatment at loads of 95 daN and at 105 daN for the heat treatment alternative with concentrated sources. High values of the wear resistance and low friction coefficient are recorded to the heat treatments with concentrated sources (see figure 8).

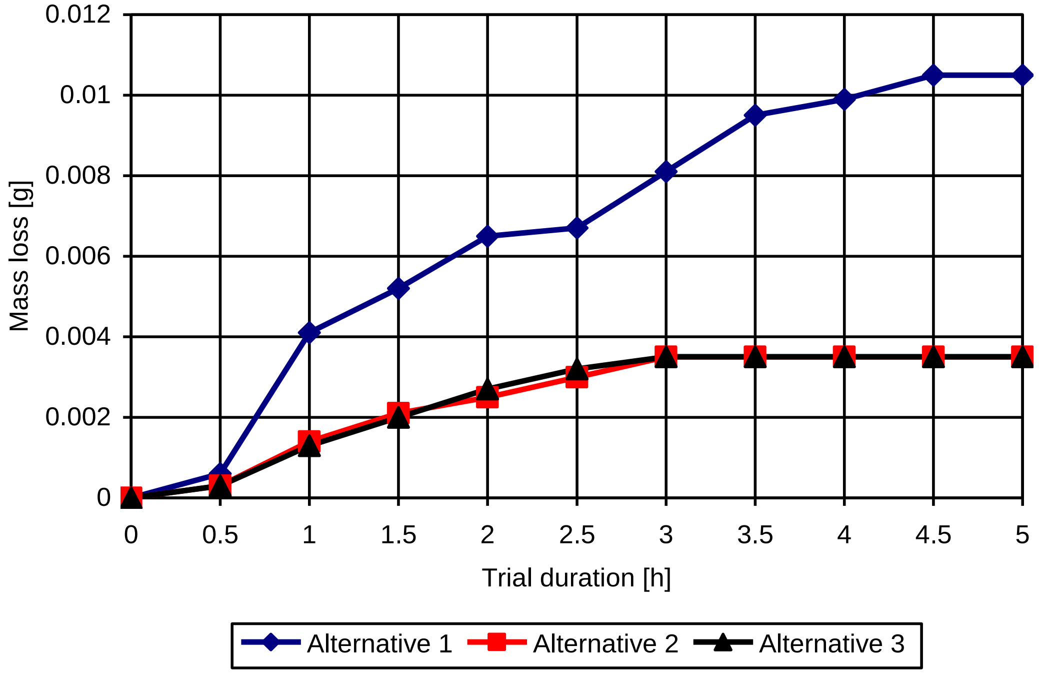

Figure 7. Heat treatment influence for X210Cr12 steel, in function of trial duration

