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Modeling surface roughness of point robot laser hardening, with emphasis on the surface

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Abstract

The topic of Machine Learning is so popular that it is not only the future trend, but also the money tide. Machine learning technique and intelligent system methods are very popular in mechanical engineering. Robot laser surface hardening is one of the most promising techniques for surface modification of the microstructure of a material to improve wear and corrosion resistance. For predicting the surface roughness of the hardened specimens, the support vector machine and multiple regression is used. The aim of this paper is to present modeling roughness of point robot laser hardened specimens with different parameters of robot laser cell.

Keywords: *modeling, surface roughness, robot, laser, hardening.*

1 Introduction

The research and construction of machine learning (Char, Shah, Magnus, 2018) is a special algorithm (rather than a specific algorithm) that allows the computer to learn from the data to make predictions. Therefore, machine learning is not a specific algorithm, but a collective term for many algorithms. Machine learning includes many different algorithms. Deep learning (Rolnick, Tegmark, 2018) is one of them. Other methods include decision trees, clustering, Bayes, etc.

Deep learning is inspired by the structure and function of the brain, which is the interconnection of many neurons. Artificial Neural Network (ANN) (Varun Kumar, Ajith, Václav, 2017) is an algorithm that simulates the biological structure of the brain. Whether it is machine learning or deep learning, it belongs to the category of artificial intelligence (AI).

Laser hardening (Babič, 2018) is rapid heating and self-excited cooling. It does not require furnace insulation and coolant hardening. It is a pollution-free and environmentally friendly heat treatment process that can easily perform uniform hardening on the surface of large molds. Because the laser heating speed is fast, the heat-affected zone is small, and the surface scanning heating and hardening, that is, the local heating and hardening are instantaneous, the deformation of the processed mold is small. Due to the small divergence angle of the laser beam, it has good directivity and can accurately local quench the mold surface through the light guide system. The depth of the hardened layer of laser surface hardening is generally 0.3～1.5mm Industrial robots ensure the proximity of laser beams to components. The laser light source of the laser is operated by an industrial robot. An attached swivel-tilt table for workpiece positioning almost completely ensures the proximity of the laser beam to the surface of the component. The industrial robot can be supplemented with linear coordinate axes when needed.

The aim of this paper is to present modeling roughness of point robot laser hardened specimens with different parameters of robot laser cell.

2 Material preparation and method

Our study was limited to tool steel of DIN standard 1.7225. The chemical composition of the material was 0.38 to 0.45% C, 0.4% maximum Si, 0.6–0.9% Mn, 0.025% maximum P, 0.035% maximum S, and 0.15–0.3% Mo. Firstly, we point robot laser hardened specimens with different temperature T∈ [850, 1300]°C and power P∈[1000, 1500] W. After point robot laser hardening (Fig. 1), specimens were polished and etched. Detailed characterization of their microstructure (Fig. 2) surface modifications was conducted using a JEOL JSM-7600F field emission scanning electron microscope (SEM). We used the program ImageJ (available from the National Institute of Health, USA) to analyze these pictures.

Figure 1. Point robot laser hardened specimen with different parameters of robot laser cell

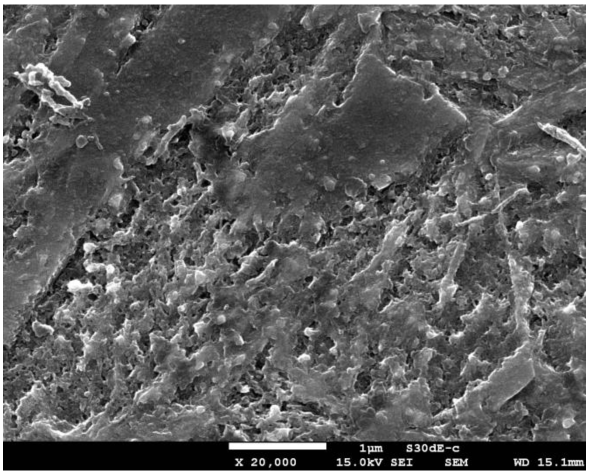

Figure 2. Microstructure (SEM) of point robot laser hardened specimen

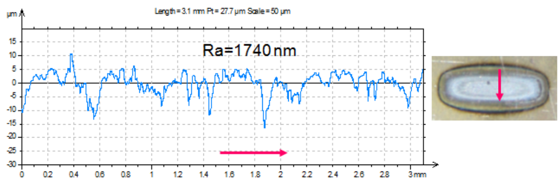

Figure 3. Roughness of point robot laser hardened specimen

On these specimens, (Fig. 3) the roughness of the robot-laser-hardening were measured. A profilometer (available from the Jožef Stefan Institute of Ljubljana) was used to measure the surface roughness parameter Ra (arithmetic mean deviation of the roughness profile) and hardness of the robot-laser-hardened specimens.

For analysis of the results, we used an intelligent system methods (Cuevas, Díaz, Camarena, 2021), namely multiple regression (Srinivasan, Murugasan, 2021) and support vector machine (Xiong, Mo, Yan, 2021).

Multiple linear regression is an extension of simple linear regression, which studies the quantitative dependence between a dependent variable and multiple independent variables. Multiple linear regression uses a regression equation to describe the dependence of a dependent variable and multiple independent variables, referred to as multiple regression. Figure 4 represent example of multiple regression.

The mathematical model of multiple linear regression is:

$$Y = b_0 + b_1X_1 + b_2X_2 + ... + b_mX_m + \varepsilon,$$

where, for i=n observations:

Y is dependent variable,
X_i is explanatory variables,

b_0 is y-intercept (constant term),
b_m is slope coefficients for each explanatory variable
ϵ is the model's error term (also known as the residuals).

