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## ПІДВИЩЕННЯ ЗНОСОСТІКОСТІ СТАЛІ 18ХГТ ПІСЛЯ ПЛАЗМОВОГО ТЕРМОЦИКЛІЧНОГО АЗОТУВАННЯ

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## ENHANCED WEAR RESISTANCE OF 18HGT STEEL BY PLASMA THERMOCYCLING NITRIDING TREATMENT

The use of external fields for the processing of new materials and coating has seen renewed interest in recent years. Enhancement techniques to improve surface properties and bulk features of materials by energy field treatment have attracted increasing attention [1, 2]. Numerous researchers have done about the advancement of material properties by magnetic, electric, and ultrasonic fields, and noteworthy results have obtained. Pulsed fields are favoured for minimizing energy consumption [3].

The surface hardening of steels and alloys using plasma nitriding is an efficient and reliable technique that will be employed in the manufacturing and machining industries primarily to treat engine components and machine tools [3, 4].

In this study, the effect of plasma nitriding treatment with thermal cycling on the wear resistance of 18HGT steel (0.2C, 0.27Si, 1.0Mn, 0.06Ti, 1.3Cr) was analyzed. Each cycle induces high temperatures in an exceedingly time in the vacuum chamber, followed by an also fast cooling down. Plasma nitriding of steel samples has been carried out using pulse DC glow discharge. Plasma nitriding was performed in an environment of a 25% N2 and 75% Ar mixture. The gas flow rate was controlled by a mass flow meter. After nitriding for the specified time, the specimens were cooled to the room temperature in the vacuum chamber. The plasma nitrided samples showed significant surface property improvements: the dissolved nitrogen and also the volume expansion of nitrides precipitation cause compressive residual stress within the diffusion layer.

The study deals with modeling wear resistance in plasma nitriding treatment. The central composite rotatable design of the second-order was found to be the most efficient tool to establish the mathematical relation of the response surface using the smallest possible number of experiments. Due to a wide range of factors, it was decided to use three factors, five levels, and the central composite design matrix to develop a mathematical model. Consistent with our previous experiences, the predominant factors, which have a significant influence on wear resistance, were identified. They are chamber pressure, temperature, and duration of the nitriding process.

The chamber pressure ($p$) was regulated in between 50 and 100 Pa. The temperature ($T$) was kept between 450 and 550°C. The duration of the nitriding process ($t$) was varied from 3 to 9 h. Wear test duration under ambient conditions was 30 minutes for each run. The wear tests were conducted using a block-on-ring arrangement. The dimension of the block specimens was 20 mm×10 mm×5 mm. A plain carbon steel ring (HRC47) with an outer diameter 40 mm and a width of 10 mm was used as the counterpart. At the end of each test, the mass loss of the block specimens was measured. Three replicate wear tests were carried out to minimize data scattering, and also the average of the three replicate test results was reported.

The mass loss ($w$) was assessed as the second-order polynomial function of input process parameters. The obtained regression equation for the mass loss is given below:

$$w = 0{,}58025 - (1{,}26295 \cdot 10^{-3}) \cdot p - (1{,}95298 \cdot 10^{-3}) \cdot T - (2{,}33277 \cdot 10^{-3}) \cdot t +$$

$$+ (5{,}49167 \cdot 10^{-5}) \cdot p \cdot t + (1{,}34064 \cdot 10^{-\backslash 5}) \cdot p^2 + (2{,}08588 \cdot 10^{-6}) \cdot T^2 + (4{,}80995 \cdot 10^{-5}) \cdot t^2$$

Fig. 1 shows a three-dimensional plot of the response surface of the mentioned mathematical model.

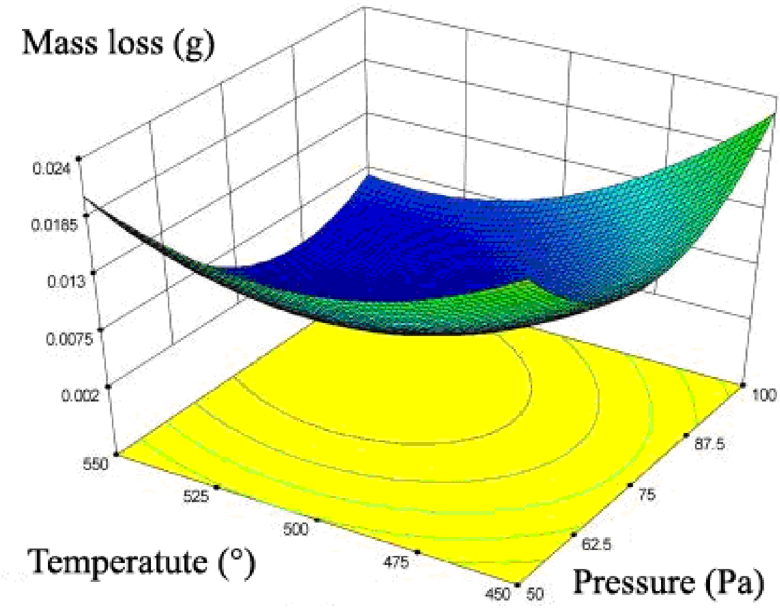


Fig. 1. Surface plot of the mass loss on the input parameters of the plasma nitriding treatment (the constant is the duration of the nitriding process: $t$ = 6 h)

With the mathematical model generated, it is possible to calculate or predict the mass loss for 18HGT steel. The obtained mathematical model contributes to the understanding of the effect of nitriding treatment parameters on the mass loss. Also, it has been shown that for the development of the model, it was necessary to require into consideration all the plasma nitriding treatment parameters.

The improvement of wear resistance for plasma-nitrided 18HGT steel is the result of a combination of microstructure and higher microhardness. Plasma thermocycling nitriding is effective in preventing surface shear deformation during the wear process, and wear of the nitrided steel occurred in a mild mode.

**Literature**

1. Guillon O. Manipulation of matter by electric and magnetic fields: Toward novel synthesis and processing routes of inorganic materials / O. Guillon, C. Elsässer, O. Gutfleisch et al. // Materials Today. – 2018. – V. 21, No 5. – P. 527 – 536.

2. Dolgov M. A. Use of the method of mathematical experiment planning for evaluating adhesive strength of protective coatings modified by energy fields / M. A. Dolgov, N. A. Zubrets'ka, A. V. Buketov, P. D. Stukhlyak // Strength of Materials. – 2012. – V. 44, No 1. – P. 81 – 86.

3. Dolgov N. A., Plasma thermocycling nitriding: An improved method for surface treatment / N. A. Dolgov, A. V. Rutkovsky // XVI International Conference Physics and Technology of Thin Films and Nanosystems (dedicated to memory Professor Dmytro Freik). Materials. / Ed. by Prof. Prokopiv V.V. – Ivano-Frankivsk : Publisher Vasyl Stefanyk Precarpathian National University, 2017. – P. 46.

4. Karamiş M. B. Wear behaviour of plasma nitrided steels at ambient and elevated temperatures / M. B. Karamiş, E. Gerçekcioğlu // Wear. – 2000. – V. 243, No 1–2. – P. 76 –84.