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MODIFICATION OF THE STEEL SURFACE BY POWERFUL ELECTRON BEAM

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Abstract. This paper deals with research on microstructure, distribution of microhardness and Cr with electron beam treated specimens made of 40X steel. The results obtained show that the modifed areas have a multilayer structure, and the underlayer has microhardness 800—850 HV. In comparison with the basic metal, the Cr concentration in the above mentioned layer was found to be increased.

Резюме. В последнее время все большее развитие получают методы поверхностной модификации металлов, основанные на приемении интенсивных электронных пучков. В работе представлены результаты исследования микротвердости и структурных изменений поверхностей образцов из углеродистых сталей. С помощью электронно-зондового микроанализатора волновых дисперсий (WDS) было исследовано распределение Cr в зоне электроннолучевой модификации. Из полученных результатов видно, что на качество и свойства модифицированного слоя существенное влияние оказывает перераспределение Cr.

Introduction

The study on the surface modificaitons induced by treatments with a powerful electron beam has both scientific and practical importance.

To improve physical, mechanical and exploitation properties of steel, technologies using the electron beam energy as a heat-treatments tool are developed [1, 2, 3]. The quick implementation of these technologies in industry is based on the effect of the surface modification (up to a few mm) in defined areas of the pieces and the elimina tion of the conventional hardening methods. But still there is no clear concept abou the mechanism of the flowing processes in electron beam modification of steel [4, 5] The aim of this paper is to try to explain the relation between the nature of the flowing processes and the changing of structure, microhardness and redistribution of alloys in the modified layers.

Experiment and results

Steel specimens having as components C = 0.36 %, Si = 0.17—0.37 %, Mn = 0.5—0.8 %, Cr = 0.8—1.1 % (according to USSR standard GOST 4543-61 or FRG, standart DIN 17200) have been treated with a powerful electron beam. The specimens have dimensions $20\times20\times5$ mm and initial sorbite-troostite structure, obtained after

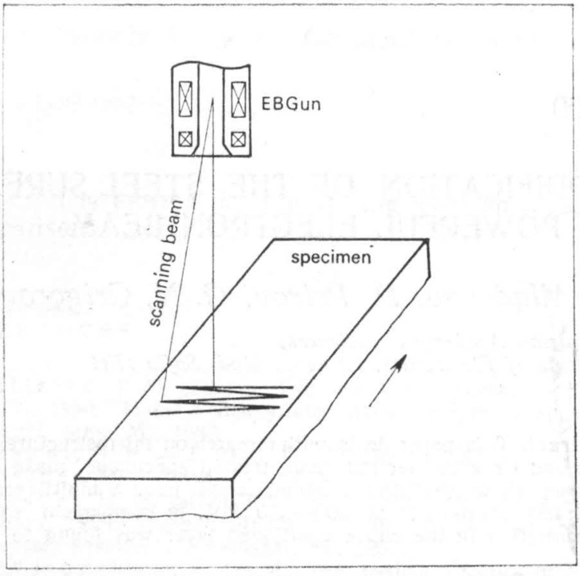

Fig. 1. Experimental setup

nprovement (tempering and annealing at 500°C). The experiment has been realized by an electron beam welder, type ESW 300/60-15 manufactured by "Leybold"-West Germany, with a scanning electron beam under the following conditions and the experiment setup shown in Fig. 1:

— electron beam current — 20 mA
— accelerating voltage — 60 kV
— specimen speed of movement — 3 cm.s^{-1}
— scanning frequency — 500 Hz
— beam diameter — 0.5 mm

The microstructure and microhardness of the prepared microcross-section have been studied as well as X-ray mapping by an WDX-analyzer.

As a result of the analysis, without melting of the specimens' surface, hardened layers have been observed whose microstructure comprises of several sublayers (see Fig. 2). The first layer of 0.1 mm depth has a martensite structure with a small amount of residual austenite. Despite the presence of residual austenite, the first layer has high hardness (800—850 HV). This effect has been explained by the residual austenite obtained with high rate cooling and heating conditions. The martensite in this layer has been finely dispersed with a high concentration of dissolved carbon particles and high density of defect obtained as a result of the high cooling rates. In the second sublayer and acicular martensite structure has been observed with particle dimensions greater than in the first sublayer. The third sublayer has a martensite-troostite-ferrite structure.

The observed structural changes of the treated specimen determine the high microhardnesses which are experimentaliy recorded (see Fig. 3).

Experiments with X-ray microdrill (X-ray analyser) for the distribution of Cr over the width of the modified layer's cross-section were carried out (see Fig. 4). The recorded change of Cr concentration in relation to Fe is shown in Fig. 5. The white

