A SYSTEMATIC APPROACH TO DETERMINING LASER CUTTING MACHINE PROCESS PARAMETERS

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Abstract

One of the greatest technologies ever created for cutting, drilling, micro-machining, welding, sintering, and heat treatment is LASER (Light Amplification by Stimulated Emission of Radiation). It is one of the novel thermal energy-based processes used to accurately and precisely cut materials with complicated profiles. The quality of the job is significantly influenced by all cutting factors. This study's objective is to establish a relationship between the CO_2 *laser cutting parameters of laser power and cutting power.*

The laser beam generally has a diameter of 0.2 mm and 1–10 kW of power. Different gases are utilized in combination with cutting depending on the application choice. The kerf breadth and roughness of the cut surface decrease with an increase in frequency and cutting speed, but they rise with an increase in power and gas pressure. Investigations were done on the relationship between the response and the input parameters. The key factor affecting how well a laser cutting process works is the laser parameter.

Keywords:- *Laser cutting, Surface roughness, Process parameter, kerf width,* CO_2 *, Heat affected zone*

INTRODUCTION

Recent years have witnessed widespread technical improvement. A high intensity pulsed laser is focused at a precise spot on the material to be cut in order for laser cutting to take place. The material's surface absorbs the energy beam, which is then transformed into heat and used to evaporate or melt the substance. Since it uses a non-contact operating mode, cutting complicated shapes with excellent precision is possible. It can cut processing materials including ceramic, stone, plastic, rubber, non-ferrous metal, and ferrous metal. Since the cut is made by the laser beam and there is no physical contact with the material, contaminants or impurities cannot enter or get trapped in the substance. Laser cutting has numerous advantages over mechanical cutting. High cutting speeds, a tiny kerf width that results in less material loss, straight cut edges, minimal surface roughness, low metallurgical deformation, and ease of integration are some of the benefits of laser cutting. CO_2 and Nd: YAG lasers are the two primary laser sources that are often utilized in laser cutting.

The 1.06 um Nd: YAG laser is a solid state laser that is optically pumped. An electrically pumped gas laser with a 10.6 m wavelength is the CO_2 laser. Laser power, spot diameter of the laser beam, cutting speed, feed rate, and depth of cut are the primary operational factors related to laser machining. Surface Hardness and Edge Surface Roughness (Ra), two characteristics of cut quality, are taken into account as output parameters. The gas flow cools the cut edge, limiting the heat affected zone's (HAZ) breadth.

Manufacturers strive to maximize productivity and cut quality while minimizing costs. Due to a lack of theoretical and practical knowledge to aid in systematic selection, laser process parameters are typically chosen based on handbook values, recommendations from other manufacturers, and prior experience. Low product quality, excessive waste, and high production costs are all results of improper cutting parameter selection. The main factor affecting how well a laser cutting process works is the laser's settings. High cutting speeds with excellent quality cuts are feasible with adequate cutting parameter management. Therefore, it's crucial to look at how cutting parameters affect cut quality.

WORKING PRINCIPLE

The production of components in large quantities with excellent precision and surface polish is ideally suited for a variety of industrial sectors because to the heat, non-contact, and highly automated nature of laser cutting. The gas nozzle receives the highly flammable oxidized gas from the gas cylinder, which is then ignited with amplified light to create a high intensity flame that imparts on the material and causes cutting action to occur.

Depending on the cutting conditions, various gases with varying pressures are adjusted to generate the flame. The most often used gases are CO_2, O_2, N_2, etc. These flames' primary goals are burning, melting, and sublimating. A small cut kerf is produced by running a focused laser beam over the surface of the work item at a consistent distance throughout the cutting operation. The material is completely penetrated along the required cut contour by this kerf.

Only when the melt zone fully penetrates the workpiece is this technique successful. Therefore, laser metal cutting is often limited to thin section. Although cutting through 100 mm lengths of steel has been documented, the procedure is most often used to metal sheets 6 mm or less in thickness.

