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Parameter Characteristic of Desktop Laser Engraving Kit Machine: A Review

NS Badrishah, N Sa'ude, M Ibrahim, MS Wahab, R Haq, OMF Marwah, RK Khirotdin*
Advanced Manufacturing and Material Centre (AMMC), Additive Manufacturing Research Group (ADDMAN), Universiti Tun Hussein Onn Malaysia, Faculty of Mechanical and Manufacturing Engineering, 86400 Parit Raja, Batu Pahat, Johor, Malaysia

*nasuha@uthm.edu.my

ABSTRACT

In today's modern age, laser engravings become the most promising technologies to be used in order to engrave or mark an object. This study will be focusing on the parameter characteristic use of a new technology desktop laser engraving kit machines on materials. The aim of the present work is to investigate the influence of the process parameters on the surface quality when machined by desktop laser engraving kit according to precise design of experiment to the materials. According to these design of experiment, we analyze the effect of these input to the output parameters. According to Yilbas [1], in the laser engraving process, the process parameters can be adjusted and tuned to achieve the quality of cut or engraved desired. However, if a different work piece material is used for engraving, all of these parameters may require re-adjustment, which consumes a considerable amount of time and effort and this is the motive driving the project at hand. Finally, this research has used some of the practitioner findings to further support the research evidence found from published sources in the literature review.

Keywords: *Laser engraving, parameters, materials, re-adjustment, time and effort.*

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1.0 Introduction

Engraving is a process of incising a design into a hard surface normally a flat surface. The design of the surface is permanent and cannot be removed. In this method, a laser beam is used to ablate a solid bulk, following predetermined patterns. A laser is a device that can emit light through a process of optical implication based on the stimulated emission of electromagnetic radiation. To be able for engraving purpose a suitable laser need to be chosen to carry out the specific task. The desired pattern is created by repeating this process on each successive thin layer. In this project, a low power laser was used as the main component part to engrave wooden product surface. Desktop laser engraving kit machine with 500mW diode laser and 405nm wavelength has been used to engrave the surface part of the product in this study. It is the medium to transfer the design virtually into a real design that can be touch and sees. This machine will have three stepper motor that will move the laser in x-axis and y-axis direction. The Benbox software will be used as a interprets instruction data and controls hardware. It is a information gathered includes different study on laser engraving process of input parameter such as laser power, frequency, pulse duration, spot diameter, number of passes, air/gas pressure, engraving speed are taken for different work piece materials such as aluminium, alloy, acrylic, semiconductor and wooden also. It is obtained that what changes are occur due to changing in these all input parameter to the output parameter like surface finish, material removal rate and depth of the material.

2.0 Study in laser engraving process

2.1 Study on laser characteristic using in engraving

In recent years, lasers have been also used for deep engraving applications. It is well known that lasers are used in many production methods such as marking, welding, drilling, scribing, sintering and cutting. G. Chryssolouris [2] and A.K. Dubey et al.[3] has discussed that laser light has the photos of same phase ,frequency and wavelength. So that, they are differs from ordinary light. Thus, unlike ordinary light laser beams are high directional have better focusing characteristic and high power density. Because of these unique characteristics of laser beam, they are useful in processing of materials. Basically, laser based machining processes use a high intensity beam as the cutting tool and non-contact to the material surface. However, during A. Kaldos et al.[4], S.L. Campanelli et al.[5] and A.K. Dubey et al.[6] study, they do not faced any difficult or problem to machine geometry and work piece material hardness on the cutting tools used.

A review on high-power diode laser applications for materials processing has been carried out in an extensive study. Lin Li [7] has presented a review of the direct applications of high power diode laser for materials processing including engraving, marking, machining, powder sintering, soldering, welding, scribing, paint stripping, synthesis, brazing, sheet metal bending and surface modification (hardening, cladding, glazing and wetting modification). These features include better morphological characteristics, less heat-affected zone, better surface finish and beam absorption, fewer cracks and less porosity generation and the result are more consistent and repeatable. However, there are some weaknesses of the high power diode lasers. It is including beam absorption dependent on work piece colors, the difficulty to produce very high-peak-powered short-pulsed beam directly and high beam divergence (thus difficult to focus to a small beam size). C. Leone et al.[8] on his study used high power diode laser of Q-switched diode pumped frequency- doubled Nd:YAG 5W green laser working with a wavelength 532 nm and the experimental result showed that the laser can be usefully used in deep engraving of different kinds of wood without carbonization of the surface.

