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SURFACE HARDENING FOR LOW CARBON STEEL (A3k) BY YAG: Nd PULSE LASER THERMAL ACTIVATION

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ABSTRACT

The paper is based on experiments for surface hardening on A3k (low carbon steel) samples using YAG:Nd pulse laser. A small x-y moving system conducted by PC was made for sample scanning, relative to fixed focused laser beam. Laser energy, frequency and defocused, influences were studied. The results of laser/sample surface interactions were investigated by macrostructure and microstructure analyses. Hardness testing was used for evaluating the changes in surface properties.

KEYWORDS: surface hardening, steel, laser, YAG:Nd

1. Introduction

Surface treatment of metals (surface modification, surface engineering, and case hardening) is subdivided into two distinctive directions: deposition and diffusion techniques. Deposition techniques are characterized as transporting a substance from a source and depositing it onto the surface of metal (electroplating, thermal flame spray PVD, CVD, etc.) [8]. Diffusion techniques are usually named thermo chemical and thermal treatment. Thermo-chemical treatments (nitriding, carburizing, carbonitriding, nitrocarburizing, boronizing) are characterized as diffusing an element or many elements, into the surface of the steel by the application of the appropriate amount of heat, time, and the steel surface catalytic reaction, [8]. Thermal techniques are those that modify the surface phases of steel containing sufficient carbon to allow the transformation from austenite to martensite when the appropriate amount of heat is applied to the immediate surface. This is sometimes known as phase hardening and is applied to processes such as flame, laser, induction, and electron beam [8]. Surface hardening of steels is generally based on energy transfer and/or mass transfer (interactions) with material and exterior media. Because interactions are conducted only at surface, structure modifications are generated and properties modifications will be obtained.

This is thermal hardening of metals and alloys that is based on local heating of a surface under the influence of exterior heating system and subsequent fast cooling of this surface [1]. Surface hardening of steels by thermal interactions consists in formation of an austenite structure at a stage of heating and its subsequent transformation in martensite in a stage of cooling [1]. Temperature and time are more important factors and these appear for all surface treatments.

Temperature influence is localized at material surfaces for high values and time for short values. At surface hardening by induction treatments, electromagnetic field energy is localized at material surface (increasing local energy) and after heating, water spray is used for decreasing local energy. Cooling speed has a primary influence on structure and properties.

2. Experimental conditions

Lasers are complex systems which transform electric energy to radiation and have a very important property: higher control of characteristics. In these conditions, surface treatments using laser radiations have a high precision and are used for small surface operations.

For experiments, it was used a pulse laser system KVANT 17 (C.I.S.) based on two YAG:Nd ($Y_3Al_5O_{12}$) units [3].

Basic applications of this system are ceramic cutting and micro welding of different materials.

Some important technical characteristics are:

- active media: 6,3 mm diameter, 100 mm long;
- glass composition: $Y_3Al_5O_{12}$;
- wave length 1,06 μm (IR);
- pulse time 2…5ms;
- pulse frequency 1…20 Hz;
- objective focused 50 mm;
- trace diameter 0,3…1,3mm;
- pulse energy min. 8J.

