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Analysis the Effect of Laser Engraving Process for Surface Roughness Measurement on Stainless Steel (304)

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ABSTRACT

Laser engraving process is non conventional machining process. By using laser engraving machine the marking/engraving is possible by with different input parameter as spot diameter, laser power, laser frequency, different wave length, engraving speed, number of passes etc, and get the changes in output parameter like material removal rate, surface finish and indentation.

Our team have used three input parameter (frequency, engraving speed and number of passes) and one output parameter is surface roughness.

The experimental results are corresponding to the effect of different Frequency (20, 50, 80 KH_Z), different Engraving speed (100, 300, 500 mm/Sec) and different number of passes (10, 15, 20), on the stainless steel (304) plate of 1.5 mm thickness.

From the experimental results It is concluded for surface roughness parameter, that it is higher for 20 KH_Z frequency , 100 mm/sec engraving speed and 10 number of pass. And it is lower at maximum frequency i.e. 80 KH_Z.

Key words: Laser engraving process, Surface roughness measurement, Frequency, Engraving speed, number of pass.

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INTRODUCTION

Laser is the acronym of Light Amplification by Stimulated Emission of Radiation. The laser is one of the most widespread technical inventions of the last century. It is both subject of intense study from scientists and engineers to further expand the field of application and develop new and/or better laser system. It is also a good example of how a fundamental theoretical concept can rest for decades until it is rediscovered for a technical application. [1]

Literature review provides the scope for the present study. It works as guide to run this analysis. Literature review plays important role to get information about the dissertation work. Literature review includes different study on laser engraving processes for better surface finish with different laser by using parametric analysis, and effect of laser power, different wave length, pulse frequency, beam speed and other so many parameters also effect of surface finish, material removal rate and indentation of engraving.

C. Leone et al. shows that Laser deep engraving is one of the most promising technologies to be used in wood carver operations.

In this work, the features and the performances given by a 5W of nominal power Q-switched diode-pumped frequency-doubled Nd:YAG green laser in the engraving of different kind of woods are discussed and the main conclusions are the following:

- The surface carbonization depends on an incorrect selection of the process parameters and, for the adopted laser, it happens at beam speeds of up to 10mm/s.
- For speed more than 40mm/s, the engraved depth is very low and multiple laser scanning are required to obtain deep engraving.
- The engraved depth is strongly affected by the mean power, the pulse frequency, the beam speed and the number of repetitions.
- Increasing the speed is possible to obtaining engraving with a reduced frequency range around the value where the maximum output power is achieved. The maximum speed necessary to obtain engraving linearly depends on the mean power.[2]

Cheng-Jung Lin et al. In this study, Moso bamboo lamina was engraved using various laser output power levels in conjunction with various feed speed ratios in order to understand the effects of feed speed ratio and laser output power on engraved depth and color difference. The results showed that the engraved depth became deeper for either higher laser power or a lower feed speed ratio. Moreover, the color difference values increased under a lower feed speed ratio and higher power, and resulted in a brownish color in the engraved zone. The average engraved depth and color difference values were 0.69–0.86mmand 46.9–51.9 pixels by different engraving parameters, respectively.

The effects of different feed speed ratios and laser output power levels on the engraved depth and color difference of Moso bamboo laminae were investigated, with the following results.

1. The laser engraved depth became deeper for either higher laser power or a lower feed speed ratio.

2. Color difference values increased under a lower feed speed ratio and higher power, and resulted in a brownish color in the engraved zone.

3. Effects of the feed speed ratio by laser power interaction regimens on the engraved depth and color difference were significant. Therefore, values of the engraved depth and color difference increased with an increase in laser output power; however, there was a decrease in the feed speed ratio.

4. The engraved depth and color difference values of Moso bamboo could be predicted and estimated by regression analyses. This prediction of two engraving performances can help laser engraving achieve varied requests and applied to the fields of decoration and gift industry.[3]

Jozef Wendland et al. has investigates deep engraving of steel and aluminium by laser. By examination of laser and scanner parameters an optimal balance between feature quality and processing speed is achieved. Material removal rate of up to 20 mm^3/min for steel and 40 mm^3/min for aluminium are demonstrated up to a maximum engraved depth of 1mm. The effect of feature shape and feature size on the process is also investigated.