Furthermore, P. Laakso et al.[9] has discuss about fiber laser that the marking process can be optimized for producing better colors with better visual appearance and quality. It also can allow independent tuning on different of laser parameters. However, laser processing material of metal surfaces will create an oxide layer on the surface. In this study, the visual appearance of laser marked surfaces was optimized by varying different laser parameters.

Antiono [10] on his study used a low powered diode laser device for the processing of soft materials by the engraving processes, as opposed to the higher consuming CO2 tubes in use by most other machines. The selected diode laser device is a TO-can packaged, blue (445 nm wavelength) laser diode. In this study project, the device was operated in a continuous mode when lasing and instead of switching off the current feed to the diode laser. The current would be lowered to levels just above the laser threshold when work piece processing power was not needed. In this experiment it can cutting out a paper sheet. The prototype also was able to process many different work pieces of materials such as wood, synthetic foam sheets and cardboard. Indeed, the prototype was able to engrave on a 30 mm thick wooden block proving that different sized of work pieces may indeed be processed.

2.2 Study on laser engraving materials

Commonly laser devices have been applied for their appreciable properties in material processing. J. Leunda et al. [11] presented that the most important issue in the manufacturing industry is about a machining of high strength material. In H. Ding et al.[12] study, has discussed during the processing of such materials, it can increased machining cost and surface roughness if high expectation for good surface quality, reduced tool wear, as well as tool-based. Furthermore, V.N. Gaitonde et al.[13] has reported that the machining strategy for a specific material is the most important criterion. It is because, a high quality surface is desired in mold and parts which are used in electronics, biomedical industries and automotive. Additionally, the machining of complex geometries with a high surface quality is mostly affected by the working forming tool and material.

C. Leone et al.[8] has discussed not all kinds of wood are suitable to be engraved. It depends on the presence of high different density values due to seasonal growth of the wood, which does not allow for flat engraved surfaces and also consideration of wood structure. In others study on material selection in laser engraving process, Cheng-Jung Lin et al.[14] reported that laser engraving has gained increasing interest in the using of bamboo material for handcraft industry. It is well suited for high volume automated manufacturing to the high processing of speed, high quality of engraved products, precision of operation and low waste.

Machining of some materials such as high strength steels and high chromium alloys is still a delicate. It is a difficult task and has received little attention from any consumer. S.H. Masood et al.[15] has presents that hard to wear materials such as metallic alloys and ceramics, it must be considered used laser assisted machining. However, the cutting tools and conventional computer numerical control machines cannot adapt easily to such materials and induce very high tooling costs for operations of rough machining or finishing. According to Jozef Wendland et al.[16] study, showed that it is possible to achieve good contrast which is needed for barcode marking on bare metals which is a high strength material.

According to F. Hnilica et al.[17] study, ledeburitic steels material produced by powder metallurgy have many advantages compared with steels whose chemical composition is fabricated using a conventional casting route. F.K. Arslan et al.[18] indicated that, compared to conventional standard steels, these types of alloyed steels show high mechanical properties such as wear resistance, high hardness and toughness.

Moreover, in Sefika Kasman[19] present study puts forward a new approach relating to the laser engraving of P/M metals by investigates the machinability of hard metal produced with powder metallurgy. The main objective of this study is to determine the impact of laser engraving process on Vanadis 10 material. However, S. Hatami et al.[20] has characterized that Vanadis 10 as a very good dimension stability and wear resistance material. He also describes Vanadis 10 as one of the high vanadium alloyed powder metallurgy tool steels.

M.M.Noor et al.[21] has reported, it's very important to verify the surface texture since the defect at the microstructure cause the materials pathetic and less strength. On this study, microscopy reveals that some of good surface roughness got defect in microstructure such as wavy surface, burning and melting. This will cause the materials to suffer in terms of less strength.

2.3 Study on laser engraving process parameters

According to Dharmesh K. Patel and Dr. D. M. Patel[22], in their study on analysis the effect of laser engraving process for surface roughness measurement on stainless steel (304), laser engraving process is a non-conventional machining process. They have been discuss that by using laser engraving machine the engraving or marking is possible with different input parameter such as engraving speed, number of passes, spot diameter, laser frequency, different wave length, laser power and get the changes in output parameter such as surface finish, indentation and material removal rate. As a result, it shows that better output parameter prediction applicability and capabilities to such industrial laser marking process or engraving leading to effective selection of machining parameter for better quality engraving.

