

Optimization & Experimental Investigation of Process Parameters on Kerf Width in Laser Cutting Process using AISI 2205

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ABSTRACT: Laser cutting is one of the most useful industrial applications. Fiber Laser cutting is used for cutting of AISI 2205. Kerf characteristics are important from the quality of cut point of view. The kerf characteristics are also changing with the profile of cutting. This research work presents parameter optimization of the kerf quality characteristics during FIBER laser cutting of AISI 2205 sheet. The kerf quality characteristics considered is kerf width. The main process input parameters were Laser power, Nozzle Diameter, cutting speed and thickness of Work piece. In this work Taguchi L27 method has been used for conducting the experiments for Straight and Circular profiles. Analysis of variance (ANOVA) has been carried out. Regression analysis will be carried out. Validation of Regression will be carried out with experimental results.

KEYWORDS: Kerf-Width, Kerf taper Laser cutting, ANOVA.

I. 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 Beam Cutting is a non-contact process and the material removal takes place through melting and vaporization of metal when the laser beam comes in contact with the metal surface. The most widely used laser types for cutting of sheet metal are continuous wave CO₂ laser, fiber Laser and pulsed Nd:YAG laser.

Avanish Kumar Dubey, Vinod Yadava^[2] presents paper on a hybrid Taguchi method and response surface method (TMRS) 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.

D. J. Kotadiya*, D. H. Pandya^[3] 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

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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.

S. Stelzer, A.Mahrlea,b, A. Wetzig, E. Beyera^[4] Concluded that experimental study on inert-gas fusion cutting stainless steel with different types of laser are presented. In particular, the cutting capabilities of a fiber and a CO₂ laser beam with similar Rayleigh length have been compared as a function of material thickness with respect to achievable maximum cutting speed, cut edge surface roughness and cut kerf geometry. The most interesting finding achieved so far concerns the observation that the cut kerfs are nearly identical in size but differ qualitatively in shape for both laser types. They Also Concluded that Fiber and CO₂ laser cutting results in AISI 304 stainless steel were compared. It was found out that a sudden increase in surface roughness is present at a particular sheet thickness. Under the defined experimental conditions, this transition occurs between 4 and 6 mm in case of fiber laser cuts and between 8 and 10 mm for CO₂ laser cutting trials. Furthermore, there were observed qualitative differences in the cut kerf shapes but with comparable kerf cross-section areas.

II.MATERIAL SELECTION

The material such as AISI 2205 is used in the experiments. Duplex stainless steels (DSSs) have a heterogeneous microstructure mainly composed of austenite (face-centred-cubic, γ -phase) and ferrite (body-centred-cubic, α -phase). The concentration of these major phases is controlled by chemical composition and thermal history during manufacturing. Basically DSSs are classified into five groups: lean DSS (UNS S32101, UNS S32304), Mo-containing lean DSS (UNS S32003), standard DSS (UNS S31803, UNS S32205), super DSS (UNS S32507) and hyper DSS (UNS S32707, UNS S33207). DSS 2205 has been used to fabricate oil and gas transport pipelines, flow lines, separators, scrubbers, pumps, manifolds, downhole production tubing and well casing.

Elements	% Composition
NI	4.89
CR	22.24
FE	BAL
MN	1.12
MO	3.20

Table-1 DSS2205 chemical composition

Table 1 shows the chemical properties of DSS 2205 as per the tested report.

III.EXPERIMENTAL PROCEDURE

The experiments were performed on 1.5 mm, 3mm and 5mm thin sheets of AISI2205. Experiments were conducted using a continuous wave fiber laser cutting machine with the 1.5 kW maximum output power. We cut 10mm \times 290 mm, 150 \times 490mm and 150 \times 160mm piece from the DSS sheet respectively.

