NEW METHOD FOR DETERMINATION MARTENSITE OF MICROSTRUCTURE OF HEAT TREATMENT MATERIALS

Abstract: In this article we present new method for determination martensite of microstructure of heat treatment materials. The martensite of a material is an important property that affects of materials. The martensite reaction in steels is the best known of a large group of transformations in alloys in which the transformation occurs by shear without change in chemical composition. The generic name of martensitic transformation describes all such reactions. Fractal characterization of surface topography is applied to the study of contact mechanics and heat treatment processes. The structure function method is used to find the fractal dimension D and the topothesy L. We develop a fractal geometry model, which predicts the wear rate in terms of these two fractal parameters for martensite structure of robot laser hardening process prediction.

Key words: hardening, fractal structure, martensite, intelligent system,
education, finance, robotics, artificial intelligence, astronomy, and more. The ability to develop machines and systems that automatically improve, puts machine learning at the absolute forefront of virtually any field that relies on data. Machine learning is at the forefront of incredible new innovations in several fields. Healthcare, education, astronomy, finance, robotics, and more are all being influenced by new developments in machine learning.

The aim of the contribution is to outline possibilities of applying intelligent system [5] namely; multiple regression [6] for the prediction of martensite structure in materials after robot laser heat treatment and to judge their perspective use in this field.

Fig. 1. Robor laser cell for hardening

2. MATERIAL PREPARATION AND METHOD

The study was undertaken using tool steel standard label 1.7225 tool steel. We change parameter of speed \( v \in [2, 5] \text{ mm/s} \) in steps of 1 mm/s, and temperature \( T \in [0, 2000] \text{ °C} \). On Fig. 2 we label with \( F \) (blue circle) ferit and with \( M \) (red circle) martensite structure.

Fig. 2. Robor laser hardened specimens

![Fig. 3. Microstructure of robot laser hardening specimens](image)

Martensite structure of microstructure of hardened specimens present area label with \( M \) (Fig. 3). We calculate area of SEM pictures of all this structures. Microstructure of robot laser hardened specimens have not self similar fractal structure but statistical self-affinity fractal structure. On Fig. 4 is presented statistical self-affinity fractal structure of robot laser hardened specimens.

![Fig. 4. Statistical self-affinity fractal structure of robot laser hardened specimens](image)

Firstly, we use program ImageJ to convert SEM images to 3D images of SEM images. Then, we find all point of 3D images od SEM images. We find coordinates \( (x,y,z) \) of graphs of 3D images od SEM images. We use new method [7] for estimating Hurst exponent \( H \) and calculating fractal dimension for 3D object with equation \( D=3-H \).

For analysis of the results, we used an intelligent system method [8], namely multiple regression [9-11]. The area of Intelligent Systems (ISs) has expanded phenomenally over the years since the 1940s; both in terms of the range of techniques and also in terms of the number of applications wherein they have often provided a competitive edge when compared with others approaches. IS includes a range of techniques that work synergistically and provides, in one form or another, flexible data/information processing capabilities for handling real life situations. IS, unlike conventional techniques, can exploit the tolerance for imprecision, uncertainty/ambiguities, approximate reasoning and partial truth in order to achieve tractability, robustness, and low cost solutions. The Multiple Regression operation studies the relationship between several predictor variables and a response
variable. Multiple regression designs are to continuous predictor variables as main effect ANOVA designs are to categorical predictor variables, that is, multiple regression designs contain the separate simple regression designs for 2 or more continuous predictor variables. The regression equation for a multiple regression design for the first-order effects of 3 continuous predictor variables \( P, Q, \) and \( R \) would be

\[
Y = b_0 + b_1P + b_2Q + b_3R
\]

On Fig. 5 is presented example of multiple regression.

3. RESULTS AND DISCUSSION

In Table 1, the parameters and hardness of hardened specimens. We mark specimens from P1 to P21. Parameter \( X_1 \) presents the parameter of temperature \( [\degree C] \), \( X_2 \) presents the hardening speed \([\text{mm/s}]\) and \( X_3 \) presents the fractal dimension estimating with new method. The last parameter \( Y \) is the martensite structure in \( (%) \) of the laser-hardened robot specimens. In Table 1, we can see that specimen P15 has the largest fractal dimension, 2.408. Thus specimen P15 is the most complex. Specimen P6 has the most martensite structure after hardening, that is 61%. In table 2, the experimental and prediction data are presented. Column 1 present name of specimens, column 2 present experimental data and column 3 present predicted data of multiple regression. Prediction with multiple regression are presented in columns 3. The measured and predicted martensite structure of laser-hardened robot specimens is shown in the graph in Fig. 6. The regression model presents a 14.21% deviation from the measured data.

Model Regression

\[
Y = 5.724788459 \times 10^{-3} \times X_1 - 1.296365336 \times X_2 + 3.987427179 \times X_3 + 35.07017084
\]
The martensite structure of a material is an important mechanical property that affects the performance of materials. We cannot apply Euclidean geometry to describe the martensite structure of hardened specimens because hardness is very complex. Here we use fractal geometry to describe the martensite structure of robot laser-hardened specimens. The fractal approach is more appropriate in the characterization of complex and irregular surface microstructures observed in the martensite microstructure surface of robot laser hardened specimens and can be effectively utilized for predicting the properties of material from fractal dimensions of the microstructure. A statistically significant relationship was found between the roughness, parameters of the robot-laser cell and fractal dimension. In addition, image analysis of the SEM images of the robot-laser-hardened specimens is an interesting approach.

4. CONCLUSION

In the paper we present new method for determining martensite microstructure of robot laser hardened specimens. We use method fractal geometry to analyze complexity of the robot-laser-hardened specimens. The main findings can be summarized as follows:
1. We describe martensite structures of the hardened specimens by using fractal geometry.
2. We describe the relationship between martensite structure and the parameters of the robot-laser cell by using the fractal dimension. This finding is important with regard to certain alloys that are hard to mix because they have different melting temperatures; however, such alloys have better technical characteristics. By varying different parameters (e.g., temperature), the robot-laser cells produce different patterns with different fractal dimension.
3. To predict the (%) of the martensite structure of robot laser hardened specimens, we use multiple regression.
4. Using the presented intelligent system, we increase production of the robot laser hardening process by decreasing time of the process.

5. REFERENCING


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