Barnekov et al.[23,24] and Yilbas et al. [1] determined that in the laser cutting process, the process parameters can be tuned and adjusted to achieve the quality of cut desired. These parameters include the cutting speed, laser power and energy coupling factor. However, all of these parameters may require re-adjustment if a different work piece of material is used for cutting, which consumes a considerable amount of effort and time. Black [25] reported that any material used in the laser machining is a complex process involving many different parameters which is all need to work concerned to produce a quality machining operation.

Moreover, Wang et al.[26] and Arai et al.[27] indicated that there is a negative relationship between engraved depth and wood density. Therefore, Cheng-Jung Lin et al.[14] in result showed that a deeper engraved depth in specimens with steam treatment occurred with engraving owing to the decrease in bamboo density compared to material without treatment process.

In addition, C. Leone et al.[8] study shows that laser engraving deep is one of the most rising technologies to be used in wood carver operations. The objective of this study is to investigate the influence of the process parameter on the material removal rates by engraving process. The examined parameters were the mean power that depends on the pulse frequency, mean power, beam speed and the number of laser repetitions. The output parameter of removal rate, surface quality during the engraving process and degree of precision of the shape are strictly depend on the laser source characteristic, materials properties and the process parameters. The working parameters and the engraved depth were related and an energy-based model was proposed in order to predict the latter. As the result, authors find that, for speed more than 40mm/s, the engraved depth is very low and multiple laser scanning are required to obtain deep engraving. The surface carbonization is depends on an incorrect selection of the process parameters and for the adopted laser it happen at beam speeds of up to 10mm/s. The engraved depth is strongly affected by the input parameter of pulse frequency, mean power, beam speed and the number of laser repetitions. It is possible for increasing the speed to obtaining engraving with a reduced frequency range around the value where the maximum output power is achieved. The maximum speed necessary to obtain engraving linearly depends on the mean power.

In Chen Yi Hong et al.[28] study shows that, one of the critical characteristics for laser engraving is photo masks and the line width that will determining the quality of masks and it's depends mainly upon the laser focus spot size. Approving experiments using a Q-switched Nd:YAG laser system and photo masks with iron oxide coatings were carried out. The obtained actual spot size was lay within 10% of the theoretical value. As a result, processing parameters such as laser power, material properties and engraving speed would also play a major role in determining the consequently the line width and spot size.

Cheng-Jung Lin et al.[14]. In this study, Moso bamboo lamina was engraved using various laser output power levels in conjunction with various feed speed ratios. The objective of this study is to understand the laser output power on engraved depth, color difference and the effects of feed speed ratio. As a result, it showed that the engraved depth became deeper for either higher laser power or a lower feed speed ratio. The average engraved depth difference values were 0.69mm to 0.86mm. Moreover, the color difference values increased under a higher power and lower feed speed ratio and also resulted in a brownish color in the engraved zone area. However, the average color difference values were 46.9 to 51.9 pixels by difference values could be predicted and estimated by regressions analyses. The author suggested that the fitting both power and laser speed is important for cost effective and valuable engraving. It is because of various desired engraving depths and color differences of product. Figure 1 below show that the laser engraved depth became deeper for either higher laser power or a lower feed speed ratio.

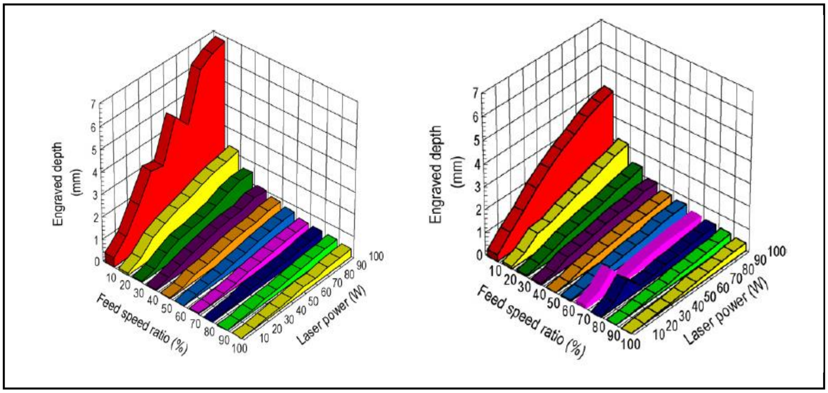

Figure 1: Engraved depth under various feed speed ratios and laser output power level for Moso bamboo with and without steam treatment.