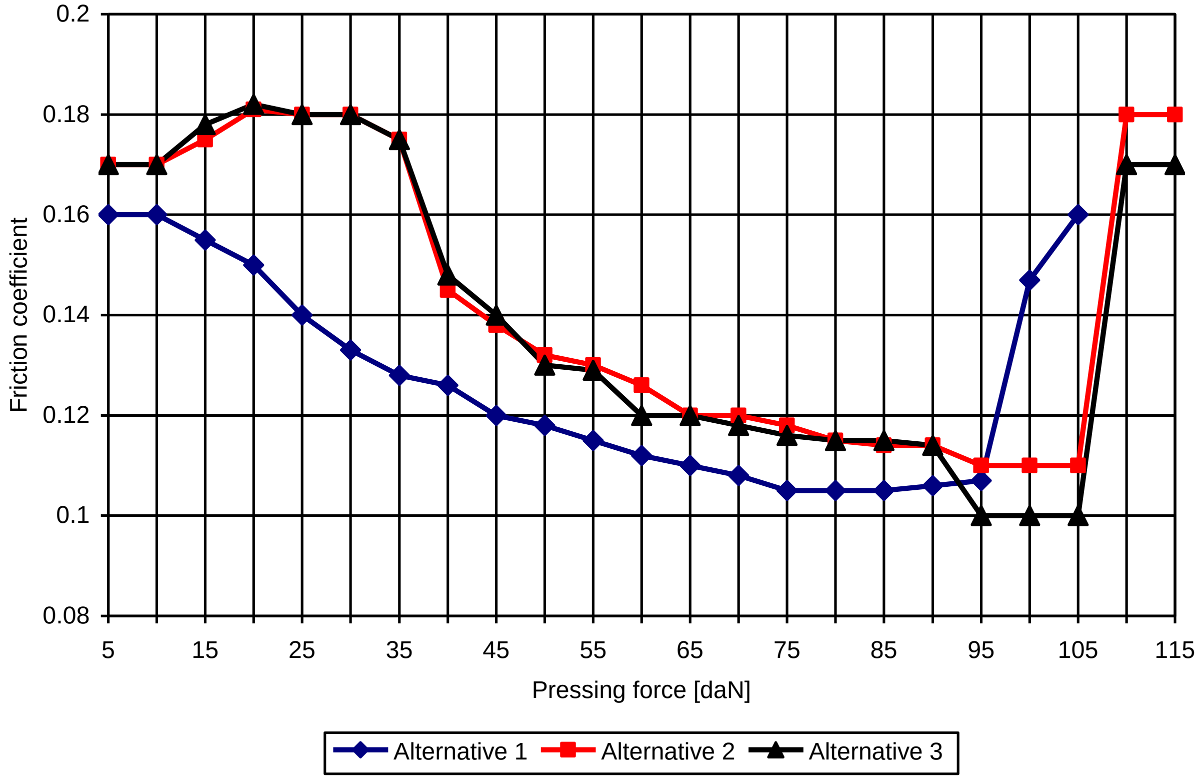

Figure 8. Friction coefficient evolution for HS 18-0-1, function of applied heat treatments

Figure 9 shows the wear trial results, in lubricant medium. The wear resistance in lubricant medium has maximum values for the heat treatment with cathode beam. For the heat treatment alternative with laser, wear resistance is lower, but higher than of the samples, treated with classical heat treatment. Also the mass loss in lubricant medium emphasizes (highlights) that high mass loss is recorded of by the samples classical heat treated.

Another test shows the mass loss, function of the trial duration. The tests reveal that stable wear appears after 5 hours for the classical heat treatment, while at the alternative with concentrated sources after 3 hours, but the mass loss is more reduced for these alternatives (see figure 10). The mass loss when the stable wear appeared, in the case of classical heat treatment for the HS 18-0-1 steel is with 296% greater than alternatives of the heat treatment with concentrated sources.

