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INFLUENCE OF THERMODIFFUSION TREATMENTS ON IMPROVEMENT OF SURFACE LAYERS PROPERTIES CREATED ON LOW-CARBON AND LOW-ALLOYED STEELS

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ABSTRACT
This paper presents investigation results of influence of thermodiffusion duplex treatments on improvement of surface layers created on low-carbon and low-alloyed steels. On chosen low-carbon and low-alloyed construction steels temperatures of phase transformations (A_3 and A_1) have been determined. Duplex thermodiffusion heat treatment (boronizing in Ekabor 3, 900 ºC / 4 h and plasma nitriding) have been performed afterwards. Deposition of elements, plasma nitriding (as a part of duplex treatment) has been performed on PN-Mono 5 device with following parameters 529 ºC / 40 min, H_2 / N_2 = 70 /30. As a result and stable layer of boride and nitride (FeB, Fe_2B, BN and others) has been formed on steel surface. Results of investigation of structure have been presented through metallographic analysis and by Scanning microscope. Surface layers have been also analyzed through Roentgen diffraction.
Keywords: duplex treatment, boronizing, plasma nitriding

1. INTRODUCTION

Duplex treatment, like those including boronizing process followed by plasma nitriding, as a thermochemical treatment of steels practically is applied for the sake of many property benefits. During boronizing and plasma nitriding processes boron and nitrogen atoms were allowed to consecutively diffuse into the surface of steel.

This contribution is result, and part of a systematic investigations designed to optimize the duplex treatment of construction steels, such as: low-carbon type (designated: C15E and C45E) and low-alloying ones (20MnCr5 and 42CrMo4). In this case duplex treatment, consisting of boronizing and subsequent plasma nitriding process, was applied to improve properties of the chosen steels, which are needed in particular engineering application. In this case efforts have been spend to investigate the microstructure and properties of the diffusion multicomponent boro-nitrided layer formed on the treated steels.

2. EXPERIMENTAL RESEARCH

In current study the four types of construction steels: low-carbon (designated C15E and C45E) and low-alloyed (20MnCr5 and 42CrMo4) were chosen. The plan of experimental investigation is shown in Table 1.

Table 1. Times new roman font, italic 11-pt. There should be one line space between tables and text

Material / steel	Boriding	Plasma nitriding	Sample No.
C15E	1B2	1 B+N	5
20MnCr5	2B2	2 B+N	5
C45E	3B2	3 B+N	5
42CrMo4	4B2	4 B+N	5

Samples with dimensions Φ20 x 5 mm were machined and surface prepared by grinding and polishing to obtain the coatings with similar surface conditions. The samples were placed in a sealed box containing the Ekabor 3 powders. The first step of treatment, boronizing process, is carried out in conventional furnace at a temperature of 900 °C for 4 h, and cooled slowly to room temperature. In the second step, carried out subsequently after boronizing, the same specimens were plasma nitrided using a commercial (PN-Mono 5) unit, at 520 °C for 40 minutes. This treatment was performed under low pressure gas atmosphere consisting of mixture: 30 vol. % nitrogen and 70 vol. % hydrogen. The microstructure of the cross-section of the treated samples was studied by means of optical metallographic microscope and SEM equipment. Also, X-ray diffraction analysis (CuK_{α} radiation, λ = 1.54178 Å) was carried out to identify the phases existing in the surface layers.
Surface hardness of the treated samples was measured at room temperature by Vickers microhardness tester by HV 0.05 load. The hardness values quoted are the average of at least 5 readings, and the experimental error in this case was less than 10 pct of average.
An optical micrograph of cross – sectional morphology and microstructure observed on treated steel samples, obtained by using enlargement 100 x are shown in Figures 1 – 4.

