M.T. WANG, Y.X. CHEN, L. GAO

ISSN 0543-5846
METABK 62(3-4) 394-396 (2023)
UDC – UDK 669.15.26.24:621.41:535.2-621.795:631.3.026=111

STUDY ON LASER SURFACE MICRO-TREATMENT OF STAINLESS STEEL

Received – Primljeno: 2023-03-01
Accepted – Prihvaćeno: 2023-04-30
Original Scientific Paper – Izvorni znanstveni rad

Laser surface micro-treatment refers to the use of appropriate laser energy to induce the surrounding gas and stainless steel reaction to produce a film or the use of large laser energy to manufacture micrometer grating. Using the principle of thin film interference or grating diffraction, the surface of stainless steel is marked with color, which can be used for information storage of metallurgical products. The relationship between laser line scanning and laser power is studied experimentally, the range of laser power density with color variation is obtained, and the optimal process parameters of uniform color are obtained.

Keywords: 304 stainless, sheet, laser surface micro-treatment, power, color marking

INTRODUCTION

Laser surface micro-treatment is a special laser surface modification technology. This technology uses laser with low energy density to induce the reaction between surrounding gas and metal on the metal surface to generate colored oxide film or uses long pulse nanosecond laser with appropriate energy density to irradiate microscopic molten pool on the metal surface, and forms regular grating-like microstructure through line scanning of galvanometer or CNC platform. The microstructure has directional color change due to grating diffraction phenomenon[1-2]. The research of this technology has opened a new field in the barcode identification of metallurgical products. The two-dimensional barcode such as Data Matrix code, PDF417 code and QR code has been introduced into the color technology scheme to improve the information density and barcode capacity, and the visual expression is better [3-4].

EXPERIMENTAL MATERIALS AND EQUIPMENT

SUS304 stainless steel was used in the experiment. The surface was treated by mirror finished. The size of laser colored sample was 10mm×10mm. CT-MF20 fiber laser marking machine was selected for the experiment, as shown in Figure 1. The laser output wavelength is 1,06 μm, the maximum power is 20 W, the instability is less than 3 %, the beam quality factor M2 is less than 2, the modulation frequency is 20 kHz~100 kHz, the pulse width is 100 ns at 20 kHz, the scanning speed is 0~7000 mm/s, the minimum line width is 0.01 mm. The experimental samples are shown in Figure 2. The process parameters of the experiment were sweep line spacing and power. The scanning speed is 100 mm/s, the repetition rate is 20 kHz, the pulse width is 100 ns, and the defocus is -0,6 cm.

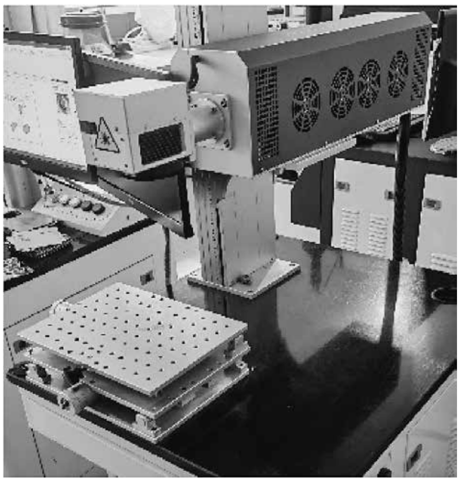

Figure 1 Laser marking machine

EXPERIMENTS

In Figure 2, the power in the first column on the left is 20 W, and then to the right, the power in each column is reduced by 2 W. When the power is reduced to a certain extent, yellow film will appear. It is composed of microfusion fringe, as shown in Figure 3(a). This yellow film is the base color of laser surface micro-treatment, on which all coloring is formed, as shown in Figure 3(b)[5-12].

In Figure 2, the spacing of the first row of line scanning is 0,01 mm, which is successively downward and increased by 0,01 mm for each row. The third row to the

M.T. Wang, Y.X. Chen, L. Gao, School of Applied Technology, University of Science and Technology Liaoning, Anshan, Liaoning China; Y.X. Chen (E-mail: chenyuxianglkd@163.com)

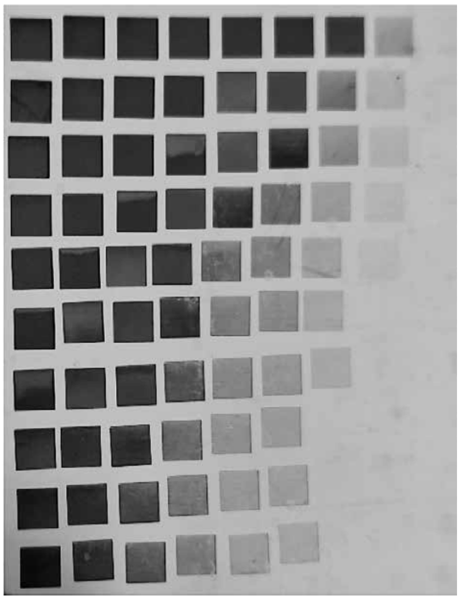

Figure 2 Laser marking samples

seventh row and the first column to the sixth column of the sample have certain color changes, indicating that stable color films are easy to form within the range of the process parameters. That is, the scanning line spacing is 0,03 mm-0,07 mm, and the power is 10 W-20 W.

