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USING GENETIC PROGRAMMING TO MODEL PROCESS OF ROBOT LASER HARDENING

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Abstract: *This article describes the fractal geometry of robot laser hardening microstructure at different parameter. We show the experimental results and analysis of fractal patterns that occur in robot laser hardening at different parameter. In the end we present fractal geometry in point robot laser hardening pattern. Robotic laser hardening is used in the aerospace, automotive and military industries. Fractals can be defined in many ways, the simplest definition being that they do not change shape with scale, and thus they exhibit self-similar properties. Their fundamental property is fractal dimension D, which yields important insights into the physical properties of geological objects. Fractals are a beautiful of mathematics and art. Perhaps this is the reason why most people recognize fractals only as pretty pictures useful as backgrounds on the computer screen or original postcard patterns. The fractal patterns look complex in robot laser hardened patterns to. Fractal structures can be find in robot laser hardened patterns to if it was observed it with electron microscope. Robot laser surface hardening heat treatment is complementary to the conventional flame or inductive hardening. In this work we have used scanning electronic microscope (SEM), search and analyze the fractal structure of the robot laser-hardened material. It was use method of intelligent system, namely genetic programming to model hardness in depth of robot laser hardening.*
Key words: *Robot, laser, hardening, genetic programming.*

Korištenje genetskog programiranja za modeliranje procesa očvršćavanja dobijenog uz pomoć robotskog lasera. *Ovaj članak opisuje fraktalnu geometriju mikrostrukture očvrsnuća laserom pomoću robota pri različitim parametrima. Prikazani su eksperimentalni rezultati i analiza fraktalnih obrazaca koji se pojavljuju pri laserskom kaljenju pomoću robota na različitim parametrima. Na kraju je prikazana fraktalna geometriju u uzorku laserskog kaljenja pomoću robota. Robotsko lasersko očvršćivanje koristi se u vazduhoplovnoj, automobilskoj i vojnoj industriji. Fraktali se mogu definisati na više načina, najjednostavnija definicija je da ne menjaju oblik sa skalom, i na taj način pokazuju slična svojstva. Njihovo osnovno svojstvo je fraktalna dimenzija D, koja daje važan uvid u fizička svojstva geoloških objekata. Fraktali su prelepa matematika i umetnost. Možda je to razlog što većina ljudi prepoznaje fraktale samo kao lepe slike korisne kao pozadine na ekranu računara ili originalne obrasce razglednica. Fraktalni obrasci izgledaju složeno u uzorcima očvrsnutih pomoću laserskog robota. Fraktalne strukture možemo pronaći u uzorcima laserski očvršćenih na robotima, ako bi se posmatrali na elektronskom mikroskopu. Termička obrada površinskog otvrdnjavanja pomoću laserskog robota komplementarna je uobičajenom plamenu ili induktivnom kaljenju. U ovom radu korišćen je skenirajući elektronski mikroskop (SEM), pretraženi i analizirani su fraktalna struktura materijala koji je očvršćen laserom. Korišćen je metod inteligentnog sistema, odnosno genetsko programiranje za modeliranje tvrdoće u dubini sloja laserski očvrsnutog pomocu robota.*
Ključne reči: *Robot, laser, kaljenje, genetsko programiranje.*

1. INTRODUCTION

Laser hardening [1] is a metal surface treatment process complementary to conventional aime and induction hardening processes. A high-power laser beam is used to heat a metal surface rapidly and selectively to produce hardened case depths of up to 1,5mm with the hardness of the martensite micro-structure providing improved properties such as wear resistance and increased strength. Fractal patterns are observed in computational mechanics of elastic-plastic transitions. The Fractal dimension is a property of the fractal, which is maintained through all the extensions and is therefore well denned. In addition, it shows how complex the fractal is. The Fractal dimension is generally not calculated by the above-mentioned procedure, as this is possible only on pure mathematical constructs, which do not exist in nature.

