A Review on Laser Engraving Process

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Abstract— This paper describes a variety of fundamental research of laser engraving of Stainless Steel 316 which the authors have recently performed. Laser engraving is machining process where material is engraved by laser process. Laser Engraving is most effective technique in the machining of hard materials and removes the material layer by layer. Basically many types of industrial lasers like, carbon dioxide (CO2) laser and neodymium-doped yttrium Aluminium garnet (Nd: YAG) laser, fiber laser, semiconductor laser which are used for laser engraving process. The aim of the present work to investigate the influence of the process parameters (laser power, scanning speed, and laser frequency) on material removal rate, Engraving depth and surface roughness is experimentally measure. This paper deals with the review of papers by authors.

Key words: Laser Engraving, Process Parameters, Optimization, Full Factorial Design (FFD)

I. INTRODUCTION

Laser engraving is the practice of using lasers to engrave or mark an object. Laser engraving is the removal of material from the top surface down to a specified depth. Laser engraving, which is different from laser marking, is the practice of using lasers to engrave an object. Laser marking on the other hand just discolours the surface, without cutting into the surface. The technique does not involve the use of inks, nor does it involve tool bits which contact the engraving surface and wear out. These properties distinguish laser engraving from alternative engraving or marking technologies where inks or bit heads have to be replaced regularly.

II. LITERATURE REVIEW

Dharmesh K. Patel *et al* (2014) [1] has been investigated Parametric Optimization of Laser engraving process for different Material using grey relational technique. Laser engraving process is non-conventional machining process used for marking/engraving of almost each material which cannot be mark by conventional machining process. In laser engraving processes the surface of material is heat up and subsequently vaporize the material. 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 and get changes in output parameter like material removal rate, surface finish and indentation. To optimization of all these parameters with multiple performances characteristic based on the grey relational analysis. By analyzing grey relational grade, it will be observed that which parameter has more effect on responses of input parameter to the output parameter. It will conclude that the laser engraved depth became deeper for either higher laser power or a lower feed speed ratio.

Sefika Kasman (2013) [2] has been investigated impact of parameters on the process response, a taguchi orthogonal analysis for laser engraving. Laser engraving is the most effective technique in the machining of hard materials has a complex geometry. The present study investigates the machinability of hard metal produced with powder metallurgy and puts forward a new approach to the relating to the laser engraving of P/M metals. The main objective of this study is to determine the impact of laser engraving process on powder metallurgy cold work tool steel: Vanadis 10. For this purpose, three process parameters like effective scan speed, frequency and laser effective power on the surface roughness and engraving depth. The taguchi and linear regression were used in the analysis. The experiments were accordance with an L9 orthogonal array based on S/N ratio for surface roughness and engraving depth. It was found that scan speed has statistically significant effect on both surface roughness and engraving depth. The scan speed appeared to be the main effective parameter for the two performance characteristics. The experimental results showed that increasing scan speed decreases both Ra and D. To minimize Ra, the scan speed should be selected at a high level (800 mm/s), whereas to maximize D, the scan speed should be selected at a low level (200 mm/s).Furthermore a mathematical model for surface roughness and engraving was established and estimated using regression.

F. Agalianos *et al* (2011) [3] has been investigated industrial application of laser engraving of influence of the process parameters on machined surface quality. Laser engraving technology removes material layer by layer and thickness of layer is usually in the range of few microns. The aim of the present work is to investigate the influence of process parameter on surface quality when machined by laser engraving. The examined parameters like pulse frequency, beam speed, layer thickness. The surface quality was determined by surface roughness for every set of parameters. Experimental results on Al7075 material showed that the surface roughness depends on the frequency and the scan speed used. Based on the experimental work of the present paper in laser engraving of Al7075 using a Q-switched Yb:YAG fiber laser, it can be summarized that the surface roughness strongly depends on the frequency and the scan speed used. In addition it was proven that the resulted roughness depends less by the layer thickness. When considering all the experimental data of the current experimental plan, the best surface roughness was achieved when using a frequency of 20kHz, a scan speed in the range of 600- 700mm/s and a layer thickness of 4 and 6μm.

