"INVESTIGATION OF LASER MACHINING FOR LOW SURFACE ROUGHNESS ON SS304"

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ABSTRACT

The quality of laser cut is the most important factor in laser cutting process. 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. It shows that by proper control of the cutting parameter, good quality cuts are possible at high cutting rates. So, an experimental investigation is presented, which analysis the surface finish at different cutting speed on the material s304 after fiber laser beam cutting. We are using different parameters like cutting speed, power, and gas pressure and measure the surface roughness using method. Results were analyzed, discussed and conclusions regarding the effect of cutting speed on surface roughness were drawn.

Keywords: *cutting speed, laser power, gas pressure, surfaceroughness, SS 304*

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1. INTRODUCTION:

LBM is a non-traditional subtractive manufacturing process, a form of machining, in which a laser is directed towards the work piece for machining. This process uses thermal energy to remove material from metallic or nonmetallic surfaces. The laser is focused onto the surface to be worked and the thermal energy of the laser is transferred to the surface, heating and melting or vaporizing the material.

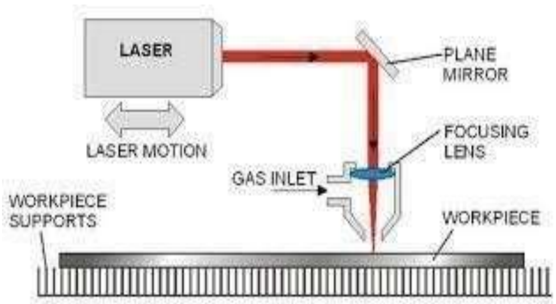

Figure-1: Laser Cutting Machine

1.1 Fiber laser machine:-

Fiber lasers belong to the solid state laser group. They generate a laser beam by means of the so-called seed laser and amplify it in specially designed glass fibers, which are supplied with energy via pump diodes. With a wavelength of 1.064 micrometers, fiber lasers produce an extremely small focal diameter; as a result their intensity is up to 100 times higher than that of CO_2 lasers with the same emitted average power.

Fiber lasers are optimally suited for metal marking by way of annealing, for metal engraving, and for high-contrast plastic markings.

A special type of fiber laser is the MOPA laser, where pulse durations are adjustable. This makes the MOPA laser one of the most flexible lasers which can be used for many applications.

1.2 Advantages:-

High beam quality which allows the user to produce spot diameters substantially smaller than conventional lasers.

High power output and high electrical efficiency greatly reduces the operating cost. Flexible beam delivery and longer work distance. The delivery beam fiber for a 1 kilowatt system is 50 microns, allows for longer working distances and more consistent processing than conventional Nd: YAG lasers with fiber delivery .Maintenance free during entire lifetime because there is no need to replace diodes .Beam shaping potential and compact processing heads with small optics.

Except cutting, welding and marking, other processes such as laser forming and rapid manufacturing are possible to establish greater levels of performance with the new generation of high power fiber lasers.

1.3 disadvantages:-

Efficiency and power consumption depends on the type of section that need to be carried out and nature of the laser. Usually, laser cutting have high energy consumption.

Laser cutting of plastic components can be expensive because when exposed to heat, plastic emits gas .Not all types of metals can be cut with laser cutting. For example, a metal like copper and aluminum can’t be cut using this technology .Fiber laser cutting machine price is expensive so that the production cost is high. Cutting thick material or high reflective material, the cutting speed is very slow.

1.4 Application:-

- It is used in part manufacture of automobile industries.
- Its manufacture also textile machine parts, aerospace parts, electronics parts. It is widely used in semiconductor Industries, Medical Sectors Etc.