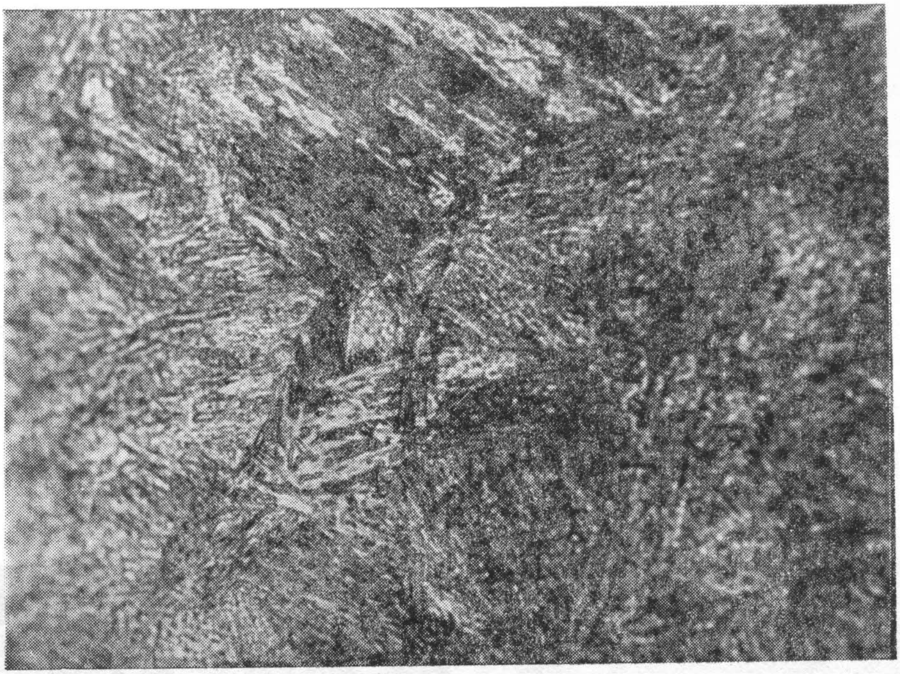

Fig. 2. Microstrucutre of the modified layer × 800

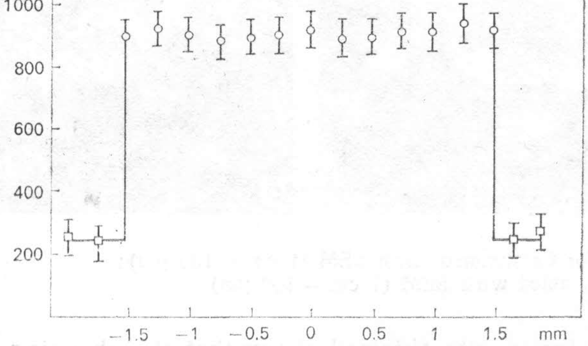

Fig. 3. Changing of microhardness along the width of modified layer's cross-section (measured 10 times in each of the 8 points at a depth of 50 μm from the surface) □ — initial surface; ○ — modified surface

dots in Fig. 5*a* show statistically the number of areas from which the characteristic radiation of Cr is recorded and Fig. 5*b* shows the areas from which the characteristic radiation of Fe is stimulated.

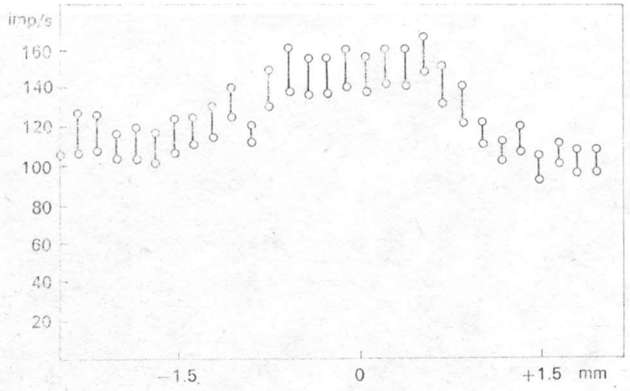

Fig. 4. Changing the Cr concentration along the underlayer width of the modified area

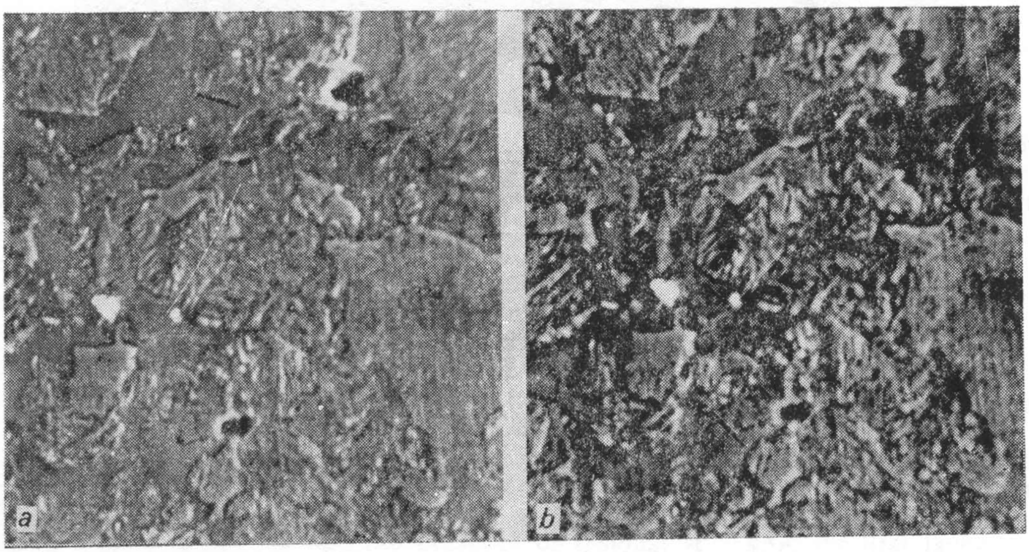

Fig. 5. *a*) WDX signal for Cr summed with SEM (1 cm = 100 μm);
b) WDX signal for Fe summed with SEM (1 cm = 100 μm)

The analysis of the results obtained shows that the changing of the microhardness in depth of the modified area is related mainly to the structural transformation as a result of high cooling rates. The multilayers of the obtained area may be explained by the fact that the deeper layers reach the temperature maximum later than the surface ones. The experimentally observed increase of Cr concentration along the underlayer width of the modified area probably appears as a result of the difficult dissolving of the Cr carbides in the residual austenite obtained with high rate heating and cooling conditions.

Conclusions

As a result of this research work we have come to the conclusion that by electron beam modification of 40X steel multilayer areas are obtained with microhardness 800÷850 HV on the underlayer. The basic causes of this effect are the high rate of heating and cooling, the distribution of the temperature field in depth of the modified area, which is uneven, and increase of the Cr concentration.

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