Fractal [2] is a letter made by Benua Mandelbrot for this purpose combine under one heading an extensive class of objects played the historical role in the development of pure mathematics. At the risk of answering the call, I thought and worked out the new geometry of Nature, and also found for its application in many diverse fields. The new geometry is capable describe many of the irregular and fragmented forms in the world around us and give birth to completely completed theories, identifying the family of figures that I call fractals. From the moment of the book B. Mandelbrot's "Fractal Geometry of Nature" began the burgeoning development of fractal geometry. Fractals found practically everyone natural phenomena and processes. Fractal models applied in medicine for early diagnosis of cancerous tumors; in material studies in the study of the processes of destruction of products; in nuclear physics and astronomy for the study of elementary particles, the distribution of galaxies in the universe, the processes of the sun; in computer science for data compression and traffic enhancement on the Internet; for analysis volatility of market prices in economics, heart rate in cardiology, weather in meteorology...

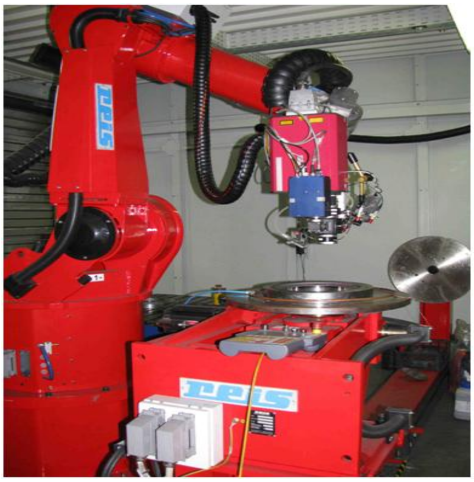

Fig. 1. Robot laser cell

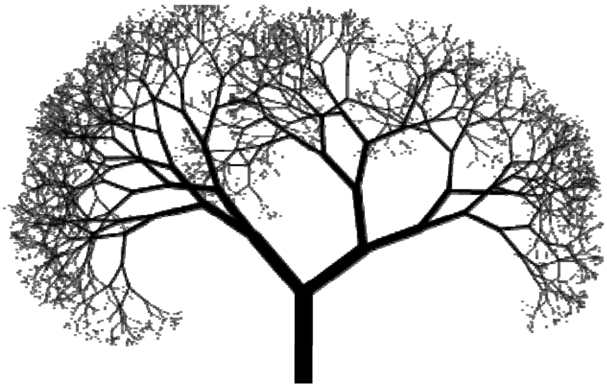

Fig. 2. Fractal

Machine learning [3] is a method of data analysis that automates analytical model building. It is a branch of artificial intelligence based on the idea that systems can learn from data, identify patterns and make decisions with minimal human intervention.

Evolutionary calculations [4], synonymous with prices in foreign countries literature is the term "evolutionary computation", proved its effectiveness as in the solution of artificial intellect (face recognition, clustering, associative search), and in solving the laborious tasks of optimization, approximation, intellectual data processing. Genetic Programming is inspired by biological evolution. It is a machine learning technique used to optimize a solution based on a fitness score. Genetic programming may be more powerful than neural networks and other machine learning techniques that are able to solve problems in a wider range of disciplines. The general idea behind genetic programming is: to start with a collection of functions and combine them randomly into programs; then run the programs and see which gives the best results; keep the best ones (natural selection), mutate some of the others, and test the new generation; repeat this process until a clear best program emerges.

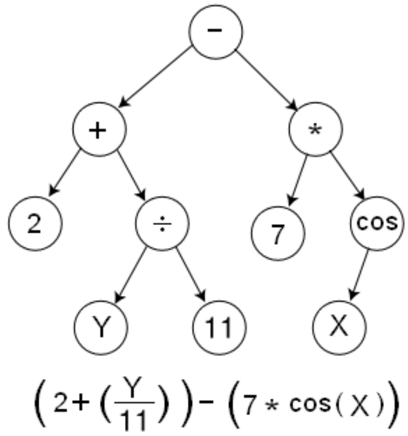

Fig. 3. Genetic programming model

2. MATERIALS PREPARATION AND METHODS

Our study was limited on tool steel standard label of DIN standard 1.7225 (Fig. 1). The chemical composition of the material contained 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. The specimen test section had a cylindrical form dimension 25×10mm (diameter×high). Speciment with the porosity about 19% to 50%, were prepared by laser technique, followed by hardening at $T \in [1000, 1400]$ °C and $v \in [2, 5]$ mm/s.

