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*Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird*
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# THE EFFECT OF ELECTRICAL - TECHNOLOGICAL PARAMETERS ON ELECTRON BEAM SURFACE HARDENING

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***Abstract:*** *This work presents the effect of several technical parameters on the electron beam hardened layer, for two steel types OLC 45 and 42 MoCr1, based on process functions determined by the authors and described in prior publications. Considering these process functions, effects were determined on the layer hardness of the main electrical and technological parameters such as: working distance, electron beam current intensity, accelerating voltage, running speed, cross deflection angle and hardened material.*
***Key words:*** *Layer hardness, parameters, hardening, electron beam*

## 1. INTRODUCTION

One of the most important applications of electron beam processing is surface layer hardening of several steel or alloy steel parts used in modern manufacturing. For these applications the specialist literature (Neagu, 1999) provides very few data to allow adjustment of working parameters to obtain specified technological characteristics, such as hardness of hardened layer, depth and width of hardened layer, degree of strip overlapping, spatial hardening distribution (Vişan et al., 1999) etc.

In this sense, the authors have developed extensive research work that focuses on determining the above-mentioned technological characteristics. This article presents the effects of principal parameters on the hardness of electron beam hardened layer. To determine these effects, process functions were used as identified by the authors and published in a previous work (Vişan et al., 2010).

The polytropic type process functions (Gheorghe et al., 1985) were determined, based on a methodology prepared by the authors (Neagu, 1999, Vişan, 1998), in five points of hardened strips, by aid of an factorial experimental programme comprising 20 experiences, for two types of steels, OLC 45 as a reference material and 42MoCr.

The effects presented, as well as those to be determined for width and depth of hardened layer are very important in preparing optimum application regimes.

## 2. EFFECT OF PARAMETERS ON LAYER HARDNESS

**Dependence of the hardness on the measuring points coordinates.** The obtained process functions confirmed the fact that the hardness *HV* varies depending on the X and Z coordinates of the measuring points and does not depend on the Y coordinate. Figure 1 shows the variation of the hardness *HV* depending on the X coordinate of the measuring point. For both research materials, the hardness has got a peak in point $a_0$, corresponding to the beam centre, and then it decreases towards the extremities, in points $a_{s2}$ and $a_{s2}$ and $a_{d2}$. Function of the material, the hardness of the hardened layer is higher in strip centre as compared to strip margins by about 27 % for steel OLC 45 and about 21 % for steel 42MoCr.

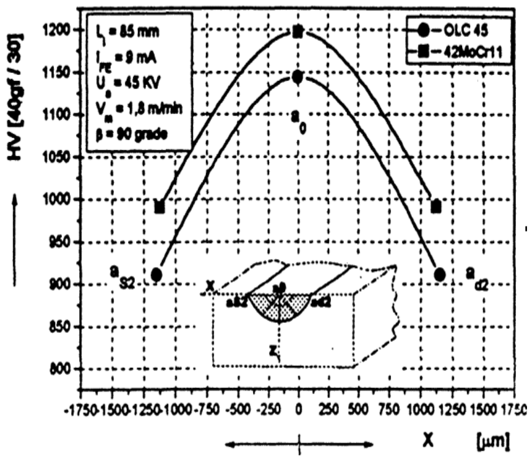

Fig. 1. The effect of X coordinate on hardness HV

The effect of the hardened material is proved by the higher hardness of steel 42 MoCr11, due to its higher hardening limit.

The variation of the hardness depending on the depth of the hardened zone *z* (Figure 2), in points $a_0$, *b*, *c* and *m*, the last one placed in the non - hardened core, indicates a complex dependence. For both materials, the hardness has a peak and then it decreases slowly at the same time as the depth *Z* increases. In point *c* that is located at the very border between the hardened zone and the non-affected core, a significant hardness reduction occurs as compared to the core value (Figure 2).

To study individually the effect on hardness of the parameters and hardened material, the process functions in point $a_0$ were graphically represented using variable values from the central area of the experiment section, and varying by turns each parameter only within the research sections, while keeping constant the rest of parameters at medium values.

