

UNCERTAINTY ESTIMATION OF DAMAGE FACTOR
OF MATERIALS PROPERTIES UNDER THE PLASMA INFLUENCE

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Abstract

Estimation of the average rate of the surface roughness depends on the power flux density, and duration of the plasma interaction with the investigated samples. The same parameters influence on the damage factor and on the roughness of the sample surfaces. This research tries to get better numerical correlation between the analysed parameters and the damage factor

Key words: correlation, power spectral density, surface roughness

1. INTRODUCTION

Plasma Focus Devices has ample opportunities for ionic-plasma processing of materials. Materials are processed for the purpose of creation of modified surface layers with changed properties and creation on this basis of new pulse technologies [1]. On the basis of conducted investigations using Plasma Focus Devices PF1000, PF6 and PF5M, the essential progress in understanding of dynamics of streams of ionic plasma [2] has been made. Investigation of a process of change of roughness of the modified surface layers is an important part of this paper. Samples of Steel of types BS 183 A, BS 92 B, as well as tungsten were investigated to compare the behavior of materials in contact with plasma. Experiment was conducted on Plasma Focus Devices PF12 (Tallinn University of Technology). The collected statistical material will allow to predict behavior of alloys in real conditions. It is shown that under the influence of high-energy impulses the erosion of materials appears, as well as superficial defects. Also micro-cracks are formed. But the rate of surface damage itself will not be estimated. The paper proposed a method for estimating the quality of surface of investigated materials using the parameters of roughness. On the other hand, from the change of micro-geometry of surfaces it is possible to estimate the density of the power. Power flux density, duration of interaction of plasma with sample materials influences the estimation of a roughness of surfaces of specimen materials. Also, the value of the coefficient of damage of the surface of specimen depends on the same set of influencing factors. The correlation can be used to decrease the dimension of the set of output data. The surface roughness was estimated from a profile which represents a fractured line of intersection of the surface by a plane which is perpendicular to the direction of irregularities. Profilogram of the surfaces of samples of the irradiated steels has been established using the „PGK 120 drive unit” and „LS10 laser pick-up”. When investigating the micro-geometry of the surface it is necessary to pay attention to the problem of filtration of the profile. Internal and external noise is present when

registering the profile. In this work a method of filtration of the profile using power spectral density of a random process is proposed. The profile of the surface is the realization of a stochastic function. The dependence of the amplitude of harmonics on the frequency is the amplitude spectrum of the profile. The surface wave-likeness, form deviation and roughness are connected to frequency of spectrum of the profile. Action of pulse streams of plasma on ferritic and chromo manganese austenitic steels is described by means of the dynamic object equation

2. MATERIALS SURFACE DAMAGE ESTIMATION

2.1 Power spectral density of random processes

Multiple pulse action of dense plasma on an alloy promotes change of micro-geometry of a surface. The pressure force of a stream of plasma on a surface of the investigated sample can be accepted as quasi-periodic. Then thermal plasma influence on an alloys are estimated using methods of non-linear dynamics. These dynamic systems are characterized by frequency transfer function. Harmonic input of a dynamic system causes the established oscillations in the output. For a fixed amplitude of the input the amplitude and the phase of the established output oscillations depend on the frequency of the input. The presence of a maximum in the amplitude-frequency characteristic testifies to a resonance in the dynamic system. In order to describe the statistical frequency of a random process, the concept of spectral density is used [3]. The profile of a surface of a material after plasma influence represents stochastic function realization. Estimation of spectral density of stationary casual sequences is done processing Periodograms [4]. The change of values of periodograms (the amplitude, the phase and frequency) indicates the existence of dissipative properties of the materials jointly with the alteration of the surface roughness. Values of the Periodogram are interpreted as the dispersion (data variation) for corresponding frequencies. It is necessary to identify frequencies which essentially influence cyclic change of geometry of a surface of investigated materials. The analysis of the form of a signal defines the parameters of a physical process to which belongs this signal. Such characteristics should reflect properties of all statistical process. Definition of any characteristic should include calculation of averages on group of values. Thus, the spectral density of physical process will allow to estimate its frequency structure. Method to find out the zero of the first derivative of the periodogram. In this paper, we show that method does, in fact, work if it is applied to an appropriately chosen monotonic function of the Periodogram.

