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Parametric Optimization of Laser Engraving Process for different Material using Grey Relational Technique- A Review

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Abstract

Laser engraving process is non conventional machining process used for marking/engraving of almost each material which cannot be mark by conventional machining processes. In laser engraving process 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 wave length etc, and get the changes in output parameter like material removal rate, surface finish and indentation. To optimization of all these parameters with multiple performance characteristic based on the Grey relational analysis. Taguchi method of orthogonal array will be performed to determine the best factor level condition. By analyzing Grey relational grade, it will be observed that which parameter has more effect on responses of input parameter to the output parameter.

Keywords: Laser Engraving, Grey Relation Technique.

Introduction

Laser is the acronym of Light Amplification by Stimulated Emission of Radiation. Laser is a coherent and amplified beam of electro-magnetic radiation. There are main three step for light emission, 1) absorption , 2)Spontaneous Emission , 3) Stimulated Emission.[1]

Laser Engraving Process

Laser engraving is the practice of using lasers to engrave or mark an object. The technique can be very technical and complex, and often a computer system is used to drive the movements of the laser head. Despite this complexity, very precise and clean engravings can be achieved at a high rate. The technique does not involve tool bits which contact the engraving surface and wear out. This is considered an advantage over alternative engraving technologies where bit heads have to be replaced regularly.[2]

Laser Engraving Machine

A laser engraving machine can be thought of as three main parts: a laser, a controller, and a surface. The laser is like a pencil - the beam emitted from it allows the controller to trace patterns onto the surface. The controller (usually a computer) controls the direction, intensity, speed of movement, and spread of the laser beam aimed at the surface. The surface is picked to match what the laser can act on. There are three main genres of engraving machines: The most common is the X-Y table where, usually, the work piece (surface) is stationary and the laser moves around in X and Y directions drawing vectors. Sometimes the laser is stationary and the work piece moves. Sometimes the work piece moves in the Y axis and the laser in the X axis. A second genre is for cylindrical work pieces (or flat work pieces mounted around a cylinder) where the laser effectively traverses a fine helix and on/off laser pulsing produces the desired image on a raster basis. In the third method, both the laser and work piece are stationary and galvo mirrors move the laser beam over the work piece surface.[2]

Literature Survey

Literature review provides the scope for the present study. It works as guide to run this analysis. Literature review plays important role to get information about the dissertation work. Literature review includes different study on laser engraving processes for better surface finish with different laser by using parametric analysis, and effect of laser power, different wave length, pulse frequency, beam speed and other so many parameters also effect of surface finish, material removal rate and indentation of engraving.

Lin li "The advances and characteristics of high-power diode laser materials processing". The author presents a review of the direct applications of high-power diode lasers for materials processing including soldering, surface modification (hardening, cladding, glazing and wetting modifications), welding, scribing, sheet metal bending, marking, engraving; paint stripping, powder sintering, synthesis, brazing and machining.

A review on high-power diode laser applications for materials processing has been carried out. These features include better surface finish, less heat-affected zone, better beam absorption, better morphological characteristics, more consistent and repeatable results, fewer cracks and less porosity generation.

The weaknesses of the high-power diode lasers include high beam divergence (thus difficult to focus to a small beam size), beam absorption dependent on work piece colours and the difficulty to produce very high-peak-powered short-pulsed beam directly (Q-switching).[3]

C. Leone et al. "Wood engraving by Q-switched diode-pumped frequency-doubled Nd:YAG green laser" Laser deep engraving is one of the most promising technologies to be used in wood carver operations. The aim of this work is to investigate the influence of the process parameters on the material removal rates by engraving panels made of different types of wood using a Q-switched diode-pumped Nd:YAG green laser working with a wavelength λ = 532 nm.