The effect 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 but there was a decrease in the feed speed ratio as show in figure 2.

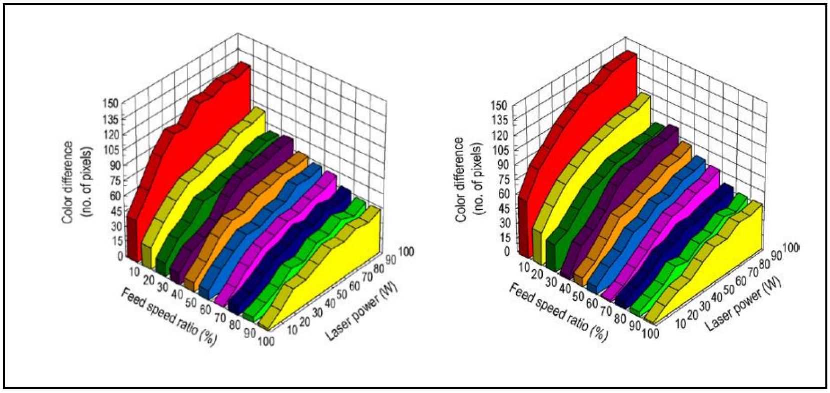

Figure 2: Color difference under various feed speed ratios and laser output power level for Moso bamboo with and without steam treatment.

Mihaiela Iliescu et al.[29] has presented the important of holograms and holography in nowadays life, especially in security and protection role. This paper is a study on holograms marks and more specifically on holograms laser engraving process parameters. The process involved is rather complex and with many parameters of influence on holograms accuracy and reliability. Some research result on holograms laser engraving process parameters are evidenced by this paper. Low speed, high frequency and small pulse duration of the laser beam should be used in order to obtain high resolution engraving results.

Jozef Wendland et al.[16] has investigates about deep engraving of steel and aluminium by using a laser and effect of feature shape and feature size on the process. This paper also reports on two such applications that require high removal rates and surface modification by using Q-switched DPSS lasers. Latest generation of Q-switched diode pumped solid state lasers was use to engrave a metals in this study. An optimal balance between feature quality and processing speed is achieved by examination of laser and scanner parameters. Material removal rate up to $20mm^3$/min for steel and $40mm^3$/min for aluminium are demonstrated up to a maximum engraved depth of 1mm. As a result, the material removal rates achieved, which are $90mm^3$/min for aluminium alloy and $25mm^3$/min for stainless steel, are very suitable for industrial applications. In conclusion, during the milling process the surface roughness can be controlled and this can be used to change optical properties of the target.

In addition, Janez Diaci et al.[30] has presents a method for rapid and flexible laser engraving and marking of tilted, curved and freeform work piece surfaces. In this paper, the author discusses main issues concerning an implementation of the method and presents typical examples of engraving and marking. The experimental of this study will demonstrate the advantages of the method with respect to the existing industrial 2D and 3D laser engraving and marking methods. The method used in this study is based on integrating a 3D laser measurement system into a 3D laser marking system. Yet, the method can also be applied to flexible laser structuring and micro processing of curved surfaces. A high peak power pulsed laser regime is used for processing while a low power laser regime is used to measure the 3D shape of a work piece surface. To determine the 3D trajectory of the processing, beam has been focus the acquired 3D surface data. Neither the 3D shape of the work piece nor its orientation needs to be known in advance as long as the processed surface lies within the working range of the 3D laser processing system. This eliminates the need for exact work piece positioning before processing and substantially improves processing flexibility. The measurement phase takes less than 10 seconds and custom software has been developed which allows 3D surface measurement, placement of the laser mark onto the measured surface and process control.

Sefika Kasman[19] in his study has using a Taguchi orthogonal analysis for laser engraving about the impact of parameters on the process response. The parameter used in this study is power 25W and 50W and frequency 20 KHz and 80 KHz. The material used is Vanadis 10, powder metallurgy cold work tool steel and it was hardened to 60 HRC. The travel length was 4mm, cutoff length (kc) and the sampling number (N) were selected as 0.8 and 5 respectively. As a result, the scan speed should be selected at a high level which is 800 mm/s, scan speed at a low level as 200 mm/s, frequency is at 30 KHz and power at 25W to minimize the Ra value.

