"INFLUENCE OF PROCESS PARAMETER ON SS321 AND SS316L USING CO2 LASER CUTTING MACHINE"

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ABSTRACT

Industrial application always want efficient process for sharp cutting for material like stainless steel, mild steel, super alloy and composite with super finishing and high precision. These are so many hard materials but the purpose does not serve by conventional machine. To satisfy these situation non-conventional machining process are used. Non- conventional processes perform super surface finish and dimensional accuracy. We can achieve these challenges by laser cutting machine also. Laser cutting processes are one of the useful processes to cut complicate shapes with high accuracy. Laser cutting is a two dimensional machining process in which material remove is obtained by focusing a highly intense laser beam on the work piece.Co2 laser cutting is a competitive and economical option for present industrial demand. This Co2 laser cutting is a complex machining process controlled by a numerous process parameter like presser of gas, laser power, cutting speed etc. These input parameter perform on response such as kerf width, material removal rate and surface roughness. This output parameter its effects and optimization of process need to be analyzed.

Keyword: - *Co2 laser cutting, Surface roughness, kerf width, MRR, Laser power, Cutting speed, Gas pressure.*

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1. INRODUCTION

Laser cutting machine is a non-traditional subtractive manufacturing process. Laser (light amplification by stimulated emission of radiation) is called a coherent and amplified beam of electromagnetic radiation. An Important element to produce laser light is the light amplification achieved by stimulated emission due to the incident photons of high energy. Three main components of laser are the lasing medium, lasing energy source, and optical feedback system. Provisions of cooling the mirrors, guiding the beam and manipulating the target are also required. Laser cutting works by directing the output of a high-power laser through optics. The focused laser beam is directly project on the material, which then either melts, burns, vaporizes away or is blown away by a jet of gas, leaving an edge with a high-quality surface finish. In industry, laser cutting used to cut flat-sheet material, structural, piping material and sculpture etc.

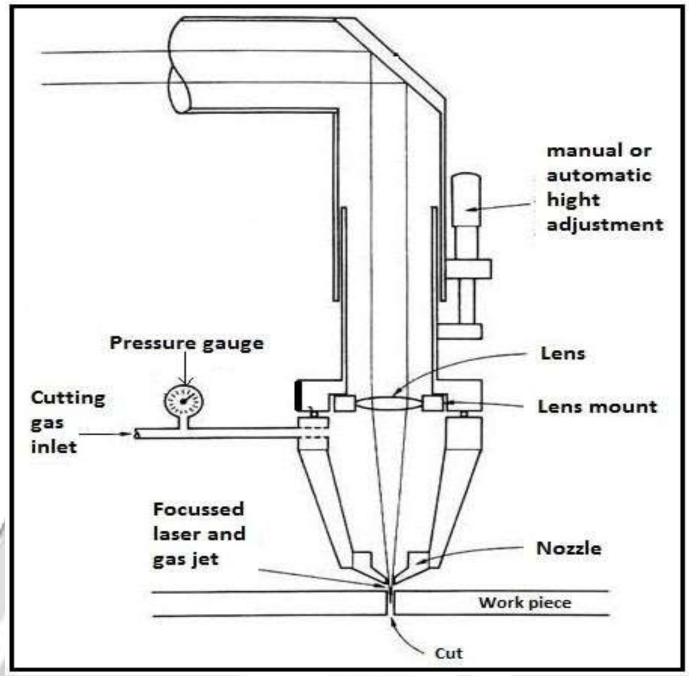

Figure-1: Laser Beam Machining

1.1 Principle of Laser Cutting Process

Laser cutting is a two-dimensional machining procedure in which substance removal is found by focusing a highly intense laser beam on the work piece. The laser beam heat consequently vaporizes the work section through the width of the material so creating a cutting front. Generation of the laser involves stimulating a lasing material by electrical discharge or lamps within a closed container. As the lasing material is stimulated, the beam is reflected internally by means of a partial mirror, until it achieves sufficient energy to escapes as stream of monochromatic coherent light. This coherent light directly focuses on lens, which focuses the light at the work piece.

