كلية الهندسة بشبرا
FACULTY OF ENGINEERING AT SHOUBRA
ERJ
PRINT ISSN 3009-6049
ONLINE ISSN 3009-6022

ENGINEERING RESEARCH JOURNAL (ERJ)
Volume (53) Issue (2)
April 2024, pp:104-109
https://erjsh.journals.ekb.eg

Study of 3D laser engraving for steel 37 and stainless steel 304 samples

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Abstract :A newcomer and fast developing category of non-conventional machining method, laser machining enables the machining of complicated geometries with high accuracy, surface quality, and productivity in a variety of materials. As a result, it has become necessary to develop a technique that will aid the operator of a laser machine in choosing the best process parameters. An experimental evaluation of how the process parameters affected the efficiency of the laser engraving process was conducted in this study. The average input power and frequency were subjected to steel 37 and stainless steel 304 respectively. Surface roughness measurement tester was used to determine the surface roughness (Ra) for the steel 37 and stainless steel 304. After the experiments, it was concluded that because it provides high-quality results with more precision and depth, stainless steel 304 is an excellent material for 3D laser engraving.

Keywords: Laser Engraving, Surface Roughness, Steel 37, Stainless Steel 304.

1. INTRODUCTION

Innovations and improvements in manufacturing techniques were brought about by the quick development of technology and the increased need for the manufacture of new and superior items. One of these was the application of lasers to manufacturing processes. The laser engraving process at the micro-scale, which is now an established technology with numerous uses in the manufacture of high-tech goods for the electronics industry, the manufacture of medical equipment [1], telecommunications, and the automotive industry, is particularly intriguing. 3D laser engraving is a process that uses a laser to create three-dimensional designs on a material [2]. It is a relatively new process, but it has quickly become popular for a variety of applications, including creating jewelry, medical devices, and industrial parts [3].

To sublimate the material of the workpiece [4], a significant quantity of heat must be locally imparted into it using the laser beam pulses used in the laser engraving process. Laser engraving technique to sublimate the material of the workpiece, a significant quantity of heat must be locally imparted into it using the laser beam pulses used in the laser engraving process [5]. The laser ablation of the materials serves as the foundation for the laser engraving process. A pulsed laser beam strikes the target during the laser ablation process [6]. 3D laser engraving machines can be a valuable tool for businesses and hobbyists alike. They can be used to create a wide variety of products, from custom awards and trophies to molds for manufacturing [7].

In this study, a comparison is done between steel 37 and stainless steel 304 due to laser engraving in surface roughness [8], accuracy, and depth of the engraving.

2. EXPERIMENTAL SETUP

A 3D laser engraving machine is a type of laser engraving machine that can create 3D designs on materials such as wood, glass, and crystal. It works by focusing a laser beam onto the surface of the material and vaporizing the material at the focal point. The laser beam is then moved around the surface of the material to create the desired design, Machine specifications of 3D laser engraving [9] are presented in Table 1.

Fig 1. 3D Laser engraving machine used for the experiments

3D laser engraving machines are typically used to create custom awards, trophies, and other decorative items. They can also be used to create molds for injection molding and other manufacturing processes. Here are some of the benefits of using a 3D laser engraving machine, first of all is Versatility where the 3D laser engraving machines can be used to engrave a wide variety of materials, including wood, glass, crystal, metal, and plastic. Second is the Precision where 3D laser engraving machines can create very precise and detailed designs. Third is the Speed where 3D laser engraving machines can engrave designs very quickly. Fourth is the Durability where 3D laser engraved designs are very durable and can last for many years.

