

An Investigation of Laser Cutting Quality of C272 Using Full Factorial Method

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ABSTRACT: Laser cutting is one of the most important industrial application. optical fiber laser cutting is used primarily for cutting of metallic and non metallic. The kerf width and kerf taper is investigated for a laser power range of 1000-1500 Watt, Cutting speed 3-7 m/min and Nozzle diameter 1.5-2.5 for C272 Brass material. This paper is studied the effect of kerf width and kerf taper. The full factorial has been used for conducting the experiments for circular profiles. The result indicated that the optimum input parameter for circular.

KEYWORDS: Kerf-Width, Kerf taper, Fiber Laser Cutting, Optical Profile Projector

1. INTRODUCTION

Laser (light amplification by stimulated emission of radiation) is a coherent and amplified beam of electromagnetic radiation. The key element in making a practical laser is the light amplification achieved by stimulated emission due to the incident photons of high energy. [1]. Laser cutting of metals has become a reliable technology for industrial production. Currently, it is considered as a feasible alternative to mechanical cutting and blanking due to its flexibility and ability to process variable quantities of sheet metal parts in a very short time with very high programmability and minimum amount of waste. Laser cutting does not need special fixtures or jigs for the work piece because it is a non contact operation. Additionally, it does not need expensive or replaceable tools and does not produce mechanical force that can damage thin or delicate work pieces. [2]. Laser cutting is the process of melting or vaporizing material in a very small, well defined area. Processes of heating, melting, and evaporation are produced by the laser beam affecting a work piece surface. A desired cut is obtained by moving the laser beam along a given contour. Laser beam is a cutting tool able to [3]To achieve a maximum efficiency from the laser, the laser beam needs to be properly focused on the work piece. [4].

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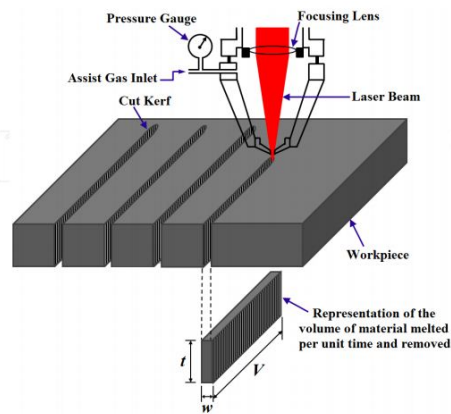


Figure 1: Laser beam cutting.

II. LITERATURE SURVEY

There are various papers investigating the effect of CO₂ and fiber laser cutting on various ferrous metal. Number of researchers have also done study of laser cutting effect on ferrous and nonferrous metal.

D. J. Kotadiya*, **D. H. Pandya**^[8] done parametric analysis of process parameters of CO₂ laser cutting system on surface characteristics of the cut section in the cutting of 5mm Stainless Steel (SS) sheet (ASTM 304). In this study, the laser cutting parameters such as laser power, cutting speed and gas pressure are analysed and optimized with consideration of work-piece surface roughness. Design of experiments (DOE), ANOVA and Response Surface Methodology (RSM) approaches are used to analyse the laser cutting variables and find out the optimum value for surface roughness. By analysing, it is observed that the laser power has more effect on responses rather than cutting speed and gas pressure.

Amit Sharma, **Vinod Yadava**, **Raghavendra Rao**^[5] done Kerf characteristics are important from the quality of cut point of view. The kerf characteristics are also changing with the profile of cutting. This paper presents parameter optimization of the kerf quality characteristics during pulsed Nd:YAG laser cutting of nickel based super alloy thin sheet. The kerf quality characteristics considered are kerf width, kerf taper and kerf deviation, and measured through Tool Makers Microscope. The essential process input parameters were identified as oxygen pressure, pulse width, pulse frequency and cutting speed. Based on the Taguchi quality design concept, an L₂₇ orthogonal array has been used for conducting the experiments for both straight and curved cut profiles. The results indicated that the optimum input parameter levels suggested for curved cut profiles are entirely different from straight cut profiles except kerf width.

Avanish Kumar Dubey, **Vinod Yadava**^[2] presents paper on a hybrid Taguchi method and response surface method (TMRSM) for the multi-response optimisation of a laser beam cutting process. The approach first uses the Taguchi quality loss function to find the optimum level of input cutting parameters such as assist gas pressure, pulse width, pulse frequency and cutting speed. The optimum input parameter values are further used as the central values in the response surface method to develop and optimise the second-order response model. The two quality characteristics Kerf width (KW), and material removal rate (MRR), that are of different nature (KW is of the smaller-the-better type, while MRR is of the higher the better type), have been selected for simultaneous optimisation. The results show considerable improvement in both the quality characteristics when the hybrid approach is used, as compared the results of a single approach.

