Optimization of Laser Engraving using Fiber Laser on EN31 & SS304 Steel

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Abstract— This Research Paper describes effects of laser Engraving on various materials by varying process parameters and by using different laser engraving machines. Laser Engraving is a non conventional machining process for engraving/marking and it is a non contact type process. Previously where only Electrical Discharge Machines were used, laser engraving and marking have replaced them due to a unique combination of speed and versatility. In Laser Engraving process material removal is done layer by layer and which is in the range of very few microns. In This paper parametric Optimization of fiber laser engraving is done on EN31 bearing and SS304 by selecting various input parameters like Engraving speed, Frequency and power and response parameters to be optimized were Surface roughness and line width.

Key words: Laser, Laser Engraving, Laser Marking, Nd-YAG laser, Fiber Laser, CO2 laser, Parametric Optimization

I. Introduction

Laser is the acronym of Light Amplification by Stimulated Emission of Radiation. There are main three steps for light emission; they are absorption, Spontaneous Emission & Stimulated Emission. In past decades, laser has been widely & mostly used in welding & cutting operations, but in recent times due to inventions and progress, research & advancement in laser technology it has been adopted in other industrial processes like Engraving, marking & machining of different materials. Laser engraving is the process of using laser machine to engrave or mark an object or surface for product identification. Laser engraving is the process of removal of material from the top surface down to a specific depth. The laser engraving process can be very complex & often a computer system is used to drive the movements of the laser head. The laser engraving technique does not involve the use of any kind of inks, nor does it involve tool bits which contact the engraving surface & wear out. Various advantages associated with laser engraving compared with conventional engraving methods are no wear on tools, high degree of automation, free programming & choice of characters.

A laser engraving machine can be thought of as three main parts: a laser, a controller, and a surface. The main advantages of laser process are non-contact working, high repeatability, higher scanning speed, best surface quality high flexibility and automation.

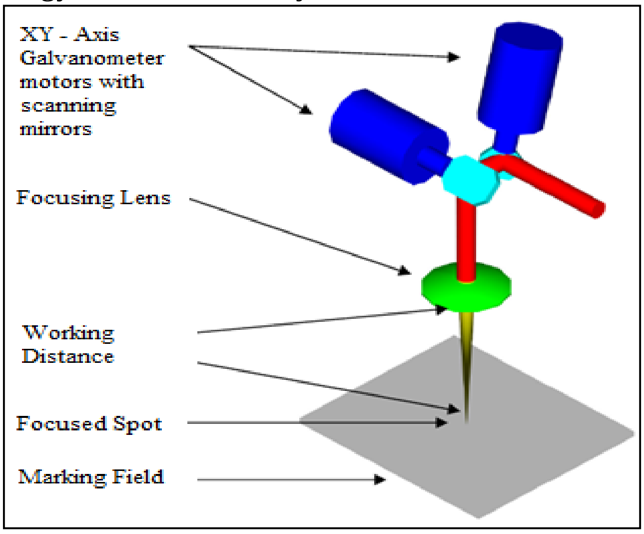

Fig. 1: Laser Engraving Process Setup

II. Literature review

A. R. Khan et al. [1] studied on the influence of the Laser Power, No. of layers removed, laser Frequency & scanning speed on Surface roughness and marking time with the help of Taguchi Approach. A TruMark station 5000 UV Laser beam was used in laser marking process of Stainless Steel AISI 316L. A convex lens with focal length of 163 mm was used in the way of laser beam to focus the laser beam on work piece with an input voltage of 230 volts. A mix hatching mode scanning strategy was adopted because in multi-layer machining cycle surface roughness was reported to be reduced by simply changing the scanning direction. On experimentation it was investigated that main contributor for marking time was number of layers removed followed by scanning speed & For Surface Roughness, scanning speed is major parameter followed by laser power. Mathematical modelling was found to be very significant statistically at 95%confidence level with error contributing to only 1.08% for the model developed for marking time and 3.16% for the model developed for surface roughness. By confirmatory test good similarity between experimental & predicted results was investigated.