TABLE 1. Machine specifications of Laser engraving

Parameters	Power (W)	Frequency (kHz)	Speed (mm/sec.)	Number of Paths	Hatching
Range	0 - 100	0 -100	20 - 1000	5	constant

TABLE 2. Properties of Material used

Property	Steel 37	Stainless Steel 304
Composition	Iron, Carbon, and other alloying elements	Iron, Chromium, Nickel, and other alloying elements
Corrosion Resistance	Low	High
Strength	High	Very High
Hardness	High	Very High
Formability	Good	Good
Machinability	Good	Good
Weldability	Good	Good
Cost	Low	High

TABLE 3. Input factors and their levels

Factors, Symbol (units)	Levels				
	Level 1	Level 2	Level 3	Level 4	Level 5
Power (W)	20	40	60	80	100
Frequency (kHz)	50	50	50	50	50
	100	100	100	100	100
Speed (mm/sec)	500				
Number of Paths	5				
Hatching	Constant				

TABLE 4. Process variables and their corresponding Responses for Stainless steel 304 and Steel 37

Stainless steel 304				**Steel 37**			
Set	Power (W)	Frequency (kHz)	Ra (µm)	Set	Power (W)	Frequency (kHz)	Ra (µm)
1	20	50	0.34	1	20	50	4.72
2	40	50	0.18	2	40	50	3.39
3	60	50	0.24	3	60	50	4
4	80	50	0.15	4	80	50	5.83
5	100	50	0.21	5	100	50	4.42
6	20	50	0.41	6	20	50	2.43
7	40	50	0.22	7	40	50	0.72
8	60	50	0.35	8	60	50	0.87
9	80	50	0.43	9	80	50	0.43
10	100	50	0.32	10	100	50	1.41
11	20	50	0.06	11	20	50	0.78
12	40	50	0.2	12	40	50	0.88
13	60	50	0.34	13	60	50	3.61
14	80	50	0.25	14	80	50	7.29
15	100	50	0.19	15	100	50	6.43
16	20	100	0.49	16	20	100	1.73
17	40	100	0.23	17	40	100	1.77
18	60	100	0.32	18	60	100	4.70
19	80	100	0.21	19	80	100	2.99
20	100	100	0.25	20	100	100	1.32
21	20	100	0.11	21	20	100	4.89
22	40	100	0.26	22	40	100	0.53
23	60	100	0.27	23	60	100	0.47
24	80	100	0.16	24	80	100	0.63
25	100	100	0.25	25	100	100	0.95
26	20	100	0.05	26	20	100	2.45
27	40	100	0.31	27	40	100	0.67
28	60	100	0.46	28	60	100	2.34
29	80	100	0.33	29	80	100	3.84
30	100	100	0.28	30	100	100	6.03

TABLE 5.Average output surface roughness

Power (W)	Frequency (kHz)	Average Ra	
		Steel	Stainless Steel
20	50	2.64	0.27
40	50	1.66	0.2
60	50	2.82	0.31
80	50	4.52	0.28
100	50	4.09	0.24
20	100	3.02	0.22
40	100	0.99	0.27
60	100	2.50	0.35
80	100	2.49	0.23
100	100	2.77	0.26

2.1 Workpiece Materials

2.2 For the experimental work, cold-rolled austenitic stainless steel AISI 304 was chosen (Ni 8,02 %, Cr 18,11 %, C 0,037 %, Si 0,35 %, Mn 1,28 %, S 0,005 %, P 0,031 % and N 0,053 % weight, with Fe being the balance) [10], The thickness of the workpiece was 2 mm and the hardness was 170±10 HV [11]. And steel 37 was chosen (Fe 99.43-99.75%, C 0.08%, Mn 0.25-0.4%, S 0.05%, P 0.04%), the thickness of the workpiece was 5 mm, with a Brinell hardness of around 100 HB [12]. The properties of these materials are shown in table 2.

2.2Design of Experiments

In this work, five factors are chosen for the experiment and the total number of experiments to be conducted is 30. Input factors and their levels are given in table 3. The experiment is repeated three times for every level.

The output of the experiment is the surface finish obtained from the machining with those input parameters shown in table 4, where the roughness (Ra) of stainless steel without cutting is 0.11μm and for steel is 0.87μm. And the average output roughness is shown in table 5.

2.3 Preparation of Specimens

The close view of plate blank used for cutting the specimens is mounted on the Laser machine is shown in Fig. 2 and the machined work piece is in Fig. 3.

