A Review on Laser marking by Nd-Yag Laser and Fiber Laser

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ABSTRACT

Laser marking provides a unique combination of speed, permanence and versatility. Laser engraving is a manufacturing method for those applications where previously Electrical Discharge Machining (EDM) was the only choice. Laser engraving technology removes material layer-by-layer and the thickness of layers is usually in the range of few microns. Also there is many types of laser machines are available in recent time. Therefore for Optimum Use of Laser energy it is necessary to optimum use of process parameters to get best marking speed, Quality. This review paper presents various important work on Laser marking and its parameters i.e. Width, Depth, Contrast of Marking.

Keyword: - *Laser Marking, Nd-YAG laser, Fiber Laser*

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1. INTRODUCTION

In the past decades, laser has been widely used in cutting and welding operations. Quite recently, this technology has been adopted in other industrial processes like marking, selective ablation and machining of different materials, thanks to the introduction of laser sources characterized by short and ultra-short pulses having from nanosecond to femtosecond duration.[3]

Marking is a process to make a mark on a product for the purpose of product identification. There are many marking methods, such as ink-marking, mechanical engraving and electro-chemical methods. Laser marking is a new marking method. There are many advantages in laser marking compared with conventional marking methods, such as no wear on tools, high degree of automation, free programming and choice of characters [1].

The main advantages of laser process are non-contact working, high repeatability, and high scanning speed, worked area comparable to the laser spot, high flexibility and automation. Furthermore, the use of shorter wavelengths, which are better absorbed by the material, allows smaller feature sizes to be worked, while the use of shorter pulses reduces heat-affected zone and opens new ways for nanometric accuracy [3].

The mark qualities, especially mark clearance, are most important in the marking process. In order to obtain a clear mark, suitable processing parameters must be selected. There are mainly three processing parameters used in laser marking: pulse frequency, Focal point and scanning speed, in which the pulse frequency of the laser has significant effects on mark quality. The laser marking process of EN8 Bearing steel with a Q-switched Nd:YAG laser and Fiber Laser was studied in this work. The aim was to find the relationship between the pulse frequency of the laser and the mark quality characteristics so as to be able to obtain high quality marks.

2. LASER MARKING PHENOMENA

(1) Vaporization

The laser beam is focused to a small spot, which greatly increases the energy density. When the energy is high enough, and the surface temperature is raised well above the melting point, most of the material on which the beam is focused will vaporize.

(2) Softening/Melting
Some materials are melted by infrared laser radiation, e.g. metals, epoxies. In the case of metals, mark contrast is achieved by oxidation or incorporation of impurities into the melt. In the case of plastics, the material melts and forms ridges. Depending on types of material, different colours may appear.

(3) Layer removal/ablation
Layer removal/ablation is actually a form of controlled vaporisation . A thin layer of plastic film, paper, ink or paint is vaporized exposing the different coloured under-layer.

(4) Colour change
At certain energy densities (below melting point), materials can undergo chemical changes when exposed to laser radiation of a specific wavelength. The chemical change can be either light or heat induced, e.g. excimer laser induced photo-chemical colour change for aircraft cable marking (white to black), and CO2 laser-induced (heat-induced) colour change on PVC (gray to red-brown). The color change is due to changes in chemical composition or in molecular structures

3. LITERATURE REVIEW

J. Qi, K.L. Wang, Y.M. Zhu [1] 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 degree of the mark. An optical microscope, scanning electron microscope and surface profile instrument were used to measure the effects of pulse frequency on the mark depth and width. An image-analysis system with a frame-grabber card and a charged-couple-device (CCD) was used to measure 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 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.

T.W. Ng, S.C. Yeo [2] has studied on the CIE colour difference formula was applied to evaluate four types of material surfaces; anodized aluminium, stainless steel, poly-butylenes tetra-phthalate (PBT), and phenol formaldehyde, marked using a Nd:YAG laser, and viewed under three common modes of illumination; tungsten, Fluorescent and daylight at different speeds. The colour difference values were based on the spectral reflectance readings obtained from a spectrophotometer. The plots of colour difference value against laser marking speed revealed different trends for the materials and illumination modes applied. In terms of operational laser marking speeds, stainless steel could be classified as low, anodized aluminium as medium, and PBT and phenol formaldehyde as high. In terms of maximal colour difference values, anodized aluminium could be classified as low, PBT and stainless steel as medium, and phenol formaldehyde as high.