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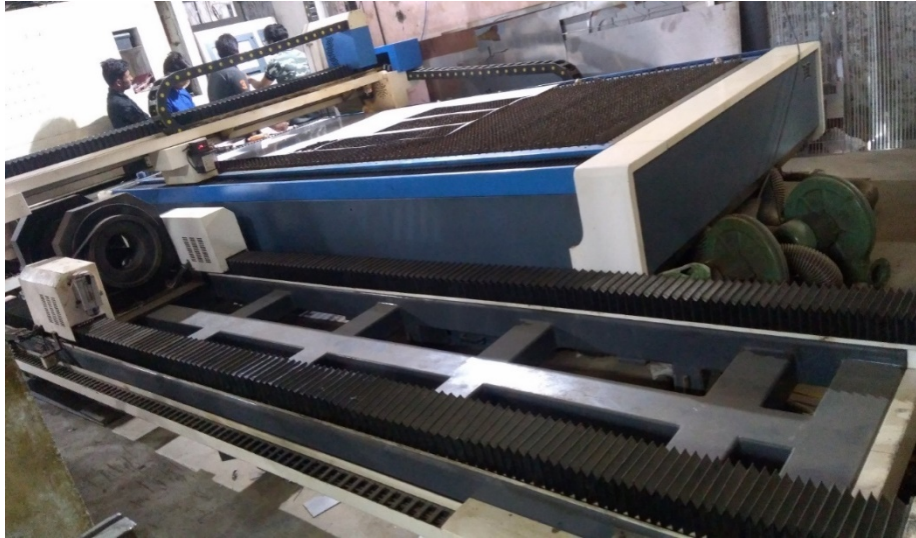


Fig: 1 Fibre Laser Cutting Machine

Figure 1 Shows the machine where experiments conducted. Specification of machine given in below table

Model	LMN3015G
Laser Type	Fibre
Working area	800*1150*650 mm
Laser power	1500 Watt
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

Table -2 Specification of fibre laser machine

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IV.PARAMETERS CONSIDERD FOR EXPERIMENT

4.1 Input Parameters

Most Effective Parameters for laser cutting are THICKNESS, CUTTING SPEED NOZZLE DAIMETER AND LASER POWER. Following table shows the factors and levels chosen for experiment.

FACTORS	UNIT	LEVEL 1	LEVEL 2	LEVEL 3
Thickness	mm	1.5	3	5
Cutting Speed	m/min	1	3	7
Nozzle Diameter	mm	1.5	2.0	2.5
Laser power	kw	1.1	1.3	1.5

Table-3 Input Parameters

4.2 Output Parameters

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.

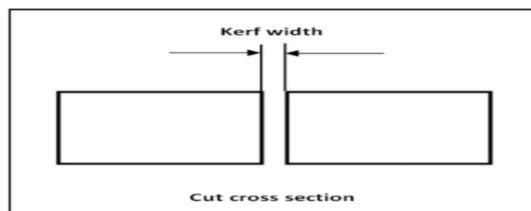


Fig-2 Kerf Width

4.2.2 Kerf Taper

The kerf taper angle is one of the most important quality characteristics because it is one of the measures for the geometrical accuracy of the machined cavities. Due to Gaussian beam distribution of the laser, the kerf taper is the inherent cut characteristics obtained on the machined surfaces. It is measuring through following equation.

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

where,

Kwt is top kerf-width,

Kwb is bottom kerf-width

t is sheet thickness.

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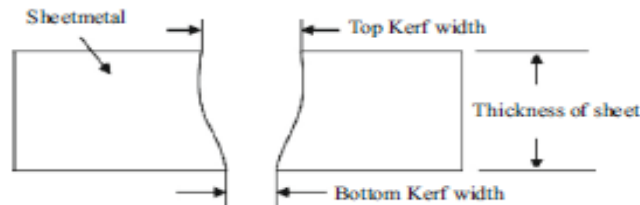


Fig-3 Kerf Taper

V. EXPERIMENTAL TABLE

Following are the Experimental run and results.