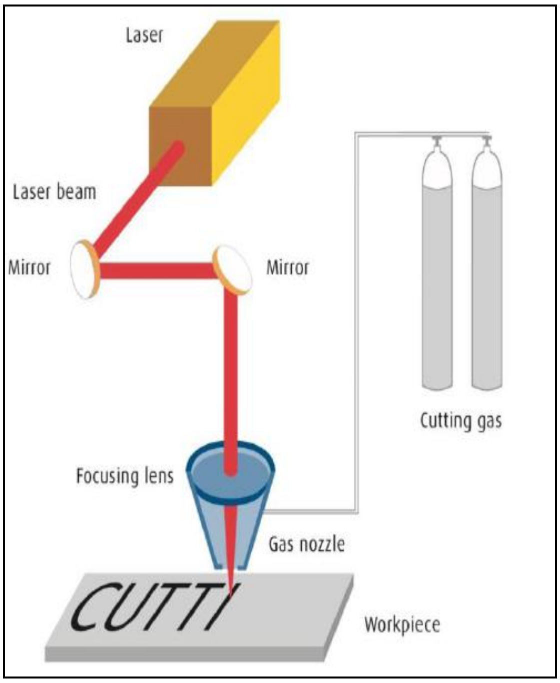

Fig .1 Schematic Diagram

3. PROCESS PARAMETER

A significant area of study for the cutting of metals has been laser cutting. The many factors, such as cutting speed, focus point, laser power, gas pressure, etc., that impact cutting quality. The numerous factors that influence the cutting process are mentioned.

Surface roughness :- It serves as a reliable indicator of a machined surface's quality. K.A. Ghany and M. Newishy expected that roughness would decrease with an increase in cutting frequency and speed as well as a decrease in laser power. The surface of the laser-cut object shows a distinct amount of unevenness.

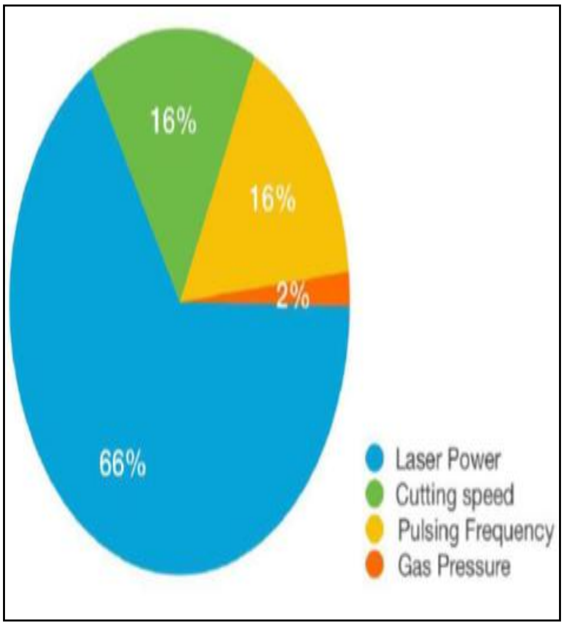

Fig 2 - Surface roughness

Kerf width:- The term "kerf" refers to the majority of the laser cutaway area. The cut's breadth is referred to as the kerf. The term "kerf width" describes the size of the slot created during through-thickness cutting, which is typically smaller at the bottom than the top of the workpiece. The quantity of material lost is indicated by the kerf width, hence a small laser's diameter is needed to minimize material waste. The quality of the laser beam and the focus optics have the greatest influence on the circular beam waist size, which is defined by the breadth of the cut kerf.