The material removal rates achieved, which are 90 mm^3/min for aluminium alloy and 25 mm^3/min for stainless steel, are very attractive for industrial applications.

The surface roughness can be controlled during the milling process, and this can be used to change optical properties of the target. [4]

Mihaiela Iliescu et al. has presented Holograms and holography become more and more important for nowadays life, Specially because of their role in security and protection. The process involved is rather complex and with many parameters of influence on holograms accuracy and reliability. Some research results on holograms laser engraving process parameters are evidenced by this paper.

Application of holography and holograms is very wide, covering: security and product authentication, packaging - consumer goods brand protection, art and interactive graphics, etc. This paper is a study on hologram marks, more specifically, on hologram laser engraving process parameters. In order to obtain high resolution engraving results low speed, high frequency and small pulse duration of the laser beam should be used.[5]

P. Laakso et al. has discussed Color marking of stainless steels as a process is known for some time but still it has not been used widely in the industry. Fiber laser allow independent tuning different laser parameters and the marking process can be optimized for producing colors with better quality and visual appearance. [6]

Mingwei Li et al. has presented that Laser micromachining of semiconductor materials such as silicon and sapphire has attracted more and more attention in recent years.

In the study, two Q switched & one mode-locked diode-pumped solid-state 355 nm lasers have been used to scribe grooves on silicon and sapphire wafer substrates at different pulse widths (10 ns, 32 ns, and 10 ps) and pulse repetition rates (30 kHz, 40 kHz, 50 kHz, and 80 MHz).

Experimental results have been compared between different pulse widths, power levels, and pulse repetition rates. It has been found that at the same average power and same repetition rate, the grooves scribed by the longer pulse width laser are deeper, while the shorter pulse width laser produces better quality cuts.[7]

This review focuses on the literature study done on the review of related journal-papers, articles available as open literature. These are covers the different laser engraving process of input parameter such as Laser power, Frequency, Pulse duration, Spot diameter, Number of passes, Air/Gas pressure, Engraving speed are taken for different work piece materials i.e. aluminium alloy, semiconductor etc and wooden also. And it is obtained that what changes are occur due to changing in these all input parameter to the output parameter like surface finish, material removal rate and indentation.

EXPERIMENTAL PROCEDURE

The experiments were conducted on Akshar Fiber-Pro Laser Engraving Machine. This machine use 1060 nm wavelength fiber laser with nominal power output of 20watt. A 1.5mm thick stainless steel (304) was used as a work piece material. The chemical composition of SS 304 is provided in Table 1 and the values are in percentage (%)

Table 1 chemical composition of SS 304

ELEMENTS	% CONTRIBUTION	ELEMENTS	% CONTRIBUTION
Carbon	0.058	Sulphur	0.012
Silicon	0.460	Chromium	18.580
Manganese	1.050	Nickel	8.090
Phosphorus	0.028	-	-

Table 2 Input and output parameters

INPUT PARAMETERS	OUTPUT PARAMETERS
Frequency(KH_Z)	Surface roughness(μm)
Engraving speed(mm/Sec)	
Number of pass	

Table 3 laser engraving factors and their levels

Symbol	Engraving factor	Level 1	Level 2	Level 3
A	Frequency(KH_Z)	20	50	80
B	Engraving speed(mm/Sec)	100	300	500
C	Number of pass	10	15	20

The summary of experimental range is listed in Table 3. The experimental results after laser engraving of Stainless Steel 304 material were evaluated in terms of the following measured machining performances: (1) surface roughness (Ra); as shown in table 2. The surface roughness of laser engraved surfaces was measured using a Mitutoyo SJ-210 instrument.

In order to achieve best engraving quality, full factorial experimental design was used for conducting experiments. For this purpose a L_{27} orthogonal array was used for experiment which is shown in Table 4. The experimental results are also summarized in Table 4.