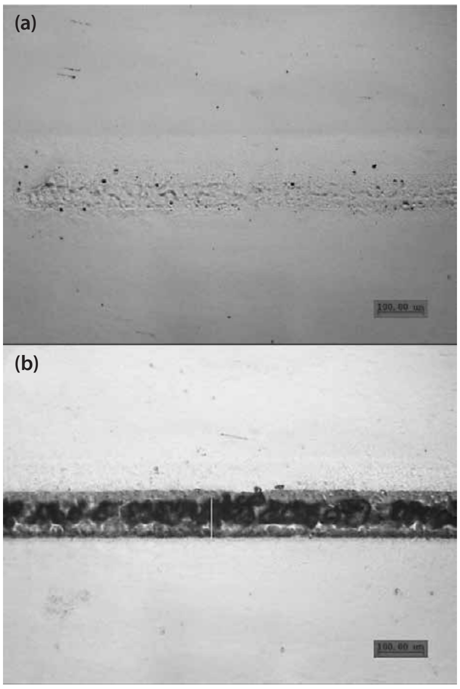

Figure 3 Laser marking colorization

By testing the line scan width shown in Figure 3, the relationship between power and line scan width can be obtained as shown in Table 1.

It can be seen from Table 1 that the laser line-scanning width is affected by the laser power. The larger the power is, the wider the line-scanning width will be. The data in Table 1 are plotted as shown in Figure 4. The linear scanning width converges with the decrease of laser power, indicating that the laser energy is concentrated in the center of the spot, which is consistent with the fact that the laser is a Gaussian beam.

Table 1 **Laser power and line width**

Power /W	10	12	14	16	18	20
Width /μm	19,65	27,51	41,93	66,8	81,21	100,86

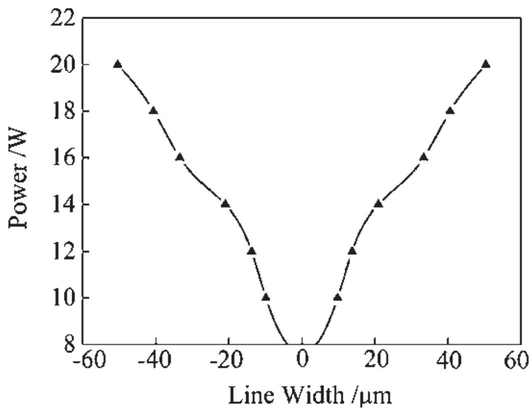

Figure 4 Laser line width

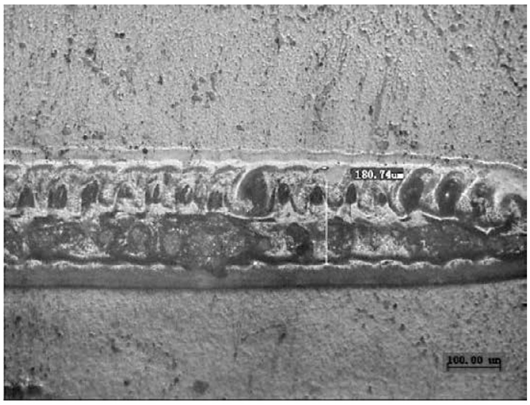

Figure 5 Laser spot diameter

In order to get the diameter of the laser spot, the paper is scanned by the laser line, and the results are shown in Figure 5. The laser spot diameter is 180.74μm. According to the spot diameter, the average laser energy density can be obtained, as shown in Table 2.

Table 2 **Laser power and energy density**

Power /W	10	12	14	16	18	20
Energy density /(mJ/cm^2)	3,9	4,68	5,46	6,24	7,02	7,8

According to the comparison between the data in Figure 2 and Table 2, the laser power density has a certain color change in the range of 3,9 mJ/cm^2-7,8 mJ/cm^2.

The uneven color of some samples is caused by two reasons. First, it is difficult for laser surface microprocessing to produce red film, which is not as stable as green and blue film. Another reason is that laser microprocessing using line scanning method, different line scanning width caused by stainless steel surface heat dissipation degree is different, have an impact on the uniform growth of color film, so the more large sample, the more difficult to get uniform color. In order to solve the problem of color uniformity of laser microprocessing, a large number of experimental results were compared, and it was found that the number of repetitiveness of laser microprocessing had a certain influence on color uniformity, as shown in Figure 6. The process parameters of the sample are as follows: defocus of -0.5cm, scanning interval 0.02 mm, scanning speed 200 mm/s, laser power 7 W, and laser repetition rate 20 kHz. The laser power density of this process parameter is 5.94 mJ/cm^2, which is just within the range of laser power density with color change analyzed above. As can be seen from Figure 6, the background color yellow sample was obtained after the first laser micro-treatment, and blue film was grown on the background color after the second time, green film after the third time, and red film after the fourth time. Except for the background color, the color changes in the 2-4 times were consistent with the color direction of the spectrum. According to the principle of film interference, the film thickness is gradually increasing, and the repetition times of laser microprocessing are helpful to the increase of film thickness uniformity, so the color uniformity is better.