Furthermore, M.M.Noor et al.[21] in his experiment was found that the surface roughness result is significantly affected by the tip distance followed by the power requirement and cutting speed. There are some defects were detected in microstructure such as burning, melting and wavy surface. It is clearly seen that the melting and burning are occur in the material structure when high power and high cutting speed used in the experimental. In this experiment, the author used a simulation graphic to gain more understanding of the surface roughness distribution in laser cutting process. As a result, the author suggested, to develop a model is suitable to be used parameter in the range of tip distance 3 to 9, power 90W to 95W and cutting speed 700mm/min to 1100mm/min. Even though the surface roughness is around 0.451 μm the surface structure is very poor. This is due to high temperature causing by cutting speed and power.

F.Agalianos et al.[31] summarized that the surface roughness strongly 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 fibre laser. In addition it was proven that the resulted roughness depends less by the layer of thickness. As a result, the author conclude that 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.

3.0 Discussion

In this review papers, it is found that no researcher have worked or study on process characteristic parameters by using low diode laser. Moreover, most of the researcher have used high power diode laser machined on their project study which is more suitable for industrial application and the result of experiment show more consistent and repeatable. However, there are some weaknesses of the high power diode lasers. It is including beam absorption dependent on work piece colors, the difficulty to produce very high peak powered short pulsed beam directly and high beam divergence, thus difficult to focus to a small beam size.

In material selection, different work piece of materials such as aluminium, plastic, paper, alloy, stainless steel, acrylic, semiconductor and many type of wooden has been used by researchers on their study. Material characteristic such as structure, volume, density value must be study before start to engrave the material. However, some of the researcher found that there are negative relationship between output parameter and material characteristic.

According to all researchers result, there are need to select effective machining parameter for better quality engraving result on material. The results shows its better output parameter prediction capabilities and applicability to such industrial laser marking or engraving leading to effective selection of input parameter for better quality engraving. Most of the researcher study on input paramaeter such as engraving speed, number of passes, spot diameter, laser frequency, different wave length, laser power and get the changes in output parameter such as surface finish, indentation, material removal rate, degree of precision of the shape are strictly depend on the laser source characteristic, materials properties and the process parameters . However, all of these parameters may require re-adjustment if a different work piece of material is used for cutting, which consumes a considerable amount of effort and time.

4.0 Research Direction

In this study, 500mw power, 405nm wavelength diode laser will be used to engrave the material part. Pine wood stick with dimension of (150x10x2) mm and WPC stick with dimension of (100x25x3)mm was selected for this study and both materials will be engraved into a pattern shape of number one (1) on each of the materials for 27 samples to measure the surface roughness.

In this study, input parameters (engraving speed, burning time and laser height) and output parameters (surface roughness and depth) will be used on desktop laser engraving kit machine according to precise design of experiment. According to these design of experiment, we analyze the effect of these input to the output parameters.

The result of the surface roughness (Ra) and engraved depth (Rz) will be measured using Surface Roughness Mitutoyo SJ-400 instrument. This instrument is from metrology laboratory, UTHM. In surface roughness, Ra and Rz is the different parameters that will been researched in this experiment. Ra is arithmetical mean roughness that is the arithmetical mean of the absolute values of the profile deviations (Zi) from the men line of the roughness profile and Rz is mean roughness depth that is mean value of the five Rzi values from the five sampling length within the evaluation length. Scanning Electron Microscope (SEM) also will be used in this study to provides the high resolution and the long depth of field images of the sample surface. It is also the type of electron microscope that was produces images of a sample by scanning it with a focusing the beam of electrons. The electrons also interact with the atoms in the sample to produce various signals that contain information about the sample surface topography and the composition. This analysis was needed in this study because the Heat Affected Zone (HAZ) effect on the engraved materials need to be discuss due to parameter selected for both materials. An analyze of variance (multifactor ANOVA by the Design Expert software) was used to determine if the input parameter significantly affected the output parameter.

5.0 Conclusion

In conclusion, this review paper has identified a gap in literature as there is generally only engineering journal-papers, articles and books that describe the terms and technical processes in great depth. However, they do not discuss the impact of using low diode lasers on materials or suggest the parameters needed to produce clear engraving on the surface. Moreover, there are some documented experimental findings produced by practitioners that have used lasers for design purposes. Also, unfortunately, they do not publish their findings through academic channels and use their research as a way of marketing the process and products on the internet. This research has used some of the practitioners findings to further support the research evidence found from published sources in the literature review.

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