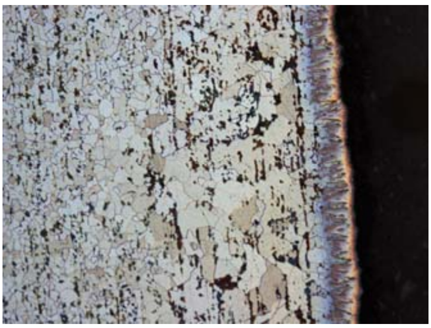

Figure 1. Duplex layers on the steel C15E

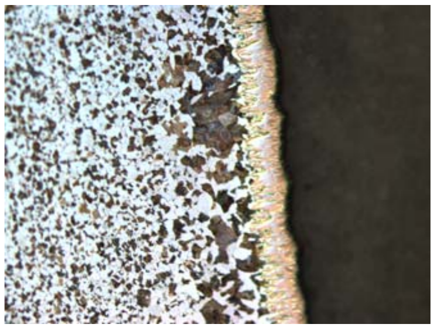

Figure 2. Duplex layers on the steel 20MnCr5

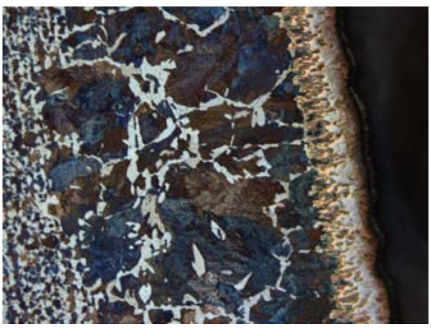

Figure 3. Duplex layers on the steel C45E

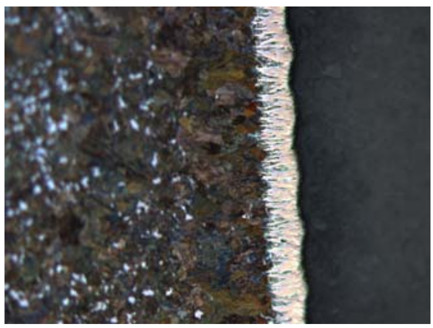

Figure 4. Duplex layers on the steel 42CrMo4

Figures 5 – 6 show X – ray diffraction pattern recorded on the treated steel samples.

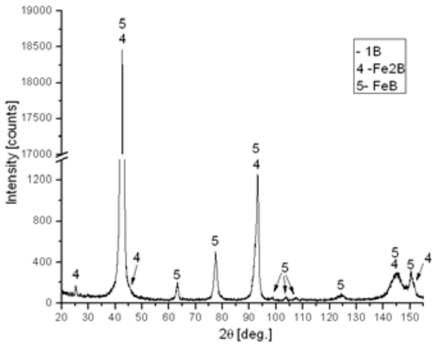

Figure 5. XRD pattern on the steel C15E

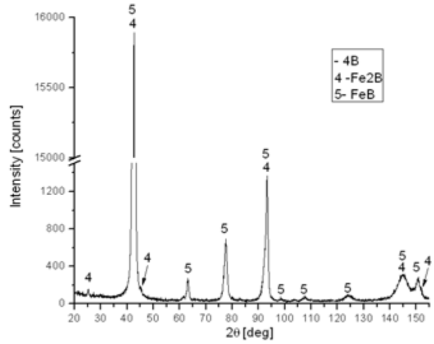

Figure 6. XRD pattern on the steel 42CrMo4

Microhardness profiles determined on the cross – section of the treated steel samples are shown in Figures 7 -10.