In this work, the features and the performances given by a 5W of nominal power Q-switched diode-pumped frequency-doubled Nd:YAG green laser in the engraving of different kind of woods are discussed and the main conclusions are the following:

- The surface carbonization depends on an incorrect selection of the process parameters and, for the adopted laser, it happens at beam speeds of up to 10mm/s.
- For speed more than 40mm/s, the engraved depth is very low and multiple laser scanning are required to obtain deep engraving. The engraved depth is strongly affected by the mean power, the pulse frequency, the beam speed and the number of repetitions.
- Increasing the speed is possible 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.[4]

A.A. Peligrad et al. "Dynamic models relating processing parameters and melt track width during laser marking of clay tiles" The author describes two dynamic models relating processing parameters and melt pool width during laser marking/engraving of clay tiles using a high-power diode laser.

This paper presented an investigation into the dynamic characteristics of the laser marking of clay tiles process, which was analysed as follows.

• A smooth, well-defined mark was obtained at a beam velocity of around 6–10 mm/s and a laser power of around 60 W.[5]

C. Leone et al. "AISI 304 stainless steel marking by a Q-switched diode pumped Nd:YAG laser"

Laser marking tests were carried out on AISI 304 steel, using a Q-switched diode pumped Nd:YAG laser. The aim was to determine the correlation occurring between working parameters (i.e. pulse frequency, beam scanning speed, and current intensity) and resulting mark visibility.

From the experimental results, both surface roughness and oxidation increased as a function of frequency, resulting in an improvement in contrast, up to a characteristic value, decreasing afterwards.

• mark contrast is affected by both surface roughness and oxidation, with the former probably prevailing at low contrast, and the latter at high contrast.[6]

Janez Diaci et al. "Rapid and flexible laser marking and engraving of tilted and curved surfaces" Author present a novel method for rapid and flexible laser marking and engraving of tilted, curved and freeform work-piece surfaces. A low power CW laser regime is used to measure the 3D shape of a work-piece surface while a high-peak power- pulsed laser regime is used for processing. This paper discusses key issues concerning an implementation of the method and presents typical examples of markings and engravings.

A novel method is presented that allows rapid and flexible laser marking and engraving of tilted, curved and freeform work- piece surfaces. The measurement phase takes typically less than 10 seconds.[7]

S.H. Masood et al. "An experimental study of laser-assisted machining of hard-to-wear white cast iron" Laser-assisted machining has been considered as an alternative for hard-to-wear materials such as metallic alloys and ceramics.

This paper presents the results of research conducted on laser-assisted machining of one such hard-to-wear material, high chromium white cast iron, used in making heavy duty mineral processing equipment for the mining industry. Results show that laser-assisted machining causes more frequent shearing of material,

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less uniform surface formation, and the heat penetration increases as the distance between laser spot and tool increases. It also leads to reduction in cutting forces with expected improvement in tool life. The results indicate that laser-assisted machining of high chromium white cast iron shows potential to be a feasible alternative to hard machining of such materials.[8]

Chen Yi Hong et al. "calculation of optical parameters in laser engraving of photomasks" In laser engraving of photo masks, the line width is one of the critical characteristics in determining the quality of masks and depends mainly upon the laser focus spot size. Confirmatory experiments using a Q-switched Nd:YAG laser system and photo masks with iron oxide coatings were carried out. The obtained actual spot sizes lay within 10% of the theoretical value.

It is found from the study that processing parameters such as engraving speed, laser power and material properties would also play a major role in determining the spot size, and consequently the line width.[9]

Matt Henry et al." Cutting flexible printed circuit board with A 532NM Q-switched diode pumped solid state laser" The authors investigate the high-speed laser cutting of flexible printed circuit boards (PCBs) using a 532nm laser to create features <40 microns in size. Comparisons are made between different laser wavelengths including that of a 532nm frequency doubled laser and a fundamental wavelength 1064nm laser. Cutting speeds of >120mm/s are reported with a high quality kerf.

Cutting Flexible PCB is possible at high velocity, 138mm/s, with a fundamental wavelength Q-switched 1064nm Nd:YAG laser. Unfortunately the cut quality is poor – displaying bulk thermal distortion, heat damage and extensive delamination – making this laser type unsuitable for this application.

It is concluded therefore that a 532nm Q-switched Diode Pumped Solid State Laser can cut Flexible PCB at high speed, with high quality kerfs and minimal thermal input.[10]

Jozef Wendland et al." Deep engraving of metals for the automotive sector using high average power diode pumped solid state lasers" This author investigates deep engraving of steel and aluminium by laser.Material removal rates of up to 20 mm3/min for steel and 40 mm3/min for aluminium are demonstrated up to a maximum engraved depth of 1mm.