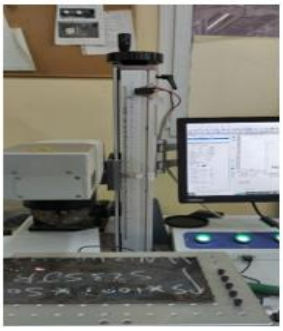

Fig 2. Plate material blank mounted on EDM machine

Stainless Steel specimen **Steel specimen**

Fig 3. The machined work piece specimens

2.1 Surface Roughness (SR)

The portable surface roughness tester SJ-201P with tip radius of 5μm has been utilized to measure surface texture as shown in Fig. 4

Fig 4. Set up for surface roughness measurement tester

3.RESULTS & DISCUSSION

3D laser engraving is a process that uses a laser to create three-dimensional designs on a material. It is a relatively new process, but it has quickly become popular for a variety of applications, including creating jewelry, medical devices, and industrial parts. Steel 37 is mild steel that is commonly used for structural applications. It is relatively inexpensive and easy to work with. However, it is not as strong or corrosion resistant as other types of steel. While Stainless steel 304 is a type of stainless steel that is known for its excellent corrosion resistance and strength. It is commonly used in applications where these properties are important, such as food processing equipment and medical devices.

Laser engraving of steel 37 and stainless steel can be used to create a wide variety of designs, including: Text, Logos, Images, Barcodes, QR codes, Serial number, Decorative patterns. When steel 37 and stainless steel 304 are 3D laser engraved, the following results can be observed, first is the Surface quality where Stainless steel 304 samples have a better surface quality than steel 37 samples, This is because stainless steel 304 is more resistant to laser-induced oxidation. Fig.5 shows the average surface roughness between steel 37 and stainless steel 304 when the frequency equals 50 kHz, While Fig.6 shows a the average surface roughness between steel and Stainless steel when the frequency equals 100 kHz. Second is the accuracy where Stainless steel 304 samples can be engraved with greater accuracy than steel 37 samples, this is because stainless steel 304 is less likely to warp or deform during the laser engraving process. Third is the Depth of engraving where Stainless steel 304 samples can be engraved to a greater depth than steel 37 samples, this is because stainless steel 304 is more resistant to laser-induced melting.

After conducting experiments, an optimization to the input parameters of a laser engraving machine to achieve optimal surface roughness for both Steel 37 and Stainless steel 304, as the power of the laser engraving increases, the metal removal rate will increase, which will affect the surface roughness.

Stainless steel as shown in the graphs when engraved with frequency 50 and 100 Hz and power as shown in table 3, resulted in decreasing the surface roughness of the material at acceptable ranges (0.2 µm) as the power increases.

While steel as shown in the graphs when engraved with frequencies 50 and 100 Hz and power as shown in table 3, it resulted in increasing the surface roughness of the material as the power increases.

