LASER ENGRAVING PROCESS PARAMETER OPTIMIZATION FOR VARIOUS MATERIALS - A SYSTEMATIC REVIEW

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Abstract

Laser engraving is a non-traditional machining technique used to mark or engrave practically any material that cannot be marked using traditional machining techniques. The surface of the material is heated during the laser engraving process, which causes the substance to evaporate. utilizing multiple input parameters, such as spot diameter, laser power, laser frequency, different wave lengths, etc., and obtaining varied output parameters, such as material removal rate, surface quality, and indentation, is achievable when utilizing a laser engraving machine. Based on the Grey relational analysis, all of these parameters were optimized for different performance characteristics. The optimal factor level condition will be ascertained using the Taguchi technique of orthogonal array. It may be determined which parameter has a greater impact on the reactions of the input parameter to the output parameter by examining the Grey relational grade.

Keywords: *Laser Engraving, Grey Relation Technique.*

Introduction

Light Amplification by Stimulated Emission of Radiation, or laser, is the abbreviation. A coherent, intensified electro-magnetic radiation beam is what a laser is. The primary steps for light emission are:

1) absorption ,

2)Spontaneous Emission ,

3) Stimulated Emission.

Laser Engraving Process

The process of engraving or marking an item using a laser is known as laser engraving. The method may be quite intricate and technological, and the motions of the laser head are often controlled by a computer system. Despite this intricacy, a high rate of very accurate and clean engravings may be produced. The method does not use tool bits that come into touch with the engraving surface and get worn out. This is thought to be an advantage over competing engraving techniques that need frequent bit head replacement.

Machine for Laser Engraving

A laser, a controller, and a surface are the three essential components of a laser engraving machine. The laser functions similarly to a pencil in that the controller may draw patterns on a surface using the laser's beam. The direction, intensity, movement speed, and spread of the laser beam directed at the surface are all managed by the controller, which is often a computer.

The surface is chosen to correspond to what the laser may affect. Three primary categories of engraving devices exist: The most popular is the X-Y table, in which the work piece (surface) is typically fixed and vectors are drawn by the laser moving in X and Y directions. Sometimes the work object moves while the laser remains still. Sometimes the laser travels in the X axis while the work item moves in the Y axis. For cylindrical work pieces (or flat work pieces positioned around a cylinder), a second genre is used in which the laser effectively travels a fine helix and on/off laser pulsing generates the required picture on a raster basis. The third approach uses galvo mirrors to move the laser beam across the work item's surface while the laser and work piece are both stationary.

Literature Survey

The scope for the current investigation is provided by the literature review. It serves as a guidance for carrying out this examination. The literature review is crucial for gathering data for the dissertation project. The review of the literature includes various studies on laser engraving procedures for better surface finishes using various lasers, as well as the effects of laser power, different wave lengths, pulse frequencies, beam speeds, and other numerous parameters, as well as the effects of surface finish, material removal rate, and engraving indentation.

The developments and features of high-power diode laser materials processing, Lin Li. A review of the direct uses for high-power diode lasers in material processing is provided by the author. These uses include soldering, surface modification (hardening, cladding, glazing, and wetting modifications), welding, scribing, sheet metal bending, marking, and engraving; paint stripping, powder sintering, synthesis, brazing, and machining.

There has been a study of high-power diode laser uses for treating materials. greater surface polish, a smaller heat-affected zone, greater beam absorption, improved morphological traits, more reliable outcomes that can be repeated, fewer fractures, and less porosity development are some of these properties.

High beam divergence, which makes it challenging to concentrate the beam to a tiny size, beam absorption based on the color of the work piece, and the challenge of producing extremely high-peak-powered short-pulsed beams directly (Q-switching) are some of the drawbacks of high-power diode lasers.

One of the most promising technologies for use in wood carving processes is laser deep engraving, according to C. Leone et al. in their paper, "Wood engraving by Q-switched diode-pumped frequency-doubled Nd:YAG green laser". The purpose of this study is to use a Q-switched diode-pumped Nd:YAG green laser operating at a wavelength of 532 nm to engrave panels made of various kinds of wood in order to evaluate the impact of the process parameters on the material removal rates.