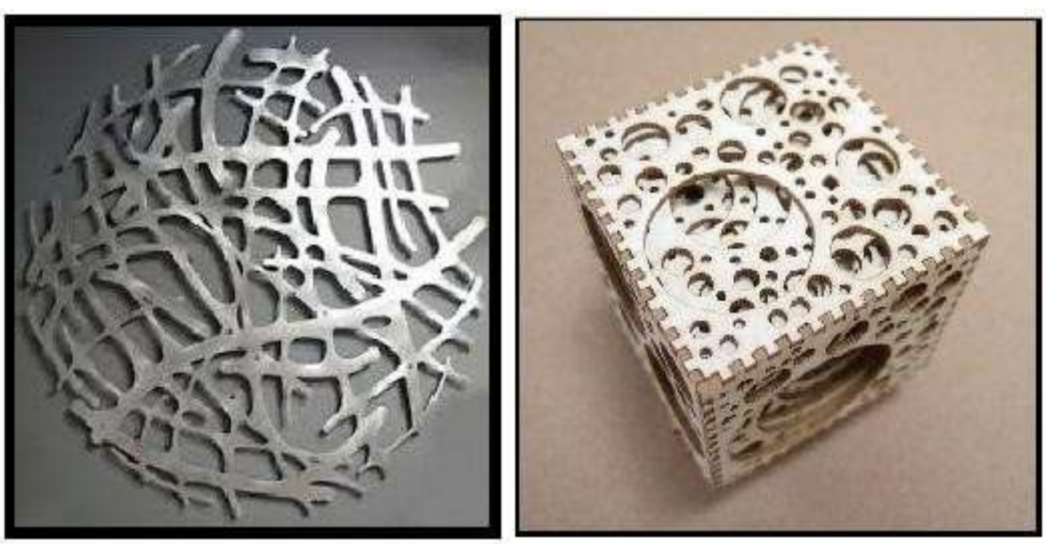

Figure-2: Laser cutting Process

The molten material is barred from the cutting front by a forced assist gas jet. The assist gas, in addition to facilitating material removal by melt expulsion, may also help in enhanced material removal through chemical response such as oxidation of the material. The cutting of the material then proceeds by the movement of the cutting front across the work surface of the material. Laser cutting is one type of high-speed, repeatable, and well-founded technique for an extensive variety of material types and thicknesses producing very small and clean cutting width. This process is particularly suited as a fully or semi-automated cutting procedure for the high production volumes. The first industrial applications of laser cutting using 200 W, laser is cutting of slots in die boards. The lasers are now able to cut a broad range of metallic materials like steels, super alloy, copper, aluminum, and brass, and non-metallic materials like ceramic, quartz, plastic, rubber, wood.

1.2 Advantages:-

Laser rays can be focused to a very small diameter and it is suitable for making accurately placed holes. Laser machining has good cutting quality. It is clean and safe process. It has good surface roughness. It has low operation cost. It has small heat affected zone.

1.3 disadvantages:-

The startup cost of machining is moderately high. An expert and trained require for Handling, maintaining and operating. It consumes a lot of energy. Deep cuts are difficult with work piece with high melting point and usually cause taper.

1.4 Applications:-

There is numerous application of laser cutting machine in industries, as below.

- 2-D and 3-D cutting of metal with a thickness up to 30 mm.
- Cutting of non-metal material.
- Surface processes like surface treatment and Hardening
- Perforating and Engraving
- Scribing and Drilling of aluminum- oxide ceramic
- Trimming, IC production, Soldering, Marking
- Sculptural art, Mural art and Metal art

2. LITERATURE REVIEW

Jarosza et. al. [1] (2016) Analyses the effect of cutting speed on heat-affected zone (HAZ) and surface roughness in laser cutting of AISI316L stainless steel. Test samples were cut with varying cutting speed, while other process parameters remained constant. Surface roughness of each test sample was measured in several places along cut depth. Photos of cut surfaces were taken with the use of stereoscopic microscope equipped with a camera. Results were analysed. Cutting speed has a visible effect on surface, heat-affected zone width and presence of macro-irregularities, such as presence of dross, molten and burnt material. With the decrease in cutting speed, HAZ width also increases, and below a certain threshold (less than 50% of maximum recommended value of cutting speed) lower part of the cut surface becomes visibly damaged.

Kotadiya et.al. [2] (2016) investigated effect of process parameter for SS-304 material using CO2 laser cutting. Stainless steel is an important engineering material that is difficult to be cut by oxy-fuel methods because of the high melting point and low viscosity of the formed oxides. However, it is suitable to be cut by laser. The objective of this work is to do 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 case, parameters of laser cutting like laser power, cutting speed and gas pressure analyzed and optimized with work piece surface roughness. Design of experiments (DOE), ANOVA and Response Surface Methodology (RSM) approaches are used to analyze the laser cutting variables and find out the optimum value for surface roughness. By analyzing, it is easily seen that the laser power produce high effect on in comparison with cutting speed and gas pressure.