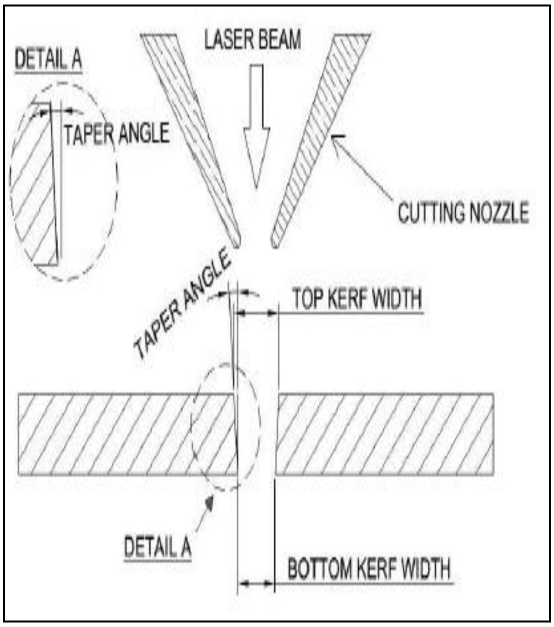

Fig 3 Kerf Width

Heat Affected Zone(HAZ):- When metal is exposed to high temperatures, the HAZ is a phenomenon that develops. It has an adverse effect on the metal's structure and design. The material's shear strength was exceeded via mechanical cutting. The bulk of the energy is converted into heat, which affects both the tool life and the metal being cut. The HAZ width increases as gas pressure and cutting speed increase. The power generated by the exothermic reaction rises as the gas pressure increases, resulting in a wider HAZ. The HAZ width is reduced as laser power and stand off distance rise, however these effects seem to be less significant than those of cutting speed and gas pressure.

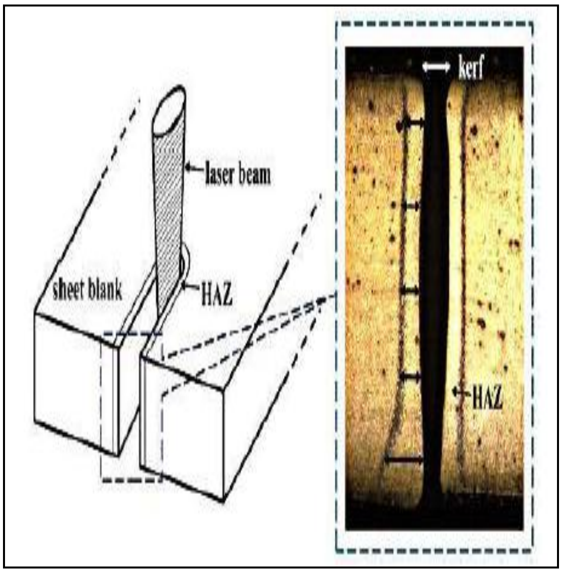

Fig 4 HAZ

Cutting Speed:- The kind and thickness of the workpiece must match the cutting speed. Too fast or too slow of a pace results in increased roughness, burr development, and a significant drag line. The energy balance for the laser cutting process is set up such that the energy delivered to the cutting zone is split into two parts: energy utilized to generate the cut and energy lost from the cut zone. It has been shown that the energy required for cutting is independent of the amount of time required, but the energy lost from the cut zone increases proportionally with the amount of time.

when a consequence, when cutting speed is increased, less energy is wasted from the cut zone, enhancing the efficiency of the cutting process. The power, gas flow rate, and cutting speed all need to be in harmony. When oxygen is used to cut mild steel, cutting too slowly causes the cut edge to burn excessively, reducing the edge's quality and widening the Heat Affected Zone (HAZ). To prevent burning, the speed must be slowed while making fast turns, and the beam strength must be adjusted in tandem. A material's thickness has an inverse relationship with its cutting speed. The Ra value achieved is presented in fig.3.4 as a result of the developed formula by M.M. Noor, K.Kadirgama, and M.M. rahman, which maintains power and tip distance constant while adjusting the nozzle speed.

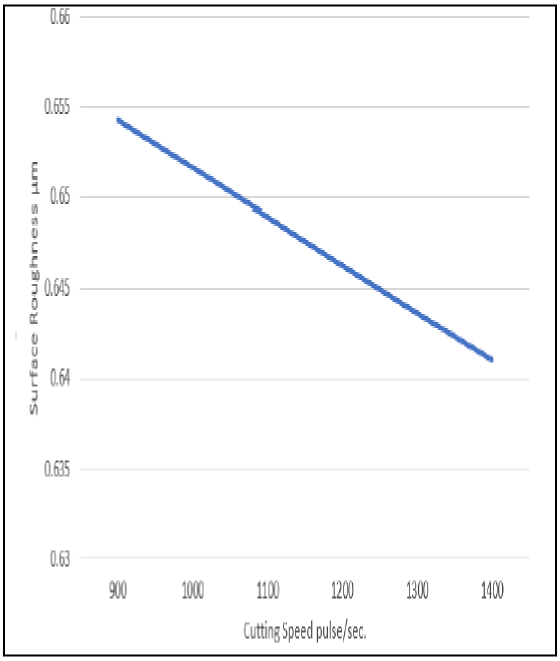

Fig 5 Cutting Speed vs Surface roughness

Laser Power:- The kind and thickness of the work piece must be taken into account while adjusting the laser power. To obtain great precision on intricately curved workpieces or very tiny components, the laser power may need to be reduced. The intensity of a laser beam is calculated by dividing the power by the region over which the power is focused. Laser power is the total energy emitted in the form of laser light per second.