The material removal rates achieved, which are 90 mm3/min for aluminium alloy and 25 mm3/min for stainless steel, are very attractive for industrial applications.

This paper show that it is possible to achieve good contrast which is needed for barcode marking on bare metals.[11]

Mihaiela Iliescu et al. "Study on Holograms Laser Engraving Process" Holograms and holography become more and more important for nowadays life, specially because of their role in security and protection. Some research results on holograms laser engraving process parameters are evidenced by this paper.

Application of holography and holograms is very wide, covering: security and product authentication, packaging - consumer goods brand protection, art and interactive graphics, etc. This paper is a study on hologram marks, more specifically, on hologram laser engraving process parameters. In order to obtain high resolution engraving results low speed, high frequency and small pulse duration of the laser beam should be used.[12]

P. Laakso et al. "Relation of laser parameters in color marking of stainless steel". Color marking of stainless steels as a process is known for some time but still it has not been used widely in the industry. Marking quality was evaluated by visual examination.

The processing results show that the main limiting factors for producing high quality markings are the pulse energy and pulse peak power. A larger spot size makes it possible to use higher pulse energies still maintaining a feasible intensity on the surface.[13]

Mingwei Li et al. "Effect of Laser Parameters on Semiconductor Micromachining Using Diode - Pumped Solid-State Lasers" Laser micromachining of semiconductor materials such as silicon and sapphire has attracted more and more attention in recent years. In the current study, two Q-switched and one mode-locked diode-pumped solid-state (DPSS) 355 nm lasers have been used to scribe grooves on silicon and sapphire wafer substrates at different pulse widths (10 ns, 32 ns, and 10 ps) and pulse repetition rates (30 kHz, 40 kHz, 50 kHz, and 80 MHz). Experimental results have been compared between different pulse widths, power levels, and pulse repetition rates. It has been found that at the same average power and same repetition rate, the grooves scribed by the longer pulse width laser are deeper, while the shorter pulse width laser produces better quality cuts.[14]

Cheng-Jung Lin et al. "Effects of feed speed ratio and laser power on engraved depth and color difference of Moso bamboo lamina" In this study, Moso bamboo lamina was engraved 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 color difference. The results showed that the engraved depth became deeper for either higher laser power or a lower feed speed ratio. Moreover, the color difference values increased under a lower feed speed ratio and higher power, and resulted in a brownish color in the engraved zone. The average engraved depth and color difference values were 0.69–0.86mmand 46.9–51.9 pixels by different engraving parameters, respectively.[15]

Result And Discussion

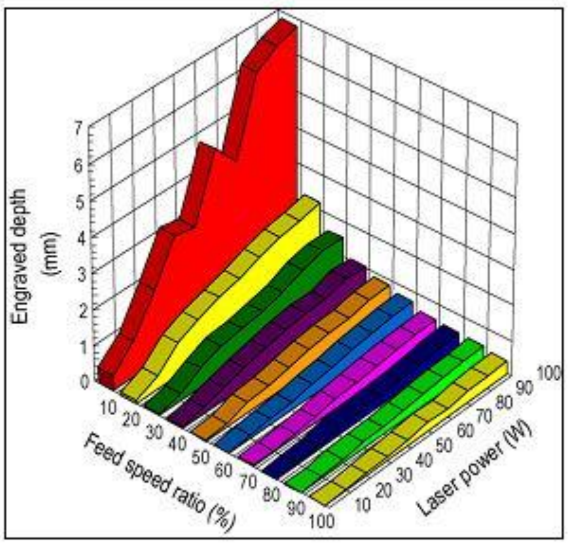

Fig. 1 – Engraved depth under various feed speed ratios and laser output power levels for Moso bamboo with steam treatment.