F. Agalianos et al. [2] has investigated Influence of the Process Parameters on Machined Surface Quality. Material used for investigation was Al7075 whose Surface roughness was observed on varying process parameters like pulse frequency, Layer thickness and scan speed using Q-switched Yb: YAG fibre laser and 63 different readings were taken by combination of process parameters. The surface quality was determined by the surface roughness for every set of parameters. On investigation it was found that the Surface roughness strongly depends on the frequency & scan speed used and it was also proven that the resulted roughness depends less by the layer thickness. On consideration of all the experimental data, the best surface roughness was achieved on using a frequency of 20 kHz, a scan speed in the range of 600-700mm/s & a When considering all the experimental data of the current experimental plan, the best surface roughness was achieved when using a frequency of 20kHz, layer thickness of 4 µm and 6µm & scan speed in the range of 600mm/s - 700mm/s.

Sefika Kasman et al. [3] investigated the machinability of hard metal Vanadis 10 produced with the help of powder metallurgy & kept forward a new approach relating to the laser engraving of Powder Metallurgy metals. The main objective of this study was to determine the impact of process parameters on Vanadis 10 material response with the help of Taguchi orthogonal analysis for laser engraving. For this mainly three process parameters namely laser effective power, effective scan speed and frequency were selected against the surface roughness (Ra) & engraving depth (D). The Taguchi and linear regression were used in the analysis and experiments were performed in accordance with an L9 orthogonal array. On Investigation & Experimental results it was determined that scan speed has statistically significant effect on both surface roughness & engraving depth. For good surface finish, a high scan speed & low power level is good. Effect of frequency was very low on both Surface roughness & Depth. Also on Increasing scan speed, Surface roughness & decreases for Vanadis 10 & to maximize engraving depth; the scan speed should be selected at a low. Also a mathematical model for surface roughness & engraving was established & estimated using regression.

C. Leone et al. [4] has investigated the effect of input parameters like pulse frequency, beam scanning speed, & current intensity against resulting mark visibility on AISI 304 steel using a Q-switched diode pumped Nd:YAG laser. From the experimental results it was concluded that within the range of process parameters employed, mark width is only moderately affected by operating conditions. Mark contrast is affected by both surface roughness & oxidation and for good mark quality low frequencies & average powers should be used. An empirical model was built, and from it the best processing conditions for optimum mark visibility, taking into account the operating constraints of the laser system used, were drawn. It was concluded that best mark visibility achievable is strictly dependent on the operating features of the particular laser system used.

Sefika Kasman et al. [5] studied & investigated the effect of scan speed on engraving depth & surface Roughness of AISI H13 tool steel using fiber laser. Process parameters selected were scan speed & frequency against responses like engraving depth and surface roughness. Also regression analysis was carried out and it was finally concluded that as scan speed increases, the Engraving depth decreases. Also laser scan speed & frequency had significant effect on the surface roughness and there was no significant correlation found between frequency & depth.

III. Experimental Setup

An EN31 Bearing and SS304 Plate were used as Work piece. Experiment was carried out on Agile Fiber Laser Marking System: AFT at Mahadev Laser Technology, Ahmedabad. A Square hatching and line has been marked on the bearing as well as plate as shown in figure 2,3. For measuring Surface Roughness and line width, Surface Roughness Tester HandySurf Flex 35B and Digital Profile Projector RP-3000 were used respectively. Materials selected were EN31 Bearing and SS304 Sheet as show in the figure 2 and Engraving Speed, Power and frequency were selected as input parameters and response parameters were surface roughness and line width with different levels as shown in table 1 below.

