A Review on Parametric Optimization of Laser Engraving using Fiber Laser on Steel

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Abstract— This Review 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. This Review paper shows progress and research in the field of laser engraving process. Different types of laser machines such as Fiber Laser, CO2 laser, Nd: YAG Lasers are industrially used & available in recent time. Therefore for Optimum Use of Laser energy it is necessary to optimize process parameters to get best Quality Engraving/Markings. This paper deals with important progress work on laser engraving and its process parameters.

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.

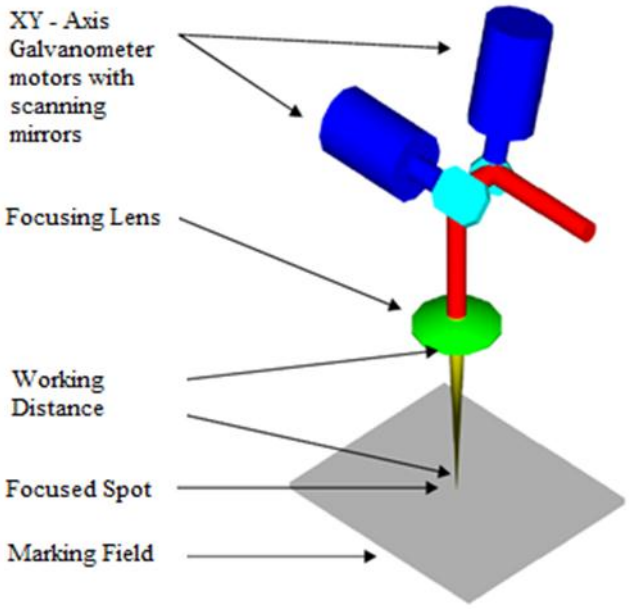

Fig. 1: Laser Engraving Process Setup

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.

D. K. Patel et al. [2] has investigated on Laser engraving process for different Material using grey relational technique. They optimized parameters for laser engraving on Stainless Steel 304 with the use of Q-switched diode-pumped frequency-doubled Nd: YAG green laser. In laser engraving processes the surface of material is heated up & subsequently vaporized. With the use of laser engraving machine the marking/engraving is possible by using different input parameter as spot diameter, laser power, laser frequency, different wavelength etc. &

accordingly the output parameters like material removal rate, surface finish and indentation experiences changes. To optimization of all these parameters with multiple performances characteristic based on the grey relational analysis was done. On analysing grey relational grade, it was well observed that which input parameter had more effect on responses of input parameter to the output parameter. On Experimentation and investigation it was concluded that the laser engraved depth became deeper for either higher laser power or a lower feed speed ratio. Engraved depth increases at higher laser power and for higher engraving speed, surface roughness decreased.

Cheng-Jung Lin et al. [3] investigated the effects of feed speed ratio & laser power on engraved depth & color difference of Moso bamboo lamina. In this study, Moso bamboo lamina was engraved on A nominal 100-W EPILOG (Epilog Radius Model 4000) 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 colour difference. Taguchi approach was used. Two kind of Moso bamboo lamina, including without and with steam treatment were investigated. Laser Beam power & cutting speed was used as process parameters against the engraving depth & colour difference as responses. The results showed:

1) Engraved depth was deeper for higher laser power or lower feed speed ratio.
2) Colour difference values increased under a lower feed speed ratio and higher power.
3) Engraved depth & colour difference increases with an increase in laser output Power.
4) The colour difference & engraved depth values of Moso bamboo could be predicted & estimated by regression analyses.

F. Agalianos et al. [4] 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. [5] 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. [6] 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.

Lechosław Tuz et al. [7] has studied & investigated the Quality of marks on various metals made with the use of the Nd: YAG laser engraving method. The Effect of process parameters like Average power, Surface scanning velocity and pulse frequency was investigated on various metals like commercial copper (Cu-ETP), Heat-resisting steel (X18CrN28), construction steel (08X) and stainless steel with the use of Q-switched diode-pumped Nd:YAG laser. On Experimentation it was concluded that lower contrast was noticed for increasing the pulse frequency and it was necessary to find an optimal set of parameters including Power, Engraving velocity & Pulse frequency which guarantees the highest quality & a high efficiency of the process.

Sefika Kasman et al. [8] 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.

Y. H. Chen et al. [9] has investigated the application of Taguchi method in the optimization of laser micro-engraving photo masks. Photo masks are required to generate various design patterns in the fabrication of LCDs. This paper discusses use of taguchi method for experimental design in optimizing process parameters for micro-engraving of iron oxide coated glass using Q- switched Nd: YAG laser. Effect of five major parameters - beam expansion ration, focal length, average laser power, pulse

repetition rate & engraving speed on the engraving line width was studied. Studies showed that shorter the focal length, bigger the beam expansion ratio. Beam expansion ratio, average laser power, engraving speed, & interaction between beam expansion ratio & focal length significantly affects engraving line width.

V. Y. Javale et al. [10] has investigated Experimental Analysis Laser marking by Nd-YAG Laser and Fiber Laser on EN8 Steel bearing. The experimental analysis compared laser marking process on Nd-YAG Laser and Fiber Laser out of which fiber laser proved out to be better laser comparatively. Material selected was EN8 thrust bearing and process parameters selected were frequency, focal point and speed against response parameters depth and width with the help of Response Surface method using Box Behnken design. On investigation it was concluded that Because of more heat concentrated at marking spot, Fiber laser gives more Depth and Sharpness than others and also Due to less concentrated laser beam it scatters more than fiber laser and Nd-YAG laser gives more width than Fiber laser but it has less sharpness.

III. Conclusion

Many researchers have worked on different type of materials with various types of laser by using various types of design of experiment (DOE) technique such as taguchi, Response Surface method, full factorial design, Box-Behnken design. Also effect of various process parameters like Laser power, Frequency, Pulse duration, Spot diameter, Number of passes, Engraving speed was studied on various materials like Al 7075, AISI 304 steel, EN8, Moso bamboo, AISI H13 tool steel, Vanadis 10, etc. and its effect on output parameters like Material removal rate, surface roughness, depth, width was studied. From this literature review, it is found that with proper optimization of process parameters of laser engraving precise output with high production can be obtained. The conclusive remarks are very beneficial to the industry people.

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