The following primary findings are drawn from a discussion of the characteristics and abilities of a 5W nominal power Q-switched diode-pumped frequency-doubled Nd:YAG green laser used to engrave several types of woods:

- For the chosen laser, surface carbonization occurs at up to 10mm/s beam rates and is caused by improper process parameter selection.
- The etched depth is quite poor for speeds more than 40mm/s, and several laser scans are necessary to produce deep engraving. The mean power, the pulse frequency, the beam speed, and the number of repetitions all have a significant impact on the engraving depth.
- It is feasible to get engraving with a smaller frequency range at the value where the maximum output power is attained by increasing the speed. The mean power determines the maximum speed required to produce engraving linearly.

- A. Peligrad et al., "Dynamic models relating processing parameters and melt track width during laser marking of clay tiles" The author discusses two dynamic models that relate processing parameters and melt pool width during high-power diode laser marking or engraving of clay tiles.
- The inquiry into the dynamic properties of the laser marking of clay tiles process was provided in this work and was analyzed in the manner listed below.
- At a laser power of around 60 W and a beam velocity of 6–10 mm/s, a smooth, well-defined mark was produced.
- "AISI 304 stainless steel marking by a" by C. Leone et al.
- Nd:YAG laser with Q-switched diode pumping.

AISI 304 steel was the subject of laser marking experiments utilizing a Q-switched diode pumped Nd:YAG laser. The goal was to establish a relationship between the operating factors (such as pulse frequency, beam scanning speed, and current intensity) and the mark visibility that resulted.

According to the experimental findings, surface roughness and oxidation both increased as a function of frequency, improving contrast up to a characteristic value before decreasing. Surface roughness and oxidation both affect mark contrast, with the former likely predominating at low contrast and the latter at high contrast.

Janez Diaci and others. "Rapid and flexible laser engraving and marking of tilted and curved surfaces" The author describes a revolutionary technique for quickly marking and engraving freeform, curved, and inclined workpiece surfaces using a laser. The 3D form of a workpiece surface is measured using a low power CW laser domain, and processing is done using a high peak power pulsed laser regime. This article offers common instances of marks and engravings and examines important concerns related to a method implementation.

A unique technique is provided that enables slanted, curved, and freeform work-piece surfaces to be quickly and adaptably marked and engraved using lasers. Typically, the measuring phase lasts less than 10 seconds.

SHAMOOD, H., et al. "An experimental study of laser-assisted machining of hard-to-wear white cast iron" Hard-to-wear materials like metallic alloys and ceramics have been given some thought as potential candidates for laser-assisted machining.

The high chromium white cast iron that is used to make heavy duty mineral processing equipment for the mining sector is one such difficult-to-wear material. The study on laser-assisted machining of this material is presented in this article. Results reveal that when the distance between the laser spot and the tool increases, laser-assisted machining results in more frequent material shearing, less uniform surface creation, and more heat penetration. Additionally, it results in less cutting power, which should extend tool life. The findings suggest that laser-assisted machining of white cast iron with a high chromium content has the potential to be a practical substitute for hard machining of such materials.

"Calculation of optical parameters in laser engraving of photomasks" by Chen Yi Hong et al. One of the key factors in judging the quality of photo masks created by laser engraving is the line width, which mostly relies on the size of the laser focus point. Confirmatory tests were performed utilizing a Q-switched Nd:YAG laser system and photo masks coated in iron oxide. The actual spot sizes that were achieved were within 10% of the theoretical value.

According to the research, processing variables including engraving speed, laser power, and material characteristics would also have a significant impact on defining the spot size and, in turn, the line width.[9]

"Cutting Flexible Printed Circuit Board with A 532NM Q-switched diode pumped Solid State Laser" by Matt Henry et al. The authors look at the high-speed laser cutting of flexible printed circuit boards (PCBs) to produce features that are around 40 microns in size utilizing a 532nm laser. Different laser wavelengths are compared, including a 532nm frequency-doubled laser and a 1064nm laser with a fundamental wavelength. Cutting speeds of more than 120 mm/s have been recorded with excellent kerf.

With a fundamental wavelength Q-switched 1064nm Nd:YAG laser, cutting Flexible PCB is achievable at a high speed of 138mm/s. Unfortunately, this laser type is inappropriate for this application because to the poor cut quality, which exhibits bulk thermal distortion, heat damage, and significant delamination.

This leads to the conclusion that a 532nm Q-switched Diode Pumped Solid State Laser may efficiently cut Flexible PCB at high speeds with high-quality kerfs.