S.Genna *et al* (2010) [4] has been study of fiber laser machining of C45 steel of influence of process parameters on material removal rate and roughness. Aim of the work is investigate the influence of the process parameters on material removal rate and surface roughness in engraving operation by using C45 carbon steel and Q-switched 20W Yb:YAG fiber laser beam with fundamental wavelength 1070mm. The examined parameters like the pulse frequency, the beam speed, the distance between the linear patterns of two consecutive laser scan, the number of replications of the geometric pattern and scanning strategy. Experimental results show that the Yb: YAG fiber laser can be successfully used to machine C45 carbon steel. Material removal rate and surface roughness strictly depends on the process parameters. From the results presented in this work, concerning the laser engraving of C45 steel by means of a Q-switched Yb: YAG fiber laser.

C.Leone *et al* (2009) [5] has been investigated wood engraving by Q-switched diode pumped frequency doubled Nd: YAG green laser. The aim of this work is to investigate the influence of the process parameters on the material removal rate by engraving panels made of different types of wood using a Q-switched diode pumped Nd:YAG green laser working with wavelength 532nm. The examined parameters like the pulse frequency, the beam speed and the number of laser scansions also called repetitions. The working parameters and engraved depth were related and energy based model was proposed in order to predict the laser. Experimental result showed that this type laser can be successfully used to machined different type of wood, obtaining decorative drawing and 3D engraved geometries without burning. However, an accurate selection of wood types and the process parameters is necessary in order to obtain deep engraving without carbonization and a homogeneous carving.

Cheng Jung Lin *et al* (2008) [6] has been investigated effect of feed speed ratio and laser power on engraved depth and colour difference of moso bamboo lamina. Moso bamboo lamina was engraved using various laser output power levels in conjunction with various feed speed ratio in order to understand the effect of feed speed ratio and laser output power on engraved depth and colour difference. The bamboo Culm was sliced into strips and then the strips were planned for obtaining smooth surface. Two kind of moso bamboo lamina, including without and with steam treatment were investigated.

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:

- The laser engraved depth became deeper for either higher laser power or a lower feed speed ratio.
- Color difference values increased under a lower feed speed ratio and higher power, and resulted in a brownish color in the engraved zone.
- 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.
- The engraved depth and color difference values of Moso bamboo could be predicted and estimated by regression analyses.

Mohd Ashraf B. Mohd Fauzan (2008) [7] has been investigated Co_2 laser engraving of stainless steel 304. This research is to study the effect of parameter on the characteristic of the engraving and the width size using conventional C02 laser machine on 304 grade stainless steel. In this study, engraving is done on 304 grade stainless steel that are done using eight experiments that involves eight parameters combination. In this study, process parameters that are identified are assisting gas, gas pressure, cutting speed, focal height and focusing lens. The experiment is done with three replications to have a better result. The work piece is than analyzed and measured using metallurgical microscope. The results are than analyzed qualitatively and quantitatively. The quantitative results are analyzed utilizing Minitab and using Design of Experiment analysis. In this experiment, the engraving width is found to be greatly affected by the cutting speed and interaction of power and speed factor. The qualitative analysis however shows various characteristic differences despite using the same parameters combination. This study shows that engraving characteristic of width size can be predicted from parameters used when using conventional $C0_2$ laser machine.

Y. H. Chen *et al* (1996) [8] has been investigated application of Taguchi method in the optimization of laser micro-engraving photo masks. Photo masks are needed to generate various design patterns in the fabrication of liquid crystal displays. This paper discusses the use of taguchi method of experimental design in optimising process parameters for micro-engraving of iron oxide coated glass using Q- switched Nd:YAG laser. The effect of five major parameters like beam expansion ration, focal length, average laser power, pulse repetition rate and engraving speed on the engraving line width. An L16 orthogonal array was used to the experiments. The study indicated that a minimum line width of 18μm could be obtain with beam expansion ratio of 5 x , focal length of 50mm, laser average power of 0.4 W, pulse repetition rate of 5kHz and engraving speed of 5000mm/min.

Arkadiusz J. Antonczak *et al* (2014) [9] has been investigated the influence of process parameters on the laser induced coloring of titanium. This paper presents the result of the measurement and analysis of influence of laser process parameters of the color obtained. The study was conducted for titanium grade 2 using a industrial pulsed fiber laser. The process parameters like laser power , the scanning speed of material, the temperature of the material, the size of marked area, and the position of sample, relative both the focal plane and center of working field of the system affecting the repeatability of the color created. The objective assessment of color changes, an optical spectrometer and CIE color difference parameter were used. Based on this analysis , a number of necessary modification are proposed to laser system commonly used for monochrome marking in order to improve repeatability in color marking.