Sr. No.	Parameter	Level 1	Level 2	Level 3
1	Engraving Speed	100	200	300
2	Power	50	65	80
3	Frequency	25	55	40

Table 1: Parametric levels Selected

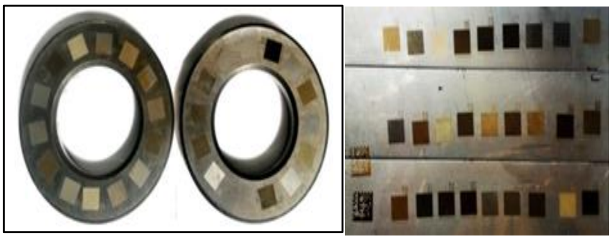

Fig. 2: Materials – EN31 Bearing & SS304

IV. Experimental Design & Results

After Experimental Setup & process on defined combination of parameters on fiber laser, the responses measured with help of surface roughness tester & profiliometer as in table 2.

SR. No.	Parameters			Readings for EN31 Bearing		Readings for SS 304 Sheet	
1	200	65	40	4.22	0.051	6.48	0.098
2	200	80	25	2.81	0.099	1.26	0.080
3	100	65	55	1.06	0.069	0.71	0.050
4	300	50	55	5.93	0.056	7.30	0.106
5	100	80	40	3.38	0.075	3.77	0.082
6	200	50	25	0.86	0.089	1.44	0.059
7	300	65	55	3.63	0.049	7.22	0.128
8	300	80	25	3.00	0.111	3.27	0.088
9	200	50	40	7.35	0.055	3.38	0.086
10	100	50	40	0.53	0.064	4.80	0.070
11	200	80	55	1.18	0.051	0.96	0.075
12	300	80	55	5.77	0.061	0.25	0.044
13	100	65	40	3.89	0.106	7.04	0.098
14	300	80	40	4.71	0.074	4.11	0.068
15	300	50	40	7.61	0.062	0.81	0.070
16	100	50	25	1.04	0.088	7.69	0.126
17	100	80	55	2.79	0.074	5.89	0.099
18	100	65	25	5.92	0.109	2.63	0.079
19	300	50	25	0.62	0.088	2.79	0.088
20	300	65	40	5.56	0.060	0.58	0.059
21	100	80	25	0.69	0.110	0.21	0.048
22	200	65	55	0.61	0.047	4.40	0.095
23	200	65	25	7.71	0.092	3.41	0.059
24	100	50	55	0.87	0.057	0.68	0.052
25	300	65	25	7.90	0.109	5.12	0.115
26	200	50	55	4.87	0.047	5.66	0.085
27	200	80	40	2.56	0.060	2.58	0.072

