Publ. Astron. Obs. Belgrade No. 99 (2020), 125 - 128 *Contributed Paper*

TREATMENT OF STEEL SURFACES BY PLASMA FLOW GENERATED IN MAGNETOPLASMA COMPRESSOR

NORA TRKLJA BOCA[1], ŽARKO MIŠKOVIĆ[2], BRATISLAV OBRADOVIĆ[1], RADIVOJE MITROVIĆ[2] and MILORAD KURAICA[1]

[1] *Faculty of Physics, University of Belgrade, Studentski trg 12, Belgrade, Serbia*
E-mail nora@ff.bg.ac.rs

[2] *University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, Belgrade, Serbia*

Abstract. Steel (type 100Cr6) samples have been treated with plasma pulses, using helium with 5% of hydrogen as a working gas. Plasma is formed within electrode system of magnetoplasma compressor, a type of magnetoplasma accelerator which accelerates and compresses plasma. Every plasma shot deposits 9 J/cm^2 of energy to the surface of the treated material. The surface modification was monitored by optical microscopy, hardness measurement, roughness measurement, and X-ray diagnostics. The experimental setup enables spectra recording at the position where plasma-material interaction is realized. Improvements in physical properties of samples were achieved after plasma treatments.

1. INTRODUCTION

Magnetoplasma compressor (MPC) is a type of magnetoplasma accelerator, it has semi-transparent electrode system, it operates in an ion current transfer regime and produce quasi-stationary compression plasma flows (CPF) [Puric et al. 2003.]. The lifetime of the compressed plasma flow is around 150 μs, plasma velocity is up to 100 km/s, electron density and temperature are close to 10^{23} m^{-3} and 2 eV, respectively.

The topic of the present paper is investigation of interaction between plasma formed within MPC and steel 100Cr6 samples. Steel 100Cr6 is mainly used for small and medium sized bearing components. It is also regularly used for other machine components that require high tensile strength and high hardness.

2. EXPERIMENTAL SETUP

In the MPC, plasma is formed within the electrode system during the process of capacitor discharge. The presented research project has been realized in the residual gas regime, using helium with 5% of hydrogen. The position of the steel samples is fixed at z = 4.5 cm, where every plasma shot deposits 9 J/cm^2 of energy to the surface of the treated samples (Trklja et al. 2019.). Scheme of the experimental setup is shown in Fig.1

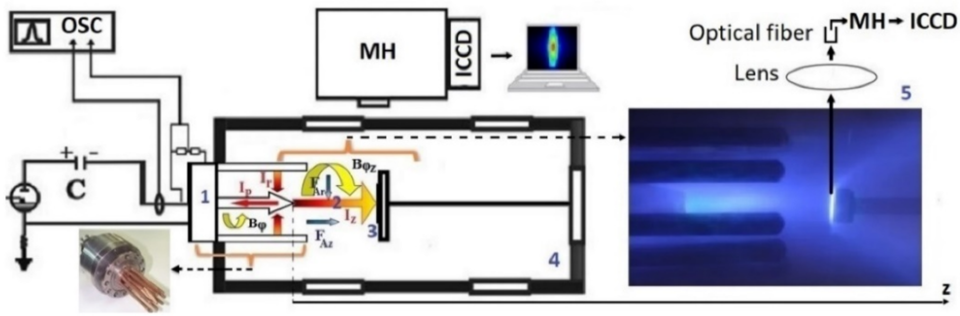

Figure 1: Experimental setup: 1. Magnetoplasma compressor, 2. Compressed plasma flow, 3. Sample, 4. Vacuum chamber, 5. Surface (steel 100Cr6) treatment by CPF.

Steel samples (1 cm x 1 cm) were mechanically cut, polished and prepared for treatment in MPC device. The general picture of the surface changes is obtained using optical microscope. Hardness and roughness of steel surfaces have been measured before and after plasma treatments using Zwick Mic 10 Hand Hardness Instrument and MarSurf XR 1 Surface Roughness Tester, respectively.

The X-ray diffraction (XRPD) investigation was conducted on automated multipurpose Rigaku Smartlab X-ray Diffractometer in $\Theta - \Theta$ geometry.

Spectral investigation of the plasma-surface interaction area is realized using one meter spectrometer and PIMAX1 ICCD camera.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Values of electron density and temperature in the plasma layer next to the sample surface are $2.4 \cdot 10^{22}$ m^{-3} and 0.5 eV, respectively. Electron density is calculated using distance between allowed and forbidden component of helium 447.1 nm line (Czernichowski et al., 1985.). The electron temperature is calculated using relative intensity ratio of Fe I and Fe II spectral lines.

