TRATAMENTE TERMICE SUPERFICIALE CU FASCICUL DE ELECTRONI

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ABSTRACT:
This report presents the results of the investigations concerning heat processing of surfaces with electron beam, using as heat source a concentrated beam induced by an electronic cannon. These investigations show a high interest being a solution to replace the classic, expensive, technologies used till now, with modern ones, based on electron beam more efficiently and economically, named by the author HARDNESS. This process induces besides the increase of strength at wearing of hardened surface, the increase of strength at tiredness.

KEYWORDS: DFE – hardening with electron beam, DAFE - hardening by alloying with electron beam, DRFE - hardening by remelting with electron beam, alloyed spot, hardened spot

1. INTRODUCTION

The use of electron beam in the field of processing by heat of surfaces, presented by the author in several papers [1, 2, 3, 4], brings innovations and definite advantages concerning the efficiency, quality and productivity vs. the conventional processes because the first run with high velocity, and the energy used represents 5% by that used in conventional processes. Processes with electron beam are focused on selected zone of sample without its deformation.
Processes are precise, thin on controlled depth and additional operations are not always necessary.

2. THE PRINCIPLE OF PROCESSING BY HEAT WITH ELECTRON BEAM OF SURFACES

Taking into account the researches lead in the processing by heat of metallic surfaces one can conclude that this process is produced in two different sequences such are:
Sequence I, figure 1, without the melting of the metal. It occurs when the electron beam with a high power density in close proximity to $10^3 \div 10^4$ W/cm^2, bombards the material surface during 1 to 3 seconds. The cooling value can touch 10.000°C/sec, which will induce the **martensite** precipitation. In this case, the heat process of the surface is called surface strength or surface hardening (DFE).
Sequence II, figure 2, with the fast melting and solidification of the material. It occurs when the electron beam with a high power density in close proximity to $10^6 \div 10^7$ W/cm^2, bombards the material surface during 10^{-2} to 10^{-1} seconds. The material transition from solid to liquid state followed by a extremely rapid return to solid state creates an improved structure and even a surface with a modified composition because of the additional material.

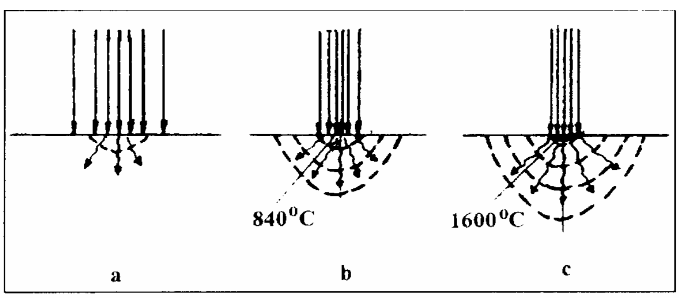

Fig. 1. Material heating sequences: a-local heating; b- heating without material melting; c- heating with material melting.

When the material cools very fast the **martensite** precipitation is induced and the surface heat process is called **hardening by remelting (DRFE)**.

When a modification of the surface composition happens, the process is called **hardening by alloying (DAFE).**

3. DEVICES OF PROCESSING BY HEAT WITH ELECTRON BEAM

Heat processing of metallic surfaces is generally made with welding devices which have incorporated a table where the sample is moving in x,y coordinates.
During the last years, around the world, in the equipments of processing with electron beam field was evident a wide diversity.
It is well to notice equipments of heat processing with electron beam helped by computers.
Figure 2 shows a complete system for heat processing with electron beam carried out by a computer.

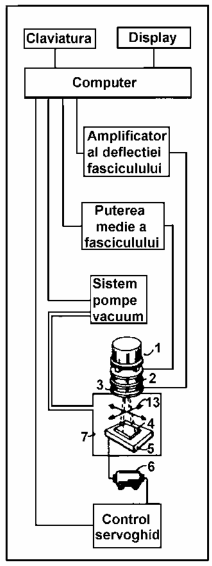

***Fig. 2. The equipment of processing with electron beam carried out by a computer*.**

4. METHOD OF PROCESSING BY HEAT WITH ELECTRON BEAM

The method of processing by heat used was that of hardening of plane surfaces by long and continuous impulses, called hardening in tapes at successive distances.