Table 4 Experimental design and results

Exp. No	Frequency (KH_Z)	Engraving Speed (mm/sec)	No. of pass	Surface roughness Ra (μm)
1	20	100	10	2.560
2	20	100	15	2.857
3	20	100	20	2.825
4	20	300	10	1.391
5	20	300	15	1.595
6	20	300	20	1.324
7	20	500	10	1.487
8	20	500	15	1.424
9	20	500	20	1.552
10	50	100	10	2.174
11	50	100	15	0.855
12	50	100	20	0.903
13	50	300	10	0.996
14	50	300	15	1.301
15	50	300	20	1.250
16	50	500	10	1.083
17	50	500	15	1.228
18	50	500	20	1.311
19	80	100	10	0.433
20	80	100	15	0.420
21	80	100	20	0.428
22	80	300	10	0.682
23	80	300	15	0.665
24	80	300	20	0.848
25	80	500	10	0.498
26	80	500	15	0.738
27	80	500	20	0.703

RESULT AND DISCUSSION

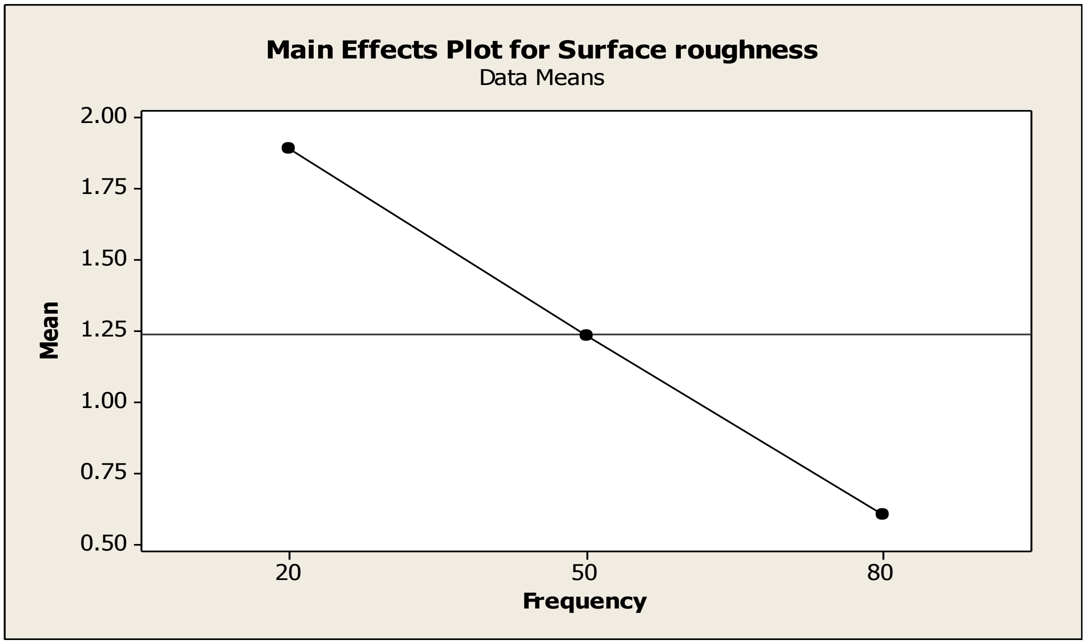

Figure 1 Main effect plot for surface roughness v/s Frequency

In figure 1, it is clearly shown that as increase of frequency the surface roughness is decreases. So that it is concluded in case of frequency that at higher frequency we can get lower surface roughness.

