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## Analysis and Optimization of Laser Machining Parameters

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**ABSTRACT:** Laser machining is a popular manufacturing process utilized to cut various types of materials economically. In this project CO<sub>2</sub> laser machining of Mild Steel has been investigated. Mild Steel is soft because of its high strength and malleability. The width of laser cut or kerf, quality of the cut edges are affected by laser power, machining speed, assist gas pressure, and stand-off distance between nozzle and the work piece material. The experiment was designed and carried out on the basis of standard L16 Taguchi's orthogonal array in which the four laser machining parameters were arranged at Four levels. From the analysis of mean values of variance, the significant laser machining parameters were identified. The Machining Time reduces with significantly with decrease in Power and Cutting Speed. The Surface Roughness decreases with the increase in Power, Cutting Speed, and Stand Off distance. The Hardness of the material increases with the increase in Power and at low Stand Off Distance. The Kerf Width is reduced with the increase in Power and Cutting Speed

**KEYWORDS:** Laser cutting, Power, Cutting Speed, Stand off distance, Surface roughness, Kerf.

### I. INTRODUCTION

Lasers are capable of producing high power laser beams of high beam quality are suitable for cutting applications. The CO<sub>2</sub> and Nd :YAG lasers are the two laser technologies have for long been the workhorses for high power applications such as cutting. The CO<sub>2</sub> laser has gained considerable acceptance as a cutting tool because a very high power density can be achieved with such a laser and CO<sub>2</sub> lasers are available in high power levels. The CO<sub>2</sub> laser and Nd:YAG laser with output power capabilities of upto 8,000 W and 4,500 W respectively are now available for cutting applications. The CO<sub>2</sub> lasers with even higher output powers (upto 20,000 W) are power horses for welding and surface treatment applications.

### II. LITERATURE REVIEW

A.M. Orishicha.et.al (2014) examined on experimental comparison of laser cutting of steel with fiber and CO<sub>2</sub> lasers on the basis of minimal roughness by considering the input parameters of Power (0.5-3.5Kw) , Thickness(5-16mm),Cutting Speed(3.45m/min), Gas pressure (0.25-2.5bar). He found that the output parameters are Roughness Test, which results in minimal cut surface roughness is leaked at certain values of laser energy I/P into unit of material volume removed from cut channel.

Alexander.V.Zaitsev & Grigory.v.Erloaev (2014) examined on plasma formation in CO<sub>2</sub> fusion laser cutting of mild steel They Considered the effects of Temperature, Thickness, Cutting speed, Stand-off distance (SOD) and the frequency of striation formed at the upper part of Kerf width. He Observed that Ignition temperature, Oxide melting Point , Wave propagation (both Radial & Vertical) and the rate of o<sub>2</sub> diffused at sub layer.

M. Lakshmi Chaitanya et .al (2014) experimented in Laser cutting of metal matrix composite, having extensive applications in aerospace and automobile industries. Keeping this in view, a fusion approach of Taguchi method (TM) and principal component analysis (PCA) has been functional for multi-objective optimization (MOO) of pulsed Nd: YAG laser beam cutting (LBC) of Al7075/SiCp metal matrix composite to achieve better qualities within obtainable possessions. The three-quality characteristics kerf width, kerf deviation (along the length of cut), and kerf taper have been measured for simultaneous optimization. The input parameters considered are pulse power, pulse frequency, assist

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gas pressure and pulse width. The results of MOO include the prediction of optimum input parameter level and their comparative implication on multiple quality characteristics (MQC). The responses at predicted optimum parameter level are in good conformity with the outcome of authentication experiments conducted for confirmation tests. Ahmet Cekic et.al (2013) examined on experimental comparison of laser cutting of steel with fiber and CO<sub>2</sub> lasers. He considered the effect of Laser power, Speed, Nozzle distance, Focus position, Wave length on Heat Affected Zone (HAZ). He observed that cutting speed reduces HAZ and even more at low gas pressure.

Mayank N Madia & Prof. Dhaval M Patel [2013], studied the Laser cutting characteristics including power level and focal length are investigated in order to obtain surface roughness with maximum cutting speed. The surface roughness is investigated for a laser power range of 1000-1500W and focal length 122-132, gas pressure 7 bar constant for brass materials. This paper is studied the effect of focal length on surface roughness 1 mm thin brass sheet using an oxygen as assist gas. The cutting cross section was measured surface roughness. The variation was analysed with laser power and focal length. They use plasma detector sensor for predetermined cutting speed. The full factorial method is used for cutting speed and surface roughness. In this study they use full factorial three level design method is used to optimize the process parameter. So from this article they found that Focal length is most significant factor for surface roughness of brass sheet. Improper focal length affects the surface roughness and cutting speed.