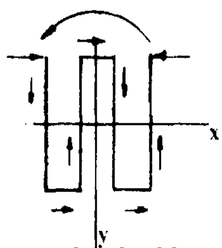

Fig. 3. The method of hardening with electron beam in tapes at successive distances

5. HARDENING WITH ELECTRON BEAM

The hardening with electron beam (DFE) is a method of processing by heat of metallic surfaces with a high power density electron beam, in vacuum.
The purpose of hardening is the modification of properties of metallic materials concerning their wear strength and their hardness.

The modification of superficial structure occurs in solid state, without the development of melting zones and without further processing.
It is generally suitable for steels in superficial tempering.

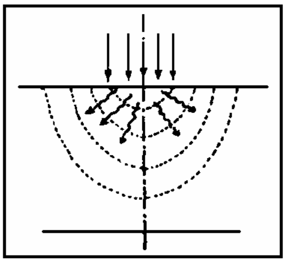

Fig. 4. Local heating of the material without the material melting

a. the schema of the hardened spot, includes four investigation directions and several points for characterisation and detemination of hardness (fig. 5).

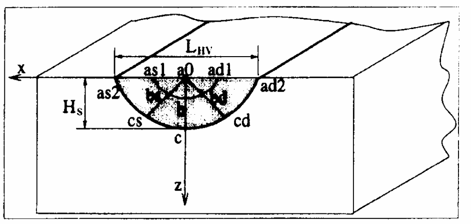

Fig. 5. The main points of the hardened spot in crosswise section on those of the electron beam action.

b. The process function hardening of the influenced layer, was established in an experimental program with five variables on two reference materials OLC545 and 42MoCr11, in the measurement points a_0, b, c, a_{s2} and c_s (fig. 5), polytrophic, and in the point a_0 it is:

$$HVa_oOLC = 11{,}881 \cdot L_l^{0{,}351} \cdot I_{FE}^{0{,}322} \cdot U_a^{0{,}495} \cdot V_m^{0{,}343} \cdot \beta^{0{,}028} \quad (1)$$

$$HVa_oMOC = 67{,}221 \cdot L_l^{0{,}275} \cdot I_{FE}^{0{,}200} \cdot U_a^{0{,}230} \cdot V_m^{0{,}263} \cdot \beta^{0{,}027} \quad (2)$$

Where the parameters varied are L_l-work distance, I_{FE}-FE intensity, U_a-acceleration voltage, V_m-work velocity, β-deflection angle, crosswise direction.

c. deviation of density notified HV, for the most significant parameters is shown in fig. 6, for I_{FE} and in fig. 7 for V_m.

d. determination of hardness in each point of the hardened spot is done using the general equation of the spatial distribution of hardness (3), of the hardness in a_0, HVa_0, L_{HV} and H_S from the Appendix IV, 10.1 şi 10.2 [1, 2] for both materials and of the hardness function notified in equations 5 and 6, one can determinate the hardness HV in every point of (x_k, z_k) coordinates from the hardened spot function of the five electro technological variables (L_l, I_{FE}, U_a, V_m and β) and the two spatial variables (x and z):

$$HV_k(x_k, z_k) = HVa_o \cdot Y_r(x_{kr}, z_{kr}) \quad (3)$$

$$x_{kr} = \frac{x_k}{L_{HV}}, \qquad z_{kr} = \frac{z_k}{H_s} \quad (4)$$

$$Y_r(x_{kr}, z_{k_r}) = 1{,}0024 - 0{,}1121 x_{k_r} - 0{,}2988 x_{k_r}^2 + 0{,}0782 z_{k_r} - 0{,}1471 z_{k_r}^2 + 0{,}0509 x_{k_r} z_{k_r} \quad (5)$$

$$Y_r(x_{k_r}, z_{k_r}) = 1{,}0052 - 0{,}2445 x_{kr} - 0{,}0688 x_{k_r}^2 + 0{,}0139 z_{kr} - 0{,}1046 z_{kr}^2 + 0{,}0724 x_{k_r} z_{k_r} \quad (6)$$

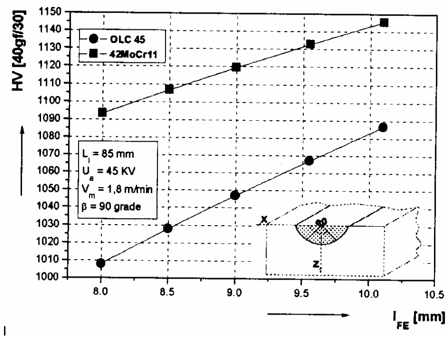

Fig. 6. Deviation of density HV function of current FE, I_{FE}

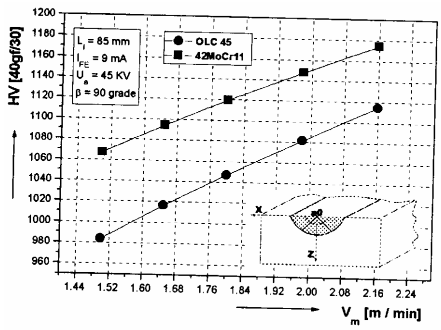

Fig. 7. Deviation of density HV function of work velocity, V_m

Fig. 8 shows the instantly increase of the density at high values in the field of hardened spot versus the core density.

