A Review on Laser Marking Process for Different Materials

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Abstract— this paper describes a variety of fundamental research of laser marking of different materials which the authors have recently performed. Product laser marking is one of the most common industrial applications of lasers. The laser marking systems using different lasers and optical delivery systems may be used to mark an almost endless list of materials including metals, plastics, ceramics, glass, woodland leather as well as painted surfaces and photographic emulsions. In this review the research and progress in laser marking of different materials are critically reviewed from different perspectives. 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 marking process. Some important laser processing parameters and their effects on MRR and surface roughness are discussed. This paper deals with the review of papers by authors.

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

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.[1]

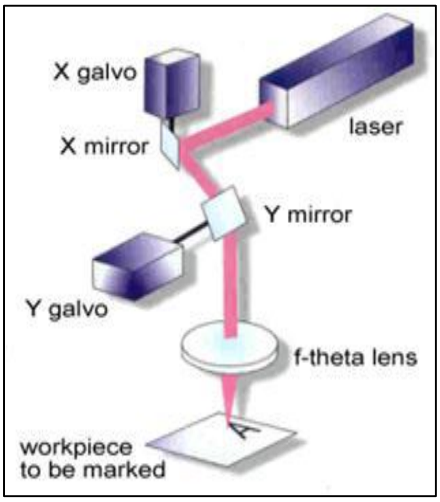

Fig. 1: Laser engraving process [1]

II. LITERATURE REVIEW

Sefika Kasman 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.[2]

Dharmesh K. Patel has been investigated Parametric Optimization of 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.[3]

Leone, S. Genna, G. Caprino , I. De Iorio 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:

1) Within the range of process parameters employed, mark width is only moderately affected by operating conditions
2) Mark contrast is affected by both surface roughness and oxidation, with the former probably prevailing at low contrast, and the latter at high contrast;
3) If the aim is obtaining good mark visibility, relatively low frequencies and average powers should be used;
4) The best mark visibility achievable is strictly dependent on the operating features of the particular laser system used.[4]

J,Qi, K.L. Wang, Y.M. Zhu studied on the influence of the pulse frequency of the laser beam on the mark depth, width and mark contrast. A Q-switched Nd: YAG laser was used in the laser marking process of stainless steel. The mark contrast is the ratio of the apparent brightness between the mark and unmarked areas which shows the clearance the mark contrast increases with increase in the pulse frequency when pulse frequency is below 8 kHz. Contrarily, when the pulse frequency increases to above 8 kHz, the mark contrast decreases. This is because vaporization of material is significant and very little material has been oxidized at low pulse frequency, while the main process is oxidization of materials at high pulse frequency. Oxidization of materials improves mark contrast.

Also they have investigated that the pulse frequency of a Q-switched Nd: YAG laser has a significant effect on the mark quality. There is maximum mark depth when the pulse frequency is about 3 kHz, while the mark width remains almost constant at different pulse frequency. With the increase in pulse frequency, evaporation of material decreases, whilst at the same time oxidization is more significant, which leads to the improvement of mark contrast. The highest mark contrast was obtained when the pulse frequency of the laser was about 8 kHz.[5]

F. Agalianos, S. Patelis, P. Kyratsis, E. Maravelakis, E. Vasarmidis, A. Antoniadis 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.[6]

Cheng Jung Lin 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:

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.[7]

Y. H. Chen et al. 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.[8]

Mohd Ashraf B. Mohd Fauzan 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.[9]

Lechosław Tuz et al. 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.[10]

E. Yasa, J. P. Kruth 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. [11]

A. R. Khan et al. 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.[12]

V.Y. Javale et al. 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.[13]

III. CONCLUSION

From this review, it conclude that:

- 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.
- It was found that scan speed has statistically significant effect on both surface roughness and engraving depth.
- 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).
- 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 surface roughness strongly depends on the frequency and the scan speed used.
- The best surface roughness was achieved when using a frequency of 20 kHz, a scan speed in the range of 600-700mm/s and a layer thickness of 4 and 6μm.
- The colour difference & engraved depth values of Moso bamboo could be predicted & estimated by regression analyses.
- Engraved depth & colour difference increases with an increase in laser output Power.

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