Optical microscope images of the treated samples indicate the formation of vortex structures. Fig. 2. represents the surface of one steel sample treated with five plasma shots (which is not positioned on the center of the CPF, but it is useful for the present description) obtained by an optical microscope. There are three areas on this surface: the right part is the untreated region where the plasma hasn`t interact with the surface; the left part of this sample is the region where CPF hits the sample directly; the middle area represents the peripheral zone of plasma – sample interaction in which material from the central area of plasma - surface interaction is blown and smooth area is formed.

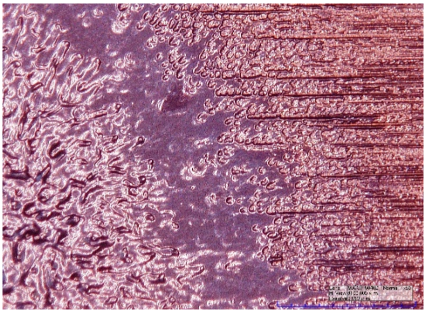

Figure 2: Untreated and treated steel 100Cr6 samples (optical microscope)

From the results of the roughness measurement it can be seen that after treatment with three and more plasma shots, the peripheral region of the treated surface becomes noticeably flat. The central area of the treated surface become significantly rough after several treatments because during each plasma-target interaction, the surface material is again melted and mixed.

Plasma shots make steel target firmer after just one plasma treatment. Three plasma shots lead to a hardness value of 350 HV and after more than three plasma shots, it comes to saturation.

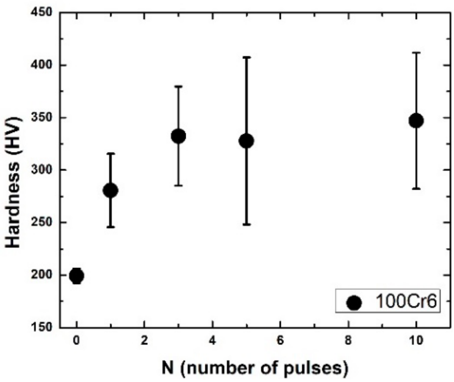

Figure 3: Hardness of the steel 100Cr6 samples depending on the number of plasma treatments

Result of x-ray analysis of the sample treated with ten plasma shots is represented in Fig.4. Starting sample (steel 100Cr6) is solely composed from α-Fe.

Treatments with plasma shots leads to partially transformation to γ-Fe of thin surface layer of sample.

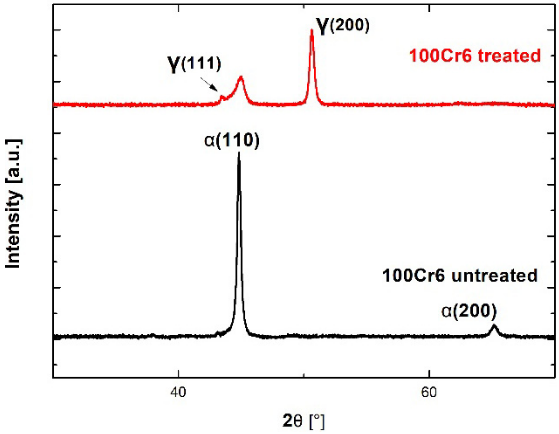

Figure 4: Hardness of the steel 100Cr6 samples depending on the number of plasma treatments

4. CONCLUSIONS

Modifications of steel 100Cr6 samples treated by a plasma produced within MPC have been monitored depending on the number of plasma treatments. Significant improvement of hardness has been achieved. Presented type of experimental investigation is useful for industry application and it is of interest for fusion related experiments concentrated on material treatment within plasma accelerators and analysis of the surface modification under high thermal loads.

References

Czernichowski, A., Chapelle, J.: 1985, *JQSRT*, **33**, 427.
Purić, J., Dojcinovic, I. P, Astashynski, V. M., Kuraica, M. M., Obradovic, B. M.: 2003, *Plasma Sources Sci. Technol.*, **13**, 74.
Trklja, N., Iskrenovic, P. S., Miskovic, Ž. Z., Krstić, I. B., Obradovic, B. M., Mitrović, R. M., Kuraica, M. M.: 2019, *JINST*, **14**, C09041.