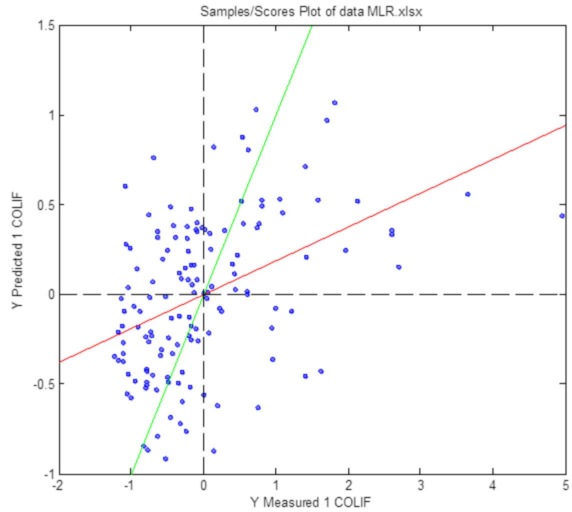

Figure 4. Example of multiple regression

Almost all machine learning courses will talk about a very classic algorithm called a support vector machine. It is very easy to apply the support vector machine to practical problems. Support Vector Machine (SVM) is a machine learning model based on statistical learning theory. It has relative advantages for small samples, nonlinearities, high dimensionality and local minimum points. This concept was actually put forward by mathematicians Vapnic and Chervonenkis as early as the 1960s and 1990s, and established this set of statistical learning theory. In addition to good results in text classification, image classification, and protein classification in medicine, it also has a wide range of applications in industry due to its advantages of fast calculation speed and low space cost. Figure 5 represent example of support vector machine.

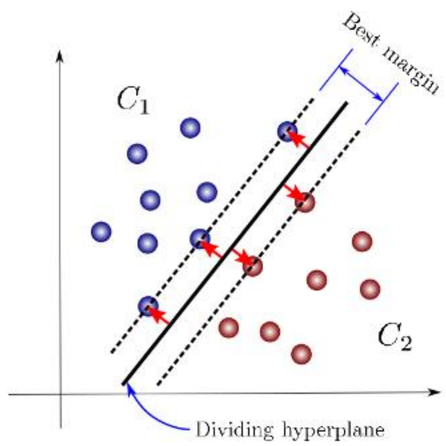

Figure 5. Example of support vector machine

3 Results and discussion

Table 1 represent parameters of robot laser hardened specimens. Column S presents notation of point robot laser hardened specimens with different power and temperature. Column X1 represents temperature of point robot laser hardening. Column X2 represents power of point robot laser hardening. The last column represents roughness of point robot laser hardening. The higher roughness has specimen P12. P12 is point robot laser hardened with parameter 900 °C and 1500 W. Minimal roughness has specimen P7. P7 is point robot laser hardened with parameter 1150 °C and 1000 W.

Table 2 represent measured and predicted roughness of point robot laser hardened specimens. In column S notation of specimens are presented. Second column represents measured data. The next column represents predicted data with support vector machine P SVM and the last one represents predicted data with multiple regression P MR.

We use v-SVM Type with regression cost (C) 1,00. Optimization parameters, we use 100 iteration limit and numerical tolerance 0,001. We use Kernel $(g\times x\times y+0.13)^3$ and g was auto.

Prediction with multiple regression has 83% precision. Prediction with support vector machine has 73% precision. Model of multiple regression is presented by equation (1).

S	X1 (°C)	X2 (mm/s)	Y (nm)
P1	850	1000	1156
P2	900	1000	892
P3	950	1000	1336
P4	1000	1000	1008
P5	1050	1000	835
P6	1100	1000	933
P7	1150	1000	760
P8	1200	1000	775
P9	1250	1000	799
P10	1300	1000	1346
P11	850	1500	1569
P12	900	1500	1740
P13	950	1500	1187
P14	1000	1500	1125
P15	1050	1500	1916
P16	1100	1500	1677
P17	1150	1500	1518
P18	1200	1500	1217
P19	1250	1500	1286
P20	1300	1500	1766

Table 1. Parameters of robot laser hardened specimens

S	Y (nm)	P SVM (nm)	P MR (nm)
P1	1156	892	1021
P2	892	1156	1013
P3	1336	1008	1005
P4	1008	1336	996
P5	835	1008	988
P6	933	835	980
P7	760	933	972
P8	775	799	963
P9	799	1346	955
P10	1346	799	947
P11	1569	1740	1537
P12	1740	1187	1529
P13	1187	1740	1521
P14	1125	1916	1512
P15	1916	1677	1504
P16	1677	1916	1496
P17	1518	1677	1488
P18	1217	1518	1480
P19	1286	1217	1471
P20	1766	1286	1463

Table 2. Measured and predicted roughness of point robot laser hardened speceimens

$$Y=-0.16406X_1 + 1.0322X_2 + 128.16515 \quad (1)$$

In process of robot laser hardening parts are not deformed. Laser hardening is clean, efficient, and does not require cooling media such as water or oil. The hardening hardness is higher than the conventional method, and the hardened layer has a fine structure and good toughness.

Intelligent System is aiming at the strategic needs, focusing on the theoretical changes and application challenges brought about by future intelligent technologies, studying the theory, technical models and key algorithms of human-computer confrontation for intelligent decision-making, forming human-computer confrontation.

4 Conclusion

In this paper is presented modeling roughness of point robot laser hardened specimens with different parameters of robot laser cell. Two methods of intelligent system namely; support vector machine and multiple regression are presented to predict surface roughness of point robot laser hardened specimens, with emphasis on the surface. Prediction with multiple regression has better precision as support vector machine.

In the future research, several parameters of point robot laser cell and several machine learning methods can be used.

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