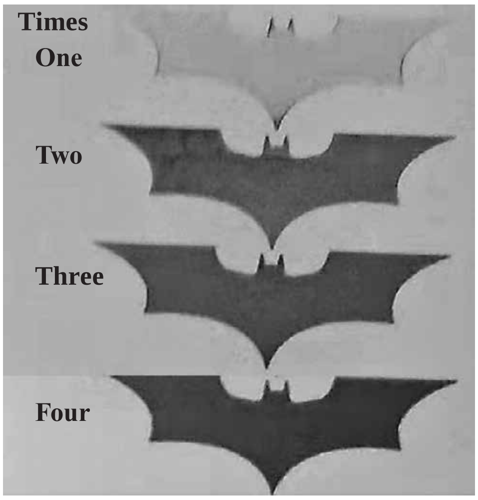

Figure 6 Repeated laser sample

CONCLUSIONS

Laser microprocessing technology can be applied to color labeling of metallurgical products. The laser line scanning width is affected by laser power, and the influence curve is similar to that of Gaussian beam. The power range of laser with color is 3,9 mJ/cm^2-7,8 mJ/cm^2. In order to improve the uniformity of color, a multi-marking scheme was proposed, and the optimal process parameters were obtained: defocusing capacity -0,5 cm, scanning spacing 0,02 mm, scanning speed 200 mm/s, laser power 7 W, laser repetition frequency 20 kHz. The laser power density of this process parameter is 5,94 mJ/cm^2, which is just within the range of laser power density with color variation.

Expectation

Multiple marking schemes are helpful for obtaining a single color sample, but increase working time, reduce productivity and raise production costs. Color heterogeneity is caused by temperature instability during scanning, and it is possible to avoid this phenomenon if an exposed laser light source is used, thus improving productivity. After a large number of marking experiments, it is found that generally when the marking times are more than 5 times, the sample color is close to the saturated state, and the color basically does not change. This phenomenon could be used for more.

Acknowledgements

This study was completed under the gui- dance of Teacher Y.X. Chen. This paper is supported by the Innovation Training Program of Chinese College Students and the Ministry of Education industry-University Cooperative Education Program (202101351003)

REFERENCE

[1] Z.M. Liu, L. Guo, Q.M. Zhang. Study on heat interaction rule and oxidation pattern of color marking on stainless steel by nanosecond laser[J]. Applied Laser 37(2017) 4, 563-568.

[2] V. Veiko, G. Odintsova, E. Ageev, et al. Controlled oxide films formation by nanosecond laser pulses for color marking[J]. Optics Express 22(2014)20,24342-7.

[3] T. Guan. Design and research on colorized data matrix barcode[D]. Tsinghua University, 2006.

[4] W.H. Niu, H.Q. Yan, Y.B. Ge. A colored qr code design principle and encoding-decoding implementation[J]. Transactions of Beijing Institute of Technology 35(2015) 10, 1067-1073.

[5] Y.X. Chen, Y. Gao, L. Gao. Coloration mechanism based on laser induced periodic surface microstructures[J]. Chinese J Lasers 47(2020)9,0902006.

[6] T.Q. Huang. Process and application research of laser induced surface coloration of stainless steel[D]. Jinan: Shandong University,2015:9-28.

[7] E.H. Amara, F. Haid, A.Noukaz. Experimental investigations on fiber laser color marking of steels[J]. Applied Surface Science,2015,351:1-12.

[8] F.F. Luo, W. Ong, Y.C. Guan, et al. Study of micro/nanostructures formed by a nanosecond laser in gaseous environments for stainless steel surface coloring[J]. Applied Surface Science, 2015,328:405-409.

[9] Z.M. Liu, Q.M. Zhang, L. Guo, et al. Influence of laser process parameters on color obtained by marking[J]. Chinese J Lasers 41(2014)4,0403011.

[10] X. Liang. Research of the laser color marking of stainless steel[D]. Harbin: Harbin Institute of Technology, 2008: 17-20.

[11] H.L. Zhao. Research on technology of laesr colorful marking on metal[D]. Beijing: Beijing University of Technology,2008:32-33.

[12] G.Q. Li, X.H. Li, H.D. Yang, et al. Fabrication of colorful metals with femtosecond laser pulses[J]. Chinese J Lasers 4(2011)1,72-76.

Note: The responsible translator for English language is Y.X. Chen, Anshan, China.