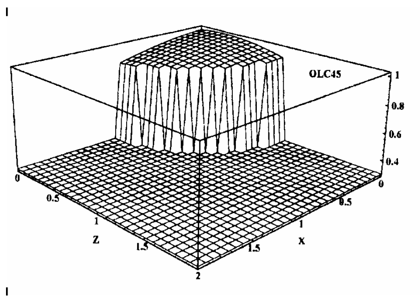

Fig. 8. Spatial distribution of hardness by points, for OLC45

e. caracterization of the hardened spot: a hardness of 994HV 40gf/30 in point b of the i_4 experiment, for OLC45 (fig. 9), and for

42MoCr11 a 1078HV 40gf/30 hardness in point b of the i_4 experiment were observed during the experimental program.

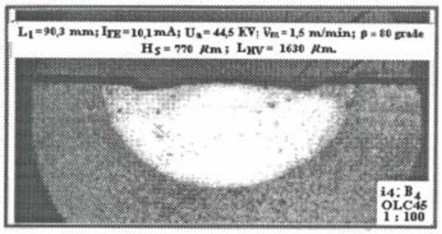

Fig. 9. The hardened spot for the experiment i=4, OLC45

6. HARDENING BY ALLOYING WITH ELECTRON BEAM

Electron beam alloying (DAFE) is the hardening process at the surface, by enriching the basis material with selected elements presented as powder or thin sheet, with the purpose of wearing protection by growing the superficial hardness on a controlled thickness. The transformation of superficial structure of both the added and basis material takes place in a liquid phase (figure 1) on certain deepness. It is usually used for strengthen steels but also for those that cannot be strengthen.

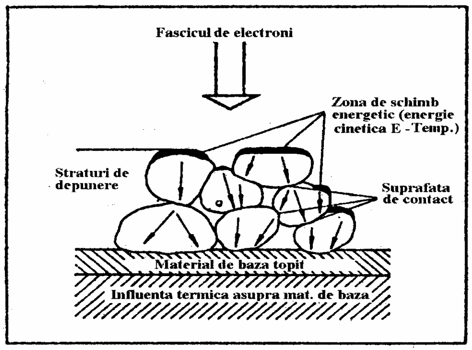

Fig. 10. Hardening by alloying of both melted basis material and the added one on a certain depth.

a. The influence of the alloying elements. The alloying elements are generally the same with those which used for steel alloying.

Specific alloying and micro-alloying with electron beam is the fact that the materials melting are produced very quickly, only in the zone of the contact between the electron beam and the material, the other material staying cool. In the adjacent zone of the melted one, a conduction soft heating occurs. The cooling of melted materials happens instantaneous behind the electron beam, through the cooled mass of material, with a velocity of approximated at 10.000°C/s.

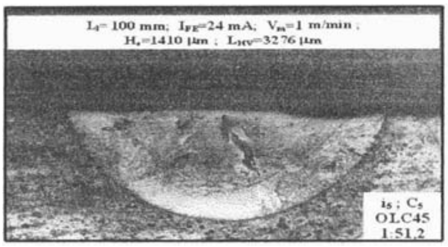

Fig. 11. The alloyed spot for the experiment i=5, OLC45

b. Some unwished phenomenon that take place during the alloying are:

Expulsion of the powder that conducts to the obtaining of an irregular alloyed layer and implicitly of some inferior mechanical performances compared on those settled. For the obtaining of an uniform alloyed layer all the powder elements must adhere one to the others and all must adhere at the basic material.

Burning of the very fine powder is another unwished phenomenon. To escape it, the sifter of the power is necessary so that subdimensional elements are eliminated and the power quality is conform STAS 12390-25.