Scintilla et al. [3] (2012) studied a three dimensional sort, semi-stationary sort, disentangled warm numerical model was innovatively best in class. The normal cutting front temperature contrast in plate andCO_2 laser bar combination cutting of 90MnCrV8 was unsurprising by registering the conductive power loss. Establishing on warmth influenced zone augmentation tentatively scale and utilizing an opposite philosophy demeanor, the obscure warm load on the cutting front amid laser cutting was ascertained. precision of the numerical power loss gauge was tallied by contrasting the outcomes from reenactment and the ones from scientific models. An excessively incredible assention was found for all the experiments ascertain in this study. The conduction misfortunes estimation was utilized for demonstrating the lower nature of plate laser cuts due to the lower normal cut front temperature. The three dimensional semi-stationary simplified model type shows a good agreement between the numerical simulation and the experimental data. The HAZ geometry and its extension predicted by the model agree well with that from the experiment. The error in the estimation of the HAZ area using the numerical approach does not exceed 10%, except in the case of 8 mm thick sheet cut with disk laser because of the great amount of recast layer.

Abhimanyu et. al. [4] (2016) obtain optimum cut quality during pulsed base CO_2 laser cutting of mild steel. Input process variables such as laser power, cutting speed and material thickness are considered for evaluation of the process. The cut quality attributes like Edge Surface Roughness (Ra) and Surface Hardness are considered as output parameters. Experimental study presented a combined application of the Taguchi method and the RSM to develop a robust CNC Laser Cutting. For this purpose, the first step in the optimization process is to determine the residual plots for all the experimental tests using the Taguchi method. The next step is to find out the objective function. The objective function is formulated using the RSM. The two machining performance characteristics are optimized. The RSM was found to be effective for the identification and development of significant relationships between cutting parameters.

Ahmet Cekic, et. al. [5] (2015) depict numerical reproductions of surface harshness and warmth influenced zone width of high-alloyed steel 1.4828. In this procedure oxygen is utilized a help gas. Relapse examination is utilized, with four autonomous factors that were far reaching at five levels. Underneath parameters are changed cutting velocity, help gas weight, position of centre and nozzle remain of separation. These reviews have out line, to accomplish these points it is required to advance a major number of compelling parameters that are in a different shared nonlinear association. To survey the nature of laser slicing it is alluring to dissect numerous parameters, similar to this: cutting width, slant and decrease of the cut, HAZ impact, surface harshness, trickling tallness, "extend marks" wonder, hardness and structure change so on. Rely on upon the exploratory information and scientific models, ideal parameters of cutting high-combination steel 1.4828 with thickness of 3 mm with CO_2 laser with the help of O_2 as a help gas all together of accomplishing a base width of cut, HAZ, as well as ideal surface harshness seem to be: $P = 2000$ W, $fs = -1$ mm, $p = 12{,}5$ bar, $Nd = 1$ mm with cutting pace of $V = 4625$ mm/min. Salaries cutting parameter assumes essential part in enhancement prepare.

Adalarasan et. al. [6] (2015) investigated the use of non-contact pulsed CO_2 laser onAl6061/Al_2O_3 composite. The parameters of process in laser cutting influence the KW, surface finish and cut edge slope. All These important characteristics were observed for the different combinations of cutting parameters like laser power, pulsing frequency, cutting speed and assist gas pressure. The cutting trials were designed related to Taguchi's L18orthogonal array and a hybrid approach of GRSM method was revealed for envisaging the optimal combination of laser cutting parameters. A substantial improvement in the surface finish was seen in the responses obtained with the optimal setting of parameters. The atomic force microscopy images and P-profile charts of the cut surface were observed for learning the surface texture.

Orishicha, et. al. [7] (2014) were looked at The fiber and CO_2 laser by two kind of laser-cutting techniques which are the oxygen-helped cutting of low-carbon steel and combination cutting of stainless steel with a nonpartisan colleague gas. The ingested laser vitality was scaled in regard to the unit of the evacuated material volume at the slicing parameters relating to the negligible harshness of the cut surface. The methodology of low-carbon and stainless steel cutting by the fiber and CO_2 lasers which can be likened tentatively, giving that the cut surface harshness ought to be minimum. The laser control assimilation coefficient was scaled cutting with hang loose, the ingested laser vitality was found in regard of the material volume unit expelled from the cut surface. Amid the oxygen-helped laser cutting of low-carbon steel, the insignificant cut-surface harshness is achieved when Energy is equivalent to 11… 13 J/mm3, in fiber and CO2 lasers. The negligible harshness is touch base at the Peclet number 0.35… 0.4 in the fiber sort laser, 0.45… 0.55 in the CO2laser case.