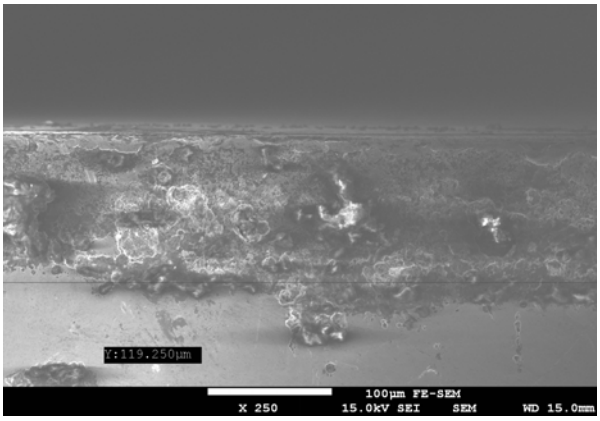

Fig. 4. Robot laser hardened specimens - hardened cone

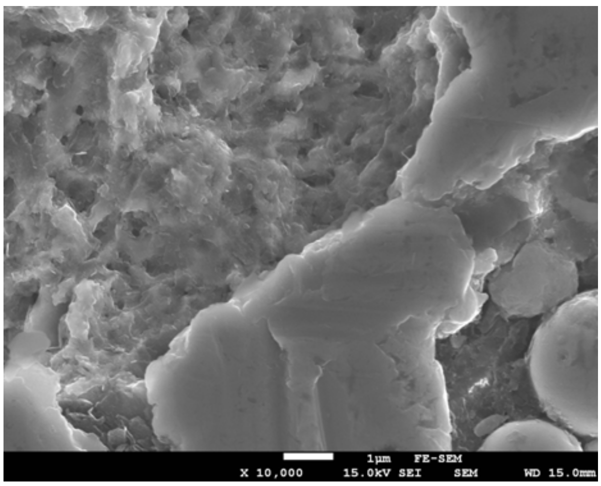

Fig. 5. Microstructure of robot laser hardened specimen

We used an intelligent system method; genetic programming for modelling hardness in depth of robot laser hardened specimens.

3. RESULTS AND DISCUSSION

In Table 1, the parameters of the hardened specimens impacting the hardness in depth of robot laser hardened specimens are presented. The specimens from P1 to P21 are marked. Parameter x_1 represents the temperature in degrees Celsius [C], x_2 represents the speed of hardening [mm/s], x_3 represents fractal dimension in 2D and Y represents hardness in depth of robot laser hardened specimens. Figure 6 represent hardness in depth of robot laser hardened specimen. Fig. 7 represent genetic programming model.

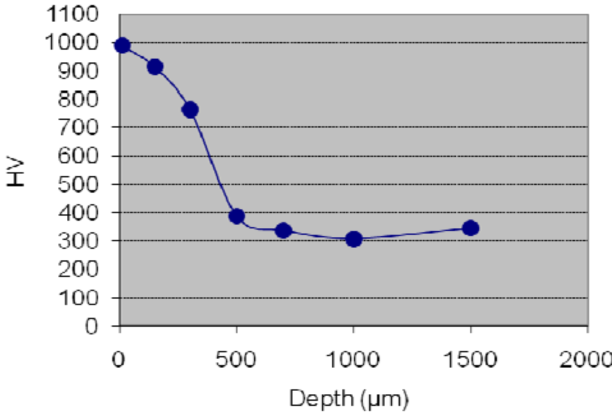

Fig. 6. Hardness (HV) in depth of robot laser hardened specimen

$$Y=\frac{X1}{X4}+\frac{X1}{-11.7+\frac{-5.356+X4}{X5}+0.17\times X1\times X6}-X5+(-5.356-X4+X6)$$
$$-\frac{6\times X4+\frac{X1}{-11.7+\frac{-5.356+X4}{X5}+0.17\times X1\times X6}+X6-\frac{X1\times X1\times X5}{X4\times\left(2\times X6+\frac{5.356\times X1}{2\times X4+2\times X6}\right)}+\frac{(X2-1.9381)\times X2}{X3-0.1768}}{(-5.356-X4)\times X5-\frac{X1}{X4+X6}-\frac{X1}{-7.513\times X4\times(-5.356-X4)+\frac{X4\times(X6-X5)}{X5}-\frac{X1\times X1\times X5}{X4\times(-X4+2\times X6)}}}$$