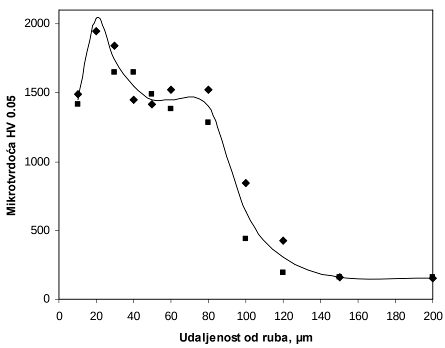

Figure 7. Microhardness profile on steel C15E

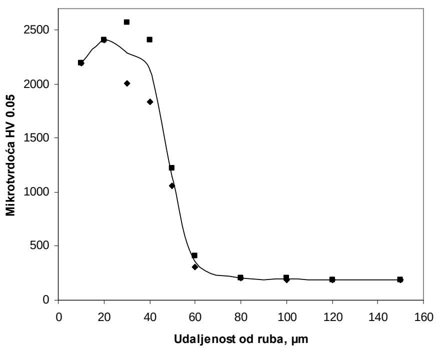

Figure 8. Microhardness on steel 20MnCr5

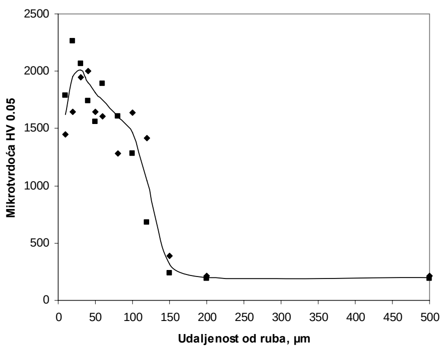

Figure 9. Microhardness profile on steel C45E

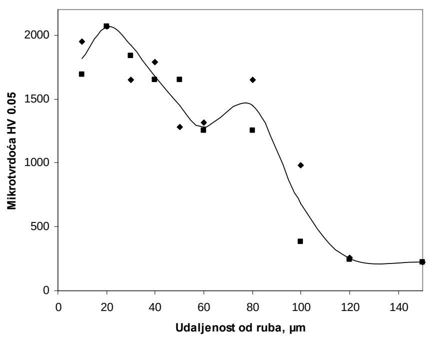

Figure 10. Microhardness on steel 42CrMo4

3. RESULTS AND DISCUSSION

Figures 1 – 4 show a morphology and microstructure of cross-section of duplex treated steel samples, observed by optical microscope. From the Figures 1 – 4 are evident that the microstructure of the treated steel surfaces shows three distinct regions: (1) a surface layer consisting of iron borides and probably hardly observable iron nitride phases, (2) a transition zone and (3) core (matrix). The dominant phases existing in the surface layer, on the bases of XRD analysis, were identified as iron borides and hardly observable iron nitride (Figures 5 – 6). It is worth to note here that interpretation of XRD spectra was not straightforward because of small line intensities and overlapping of lines belonging to the different phases present. Figures 7 – 10 show the microhardness profile determined on the cross-section of the treated steel samples, and from Figures 7 – 10 is evident that the hardness of diffusion layer is much higher than that of matrix because the presence of hard boride phases. It is demonstrated that valuable empirical information can be obtained by means of microhardness measurements, but for the sake of its proper interpretation one must turn to other techniques by which the changes in structure and microstructure can be revealed and correlate with the microhardness behaviour.

4. CONCLUSION

This preliminary contribution is part of systematic investigation designed to optimize the duplex treatment of construction steels, such as: low-carbon type (C15E and C45E) and low-alloying ones (20MnCr5 and 42CrMo4). In the scope of the results it can be emphasized:

(1) Main objective of this study was investigation of microstructure and properties of the treated steels after the thermodiffusion treatment. Attention is paid particularly to the thermodiffusion multicomponent boro-nitrided compound layer formed on the free surface in the treated steel samples.

(2) Duplex treatment, including boronizing and subsequent plasma nitriding processes, was selected and applied to the chosen steel samples in order to optionally improve their properties for particular engineering application.

(3) From an engineering point of view it is very important to define and select the process parameters that influence, by the boriding and nitriding processes, on the microstructure, and thus, respectively, on the end properties; and to be capable in advance to predict in particular case of steel and treatment, the formation of thermodiffusion layer with desired thickness and functional properties needed.

Additional investigation on the treated steel samples, including more favorable techniques, such as EDS, Raman spectroscopy and the other techniques, are in progress.

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