2.2 Description of the method

The methodology includes the definition of a Periodogram $L(\omega)$, which for discrete values of parameters of a roughness $R_a(\frac{\Delta y_k}{v})$, $k = \overline{1, n}$ is calculated using the formula:

$$L(\omega) = \frac{1}{n^2} \left| \sum_{k=1}^{n-1} R_a\left(\frac{y_k}{v}\right) \cos\left(\omega \frac{y_k}{v}\right) - i \sum_{k=1}^{n-1} R_a\left(\frac{y_k}{v}\right) \sin\left(\omega \frac{y_k}{v}\right) \right|^2 \quad (1)$$

where n – quantity of discrete values of indicators of a roughness of a surface;

R_a – an average arithmetic deviation of a profile of a surface of an investigated material;

v – speed of moving of a diamond needle of the feeling device on a material surface.

The power spectral density of the surface geometry change of the processed material is estimated by the (1). As we deal with real process and real supervision a discrete series of measures is analyzed

$R_a(\frac{y_k}{v})$. Feeling device Perthometer Concept MFW 250 (Mahr) allows to choose the minimum step of displacement on a surface $\Delta y = 0,1$ mm and to measure at equal time intervals. It allows to simplify the analysis of series and to simplify statistical processing of signals with an estimation of measurement uncertainty.

2.3 Estimation of measurement uncertainty

When sensing a surface along imposed direction a gauge needle could slide off sharp edges, feeling only hollows. One profile cannot give the trustworthy information about change of geometry of a surface of investigated materials. Thus, the roughness parameter was calculated for profiles of the processed surfaces with a change of direction of a profile from longitudinal to the transverse one. From the results of experiments it has been concluded that the roughness parameter depends on number of impulses of irradiation of ferrite steels n , on power flux density of a stream of radiation q , on distance to the anode and on duration of pulse influence t . The damage coefficient of a surface of materials depends on the same influencing factors F . Having defined with sufficient accuracy the roughness parameters of a surface, it is possible to improve estimation of the damage coefficient. The improved estimation of the damage coefficient can be achieved only under condition of linear correlation between the damage coefficient and roughness parameter.

2.2.3 Estimation of Power spectral density

If one determines the frequency at which the spectral power density of a random sequence reaches a maximum it will be possible with sufficient accuracy to get the information about the deviations of the surface form. It is easy to determine frequencies corresponding to the maximum value of a power spectrum. The power frequency spectrum depends on frequency of influence according to the following formula (2):

$$\begin{aligned} & - \sum_{k=0}^{n-1} R_a(\frac{y_k}{v}) \cos 2\pi f(\frac{y_k}{v}) \sum_{k=0}^{n-1} R_a(\frac{y_k}{v})(\frac{y_k}{v}) \sin 2\pi f(\frac{y_k}{v}) + \\ & + \sum_{k=0}^{n-1} R_a(\frac{y_k}{v}) \sin 2\pi f(\frac{y_k}{v}) \sum_{k=0}^{n-1} R_a(\frac{y_k}{v})(\frac{y_k}{v}) \cos 2\pi f(\frac{y_k}{v}) = 0 \end{aligned} \quad (2)$$

According to the formula (2) the random process determined by a finite set of the real values is investigated $R_a = R_a(\frac{y_k}{v})$. The estimation of power (Periodogram) will define the frequency of harmonics that contribute most to the Fourier series.

Having constructed Periodogram, it is possible to define resonant frequency on which the true peak of the response of parameters of a roughness is observed with big accuracy.