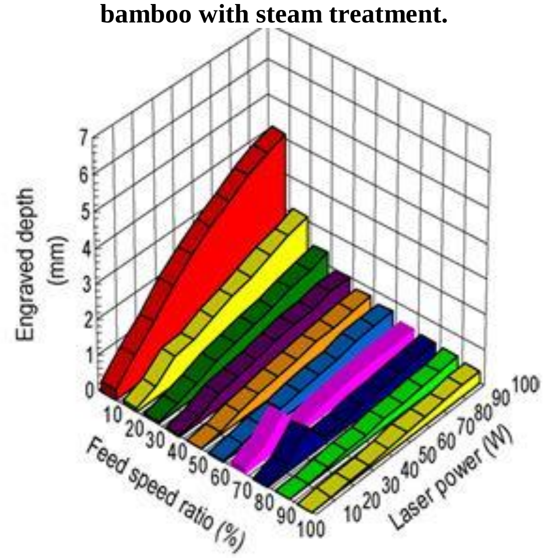

Fig. 2 – Engraved depth under various feed speed ratios and laser output power levels for Moso bamboo without steam treatment.

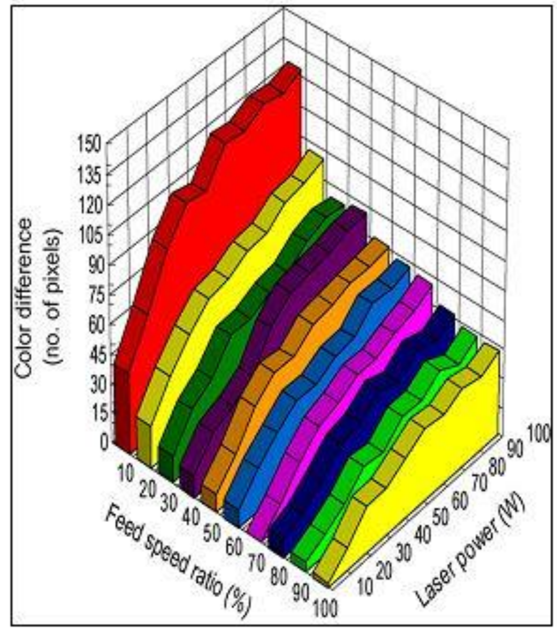

Fig. 3 – Color difference under various feed speed ratios and laser output power levels for Moso bamboo with steam treatment.

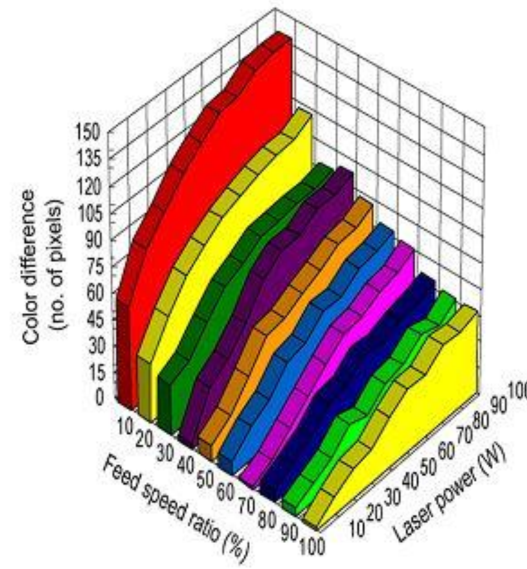

Fig. 4 – Color difference under various feed speed ratios and laser output power Levels for Moso bamboo without steam Treatment.

Conclusion

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.
This prediction of two engraving performances can help laser engraving achieve varied requests and applied to the fields of decoration and gift industry.

This above literature focuses on the literature study done on the review of related journal-papers, articles available as open literature. This literature covers the different laser engraving process of input parameter such as Laser power, Frequency, Pulse duration, Spot diameter, No.of passes, Engraving speed are taken for different work piece materials i.e, Aluminium Alloy, semiconductor etc and wooden also. with the applications of different methods. And 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 indentation.
From these literature review, it is lake with proper justification for optimization of process parameters of laser engraving using grey relational analysis.
Objective of this research is to very available input parameters of laser engraving machine according to precise design of experiment. Measurement will carry out and analysis will done using GRA technique. The conclusive remarks is very beneficial to the industry people.

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