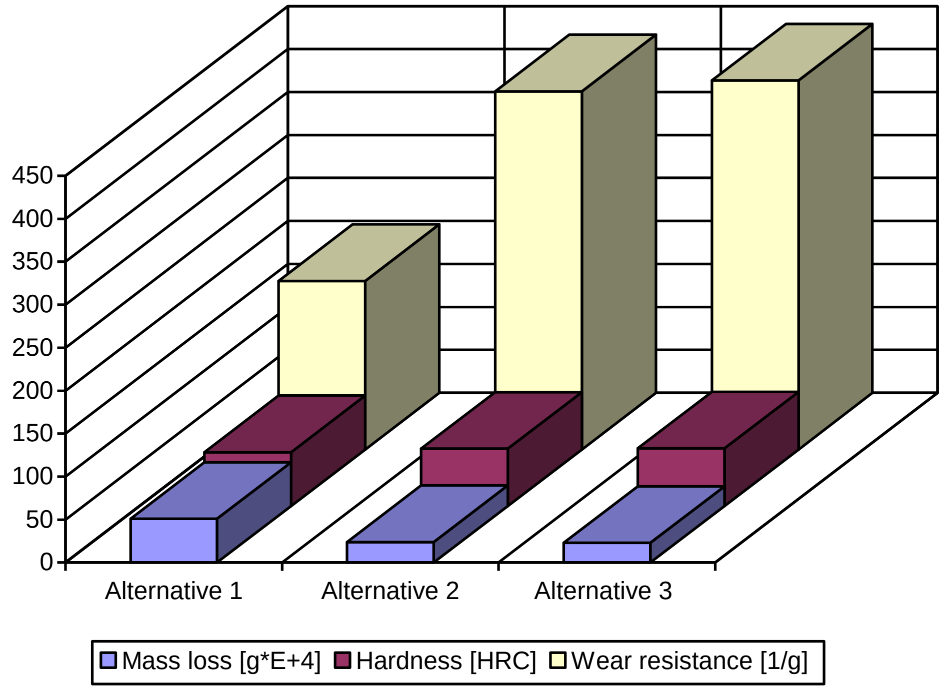

Figure 9. Heat treatment influence on HS 18-0-1 steel mechanical properties

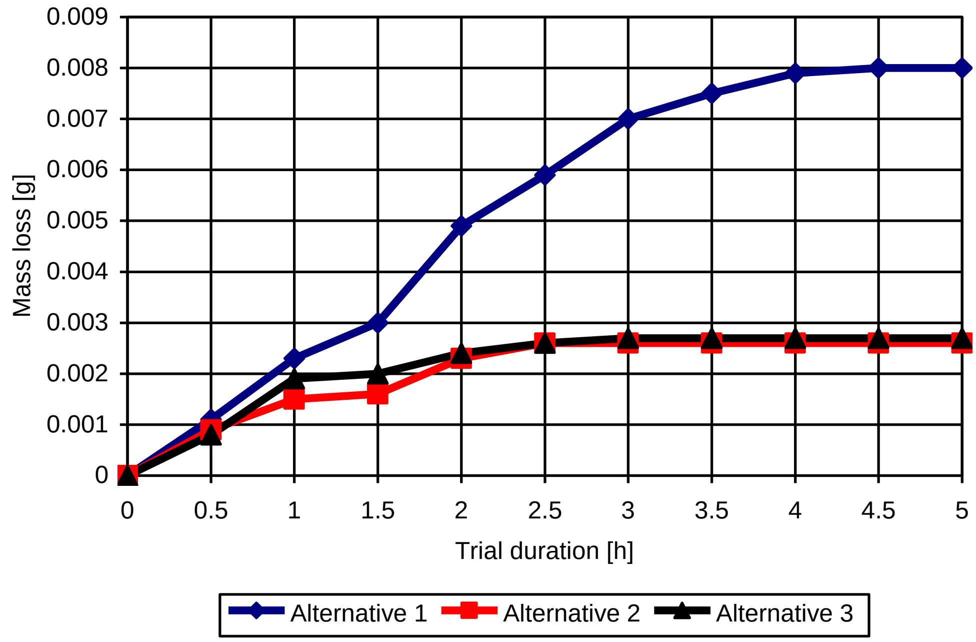

Figure 10. Heat treatment influence for HS 18-0-1, function of trial duration

4. CONCLUSIONS

The main application of the concentrated sources in the heat treatment domain consists in the superficial hardening of the alloy steels pieces or tools. In the heat treatments domain, the concentrated sources began to replace some thermo chemical treatments and the superficial quenching with flame or induction heating. The cooling at superficial quenching with concentrated sources is made spontaneous, by conduction in the large and cold piece mass, which provides cooling speed of 10^{-2} – 10^{-4} grad/s, these exceeding with more the quenching critical speed of the steels. The performed tests have enabled the following conclusions:

- for the X210Cr12 steel, heat treated with laser, hardening depth was of 0.3 – 0.5 mm, measured micro hardness being of 880 HV, respectively 66.3 HRC; the micro structure is of fine martensite type, the carbides are very fine; close values, but more reduced are recorded for the samples heated with cathode beam;
- for the HS 18-0-1 steel, heat treated with laser, the hardening depth was of 0.3 – 0.5 mm, the micro hardness of 900 HV; the application of heat treatment with cathode beam determined the same depth obtaining, on the other hand the micro hardness was of 950 HV, superior to that obtained with laser;
- the wear resistance of the X210Cr12 steel, laser heat treated, is with 245% higher than that obtained by classical heat treatment and with 221% higher, in the case of the cathode beam heat treatment;
- the wear resistance of the HS 18-0-1 steel, laser heat treated, is with 204% higher than that obtained by classical heat treatment and with 210% in the case of the cathode beam heat treatment;
- independently of the tested steel type, for the heat treatment with concentrated sources, the gripping appears at the superior values of the force, in comparison with the case of the classical heat treatment.

In the case of the high-speed steel, heat treated with cathode beam, the mechanical properties are better than those obtained in the laser heat treatment, but in the case of the X210Cr12 steel, the mechanical properties evolution is vice versa (the laser treatment properties are better than cathode beam).

For the parts with complex geometric configuration, the hardening cost with concentrated sources, is lower than when is utilised other heating sources.

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