Table 2: Experimental results for EN31 Steel Bearing & SS304 Sheet

V. RESULTS & DISCUSSION

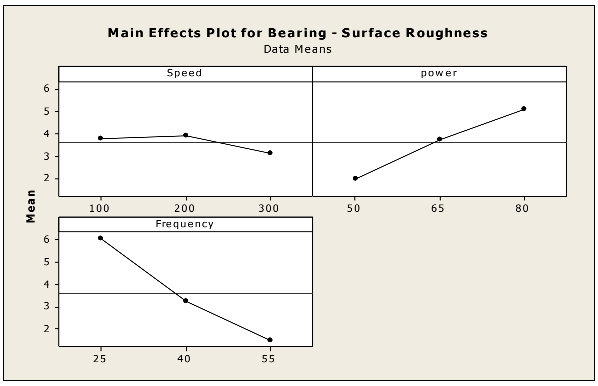

Fig. 3: Main Effects Plot for EN31 Surface Roughness

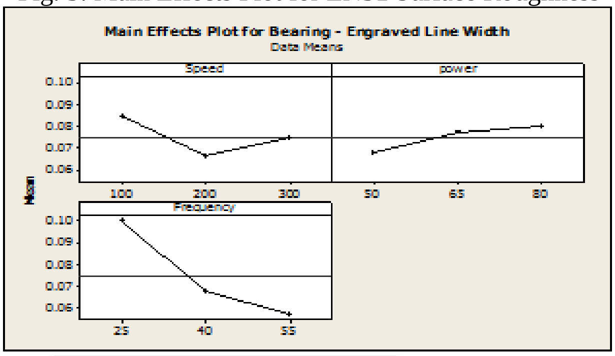

Fig. 4: Main Effects plot for EN31 Line Width

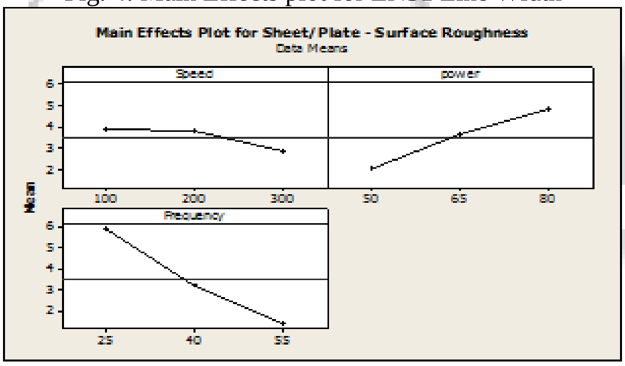

Fig. 5: Main Effects Plot for SS304 Surface Roughness

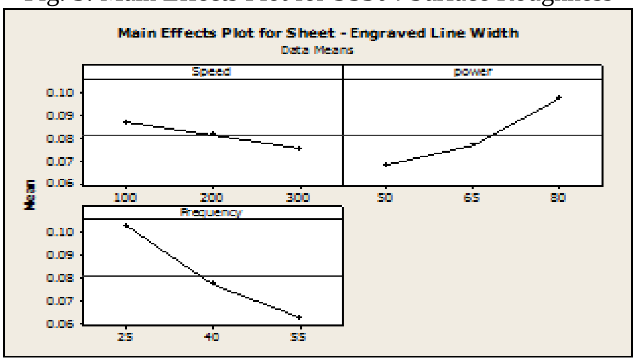

Fig. 6: Main Effects Plot For SS304 Line width

EN31 Bearing analysis shows the percentage contribution of individual parameters on Engraved line width on EN31 Steel Bearing. The percentage contribution of engraving speed is 11.74%, Power is 5.6 % and Frequency is 70.18 % and the error is 12.48%.

SS304 Analysis shows the percentage contribution of individual parameters on Surface Roughness on SS 304 Plate/Sheet. The percentage contribution of engraving speed is 3.9%, Power is 23.51% and Frequency is 58.87% and the error is 13.72%.

VI. CONCLUSION

It was concluded that With the use of Grey relational Analysis, a set of optimum parameters were found for EN31 Steel Bearing as 100mm/s, 80W and 25KHz and similarly for SS304 it were found to be 300mm/s 65W and 55KHz.And finally For Surface Roughness in EN31 & SS304:

– In EN31 and SS304 both, with increase in Frequency the surface roughness decreased, because of that if frequency increase within conformed time period, the impact of laser beam also increase as a result of which, waviness of surface decreases that is why surface roughness decreases as increase of frequency.
– In EN31 and SS304 both, with increase in power the surface roughness increases due to high amount of energy melts and evaporates more amount of material from the micro-groove zone.
– In EN31 and SS304 both, with the higher scan speed, the surface roughness has a tendency to gradually decrease due to low spot over lapping, discontinuous power density.
– And For Line width in EN31 & SS304:
– In Both EN31 and SS304 Line width tends to decrease with the higher Engraving speed due to gradually decreasing spot over lapping.
– In Both EN31 and SS304, With the increase of frequency power of the fibre laser tends to decrease thus causes reduction the dimensions of width
– In EN31 and SS304 both, As the power increases, width increases due to high amount of more energy melts and evaporates more amount of material from the micro-groove zone The conclusive remarks are very beneficial to the industry people.

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