Jozef Wendland et al. "Deep engraving of metals for the automotive sector using high average power diode pumped solid state lasers" This author studies laser-based deep engraving on steel and aluminum.Up to a maximum etched depth of 1mm, material removal rates of up to 20 mm3/min for steel and 40 mm3/min for aluminum have been demonstrated.

For industrial applications, the material removal rates achieved—90 mm3/min for aluminum alloy and 25 mm3/min for stainless steel—are particularly appealing.

This study demonstrates that barcode marking on bare metals may be done while maintaining the excellent contrast that is required.

"Study on Holograms Laser Engraving Process" by Mihaila Iliescu et al. Holograms and holography are becoming more and more crucial to modern life, particularly in terms of security and safety. This article presents some study findings on the laser engraving process parameters for holograms.

Holography and holograms have a broad range of uses, including security and product authentication, packaging and brand protection for consumer products, art and interactive graphics, among others. The study of hologram markings, more precisely the holographic laser engraving process parameters, is the subject of this research. Low speed, high frequency, and short pulse length of the laser beam should be employed to produce engraving with high resolution.

"Relation of laser parameters in color marking of stainless steel" by P. Laakso et al. Although the method of color marking stainless steels has been around for a while, it is still not frequently employed in the business. Visual inspection was used to assess the marking quality.

The processing findings demonstrate that the pulse energy and pulse peak power are the key constraints for obtaining good quality marks. Higher pulse energies may be used while still keeping a workable intensity on the surface when the spot size is bigger. The article "Effect of Laser Parameters on Semiconductor Micromachining Using Diode- Pumped

Solid-State Lasers" by Mingwei Li et al. In recent years, laser micromachining of semiconductor materials like silicon and sapphire has gained increasing interest.

In the present work, grooves were scribed on silicon and sapphire wafer substrates using two Q-switched and one mode-locked diode-pumped solid-state (DPSS) 355 nm lasers at various pulse widths (10 ns, 32 ns, and 10 ps) and pulse repetition rates (30 kHz, 40 kHz, 50 kHz, and 80 MHz. Different pulse widths, powers, and pulse repetition rates were used in the experiments, and the outcomes were compared. It has been discovered that the grooves scribed by the longer pulse width laser are deeper, while the shorter pulse width laser gives superior cuts at the same average power and repetition rate.

According to Cheng-Jung Lin et al., "Effects of feed speed ratio and laser power on engraved depth and color difference of Moso bamboo lamina" In order to understand the impacts of feed speed ratio and laser output power on engraved depth and color difference, Moso bamboo lamina was engraved using a variety of laser output power levels in combination with a variety of feed speed ratios. The findings demonstrated that with either a greater laser power or a lower feed speed ratio, the etched depth deepened. Additionally, the color difference values rose with greater power and a lower feed speed ratio, which produced a brownish tint in the engraved zone. By using various engraving settings, the average engraved depth and color difference values were 0.69-0.86mm and 46.9-51.9 pixels, respectively.

Conclusion

Higher laser power or a lower feed speed ratio resulted in a deeper laser etched depth.

A brownish hue was produced in the engraved zone due to an increase in color difference values caused by a lower feed speed ratio and greater power.

The difference in engraved depth and hue was significantly affected by the feed speed ratio via laser power interaction regimes. As a result, values of the engraved depth and color difference rose with increasing laser output power, while the feed speed ratio fell.

Regression analysis might be used to estimate and forecast the etched depth and color difference values of Moso bamboo.

The application of laser engraving to the sectors of décor and the gift business may benefit from this forecast of two engraving performances.

The material mentioned above focuses on a review of relevant journal articles and other pieces of open access literature. This article discusses various laser engraving processes with input parameters including laser power, frequency, pulse duration, spot diameter, number of passes, engraving speed, and applications of various techniques on a variety of workpiece materials, including aluminum alloy, semiconductors, and wooden materials. The results show what changes are brought about by altering the surface finish, material removal rate, and indentation, among other output parameters. These reviews of the literature provide enough support for the use of gray relational analysis to optimize the process parameters for laser engraving.

The purpose of this study is to determine readily accessible laser engraving machine input settings in accordance with a well planned experiment. The GRA method will be used for measurement and analysis. The last observations are highly helpful to those in the industry.

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