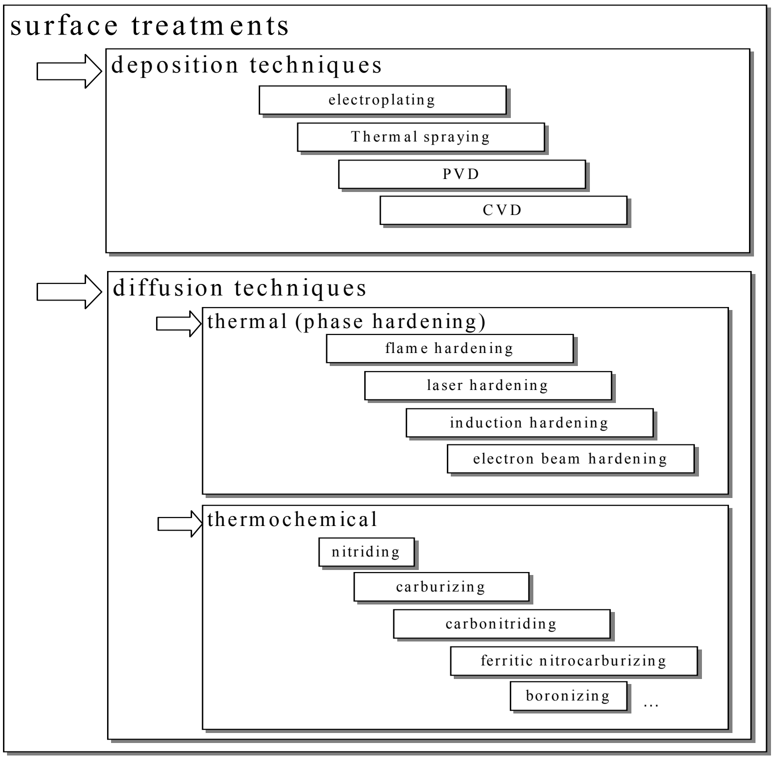

Fig.1. *Principal technique for surface treatments of metals.*

Table 1.*Experimental conditions and results*

No.	Working supply	Defocalisation	Hardness (HV_5)						
			d1	HV1	d2	HV2	d3	HV3	HVm
UM	V	mm	mm	daN/mm^2	mm	daN/mm^2	mm	daN/mm^2	
1	550	5,0	0,308	98	0,298	104	0,293	108	103
2	600	5,0	0,270	127	0,263	134	0,275	123	128
3	600	7,5	0,287	113	0,288	112	0,279	119	114
4	650	5,0	0,242	158	0,227	180	0,227	180	173
5	650	7,5	0,267	130	0,267	130	0,267	130	130
6	650	10,0	0,274	124	0,289	111	0,274	124	119
7	700	5,0	0,234	169	0,233	171	0,234	169	170
8	700	7,5	0,241	160	0,249	150	0,241	160	156
9	700	10,0	0,272	125	0,267	130	0,272	125	127
10	750	10,0	0,251	147	0,259	138	0,251	147	144

Fig.2. *Pulse laser system KVANT 17 (working module, supply and command module and technological module*

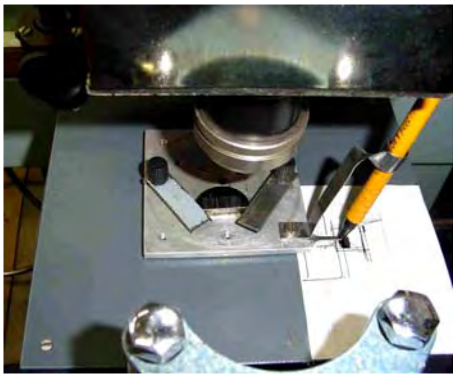

Fig.4. *Sample and technological xy system*

Fig.3. *Working module of KVANT 17 system*

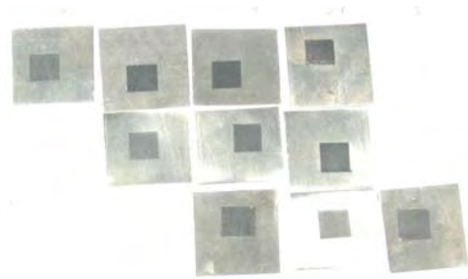

Fig.5. *Hardening surfaces on A3k samples arranged by laser energy and defocused*