3. DAMAGE FACTOR AND ROUGHNESS PARAMETER CORRELATION

For the surfaces of materials damaged by plasma, with various structural defects (Figure 1-5), the dependence has been defined between the harmonics' amplitude and the frequency influence.

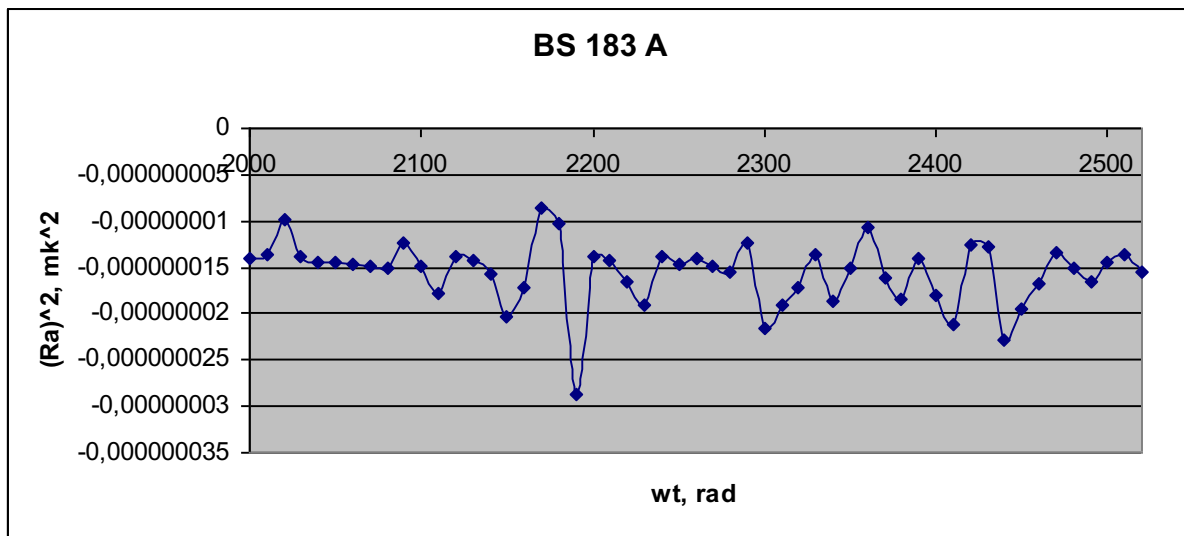


Figure 1 Steel BS 183A,
(8 shots, distance 6,5 cm)