Sr no.	INPUT PARAMETERS				OUTPUT PARAMETERS			
	Thickness (mm)	Nozzle Diameter (mm)	Cutting Speed (m/min)	Laser power (kw)	Kerf Width (mm)		Kerf Taper (degree)	
					Straight	Circular	Straight	Circular
1	1.5	1.5	7	1.3	0.26	0.16	2.121	2.981
2	1.5	1.5	7	1.5	0.28	0.28	2.140	2.981
3	1.5	1.5	7	1.1	0.19	0.15	2.694	2.312
4	1.5	2	7	1.3	0.14	0.20	3.096	1.705
5	1.5	2	7	1.5	0.16	0.29	2.713	2.150
6	1.5	2	7	1.1	0.10	0.12	2.045	3.024
7	1.5	2.5	7	1.3	0.15	0.13	1.548	1.697
8	1.5	2.5	7	1.5	0.15	0.29	2.790	1.697
9	1.5	2.5	7	1.1	0.14	0.11	2.771	2.752
10	3	1.5	3	1.3	0.23	0.91	1.720	4.739
11	3	1.5	3	1.5	0.30	0.69	1.213	4.414
12	3	1.5	3	1.1	0.05	0.79	1.596	1.968
13	3	2	3	1.3	0.22	1.16	2.255	3.669
14	3	2	3	1.5	0.27	0.52	0.860	1.849
15	3	2	3	1.1	0.00	0.00	0.000	0.000
16	3	2.5	3	1.3	0.31	0.31	0.516	1.158
17	3	2.5	3	1.5	0.34	0.39	0.182	0.355
18	3	2.5	3	1.1	0.09	0.00	1.854	0.000
19	5	1.5	1	1.3	0.28	0.23	3.302	8.790
20	5	1.5	1	1.5	0.59	0.41	0.092	1.108
21	5	1.5	1	1.1	0.00	0.48	0.000	0.554
22	5	2	1	1.3	0.44	0.54	0.785	1.361
23	5	2	1	1.5	0.49	0.39	0.791	2.508
24	5	2	1	1.1	0.00	0.51	0.000	0.315
25	5	2.5	1	1.3	0.60	0.34	1.072	3.222
26	5	2.5	1	1.5	0.62	0.29	0.464	2.465
27	5	2.5	1	1.1	0.00	0.54	0.000	0.734

Table-4 Measurement of Response Parameter

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VI.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	DF	Adj SS	Adj MS	F-Value	P-Value
Thickness	2	0.313522	0.156761	11.34	0.001
Nozzle Dia	2	0.001172	0.000586	0.04	0.042
Power	2	0.023993	0.011996	0.87	0.035
Cutting Speed	2	0.03135	0.15676	12.47	0.00
Error	20	0.276475	0.013824		
Total	26	0.615161			

S	R-sq	R-sq(adj)	R-sq(pred)
0.117574	85.06%	83.57%	79.09%

Table-6 Result table of ANOVA for Kerf Taper

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Thickness	2	14.3897	7.1948	11.17	0.001
Nozzle Dia	2	0.7712	0.3856	0.60	0.039
Power	2	2.0948	1.0474	1.63	0.022
Cutting Speed	2	0.04735	0.17896	13.55	0.03
Error	20	12.8800	0.6440		
Total	26	30.1357			

S	R-sq	R-sq(adj)	R-sq(pred)
0.802496	87.26%	84.44%	80.11%

- Minimum kerf width generates for Straight Profile at lower power of 1.1kw with is 0.05mm
- Minimum Kerf Taper generates at Straight Profile Maximum power of 1.5 kw is 0.09°
- Minimum kerf width generates for Curved Profile at lower power of 1.1kw with is 0.11mm
- Minimum Kerf Taper generates at Curved Profile Maximum power of 1.5 kw is 0.32°

Regression Equation

$$\text{Kerf Taper} = 0.78 + 0.398 \text{ Thickness} - 1.752 \text{ Nozzle Dia} + 2.19 \text{ Power} + 0.237 \text{ Cutting Speed}$$

$$\text{Kerf Width} = -0.672 + 0.1658 \text{ Thickness} - 0.0148 \text{ Nozzle Dia} + 0.180 \text{ Power} + 0.0570 \text{ Cutting Speed}$$

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