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III. EXPERIMENTAL PRODUCER.

The Experiment were performed on as received 1.5 mm thin sheets of C272 brass. Experiments were conducted using a fiber laser cutting machine 1.5 KW maximum output power.



Figure 2: Fiber laser cutting machine.

3.1 MACHINE SPECIFICATION

Table 1-Machine specification

Model	LMN3015G
Working area	800*1150*650
Laser power	1500W
Operating voltage AC	380V AC 50/60HZ
Output fibre length	15
Beam delivery optics	QBH
Operating Temperature range	10~ 35
Maximum velocity of movement	100m/min
X/Y Positioning Accuracy	±0.02mm/m
X/Y Repeated Positioning Accuracy	±0.02mm

we cut OD ϕ 50 mm ID 25 mm Washer piece from the brass sheet. the kerf width and kerf taper was inspected using optical profile projector.

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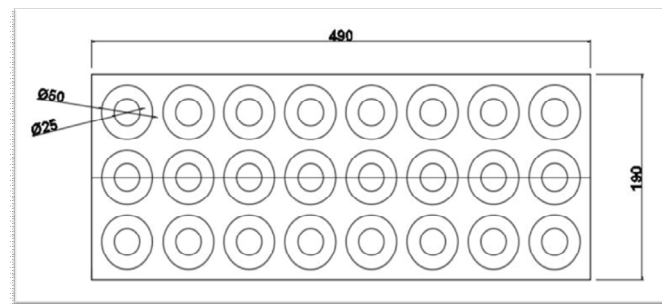


Figure 3: laser cut profile

3.2 MATERIAL COMPOSITION

Table 2-Chemical composition

Chemical Element	Percentage
Cu	62.0-65.0
Al	0.30-1.30
Fe	0.07
Pb	0.07
Ni	0.0-0.3
Mn	0.80-1.80
Sn	0.20-1.0
Zn	Balance

IV. FULL FACTORIAL METHOD FOR PARAMETER DESIGN

In statistics, a full factorial experiment is an experiment whose design consists of two or more factors, each with discrete possible values or "levels", and whose experimental units take on all possible combinations of these levels across all such factors. A full factorial design may also be called a fully crossed design. Such an experiment allows the investigator to study the effect of each factor on the response variable, as well as the effects of interactions between factors on the response variable.

For the vast majority of factorial experiments, each factor has only two levels. For example, with three factors each taking three levels, a factorial experiment would have twenty-seven treatment combinations in total, and is usually called a $3 \times 3 \times 3$ factorial design.

If the number of combinations in a full factorial design is too high to be logistically feasible, a fractional factorial design may be done, in which some of the possible combinations.

Total number of runs required are:- $N = (\text{No. of LEVE})(\text{No of factors})$,

where N is total number of trials, so it will be,

$$3^3 = 27$$

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4.1 INPUT PARAMETER.

the input parameter chosen and the level of each presented in table:3

Table 3-Input process parameter and their Level

Input Parameter	Unit	Level-1	Level-2	Level-3
Nozzle diameter	mm	1.5	2	2.5
Laser Power	Watt	1100	1300	1500
Cutting Speed	m/min	3	5	7

Gas pressure is constant at Oxygen at 6 bar. for all runs and all other parameters are constant. focus position on the surface (0.0 mm)

4.2 OUTPUT PARAMETER.

In this paper, output parameter is kerf width(mm) and kerf taper(deg) .

Table 4 -Experimental runs and their results

Runs	Nozzle (mm)	Power (Watt)	Cutting speed (m/min)	Kerf width (mm)	Kerf taper (deg)
1	1.5	1100	3	0.092	1.76
2	1.5	1100	5	0.107	2.04
3	1.5	1100	7	0.107	2.04
4	1.5	1300	3	0.114	2.18
5	1.5	1300	5	0.084	1.61
6	1.5	1300	7	0.087	1.66
7	1.5	1500	3	0.137	2.62
8	1.5	1500	5	0.137	2.62
9	1.5	1500	7	0.14	2.68
10	2	1100	3	0.094	1.80
11	2	1100	5	0.099	1.89
12	2	1100	7	0.11	2.10
13	2	1300	3	0.09	1.72
14	2	1300	5	0.078	1.49
15	2	1300	7	0.095	1.82
16	2	1500	3	0.141	2.69
17	2	1500	5	0.134	2.56
18	2	1500	7	0.134	2.56
19	2.5	1100	3	0.064	1.22
20	2.5	1100	5	0.076	1.45
21	2.5	1100	7	0.07	1.34
22	2.5	1300	3	0.077	1.47

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23	2.5	1300	5	0.076	1.45
24	2.5	1300	7	0.078	1.49
25	2.5	1500	3	0.142	2.71
26	2.5	1500	5	0.144	2.75
27	2.5	1500	7	0.142	2.71

4.2.1 KERF WIDTH.

Kerf width is defined as the width of material that is removed by a cutting process.