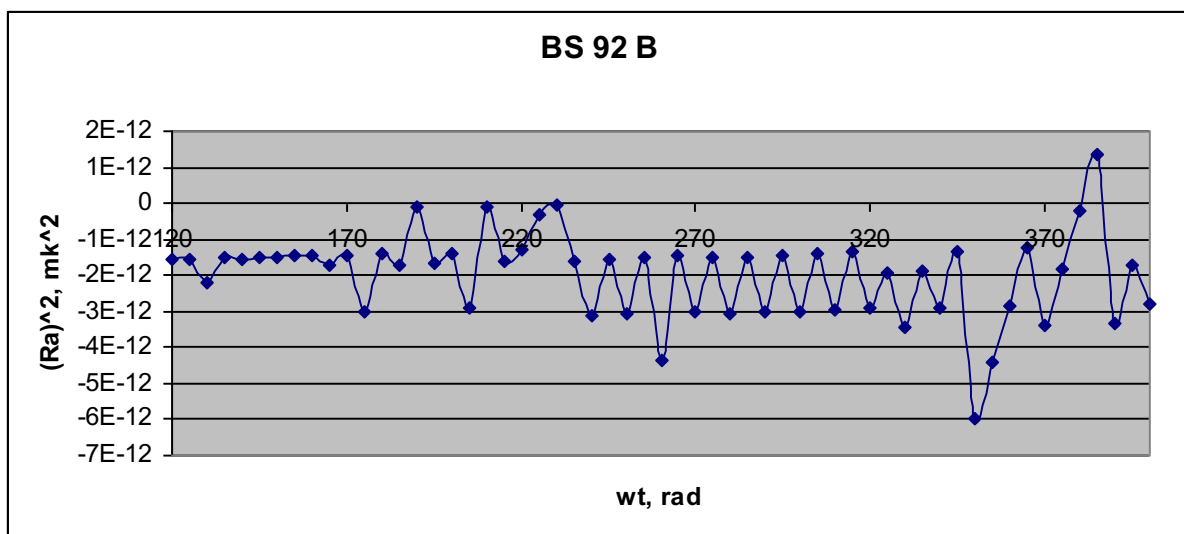


Figure 2 Steel BS 92 B
(2 shots, distance 3,5 cm)

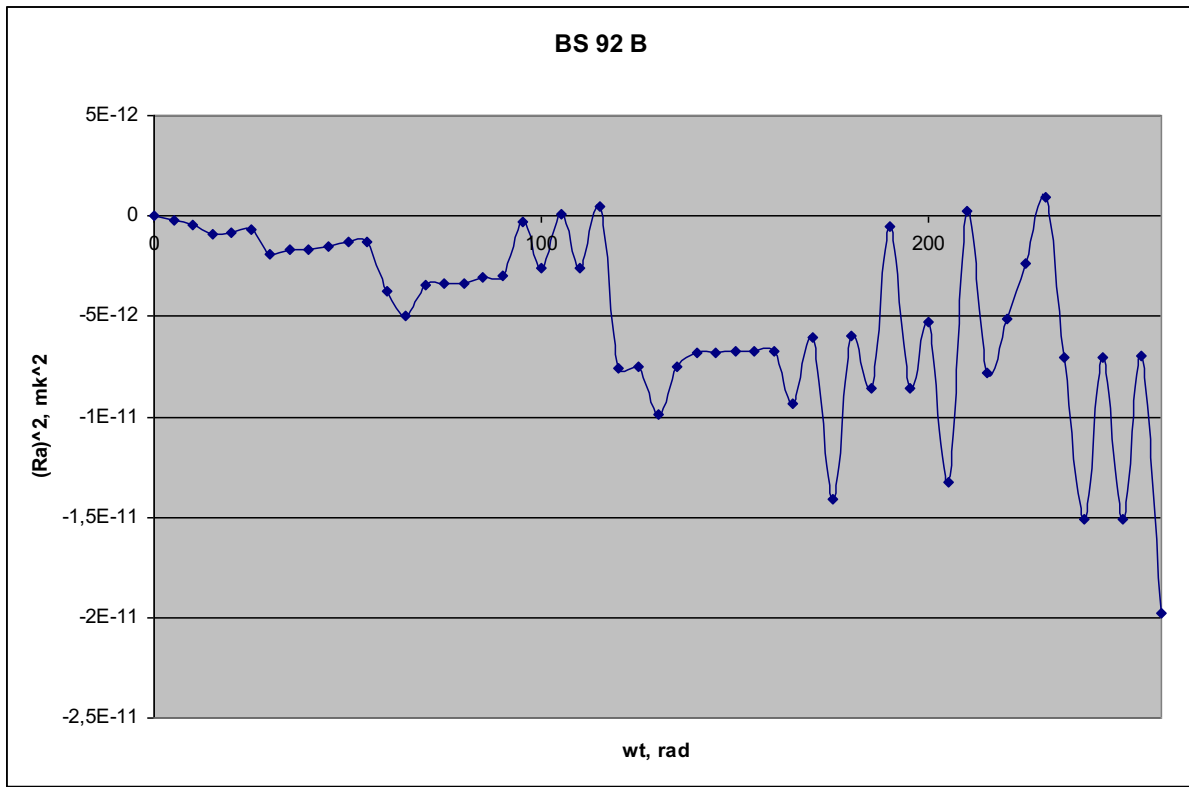


Figure 3 BS 92 B
(4 shots, distance 3,5 cm)