For cutting applications, a high beam intensity that is attained by narrowly concentrating the laser beam is preferred because it quickly heats the kerf and gives the surrounding area little chance to cool, leading to fast cutting rates and good cut quality. Furthermore, cutting thicker materials needs greater intensities because most metals have strong reflectivity at low beam intensities but significantly reduced reflectivity at high intensities.

The ideal incident power is determined during method development since inadequate power cannot start cutting while excessive power causes a wide kerf width, a thicker recast later, and a rise in dross. High power lasers can produce high power beams in both pulsed and continuous modes, however they do not always produce high intensity beams. The laser beam's ability to concentrate is therefore a crucial feature to take into account.

Gas Pressure:- The gas pressure must be compatible with the material workpiece thickness. Thin metal material is cut with a greater gas pressure when using a torch than thicker metal material. Because even little variations in gas pressure may have an impact on the quality of the cut, gas pressure must be carefully managed. A permanent burr will develop or the kerf will once again close if the pressure is too low and the fluid slag is left stuck to the base material. When the pressure is too high, the cut's bottom edges burn off and are often rendered useless. In contrast, thicker workpieces are cut at greater gas pressure when using extremely high pressure.

Nozzle diameter and standoff distance :- The nozzle stabilizes the pressure on the workpiece and feeds the cutting gas to the cutting front, ensuring that it is coaxial with the laser beam. The nozzle aperture controls the cut's quality and the form of the cutting gas jet. Typically, nozzle diameters fall between 0.8mm and 3mm. The cut kerf is often less than the nozzle diameter due to the reduced size of the beam. This distance affects the gas flow patterns, which directly affect the effectiveness and quality of the cut. If the stand-off distance is higher than about 1mm, significant pressure differences may happen. Because greater stand-off lengths generate turbulence and significant pressure fluctuations in the space between the nozzle and work piece, a short standoff distance is advised because the kerf operates as a nozzle and the nozzle shape is less important.

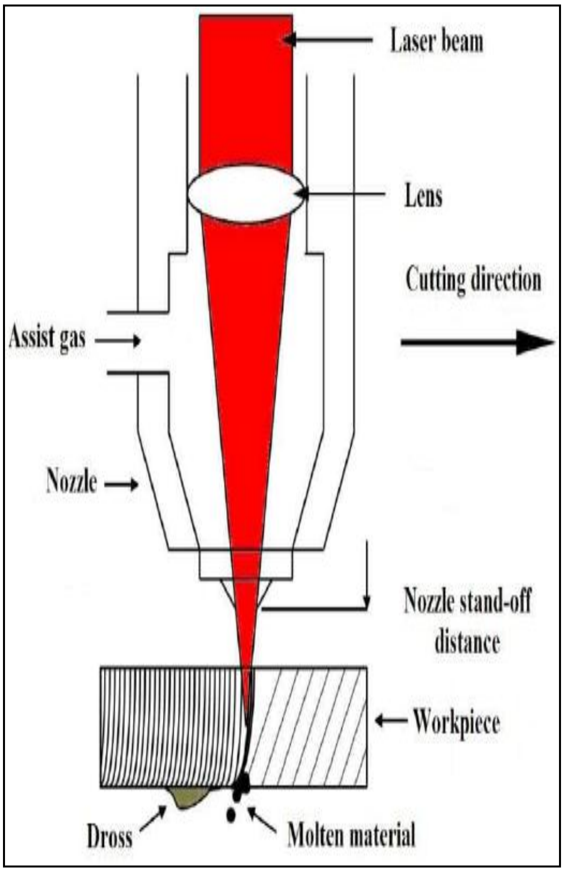

Fig 6

ITERATURE REVIEW

i. Avanish Dubey's 2008 It has been discovered that the kerf width during the laser beam cutting (LBC) process is not uniform over the length of the cut, and the unevenness is more pronounced in the pulsed mode of LBC. In this study, the Taguchi quality loss function was used to concurrently maximize the two kerf qualities of kerf deviation and kerf width during the pulsed Nd: YAG laser beam cutting of a very challenging-to-cut aluminum alloy sheet (0.9 mm thick). The quality of the kerf has significantly improved.