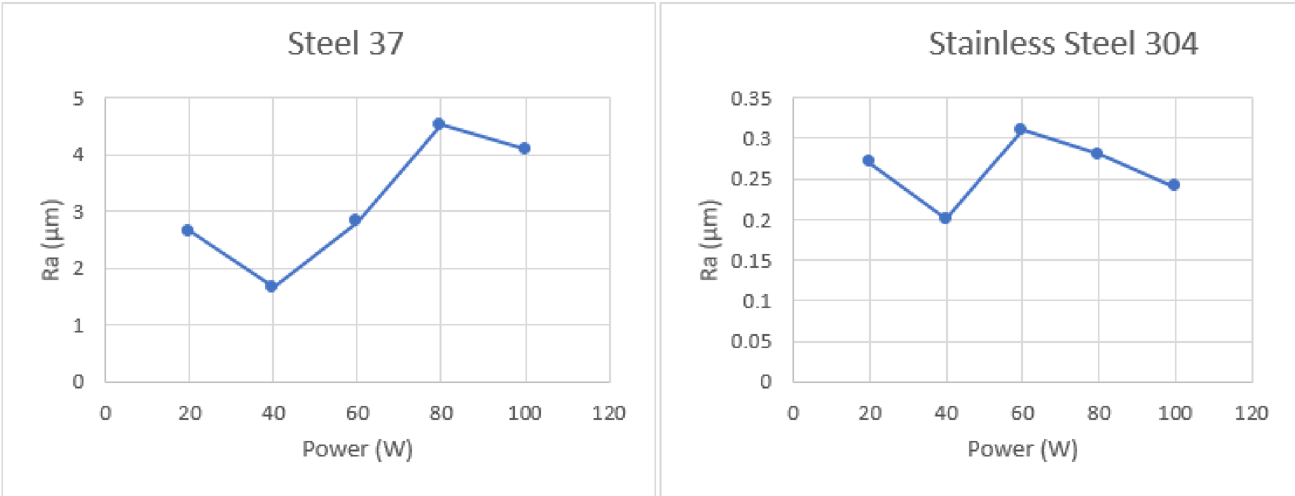

Fig 5. Comparison of the average surface roughness between steel and Stainless steel for a frequency of 50 kHz

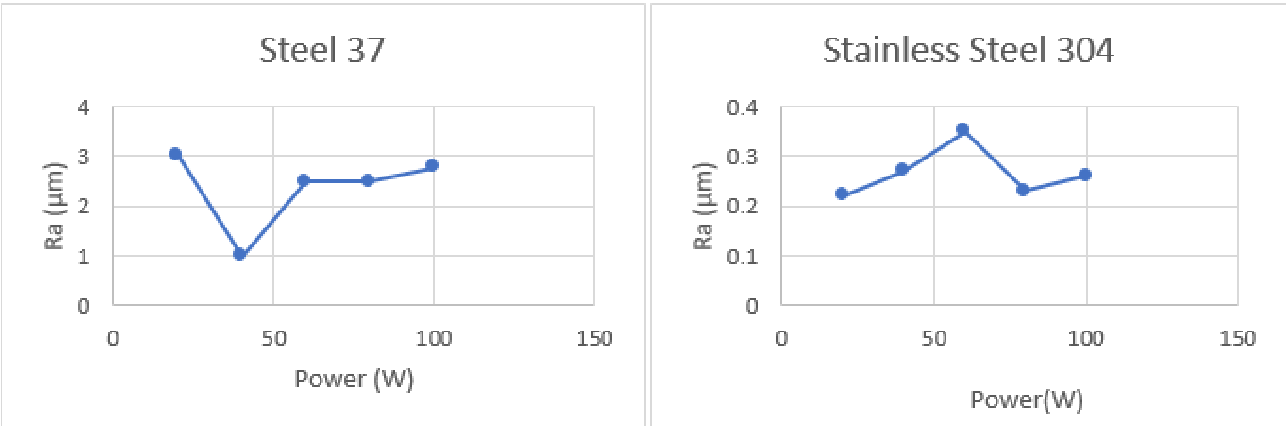

Fig 6. Comparison of the average surface roughness between steel and Stainless steel when the frequency equals 100 kHz

2.4 4.CONCLUSION

2.5 Laser engraving on steel 37 creates a permanent mark by removing the top layer of material, exposing the underlying metal. The depth of the engraving can be controlled by varying the power and speed of the laser. The engraving process also produces heat, which can cause the metal to discolor or anneal.

2.6 Laser engraving on steel 37 creates a permanent mark by removing the top layer of material, exposing the underlying metal. The depth of the engraving can be controlled by varying the power and speed of the laser. The engraving process also produces heat, which can cause the metal to discolor or anneal.

2.7 The results of laser engraving on steel 37 can be affected by several factors, including the type of laser used, the power and speed of the laser, the focus of the laser, and the surface finish of the steel. In general, laser engraving on steel 37 produces a high-quality, durable mark that is resistant to wear and tear.

Laser engraving on stainless steel is a popular technique for creating permanent, high-contrast marks on this versatile material. The process involves using a focused beam of laser light to heat and vaporize the surface of the steel, creating a precise and durable engraving.

Overall, laser engraving is a versatile and effective way to mark and decorate stainless steel. It produces a high-quality, durable mark that is resistant to wear and tear, and it can be used to create a wide variety of designs and patterns.

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