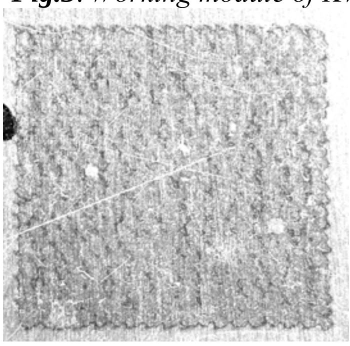

Fig.6. *Surface macrograph for sample no.5 600V/7,5mm/ 0,3Hz).Magnitude 5x.*

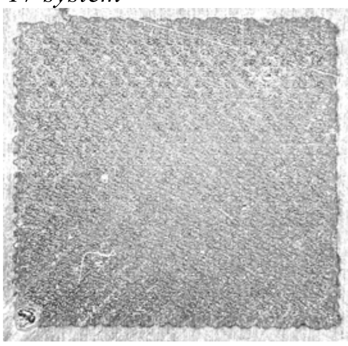

Fig.8. *Surface macrograph for sample no.9 (700V/10mm / 0,3Hz). Magnitude 5x.*

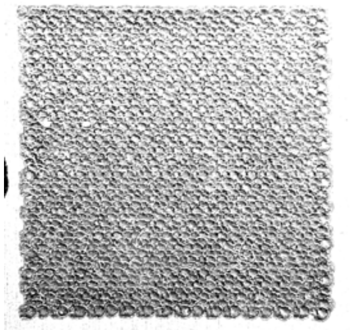

Fig.10. *Surface macrograph for sample no.3 (650V/5mm/ 0,3Hz). Magnitude 5x.*

Fig.7. *Surface macrograph for sample no.7 700V/ 7,5mm/ 0,3Hz). Magnitude 5x.*

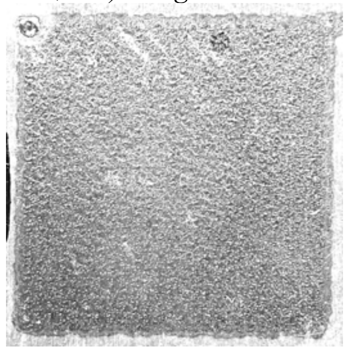

Fig.9. *Surface macrograph for sample no.10 750V/10mm/ 0,3Hz). Magnitude 5x.*

Fig. 11. *Surface macrograph for sample no.4 (700V/5mm/ 0,3Hz). Magnitude 5x.*

***Fig.12**. Surface micrograph (350x) for sample no.1 (550V/5mm/0,3Hz) Magnitude 150x*

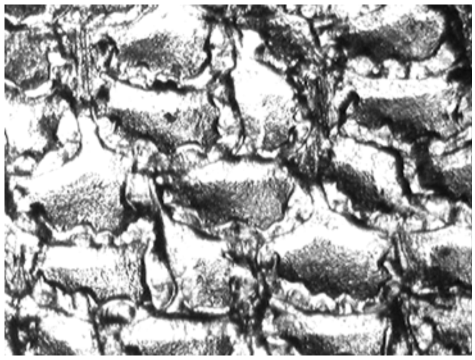

***Fig.14**. Surface micrograph for sample no.3 (650V/5mm/0,3Hz). Magnitude 150x*

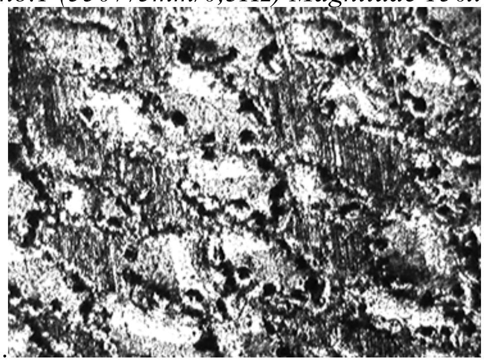

***Fig. 13.** Surface macrograph (350x) for sample no.2 (600V/5mm/0,3Hz). Magnitude 150x*

***Fig.15**. Surface macrograph for sample no.4 (700V/5mm/0,3Hz Magnitude 150x*

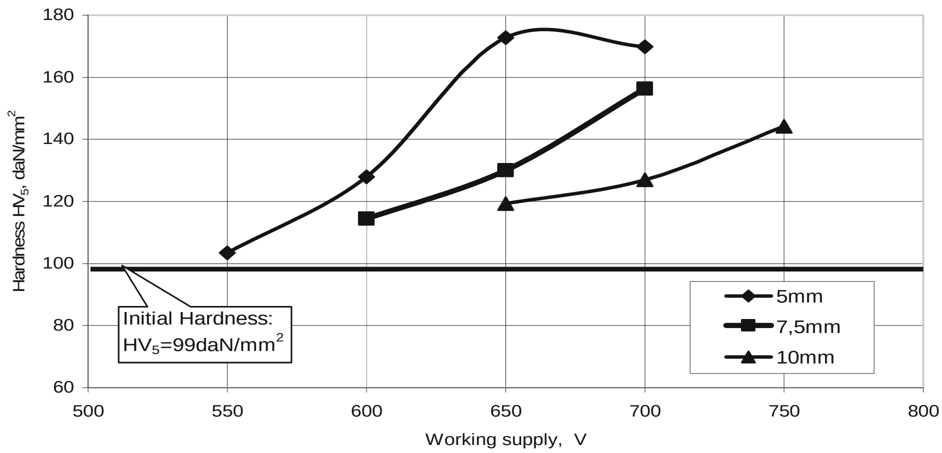

***Fig.16.** Hardness variation on the sample surface after pulse laser hardening.*

3. Results and discussion

The sample surfaces were relatively scanned by laser beam and *sample surface/laser pulses* interaction was present. In function of pulse energy, pulse frequency and defocused, surface interaction appears and has a specified macroscopic aspect (***Fig.6 …Fig.11***). Macroscopic analyses for A3k representative steel samples are showing in (***Fig.12 …Fig.15,** Magnitude 150x*).

Thermal zone influence is visible in ***Fig.12*** and the energy is insufficient for local quenching, [0]. By increasing the laser energy, the traces are larger and surface modifications is present (***Fig.13).*** If energy increasies a local melting is present that conduced to a major modifications on surfaces and to local quenching from melt steel (***Fig.14…Fig.15***). Hardness testing (HV_5) was used for evaluating surface properties modifications (***Table 1***).

4. Conclusions

By increasing defocused, specific energy on the interaction surface decreases and hardness is lower. If pulse laser energy increases, the hardness increases too, but the quenching process is limited by the melting phenomenon. For all regimes, a hardness increasing with 50%... 80% was measured in conditions when A3k steel has < 0.1%C in its chemical composition. The applications of YAG:Nd pulse laser are recommended to very small surfaces, because of the lower efficiency of laser (2…5%), [7].

References

[1]. Ganeev R. E., 2002, *Low power hardening of steels*, Journal of Materials Processing Technology 121 414-419
[2]. Popescu N., 1990, *Tratamente termice neconvenţionale*, Editura tehnică, Bucureşti pag.223…245
[3]. Samoila C., Ionescu M.S., Drugă L., 1986, Tehnologii şi utilaje moderne de încălzire, Editura Tehnică, Bucureşti, pag.291…360
[4]. Ursu I., Mihăilescu I.N., Prokhorov A.M., Konov V.I., 1986, *Interacţiunea radiaţiei laser cu materialele*, Editura Academiei, Bucureşti
[5]. Donţu O., 1985, *Tehnologii de prelucrare cu laser*, Editura Tehnică, Bucureşti
[6]. Savin Gh., 1981, *Laseri*, Editura Facla
[7]. De Kock J., 2001, *Lasers Offer Unique Heat Treating Capabilities*, Industrial Heating, oct. Laser Machining Inc., Somerset, Wis.