Eltawahni et al. [8] (2012) examined CO2laser cutting of SS of AISI316L. DOE was executed by applying Box–Behnken configuration to build up the design. The objective of this work which is relate the forefront quality parameters in particular: upper kerf, bring down kerf and the proportion between them, cut area unpleasantness and working expense to the procedure parameters appeared previously. At that point, a general improvement routine was connected to discover the ideal cutting setting that would upgrade the quality or limit the working expense. Numerical models were created to depict the connection between the procedure parameters and the edge quality components. Be that as it may, prepare parameters enhancements on the nature of new elements have been all around characterized.

3. EXPERIMENTAL PROCEDURE

3.1 Material Selection and Its Dimensions:-

Material- 1 SS316L

An Austenitic Stainless Steel Holding Molybdenum Which has high Corrosion Resistant than the Conventional 304/304L Stainless Steel Alloy. SS316/316L is a chromium-nickel molybdenum austenitic stainless steel developed to give better corrosion resistance to Alloy 304/304L in corrosive environments. It is often utilized in procedure streams containing halides. The adding of molybdenum improves corrosion and chloride pitting resistance. It also gives high creep, stress-to-rupture and tensile strength at elevated temperatures. It is usually common practice for 316L to be twin certified as 316 and 316L. The low carbon chemistry of 316L joint with calculation of nitrogen enables 316L to encounter the mechanical properties of 316.Alloy 316/316L fights atmospheric corrosion, as well as, moderately oxidizing and reducing environments effect. It also fights with corrosion in polluted marine atmospheres. The alloy has excellent resistance to intergranular shape corrosion in the welded condition.

Material- 1 SS321

SS321 is an austenitic stainless steel similar like SS304 but addition of titanium is at least five times the carbon content. Addition of titanium reduces carbide precipitation in welding and in 427 to 816 °C service. It also makes better the elevated temperature of the alloy.SS321 gives high resistance to oxidation and corrosion and also gives high creep strength. It is used for applications which are involving continuous and sporadic service temperatures within the carbide precipitation range of 427 to 816 °C. Basic uses cover annealing covers, high temperature tempering devices, diesel automotive system, and heavy duty automotive exhaust systems, firewalls, stack liners, casings of boiler, pressure vessels, aerospace industry, radiant super heaters, bellows and oil refinery equipment. Thickness of work piece material is 3mm considered.

Table-1: Chemical composition of SS316L and SS321

Element	SS316L		SS321	
	Found in Test	Required	Found in Test	Required
Carbon	0.026	0.030	0.030	0.080
Silicon	0.43	0.75	0.610	0.750
Sulfur	0.001	0.030	0.001	0.030
Phosphorus	0.027	0.045	0.024	0.045
Manganese	1.180	2.000	1.42	2.00
Nickel	10.1	10.0 – 14.0	9.02	9.00 – 12.00
Chromium	16.63	16.60 – 18.00	17.09	17.00 – 19.00
Titanium	0.3	0.4	0.3	0.7

3.2 Experimental Details

3.2.1 Selection of input process parameter

In this experimental work, the sample is laser cutting at five different level of cutting parameter i.e. Laser power, Cutting speed and Gas pressure as shown in Table-2.

Table-2: Input Process Parameter and their Levels

Machining Process parameter		Level				
		1	2	3	4	5
1	Laser Power (watt)	1636	1500	1300	1100	964
2	Gas Pressure (bar)	17.34	15	11.5	8	5.61
3	Cutting Speed (m/min)	1.64	1.5	1.3	1.1	0.96

3.2.2 Selection of output process parameter

This experimental study includes laser cutting and three output parameters have been selected for process based on the literature survey. The factors are shown in Table-2.