Riveiro et.al [2013], in their result showed that processing in CW mode substantially increases the cutting speed as compared to pulsed mode. Further more, the superior quality obtained in this processing mode is obvious. Results indicate that high cutting speed and good quality can be obtained using high laser powers and focusing the laser beam onto the surface or slightly underneath the upper face of the work piece. The high relevance of the assist gas on cut quality was pointed out. The ability of the assist gas to remove the molten material is a key factor to achieve high quality cuts.

Prof. Dhawal et.al (2012), investigated Optimization of CO<sub>2</sub> laser machining of stainless steel by experimental analysis considering the input parameters Power (700-900W), Thickness (2-8mm), Cutting Speed (800-3000m/min) and Gas Pressure (7-10 kpa). They found that the output parameters are KERF WIDTH and HAZ (heat affected zone) and obtained the inference that the kerf width increases with increase in pressure, power with the reduction of speed.

Prof. E. Fallahi Sichani et.al (2012) has examined on plasma formation in CO<sub>2</sub> fusion laser cutting of stainless steel by considering the input parameters of Power (4Kw), Thickness (6mm), Cutting Speed (1.26-2.94m/min), Gas pressure (18bar). He found that the output parameters are Kerf Width & HAZ (heat affected zone) which results in increase of cutting speed & heat transfer from melt pool to assist gas.

PradiPKumar S. Chaudhary & Prof. D. M. Patel [2012], investigated experimentally the quality of laser cutting for the mild Steel IS- 2062 Grade-A, with the use of a pulsed fiber laser 915, 930 and 965 Watt laser cutting system. The quality of the cut has been monitored by measuring the edge roughness (Surface Roughness). This work aims at evaluating processing parameters, such as the laser power, the cutting speed and the gas pressure, for the laser cutting of mild Steel. Result revealed that good quality cuts can be produced in mild steel sheets and Cutting Speed is most significant factor for Surface Roughness of Mild Steel 5mm thickness sheet.

Prof D. M. Patel & Dipesh Patel [2012], focus mainly on cut quality and the cut quality mainly decided by surface roughness, kerf width, and perpendicularly. The experiment was carried out on 5mm thickness M.S. plate by varying the parameter like; laser power, gas-pressure, and cutting speed. The factorial design was used for design of experiment and to find out the percentage contribution of process parameter used Minitab 15 software. Surface roughness was measured by Surface roughness tester SJ-201 and kerf width was measured by equipment including digital camera and the UTHSCSA image tool version 3.0 program.

B.D. Prajapati et.al [2011], studied the effect of laser machine processing parameters such as laser power, gas pressure, cutting speed and thickness effect on measured response such as surface roughness. The experiment was designed according to Taguchi L27 orthogonal array with three different level of each input parameter. For result interpretation, analysis of variance (ANOVA) was conducted and optimum parameter is selected on the basis of the signal to noise ratio, which confirms the experimental result. The result indicated that cutting speed and work piece thickness play important role in surface roughness. Cutting speed and thickness of plate have high contribution on surface roughness for both materials. Laser power had less effect for surface roughness might be due to small variation in their level. Gas pressure had higher effect for cutting of mild steel and for hardox-400 had less effect. The S/N ratio suggests the optimum parameter setting for selected operating range of experiment

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Hu, J. Luo [2010], established a three-dimensional axial symmetrical model of laser cutting is established by adopting N–S equation and RNG k– $\epsilon$  onflow model in the paper, and numerical simulation is put up to analyze the flow field of shield gas in cutting slot. The investigation reveals the law about how stand-off distance affects the dynamic characteristic of gas jet in cutting process, and the 35

distribution of pressure and velocity of gas jet with different stand-off distances. Two typical subsonic nozzles: convergence nozzle and taper nozzle are designed for the laser cutting experiment. In this experiment the power is 2.5 kW the cutting slot width is 0.35 mm and cutting speed is 4.0 m/min. The work piece is normal carbon steel plate with thickness of 2 mm, and shield gas is nitrogen with pressure of 3.0 atm.

