



Effect of process parameter On kerf width for SS-316 material in CO2 Laser cutting

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ABSTRACT : Laser cutting is a specialized non-conventional advance cutting process. This machining process is widely used for cutting intricate shape from various sheet materials. It is a two-dimensional machining process in which material removal is obtained by focusing a highly intense laser beam on the work piece. Laser cutting machine required to set parameters like power, gas pressure, cutting speed etc. for cutting operation. Set parameters need to be identified for analyses its effect on various outcomes for better result. In this paper effect of parameters are identified for kerf width. Lower kerf width is desired objective for optimum utilization. Experiments are carried out using L27 Orthogonal array by varying four parameters with 3-level. S/N ratio calculated for as lower is better for MRR. Analysis helps for setting parameters which gives maximum MRR.

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Keywords: CO2 laser, S/N-Ratio, Orthogonal array, MRR

1. Introduction

During last two decades a rapid growth in the development of harder and difficult to machine metals and alloys. Conventional tool machining is uneconomical for such materials and the degree of accuracy and surface finish attainable is poor. The advancing strength level would have a catastrophic effect on cost of machining. The newer machining that developed is known as non-traditional machining process. These methods are not limited by hardness, toughness, and brittleness of the material and can produce any intricate shape on any work piece material by a suitable control over various physical parameter of the process [1]. Various Non-conventional machining processes are having different impact on various aspects. The major applicable non-conventional machining methods are Abrasive jet machining, Electro discharge machining, Laser jet machining, Water jet Machining, Ultrasonic machining etc. In laser cutting thermal energy in terms of laser utilizes for cutting of sheet having limited thickness.

Laser stands for light amplification by stimulated emission of radiation. It is a coherent and amplified beam of electromagnetic radiation. Laser produced by light amplification achieved by stimulated emission due to the incident photons of high energy. Laser light differs from ordinary light because it has the photons of same frequency, wavelength and phase. Thus, unlike ordinary light laser beams are highly directional, have high power density and better focusing characteristics. These unique characteristics of laser beam are useful in processing of materials especially for intricate shape.

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1.1 Principle Of Laser Cutting Process

Laser cutting is a two-dimensional machining process in which material removal is obtained by focusing a highly intense laser beam on the work piece. The laser beam heat subsequently melts/vaporizes the work piece throughout the thickness or depth of the material thus creating a cutting front[2]. The molten material is expelled from the cutting front by a pressurized assist gas jet. The assist gas, in addition to facilitating the material removal by melt expulsion, may also help in enhanced material removal through chemical reactions such as oxidation of the material. The cutting of the material then proceeds by the movement of the cutting front across the surface of the material. This is carried out by the motion of either focused beam and/or the work piece relative to each other in figure 1

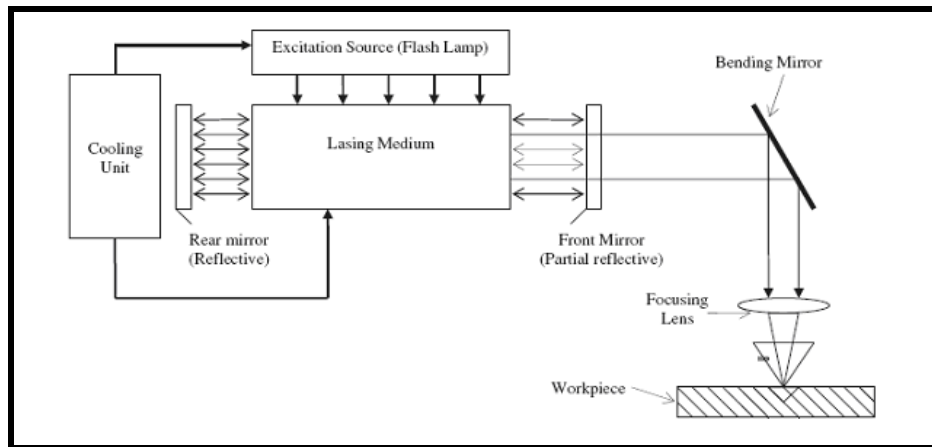


Fig.1 schematic diagram of laser cutting process

Laser cutting is a high-speed, repeatable, and reliable method for a wide variety of material types and thicknesses producing very narrow and clean-cut width. The process is particularly suited as a fully or semi automated cutting process for the high production volumes. One of the first industrial applications of laser cutting using 200 W laser is cutting of slots in die boards. The lasers are now capable of cutting a wide range of metallic materials such as steels, super alloy, copper, aluminum, and brass, and nonmetallic materials such as ceramic, quartz, plastic, rubber, wood.