C. Leone, S. Genna, G. Caprino, I. De Iorio [3] has carried out Laser marking tests to determine the correlation occurring between working parameters (i.e. pulse frequency, beam scanning speed, and current intensity) and resulting mark visibility on AISI 304 steel, using a Q-switched diode pumped Nd:YAG laser. The latter was evaluated as the contrast index measured from digital images of the marks. . To characterize mark features, its width and roughness were estimated, and analyses employing optical and scanning electron microscopy coupled with energy dispersive X-ray technique were carried out. From the experimental results they have 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 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. 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.

Janez Diaci, Drago Bracun, Ales Gorkic, Janez Mozina [4] has presented a novel method for rapid and flexible laser marking and engraving of tilted, curved and freeform work-piece surfaces. The method is based on integrating a three-dimensional (3D) laser measurement system into a 3D laser marking system. The same laser source and optics for measurement and processing with a minimum of additional hardware components were used. A novel method is presented that allows rapid and flexible laser marking and engraving of tilted, curved and freeform work-piece surfaces. An implementation is described where a digital camera is integrated into a 3D laser marking system in such a way that it is possible to measure the 3D shape of the work-piece surface just before processing. The measurement phase takes typically less than 10 seconds. Custom software has been developed which allows 3D surface measurement, placement of the laser mark onto the measured surface and process control. Examples are presented which demonstrate the advantages of the novel 3D system with respect to the existing industrial 2D and 3D systems. This paper has discussed key issues concerning an implementation of the method and presents typical examples of markings and engravings, which demonstrate the advantages of the method with respect to the existing industrial 2D and 3D laser marking and engraving methods. The method can also be applied to flexible laser structuring and micro processing of curved surfaces.

F.Agalianos, S.Patelis, P. Kyratsis, E. Maravelakis, E.Vasarmidis, A.Antoniadis[5] has investigated on the influence of the process parameters on the surface quality when machined by laser engraving. The examined parameters were: the pulse frequency, the beam speed and the layer thickness. The surface quality was determined by the surface roughness for every set of parameters. Based on the experimental work of the present paper in laser engraving of Al7075 using a Q-switched Yb:YAG fibre 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 20 kHz, a scan speed in the range of 600-700mm/s and a layer thickness of 4 and 6μm. Experimental results on Al7075 material showed that the surface roughness strictly depends on the process parameters used.

Sefika Kasman[6] has investigated the machinability of hard metal produced with powder metallurgy and puts forward a new approach 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 Vanadis 10. For this purpose, three process parameters – namely effective scan speed, frequency, and laser effective power – were correlated with the surface roughness (Ra) and engraving depth (D). The Taguchi and linear regression were used in the analysis. The experiments were performed in accordance with an L9 orthogonal array. Based on the S/N ratio for Ra and D, the optimal condition was found as SS3F2P1 for Ra and SS1F2P3 for D. the ANOVA was performed to evaluate the statistical significance of each parameter on the performance characteristics. Also he has determined that

(1) 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).

(2) The optimal level for Ra is where the scan speed is at 800 mm/s, the frequency is at 30 KHz, and power is at 25W (SS3F2P1). Optimal levels for D for each material type were obtained at a scan speed of 200 mm/s, a frequency of 30 KHz, and with power at 50W (SS1F2P3).

(3) After determining the optimal level for each parameter, a confirmation experiment was performed for both Ra and D. The predicted and experimental results were compared, and the results show that there is a high correlation between them. To achieve a good surface finish, a high scan speed at the lower power level is recommended.

(4) ANOVA was performed using the S/N ratio to investigate the significance of each parameter and to determine the percentage contribution to both Ra and D. The effect of scan speed on both Ra and D is 83.84% and 76.69%, respectively. However, the effect of frequency has little that determined by the p value (0.367). The percentage contribution of frequency is 3.47% and 0.56% to the Ra and D, respectively.

(5) To test the predicted linear regression model, a set of experiments at different condition were used to predict both Ra and D. Results show that the predicted results (test results) are very close to the actual value. This means that Ra explains the model of laser engraving process for Vanadis 10. Besides this, the data taken from the test experiments also explain the model for D

4. CONCLUSION

1. In terms of operational laser marking speeds, stainless steel could be classified as low, anodized aluminium as medium, and PBT and phenol formaldehyde as high.

2. In terms of maximal colour difference values, anodized aluminium could be classified as low, PBT and stainless steel as medium, and phenol formaldehyde as high.
3. Mark contrast is affected by both surface roughness and oxidation, with the former probably prevailing at low contrast, and the latter at high contrast.
4. 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.
5. To achieve a good surface finish, a high scan speed at the lower power level is recommended. 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.

5. REFERENCES

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