Riveiro et. al [2010], studied that the process relies on the removal of the melted material with the aid of a pressurized assist gas. Among the main variables controlling the process, the assist gas type is an essential factor. This gas is normally chosen taking into account the material to be processed and the required cut quality. While the effect of the utilization of different assist gas is perfectly studied in cutting steels, the influence of the assist gas type during laser cutting of aluminium alloys is not well studied. This work presents a study on the influence of different assist gases (argon, nitrogen, oxygen and air) on the edge quality and its surface chemistry during laser cutting of a typical Al-Cu alloy. After investigation the Results indicate a clear influence of the assist gas nature on the finishing characteristics. Formation of oxides and nitrides were observed to modify the cut quality and cutting speed. Oxygen, nitrogen and compressed air react to a greater or lesser extent with the molten material generating a large amount of oxides and/or nitrides. This largely affects the cutting speed and cut quality of the obtained cuts. On the other hand, argon was arisen as the more efficient assist gas to obtain best quality results and with the higher efficiency. Then, from the point of view of quality and efficiency argon is the best choice for processing Al-Cu alloys.

## III. METHODOLOGY

### 3.1 Design of Experiments:

Based on the review of the literature, the selected parameters to be investigated were four, namely the laser power, the cutting speed, the stand-off distance and the pressure of the assist gas. This led to the use of an L16 orthogonal array. The experimental regions of these parameters were determined after the first experiments had been conducted that would identify the initial process parameters settings for which through cuts could be obtained. The Levels of each parameter are listed below

Levels & parameter	Level 1	Level 2	Level 3	Level 4
Power (W)	1600	1750	2000	2250
Speed (mm/s)	2200	2500	2800	3100
Pressure (Bar)	0.3	0.4	0.5	0.6
SOD (mm)	0.7	0.9	1.1	1.3

Table 1 Experiment parameters

According to L16, four parameters with three levels are considered. The parameters to be examined and the levels of each parameter are sorted out. The L16 orthogonal array used is presented below.

EXPT NO.	POWER	SPEED	PRESSURE	STAND OF
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	1	4	4	4
5	2	1	2	3

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6	2	2	1	4
7	2	3	4	1
8	2	4	3	2
9	3	1	3	4
10	3	2	4	3
11	3	3	1	2
12	3	4	2	1
13	4	1	4	2
14	4	2	3	1
15	4	3	2	4
16	4	4	1	3

Table 2 Taguchi L16 Orthogonal array DOE

## ***Machining Operations:***

A CO2 laser cutting system was used for the performance of the experiments. The cuts were performed on 3 mm thickness Mild Steel plate, with the use of CO2, as assist gas and a 5 in. (127 mm) focussing lens. The specimens were made up of a linear cut of 50 mm in length for measuring kerf width and a square cut of a 50 mm side in order to measure the cutting edge roughness. The machine used for this machining was Truflow 4000. An Mild Steel plate of 200 x 200 mm length work



Fig. 1 CO2 Laser cutting Machine



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**Fig. 2 The Work Piece After Cutting Process Is As Shown**

## IV. RESULT AND DISCUSSION

The below response was analysed with the help of above instruments and following the graphs and mathematical equations are obtained.

Expt. no	Roughness Microns	Machining Time Secs	Kerf Width mm
1	2.58	4	0.62
2	0.74	5.003	0.66
3	1.12	4.801	0.71
6	1.26	4.472	0.62
6	0.93	5.922	1.33
6	0.59	5.459	0.33
7	0.74	4.725	0.66
8	1.69	3.967	0.62
-9	0.82	6.051	1.68
10	0.77	5.076	1.09
11	0.69	4.852	2.16
12	0.92	4.486	1.28
13	0.86	5.501	0.66
14	0.7	5.033	0.67
15	0.61	4.829	0.81
16	0.62	4.485	0.81