These Lasers are capable of producing high power laser beams of high beam quality. Three main types of lasers are suitable for cutting, boring and engraving applications [1]. The CO₂ and Nd: YAG lasers are the two laser technologies which have wide cutting applications. The CO₂ laser and Nd:YAG laser with output power capabilities of up to 8,000 W and 4,500 W respectively are now available for cutting applications. The CO₂ lasers with even higher output powers (up to 20,000 W) are power horses for welding and surface treatment application [3]

2. Experimental Setup

For research work all experiments carried out at ALPHA NIPPON INNOVATIVE LIMITED at Changodar-Ahmedabad. The company uses omada laser technology for metal sheet cutting process. Machine model LST301580 (OMADA CO. LTD) used for experimental work. The LST301580 laser represents the third generation of Amada's proven LST series that was introduced in 2000 and combines features available on the LST series of lasers as well as some of the leading edge technology available on Amada's F1 linear drive systems. The objective of this research is parametric analysis and effective utilization of machine for SS-316.

2.1. Selection of Material

Steel has wide applications in automobiles and sheet metal work. It has a very excellent quality in welding. Various options are available in industry for profile a sheet; laser cutting, plasma cutting, gas cutting, Water-jet etc. laser cutting is cheaper and faster option than plasma or water jet cutting. It provides better edge finish than any other machining process. SS -316 plate having hardness 400HB is used for research work. It has wide

application as corrosion resistance. It is also difficult to cut for intricate shape. Its chemical composition is under given:

Table:2.1 : Chemical composition of SS-316 Material

C	Si	Mn	P	Cr	Mo	Ni	S	N
0.08	0.75	2.0	0.045	18.0	3.00	14.0	0.03	0.10

2.2 Response objective: Kerf width

The kerf width refers to the width of the slot that is formed during through-thickness cutting and is normally narrower at the bottom surface of the work piece than at the top surface. The kerf width represents the amount of material removed during the cutting process, which is essentially wasted material; therefore, a smaller kerf width is always desirable especially when small details are to be cut. The width of the cut kerf corresponds to the circular beam waist size which is determined mainly by the laser beam quality and focusing optics. The power at the focused spot, cutting speed and the assist gas jet also have influence on the size of the cut kerf[4,5].

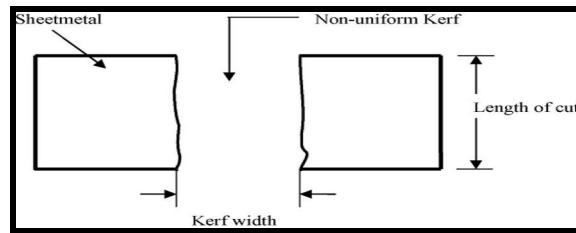


Fig. 2 kerf width

3. Experimental data and Result discussion

Experiments carried out for laser cut machine by varying four control factors. The objective is to analyze the effect of process parameters for kerf width. Control factors along with their levels are listed in Table 3.1. Selection of control parameters are based on literature search. The selection of Full factorial design of experiments would require a large no. of runs; Hence Taguchi based design of experiment method was implemented. In Taguchi method Orthogonal Array provides a set of well-balanced experiments It helps to analyze the whole parameter space with a minimum experimental runs. Taguchi replaces the full factorial experiments with a lean, less expensive, faster partial factorial experiment. L27 OA was chosen for experimentation to achieve higher resolution.

Table 3.1 : Parameter Range - 3 Level

Symbol	Factor	Unit	Level-1	Level-2	Level-3
A	Power	watt	3000	3500	4000
B	Gas pressure	Bar	0.6	0.8	1.0
C	Cutting speed	Mm/min	600	800	1000
D	Pulse frequency	hz	425	500	575

Table 3.2 : Results Table for kerf width

Trial no	A Power (watt)	B Gas pressure (bar)	C Cutting Speed (mm/min)	D Pulse Frequency (hz)	Measured Kerf width (mm)
1	3000	0.6	600	425	0.41
2		0.6	800	500	0.40
3		0.6	1000	575	0.46
4		0.8	600	500	0.42
5		0.8	800	575	0.37
6		0.8	1000	425	0.42
7		1.0	600	575	0.40
8		1.0	800	425	0.41
9		1.0	1000	500	0.39
10	3500	0.6	600	500	0.40
11		0.6	800	575	0.40
12		0.6	1000	425	0.40
13		0.8	600	575	0.41
14		0.8	800	425	0.43
15		0.8	1000	500	0.44
16		1.0	600	425	0.38
17		1.0	800	500	0.42
18		1.0	1000	575	0.43
19	4000	0.6	600	575	0.43
20		0.6	800	425	0.37
21		0.6	1000	500	0.42
22		0.8	600	425	0.40
23		0.8	800	500	0.41
24		0.8	1000	575	0.42
25		1.0	600	500	0.38
26		1.0	800	575	0.38
27		1.0	1000	425	0.41

3.1 Experimental Analysis

Kerf width measured at INDO GERMAN Tool room with Baty International Profile meter. After measurement an analysis carried out using stastical analysis software. The analysis carried out on MINITAB 15 software. SN ratio can be calculated based on lower is better.

$$SN \text{ for Lower is better} = -10 \log_{10} \left[\frac{1}{n} \sum_{i=1}^n y_i^2 \right] \dots \dots \quad (1)$$