When a part is cut on laser, the objective is to produce accurate cut with final dimension as close as possible. ^[5]

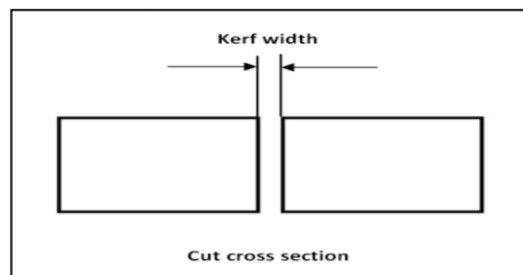


Figure 4: Kerf width

4.2.2 KERF TAPER.

LBC of sheet metals has always been a major research area for getting the exceptionally good quality of cut. Due to converging-diverging shape of laser beam profile a kerf taper (Kt) always exists in cut sheet specimens. ^[5]

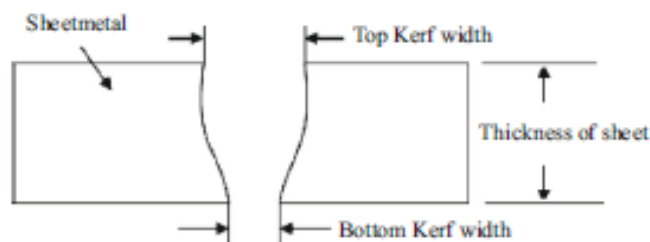


Figure 5: Kerf Taper

$$K_T(\text{deg}) = \left(\frac{K_{WT} - K_{WB}}{2\pi t} \right) \times 180$$

Where K_{wt} is top kerf width, K_{wb} is bottom kerf and t is sheet thickness.

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V. RESULTS AND DISCUSSION

As per ANOVA Analysis we can find the percentage contribution of input parameters for Kerf width as shown in below Table.

Table 5 - Result table of ANOVA for Kerf Width

Source	DOF	Sum of square	Mean of square	F- value	P- Value
Nozzle Diameter	2	0.001135	0.000567	4.61	0.023
Power	2	0.015223	0.007611	61.83	0.000
Cutting Speed	2	0.000044	0.000022	0.18	0.838
Error	20	0.002462	0.000123		
Total	26	0.018863			

S	R-sq	R-sq(adj)	R-sq(pred)
0.0110947	86.95%	83.03%	76.21%

As per ANOVA Analysis we can find the percentage contribution of input parameters for Kerf Taper as shown in below Table

Table 6 - Result table of ANOVA for Kerf Taper

Source	DOF	Sum of square	Mean of square	F- value	P- Value
Nozzle Diameter	2	0.001135	0.000567	4.61	0.023
Power	2	0.015223	0.007611	61.83	0.000
Cutting Speed	2	0.000044	0.000022	0.18	0.838
Error	20	0.002462	0.000123		
Total	26	0.018863			

S	R-sq	R-sq(adj)	R-sq(pred)
0.169782	91.63%	89.12%	84.74%

- Minimum kerf width generates at lower power of 1.1 kw with is 0.064mm.
- Minimum kerf taper generates at lower power of 1.1 kw with is 1.22°.

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5.1 REGRESSION EQUATION

$$\begin{aligned}\text{Kerf width} &= -0.0249 - 0.01511 \text{ nozzle} + 0.000120 \text{ power} \\ &\quad + 0.00133 \text{ cutting speed} \\ \text{Kerf taper} &= -0.419 - 0.289 \text{ nozzle} + 0.002293 \text{ power} + 0.0064 \text{ cutting speed}\end{aligned}$$

VI. CONCLUSION

This paper discussed the experimental investigation on laser cutting of nonferrous metal sheet (brass C272) of 1.5 mm thick, using fiber laser. The effect of the control factors like Nozzle Diameter, laser power and cutting speed on the kerf width and kerf Taper were analyzed. After Performing the experiment, it was found that optimal value for kerf width and kerf taper are 0.064 and 1.22° respectively at laser power 1100 Watt, cutting speed 3 mm/min and nozzle diameter 2.5 mm.

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