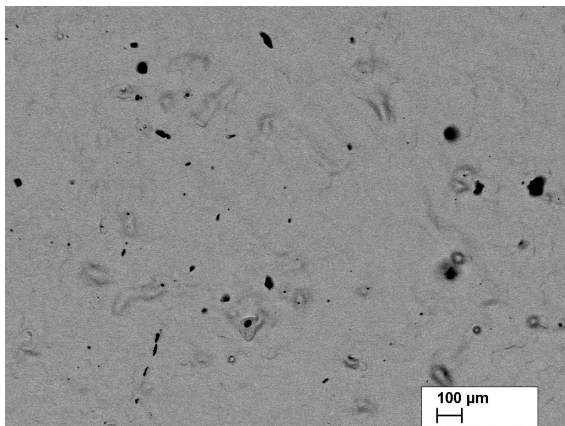


Figure 4 Steel BS 183A, BE-50x
(8 shots, distance 6,5 cm)

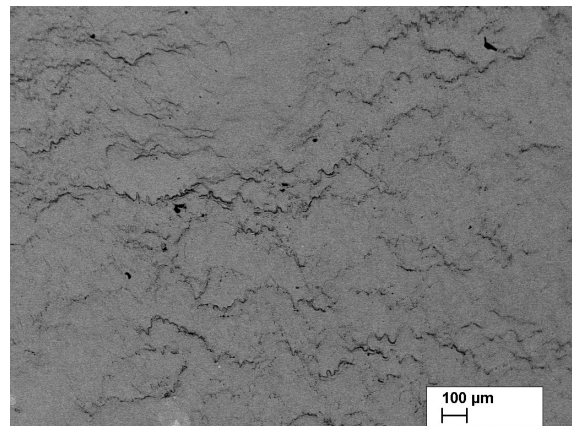


Figure 5 Steel BS 92 B, BE-50x
(2 shots, distance 3,5 cm)

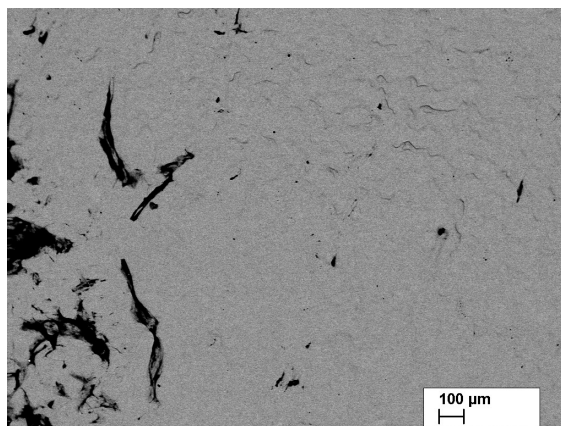


Figure 6 BS 92 B, BE-50x
(4 shots, distance 3,5 cm)

That fact that infringements in periodicity for different intervals of frequencies are observed means that for these given frequencies there are deviations from the surface form, a sinuosity, an essential roughness and noise.

4. CONCLUSIONS

The experiments conducted and processing of data gathered have allowed to formulate following conclusions:

- The dynamic model has been proposed to estimate the influence of pulse streams of plasma on ferritic and chromo manganese austenitic steels.
- By changing the density of the stream of plasma, basic pressure and partial pressure of gas in the chamber it is possible to investigate the change of geometry of the surface of materials. Correlation between the coefficient of damage and the parameter of roughness will allow to lower the dimension of a set of output data.
- From the change of the value of the parameter of surface roughness, it is possible to estimate the extent of surface damage of investigated materials. All influencing factors give rise not to a cumulative change of the surface geometry but to a precise part of these changes.

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