**Table 3 Response Values for the experiment**

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## SURFACE ROUGHNESS

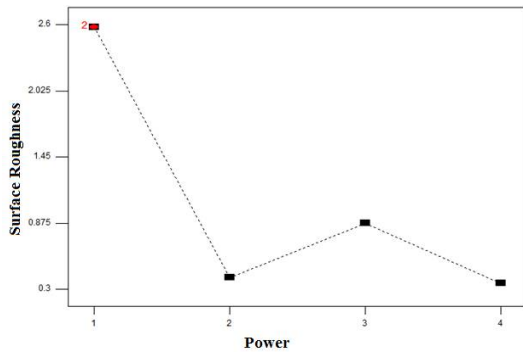


Fig. 3 Surface Roughness Vs Power

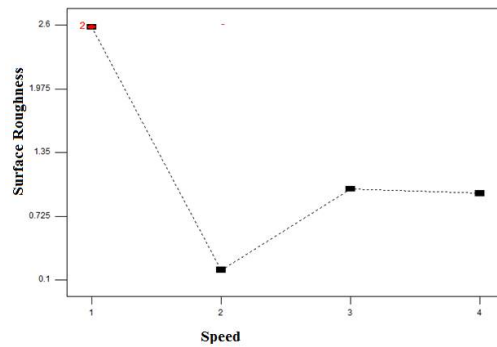


Fig. 4 Surface Roughness Vs Speed

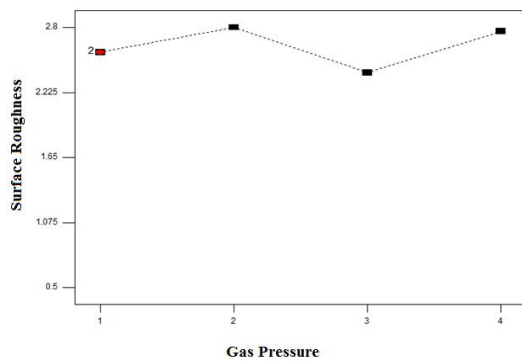


Fig. 5 Surface Roughness Vs Gas Pressure

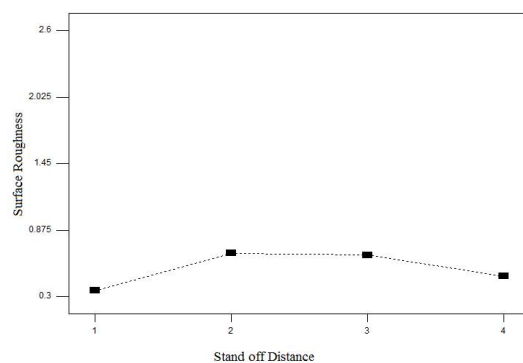


Fig. 6 Surface Roughness Vs SOD

From the graph it is observed that

The Surface Roughness is reduced with increase in value of Power, cutting speed and stand-off distance. While the Surface Roughness does not varies much in Gas Pressure and the Stand-off Distance.

## MACHINING TIME:

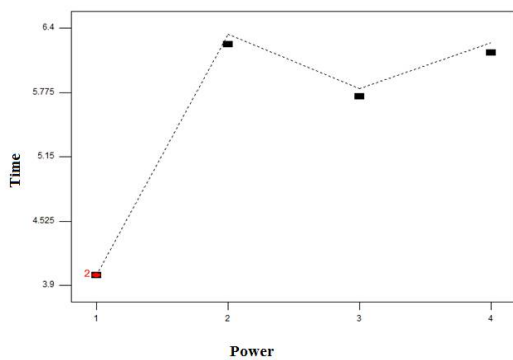


Fig. 7 Machining Time Vs Power

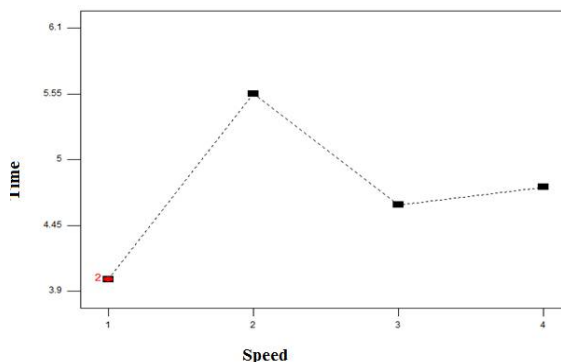


Fig. 8 Machining Time Vs Speed

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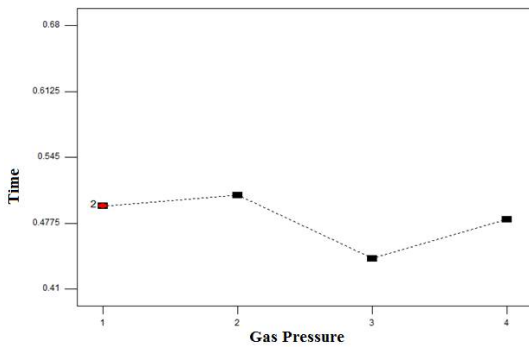


Fig. 9 Machining Time Vs Gas Pressure

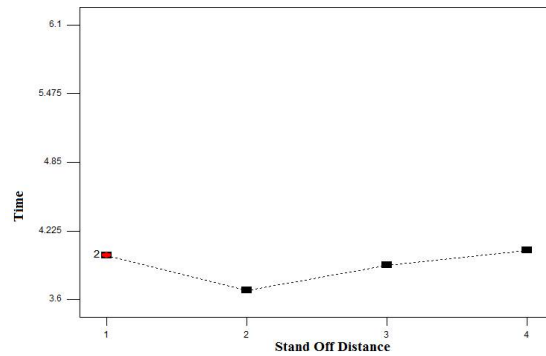


Fig. 10 Machining Time Vs SOD

From the graph it is observed that

The value of Machining Time is minimised with decrease in Power, Cutting Speed and with medium Gas Pressure. The effect of Stand Off Distance on Machining Time is not significant.