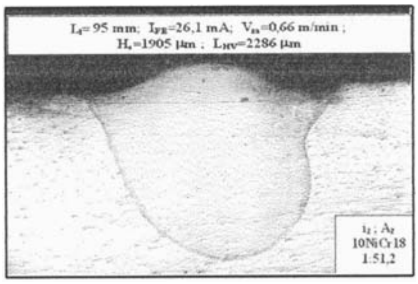

Fig. 12. The alloyed spot for the experiment i=2, 10NiCr 180

Repression of the liquid material occurs at high specific power of the electron beam, until 10^6W/cm^2, when the phenomenon of creation of vapor crater arises too. Repression of the liquid material from the way of the electron beam must be obviated. The alloying process takes place without the vapor crater development.

c. The characterisation of the spot hardened by alloyng was established in an experimental program with three variables. A maximum hardness of HV=1191 40gf/30 in point c, for the experiment i_5 for the material OLC 45, fig. 11, of HV=480 40gf/30, fig. 12, in point a_0, for the experiment i_2 for the material 10NiCr180 and a maximum hardness of HV=414 40gf/30 in point a_0, for the experiment i_2 for the material AMRCO (KPS or MK3, used in electrotechnical field, called technical iron), fig. 13, were obtained.

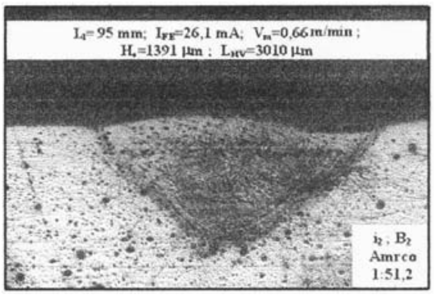

Fig. 13. The alloyed spot for the experiment i=2, AMRCO

7. HARDENING BY REMELTING WITH ELECTRON BEAM

Hardening by remelting with electron beam (DRFE), is a method of heat processing of metallic surfaces using a high power density electron beam, in vacuum.

The process of remelting by electron beam leads to the change of the superficial material structure passing in liquid state followed by solidification very quickly with the purpose to increase the strength to tiredness and to harden the superficial layer.

Hardening by remelting happens similar with the blind welding using electron beam (fig. 14), with the difference for the remelting that the welding girdle are not separated, but over layered, to assure a plate surface and a uniform distribution of the hardened layer.

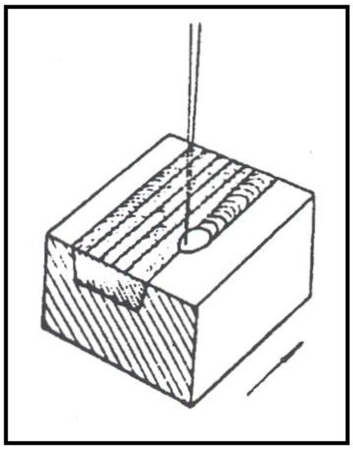

Fig. 14. Hardening by remelting with electron beam.

a. **Characterization of the strength to tiredness by remelting with electron beam** is done by several tests to tiredness with axial charges, STAS 8027-78, in environmental conditions described in STAS 6300-64.

Fig. 15 shows the increase of strength to tiredness with 45% on the material X20CrMoV121, compared with the material none hardened by remelting with electron beam. The test takes place on a sample made in a broad bar with a transversal section of 20 x 10mm, polished.

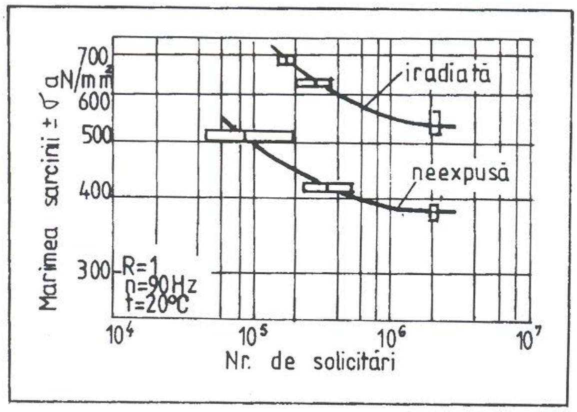

Fig. 15. The increase of strength to tiredness by remelting with EB compared with the same material non processed.

8. APLICAȚII ALE TRATAMENTELOR TERMICE CU FASCICUL DE ELECTRONI

a. DFE applications: In the high technology mechanic and electrotechnical field: cogged wheels, catch-wheels hardened on cogging only, cams, fig. 16, hardened on outline only, on a breadth of maximum 3mm.