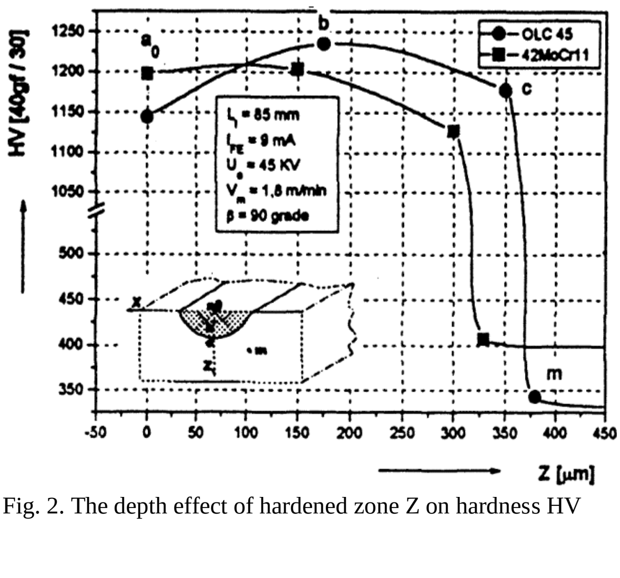

Fig. 2. The depth effect of hardened zone Z on hardness HV

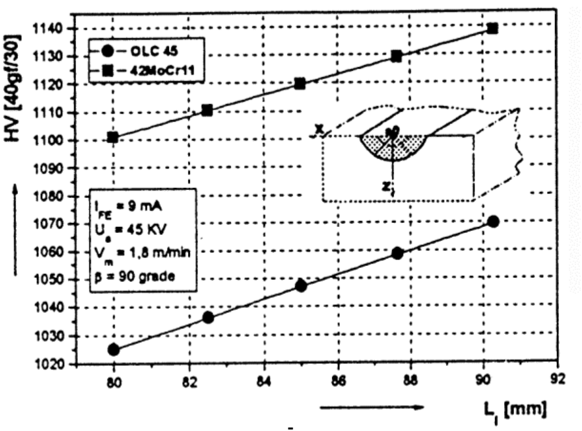


Fig. 3. The effect of the working processing distance $L_l$ on hardness *HV*

**The effect of working processing distance on hardness.** The analysis of the hardness dependence on the working processing/shooting distance $L_l$ , represented shown in figure 3, proves that, for both research materials, the increase of the processing distance produces hardness enhancement due to increase of beam focus and intensity, which entails a higher heating of the work-piece material.

**The effect of electron beam current strength on hardness.** The dependence of hardness on electron beam current strength $I_{FE}$, show in figure 4, shows that, for both materials, higher current strength $I_{FE}$ , generates higher hardness, owning to increase of the beam energy and power which leads to higher material heating.

Similar cause and effect relations were obtained considering the effect of accelerating voltage $U_a$ and work-piece travel speed $V_m$ under the hardness. In this case too, for both research materials, the hardness increase with the increasing of the voltage. This variation is determined by the increase of beam energy and power. The enhancement of beam energy due to increase of voltage $U_a$ is limited by the beam defocusing phenomenon, which determines a decrease of heating temperature and implicitly, a diminution of hardness.

When the working speed increases, a very important hardness increase occurs. At lower processing speed, the duration of action of the beam on the work-piece increases, thus resulting in material heating over the hardening temperature, as well as decarbonisation of the superficial layer resulting in lower hardness. Due to the increase of the processing speed, the carbon has not the necessary time to precipitate outside the solution and remains within the structure producing a solution supersaturated in ferrite, the martensite, consequently resulting in hardness increase.

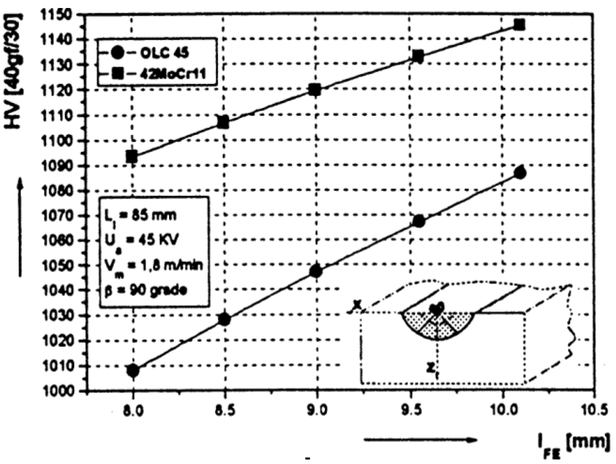


Fig. 4. The effect of electron beam current strength $I_{FE}$ on hardness HV

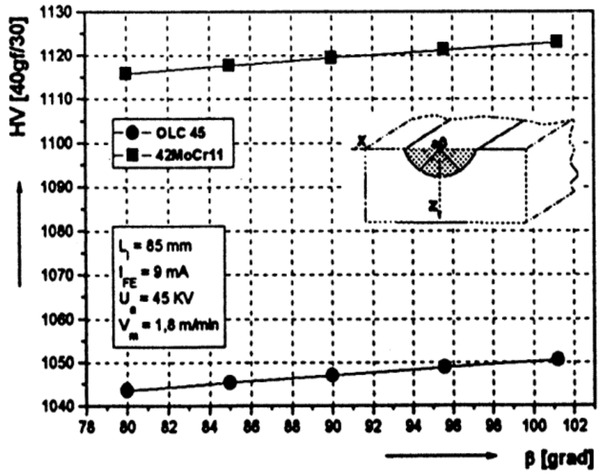


Fig. 5. The effect of cross deflection angle β on hardness *HV*

**The effect of cross deflection angle on hardness.** The cross deflection angle $\beta$ represents the deflection angle of the beam against the optical - electronic axis, on direction OX (Figure 1). As a result, in figure 5, the value of the angle $\beta$ determines a very small increase of hardness. The angle $\beta$ affects the spot centring as against the work-piece surface and, to a lesser extent, its hardness, which is a more or less relevant parameter.

**The effect of work-piece material on hardness.** The analysis of the process functions given by the relations established by the authors (Vişan et al., 2010) and the dependences relations depicted in figures 1 to 5 showed that the hardness obtained by electron beam hardening definitely depends on the type and proprieties of the work-piece material, which is a rather complex dependence. The hardness reached for 42 MoCr11 steel was higher than that for the OLC45 steel.

## 3. CONCLUSIONS

Through mathematical and experimental modelling and defining several process functions already published in prior works, it has been determined the effect of the principal process parameters on layer hardness in electron beam hardening for two types of steels. The results presented that are part of a wider research of the authors are very important in defining optimum regimes of practical application of part surface electron beam hardening. The limitations of this research work consist in its applicability only for experimental domain mentioned in the above figures.

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