3.1.1 Plot for SN Ratio V/S Input parameter

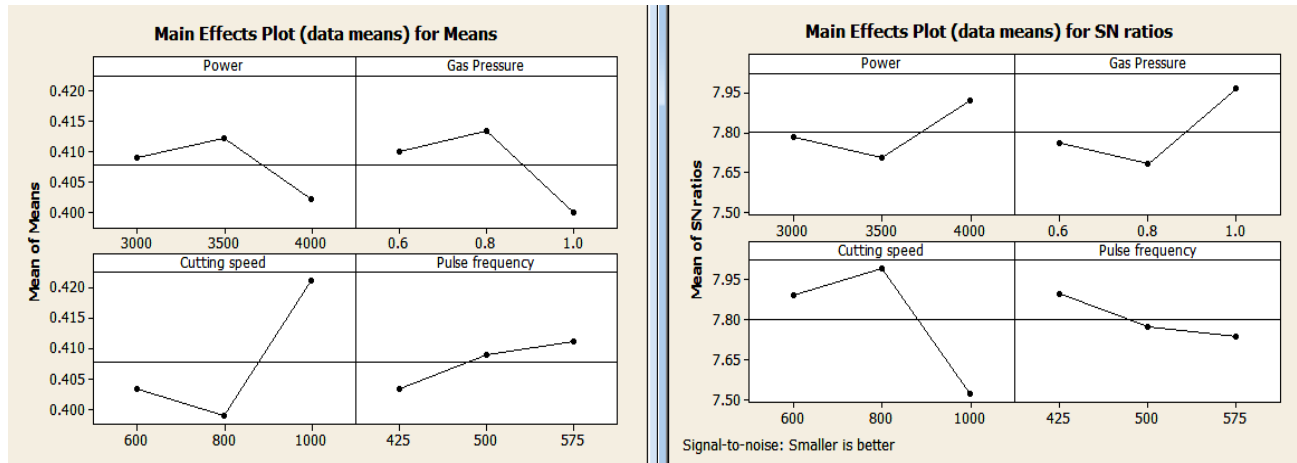


Fig. 3 Effect of s/n ratio on input parameters

Table 3.3 : Response table for S/N Ratio

level	laser power (watt)	gas pressure (bar)	cutting speed (mm/min)	pulse frequency (Hz)
1	7.782	7.758	7.893	7.895
2	7.706	7.683	7.994	7.776
3	7.921	7.967	7.521	7.738
delta	0.216	0.284	0.473	0.157
rank	3	2	1	4

Table 3.4 : Analysis of Variance for Kerf width, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Power	2	0.0004667	0.0004667	0.0002333	0.54	0.591
Gas Pressure	2	0.0008667	0.0008667	0.0004333	1.01	0.385
Cutting speed	2	0.0024889	0.0024889	0.0012444	2.89	0.082
Pulse frequency	2	0.0002889	0.0002889	0.0001444	0.34	0.72
Error	18	0.0077556	0.0077556	0.0004309		
Total	26	0.0118667				

4. Result Discussion

Effect of laser power (watt) on response

Laser power is the total energy emitted in the form of laser light per second while the intensity of the laser beam is the power divided by the area over which the power is concentrated. High beam intensity, obtained by focusing the laser beam to a small spot, is desirable for cutting applications because it causes rapid heating of the kerf leaving little time for the heat to dissipate to the surrounding [6]. The optimum incident power is established during procedure development because excessive power results in a wide kerf width, a thicker recast later and an increase in dross while insufficient power cannot initiate cutting. Graph shows that at maximum level kerf width is more while too less power also lead to poor result, hence for optimum condition need to select at level 2.

Effect of gas pressure (bar) on response

The cut edge is cooled by the gas flow. Higher gas pressures to remove the molten material from the cut kerf. The high gas pressure provides an extra mechanical force to blow out the molten material from the cut kerf. Increase in gas pressure initially reduced the kerf and then increases. Rank order is 2.

Effect of Cutting Speed (mm/min) on response

The energy balance for the laser cutting process is such that the energy supplied to the cutting zone is divided into two parts namely; energy used in generating a cut and the energy losses from the cut zone. Lower the cutting speed higher is the kerf and vice versa. Probability (P) is near to 0.05 (Table 3.4) which state that is most affecting parameter for kerf with rank order 1.

Effect of Pulse frequency (hz) on response

As pulse frequency increases from 425 hz to 575 hz, the kerf width reduces. In kerf analysis it's rank order identified as 4 among all four parameters.

From above analysis it is clear that each process parameter considered as affecting process parameter towards the response. The nature of each parameter is different with varying parameter range

Conclusion

Kerf is an important parameter in laser cutting. This response parameter is varied by varying various controlled process parameters like Power, Gas Pressure, Cutting speed and Pulse frequency. Analysis shows that selection of these parameters are important as it's contribution towards response varies. The most affecting parameters is decided by rank based on S/N ratio. The rank order based on analysis identified as Cutting speed, Gas pressure, Power and pulse frequency. Optimum kerf width can be obtained to minimize loss is by setting the above parameters with their contributing effect.

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