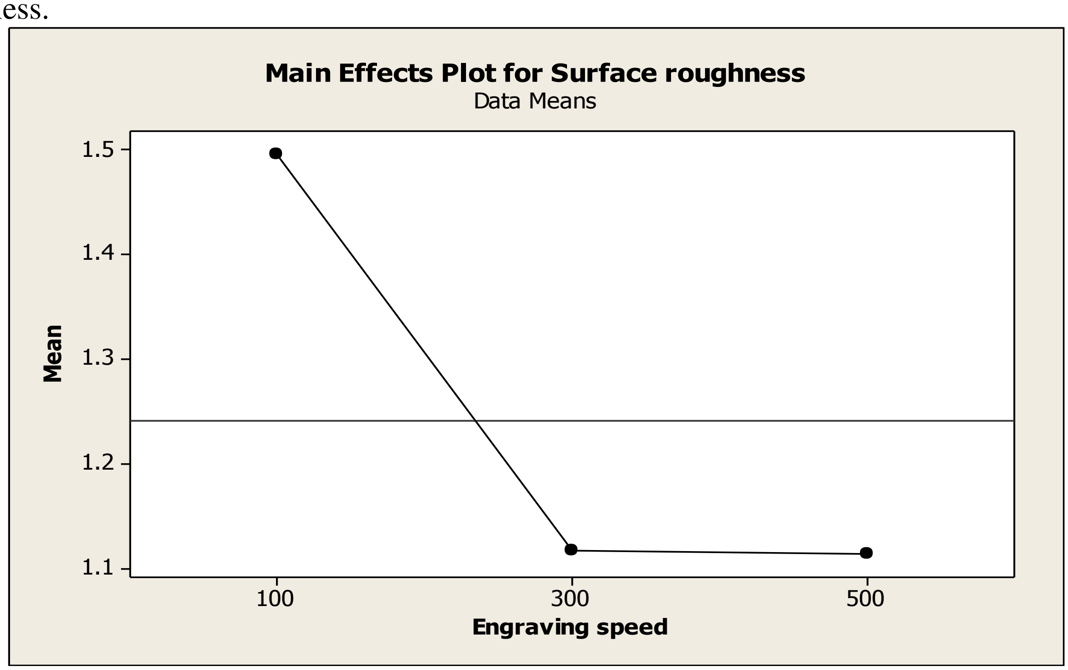

Figure 2 Main effect plot for surface roughness v/s Engraving speed

In figure 2, it is shown that at 100mm/sec engraving speed surface roughness is higher and for higher engraving speed surface roughness is decreases.

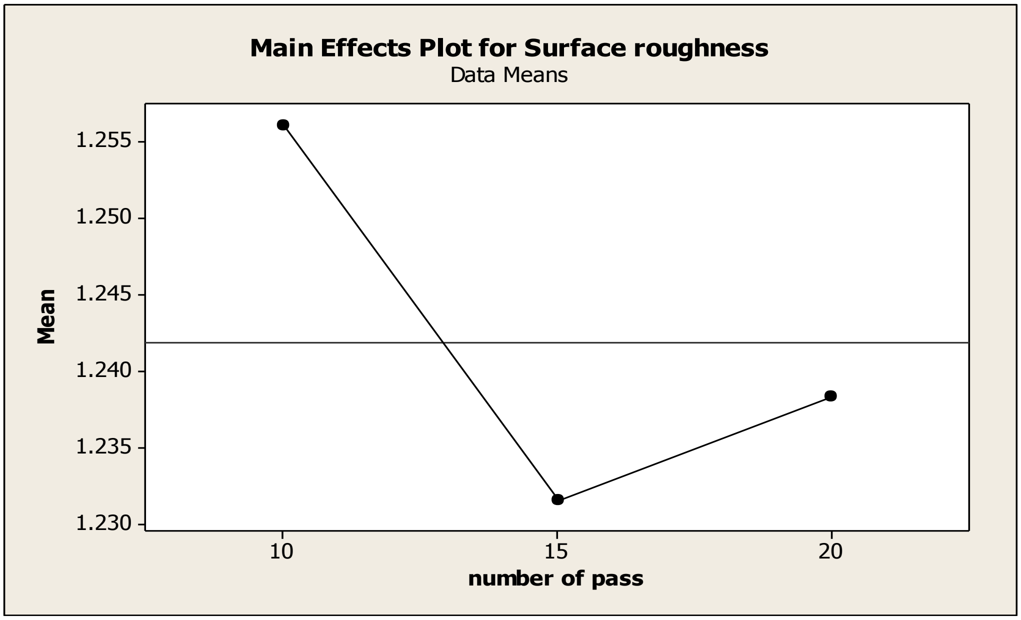

Figure 3 Main effect plot for surface roughness v/s Number of pass

In this graph, at 10 number of pass, surface roughness is higher and at 15 and 20 pass it is decreases.

CONCLUSION

It is concluded for surface roughness parameter, that it is higher for 20 KH_Z frequency, 100 mm/sec engraving speed and 10 number of pass. And it is lower at maximum frequency i.e. 80 KH_Z. The reason behind that is, the increasing of frequency, surface roughness decreases because of that if frequency increase than the within conformed time period the impact of laser beam increase as a result of that waviness of surface decreases that is why surface roughness decreases as increase of frequency.

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