Table-3: Output Process Parameter

Output Parameter
Material Removal Rate (MRR) (mm^3/ min)
Surface Roughness (SR) (µm)
Kerf Width (KW) (mm)

4. RESULT AND DISCUSSION

Table-4: Result Table for SS316L

Run Order	Laser Power	Cutting Speed	Gas Pressure	Surface Roughness	Metal Removal Rate	Kerf Width
1	1300	1.3	11.5	9.7196	15.8706	0.4766
2	1500	1.5	8	10.3509	18.7762	0.4744
3	1300	1.3	11.5	9.7052	15.6896	0.4699
4	1300	1.3	11.5	9.7210	15.6443	0.4372
5	1100	1.5	8	9.7097	17.6034	0.4756
6	1100	1.1	8	9.7098	13.2681	0.4301
7	1300	1.3	11.5	9.7246	15.8365	0.4756
8	1100	1.5	15	10.1703	16.9785	0.4301
9	1500	1.1	8	9.6885	13.7618	0.4633

10	1300	1.64	11.5	9.7096	18.1193	0.4361
11	1100	1.1	15	10.4901	13.5002	0.4554
12	1300	0.96	11.5	10.1793	11.5866	0.4357
13	964	1.3	11.5	10.5012	15.1365	0.4339
14	1500	1.5	15	10.7707	17.9129	0.4657
15	1300	1.3	5.61	10.2563	16.3929	0.4514
16	1300	1.3	11.5	9.7145	15.8033	0.4746
17	1636	1.3	11.5	10.3533	14.9167	0.4773
18	1300	1.3	11.5	9.7096	15.7240	0.4722
19	1300	1.3	17.34	11.03920	17.0351	0.4920
20	1500	1.1	15	10.4763	15.1057	0.5000s

Table-5: Result Table for SS321

Run Order	Laser Power	Cutting Speed	Gas Pressure	Surface Roughness	Metal Removal Rate	Kerf Width
1	1300	1.3	11.5	11.9620	10.5650	0.3705
2	1500	1.5	8	13.1578	13.1171	0.3935
3	1300	1.3	11.5	11.7015	10.5371	0.3695
4	1300	1.3	11.5	11.8123	10.5941	0.3715
5	1300	1.5	8	11.8152	16.7159	0.3900
6	1100	1.1	8	11.8153	12.8459	0.4282
7	1300	1.3	11.5	11.8025	1.7937	0.3785
8	1100	1.5	11.5	13.9231	17.0091	0.3969
9	1500	1.1	8	11.9613	17.1892	04730
10	1300	1.64	11.5	11.8150	18.4165	0.4297
11	1100	1.1	15	13.8624	18.6859	0.4983
12	1300	0.96	11.5	12.6835	14.5417	0.5336
13	964	1.3	11.5	12.3401	16.6097	0.4983
14	1500	1.5	15	14.1020	18.9113	0.4413
15	1300	1.3	5.61	12.4728	17.2806	0.4608
16	1300	1.3	11.5	11.8233	10.6255	0.3726
17	1636	1.3	11.5	13.4487	16.8605	0.4496
18	1300	1.3	11.5	11.8146	10.6568	0.3737
19	1300	1.3	17.34	14.8747	14.8551	0.4457
20	1500	1.1	15	13.9778	14.4601	0.4820

In this experimental analysis, only three laser parameters namely laser power, cutting speed and gas pressure duration were considered for surface roughness. Other parameters such as nozzle diameter, focal length, focus point position, work piece material and work piece thickness were kept constant here. These variables could be varied to explore their effect for surface roughness, kerf width.

A further improvement about the cut quality might be possible by proper selection of process parameters, especially on the combination of the focal point position, focal length, working distance & nozzle diameter. A future study might be able to be focused on cutting different thickness mild steel in order to investigate the cutting performance more clearly. And after that, a 2D cutting such as circular and angular shape even 3D cutting can be investigated in future study.

Investigation of cutting quality on different material with different thicknesses using carbon dioxide gas assisted laser cutting. Also one can make comparison of cutting quality of different materials with different thicknesses using nitrogen and oxygen gas assisted.

4. CONCLUSIONS

- Parametric analysis for MRR, surface roughness and kerf width shows that effect of process parameter is always vary with response. Significant parameter may be different for different response output.
- As Cutting speed increases the kerf width decreases. This is because less time over surface area observed with increase of speed.
- As Pressure increases the kerf width continuously increases. Increases in pressure accelerate kerf drag in both SS321 and SS316L.
- As Power increases MRR initially decreases and then after it increases. This is because of increase in heat energy which leads to more material removed over the cut area. Increase in cutting speed increases the MRR. As Pressure increases the MRR decreases. Increase in Gas pressure leads to more focused cutting zone.
- Increase in power and cutting speed reduces surface finish means increases roughness while increase in pressure improves the surface finish.
- Single objective optimization need to set process parameter as per below required response.

1500	1.5	15	Maximum MRR
1100	1.5	15	Minimize Kerf Width
1500	1.1	8	Minimize Surface Roughness

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