ii. On an experimental examination and optimization of the CO_2 laser cutting process on stainless steel plates, M. Madic began working in March 2015. This study examines multi-objective optimization of stainless steel CO2 laser cutting cut quality parameters such surface roughness, HAZ width, and kerf width. The used methodology combines the formulation of the multi-objective optimization problem using the weighting sum method and its solution by CSA (Comparative Sequence Analysis) with modeling of the relationships between the laser cutting factors (laser power, cutting speed, assist gas pressure, and focus position) and cut quality characteristics using ANNs.The cuckoo search technique is used for optimization.

iii. According to Yusof et al. (2008), increasing laser power reduces sideline length and percentage over length whereas increasing laser power increases kerf width at all cutting speeds. In CW mode, increasing the cutting speed with an equal increase in power resulted in greater quality and a smoother cut surface up to 8 m/min cutting speed. Increasing the cutting speed in pulsed mode caused rough surfaces and insufficient cutting. By raising the peak power, gas pressure, pulse frequency, and duty cycle, the SR also rises. Spot overlap and pulse width adjustments may also alter the cut specimen's surface roughness.

iv. Miroslav and Predrag focused on surface roughness using laser cutting in 2006. High quality is crucial. Two zones may be seen by looking at the sliced surface: one higher zone near the laser beam entry side and one lower zone near the laser beam exit side. While the latter has a rougher surface marked by both slag and molten metal deposits, the former has a beautifully machined surface with correct grooves that are spaced apart by 0.1–0.2 mm.

The standard roughness Rz goes up with sheet thickness but goes down with laser power. Standard roughness R when cutting with an 800 W laser is 10 m for 1 mm thick sheets, 20 m for 3 mm, and 25 m for 6 mm thick sheets. It is possible to employ a correlation between the mean arithmetic profile deviation and the standard roughness (ten point height of irregularities), as well as linear and exponential correlations.

v. Sneana Radonji and Pavel Kova developed a laser machine process parameter in 2012. An ideal cut was produced through experimental study that was done during the laser processing of AISI 314 material. The following processing settings are used to create the ideal cut: feed rate of 1250 mm/min, laser power of 4400 W, focus point of 16 mm, gas pressure of 17 bars, and nozzle distance of 7 mm.

vi. In august 2011 B.S.Yilbas has researches on Laser hole cutting into Ti-6Al-4V alloy and thermal stress analysis.

vii. In April 2012, Martin Grepl1, Marek Pag ac1, and Jana Petr 1 conducted research on laser cutting of materials of various thicknesses and discovered that Haynes may be sliced with the right conditions.The re-cast layer should be measured using a microprobe, followed by a microchemical examination, to prevent any impact from the environment on the cut. We urge more focus on a study of the recast layer and its heightened reliance on cutting parameters. The original material's melting limit would be a good place to test micro-hardness, but more crucially, the recast layer itself. Our work has made a significant contribution by providing a thorough analysis of how certain process factors affect a specific subset of materials used in the aerospace industry.

CONCLUSION

By consulting various reviews and research papers, we have come to the conclusion that as the power changes, the material's roughness decreases, and that the gas pressure also has a significant impact on the surface roughness, but that as the speed increases, the roughness increases and may result in a wider kerf width. This value affects the material's roughness and surface finishing more than other parameters since various gases are utilized for different materials. Typically, CO_2, O_2, and N_2 are used for cutting, although using oxygen gas may sometimes cause the material's surface to break, which can result in workpiece failure. All of the quality criteria, including HAZ width, kerf width, and roughness, are significantly influenced by gas pressure.

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