C. Leone *et al* (2010)[10] has been investigated AISI 304 stainless steel marking by a Q- switched diode pumped Nd: YAG laser. The aim was to determine the correlation occurring between working parameters like pulse frequency, beam scanning speed, and current intensity and resulting mark visibility. To characterize mark feature, its width and roughness were estimated and analyses optical and scanning electron microscopy coupled with energy were dispersive X-ray technique were carried out. Laser marking tests were carried out on AISI 304 steel, using a Q-switched diode pumped Nd:YAG laser, in order to determine the best working parameters to obtain a given visibility. From the results obtained, the main conclusions are as follows:

- Within the range of process parameters employed, mark width is only moderately affected by operating conditions
- Mark contrast is affected by both surface roughness and oxidation, with the former probably prevailing at low contrast, and the latter at high contrast;
- If the aim is obtaining good mark visibility, relatively low frequencies and average powers should be used;
- The best mark visibility achievable is strictly dependent on the operating features of the particular laser system used.

E. Yasa *et al* (2010) [11] has been investigation of laser and process parameters for selective laser erosion. To study of the effects of different process and laser parameters on the process outputs such as surface quality and erosion rate. The SLE process is a direct method to remove material in a layer by layer fashion due to high energy densities provided by the laser beam. However, one of the major problems involved in SLE process is high number of laser and process parameters like laser power, pulse frequency, scan speed, scan, spacing, ambient atmosphere etc. and the complexity of the relations between them which has not yet been investigated. The results of several single factor experiments that were carried out to determine the influence of the major parameters on the depth of erosion per layer and surface roughness. The results from single factor experiments showed that some relations were highly governed by the power intensity of the laser beam and that cross interactions between the parameters play an important role on the output characteristics. The paper explains how multiple parameters can be combined to define two indirectly controlled geometrical parameters likes scan and pulse overlap factors. Those two parameters allow calculating the number of hits the laser beam on a same location on the work piece which is the first step in physical modelling the topography of the surface.

This paper has presented an overall view of the Selective Laser Erosion process for pulsed laser mode with nano-second durations. The results of single-factor experiments are analyzed in order to investigate the influence of several parameters on the process. The studied parameters, such as scan strategy, scan speed, scan spacing, pulse frequency, laser pump current (laser power) and spot size, and generally exhibit a behaviour that is not consistent for all testing conditions although the general trends are the same. This is due to the fact that the relations highly depend on the selection of the other parameters, which suggests that cross interactions between the parameters play an important role on the responses (depth of erosion and roughness) of the process.

J. Qi et al (2003)[12]has been investigated a study on the laser marking process of stainless steel using a Q-switched Nd: YAG laser was used in this process. The influence of laser beam on the mark depth, width and mark contrast have been studied in this paper. The mark contrast is the ratio of the apparent brightness between the mark and unmark area which shows the clearance degree of the mark. An optical microscope, scanning electron microscope and surface profile instrument were used to measure the effect of pulse frequency on the mark depth and width. An image analysis system with frame grabber card and charged couple device was used to measure mark contrast. It has been measure the mark depth, width, mark contrast on influence by the pulse frequency. There is maximum mark depth when the pulse frequency is about 3 kHz while mark width almost keeps constant at different pulse frequency. With the pulse frequency increasing, evaporation of material becomes less and at the same time oxidization become more significant which leads to improvement of mark contrast. The highest mark contrast obtained when pulse frequency of laser was about 8 KHz.

III. CONCLUSION

Many researchers have worked on different type of materials with various types of laser. Researchers have used varieties of design of experiment (DOE) technique like as full factorial design, Taguchi method, Box-Behnken design and Response surface methodology and different types of techniques for optimization like GLA technique, Grey relational technique, anova analysis. Some studies conducted on various behaviours like effect of process parameters on different types of material like AISI 304 steel, C45 steel, wood, moso bamboo, Al 7075 and output parameters like MRR, surface roughness, depth, kerf width.

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