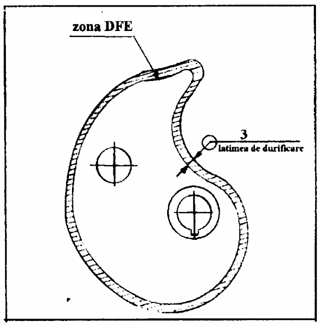

Fig. 16.The profile of the hardened cam

In switching devices, bold, fig. 17, piece included in resin, hardened on the contact zone only, fasteners, contact levers, checks, etc.

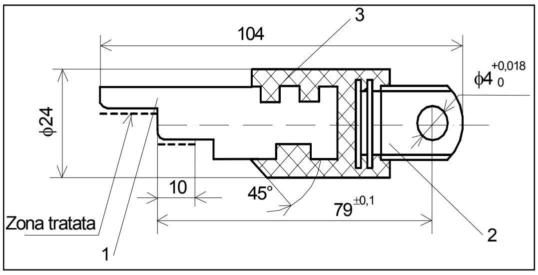

Fig. 17. Bold hardened on the stressed zone only, after it was included in resin.

In SDV field, the cutting edge of the cut up stencils, guiding columns, stamps, lathe knifes, augers, milling machines, etc.
In the cars industry: lugs, rings, cogged wheels fig. 18, in the strongly stressed zone.
In the farming machines field: cutting knives, hardened on the cut up zone only.
b. DAFE applications. These applications are on pieces in non strengthened materials, which, on a certain zone, are stressed, so they must have a high hardening.

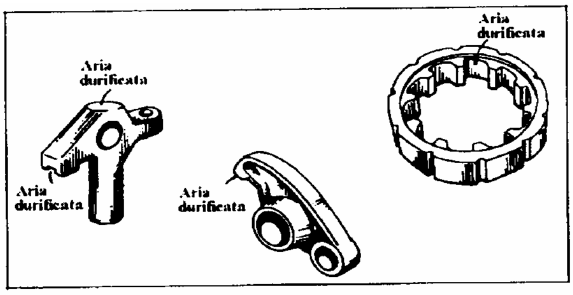

Fig. 18. Lugs and rings hardened in the strongly stressed zone only.

These pieces are generally electrical connections, levers and S. Fork, the main component of DC very fast switches type IUCC, fig. 19, which on the plate zone has a very harden alloyed layer.

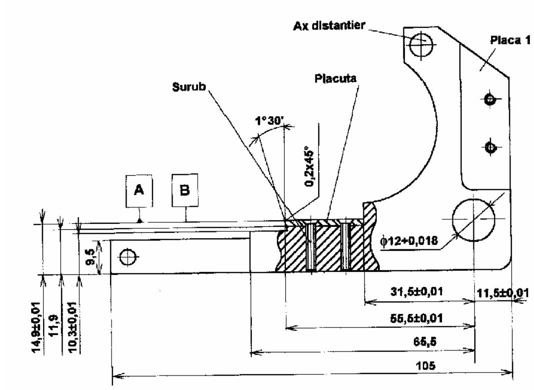

Fig. 19. S. Fork (sideway view) – hardening of A and B surfaces by the classic method.

c. DRFE applications are represented by the pieces which must resist at variable demands and have a high resistance at stress such are: rotors of electrical machines, rotors of turbines, rotors of mills, of farming machines and all axes which turn in bearings and that are fixed on mechanisms which solicit them on axial direction.

REFERENCES

1. NEAGU D., Hardening by electron beam, Ed. Printech, Bucharest, 2001, 2002.
2. NEAGU D., Heat superficial processing with electron beam, Editura Curtea Veche, Bucureşti, 2006.
3. NEAGU D., VIŞAN A., IOAN D., TACHE V., s.a. Contributions at the study of spatial distribution hardening of the hardened metallic surfaces with electron beam, Non conventional technologies Revue No.2, Ed. Augusta, Timişoara, 1999, pag. 68÷72.
4. NEAGU D., Hardening by alloying with electron beam of components made of non-hardened electrotechnical materials, Non conventional technologies Revue No.4, Ed. Bren, Bucharest, 2005, pag. 45÷50.
5. HILLER, W., (1984), Steigerung der Danerfestigkeit von Werkestucken durch Orttliches Umshmelzen mit den Elektronenstrahl, Deutscher Verlag fur Schweisstehnik (DVS), Dusseldorf, 1984.