Fig. 7. Model of genetic programming

S	X_1	X_2	X_3	Y
P1	1000,0	2,0	1,9135	60
P2	1000,0	3,0	1,9595	58,7
P3	1000,0	4,0	1,9474	56
P4	1000,0	5,0	1,9384	56,5
P5	1400,0	2,0	1,9225	58
P6	1400,0	3,0	1,9784	57,8
P7	1400,0	4,0	1,9540	58,1
P8	1400,0	5,0	1,9776	58,2
P9	1000,0	2,0	1,9720	57,4
P10	1000,0	3,0	1,8580	56,1
P11	1000,0	4,0	1,9784	53,8
P12	1000,0	5,0	1,9410	56
P13	1400,0	2,0	1,9784	55,3
P14	1400,0	3,0	1,5810	57,2
P15	1400,0	4,0	1,9650	57,8
P16	1400,0	5,0	1,8113	58
P17	800,0	0,0	1,9669	52
P18	1400,0	0,0	1,9753	57
P19	2000,0	0,0	1,9706	56
P20	950,0	0,0	1,9631	58
P21	850,0	0,0	1,9537	57

Table 1. Parameters and hardness (HRc) of hardened specimens

Table 2 presents experimental and prediction data regarding the hardness in depth of robot laser hardened specimens. In Table 2, the symbol S represents the name of the specimens, E experimental data and GP prediction with genetic programming, Figure 8.

The hardness structure of a material is an important mechanical property that affects the hardness of materials. Here we use fractal geometry to describe the hardness of robot laser-hardened specimens. In this paper, we describe how the parameters (speed and temperature) of the robot laser cell affect hardness metal materials using a new method, for calculating fractal dimension in 3D space.The fractal analysis of a series of digitized surface microstructures from the robot laser surface modified specimens indicated that useful correlations can be derived between the fractal dimensions and the surface microstructural features such as hardness.

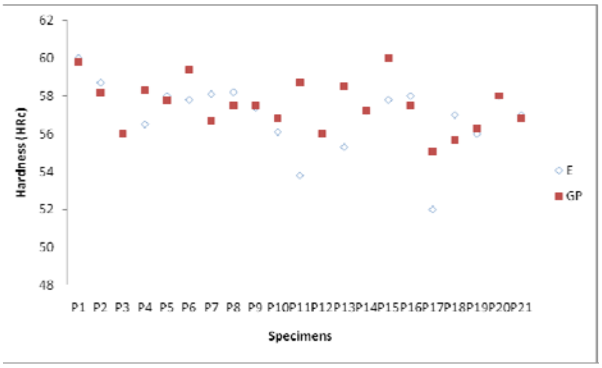

Fig. 8. The measured and predicted volume of robot laser hardened specimens

S	E	GP
P1	60	59,8
P2	58,7	58,2
P3	56	56,0
P4	56,5	58,3
P5	58	57,8
P6	57,8	59,4
P7	58,1	56,7
P8	58,2	57,5
P9	57,4	57,5
P10	56,1	56,8
P11	53,8	58,7
P12	56	56,0
P13	55,3	58,5
P14	57,2	57,2
P15	57,8	60,0
P16	58	57,5
P17	52	55,1
P18	57	55,7
P19	56	56,3
P20	58	58,0
P21	57	56,8

Table 2. Experimental and prediction data

4. CONCLUSION

The paper present using of genetic programming to predict hardness of depth of robot laser hardened specimens. With fractal geometry we describe the complexity of robot laser hardened specimens. The hardening of various metal alloys has shown that when melting occurs, fractal geometry can be used to calculate the fractal dimension. In the future, we want to explore new method for calculating fractal dimension in 3D space as a function of the parameters of a robot cell for laser hardening for pinned robot laser hardening: laser parameters such as power, energy density, focal distance, energy density in the focus, focal position, the shape of the laser flash, flash frequency, temperature and speed of hardening.

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