## Kerf Width (Kw)

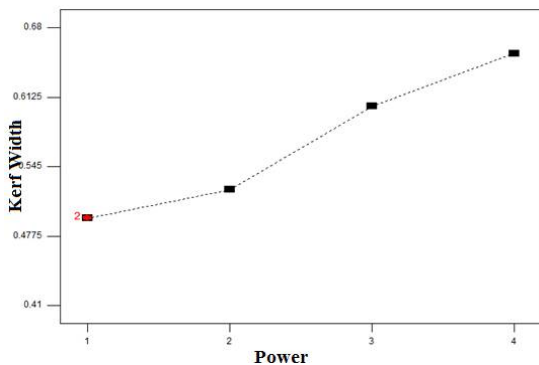


Fig. 11 Kerf Width Time Vs Power

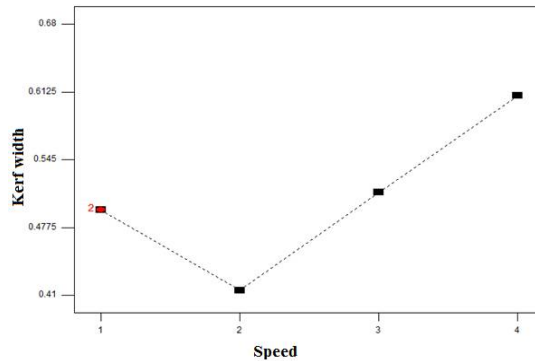


Fig. 12 Kerf Width Vs Speed

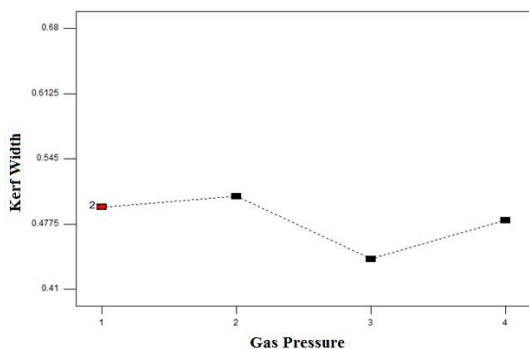


Fig. 13 Kerf Width Vs Gas Pressure

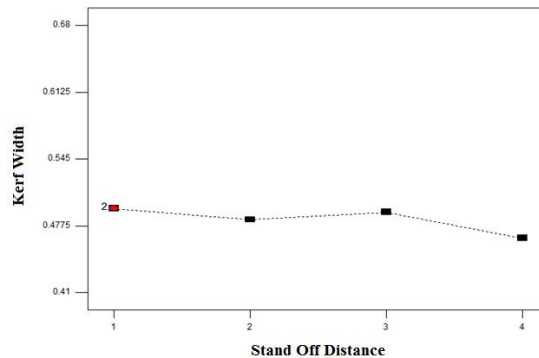


Fig. 14 Kerf Width Vs SOD

From the graph it is found that

For minimising the Kerf Width the Power and the Cutting Speed should be in maximum value but the Gas Pressure and the Stand Off Distance does not show much difference in the Kerf Width.

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## V. CONCLUSION

The experiment presented here is an overview of research work carried out in laser Machining process. From the above discussions it can be concluded that

1. The value of Machining Time is minimised with decrease in Power, Cutting Speed and with medium Gas Pressure. The effect of Stand Off Distance on Machining Time is not significant.
2. The Surface Roughness is reduced with increase in value of Power, cutting speed and stand-off distance. While the Surface Roughness does not varies much in Gas Pressure and the Stand-off Distance.
3. The Hardness value of material increases with Power increases and at low Stand off Distance, But there is a decrease in Hardness value at high in Cutting Speed and also in Gas Pressure.
4. For minimising the Kerf Width the Power and the Cutting Speed should be in maximum value but the Gas Pressure and the Stand Off Distance does not show much difference in the Kerf Width.

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