2. LITERATURE REVIEW:

Smita Patil, Hemant Adhale, Pankaj Bagav, Shweta Shinde, and Aniket Jadhav: The use of stainless steel (SS) in the recent years has grown worldwide. A wide spectrum of industries rely on stainless steel including constructions, automotive and much more. Different shapes like plate, bars, sheets and tubing can be manufactured using stainless steel for using industrial and domestic settings. It cannot be easily cut by laser cutting process. In this research work effect of fiber laser cutting for SS has been considered. Fiber laser has capacity to cut hard materials due to its higher efficiency, better beam quality, reliability and ease of beam delivery through optical fiber. In this study, the laser cutting parameters such as laser power, cutting speed and gas pressure are analyzed and optimized with consideration of work piece surface roughness. Surface roughness is considered as one of the performance parameter. [1]

D. J. Kotadiya, D. H. Pandya: 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 study, the laser cutting parameters such as laser power, cutting speed and gas pressure are analyzed and optimized with consideration of 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 observed that the laser power has more effect on responses rather than cutting speed and gas pressure. It is clearly shown that the above performance characteristics in laser cutting process can be optimized effectively through this approach. [2]

Pradipkumar S. Chaudhari, prof. Dhaval M. Patel: Mild Steel are widely used in the fabrication industry and nowadays have become of importance to other industry as well. This paper investigates 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, at a window of laser cutting speed 1450 mm/min and at a heat input of 915 watts under an assisting O2 gas pressure of 0.8 bar. [3]

Vikrant B. Mahajan, Vidya N. Nair: The recent up gradation of newer and high strength materials have made the machining task in fiber laser cutting is quite challenging. Thus for the optimum use of all the resources it is essential to make the required mechanical properties, accuracy and quality. This paper reviews the various notable works in field of fiber laser cutting and magnifies on effect of machining parameters on strength, kerf width and surface roughness. [4]

Erica librera, giovanni rivaa, Hossein safarzadeha, Barbara previtalia: Laser cutting provides various advantages such as high flexibility in terms of process parameters and cut material type, as well as the possibility to obtain complex geometry in different dimensions with high precision. From industrial point of view, the two more competitive laser cutting technologies are based on the use of CO2 and active fiber sources, which produce samples visually different, with non-uniform surface and different depth of the striations. The quality assessment between the two laser systems within the industry is commonly based on standard ISO 9013; that covers several aspects of quality, the most used are the surface roughness and edge perpendicularity; however 2D profile meters adopted for measures are not able to analyze the complex 3D surface topography of the cutting edge. As a result, despite the fact that the differences are visually appreciated, measured 2D roughness values of different CO2 and fiber laser cutting conditions are very similar. Recently, a greater diffusion of 3D surface profile metry devices is present. These devices allow areal surface roughness parameters to be defined, which are potentially suitable to better quantify the laser cut quality. This work points out the use of a focus-variation microscopy to acquire 3D surfaces and evaluate analytically the surface quality of laser cut edges using a real surface roughness parameters. [5]

S. Stelzera, A.Mahrlea, b, A. Wetziga, E. Beyera, b: First results of an 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. [6]

Krzysztof jarosza, piotr löschnera, piotr niesłonya: This article presents 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 analyzed, discussed and conclusions regarding the effect of cutting speed on surface roughness and HAZ were drawn. [7]

Ahmet Cekic, Derzija Begic-Hajdarevic, Malik Kulenovic and Alma Omerspahi: Laser beam machining (LBM) is one of the most widely used thermal energy based non- contact type advance machining process which can be applied for almost whole range of materials. This paper defines mathematical models for surface roughness prediction (Ra, μm) and width of heat affected zone (HAZ, mm) during laser cutting of alloy steels 1.4571 and 1.4828 with nitrogen as assist gas. For defining appropriate mathematical models multiple regression analysis is used with four independent variables. Following parameters are varied: cutting speed, focus position, nitrogen assist gas pressure and stand-off. Obtained mathematical models describe dependence of Ra and HAZ from varied process parameters. [8]

D.Pessoaa, A.Grigorescuc, P.Herwiga, A.Wetziga, M.Zimmermanna: Laser cutting is an attractive and innovative manufacturing process which has many advantages compared to conventional cutting methods. However, with increasing work piece thickness an increase of the roughness along the kerf surface can be observed, which, in turn, can negatively affect the mechanical properties, in particular the fatigue strength. In this context, the purpose of the present study is to investigate the impact of the geometrical surface characteristics and micro structural changes after laser cutting in order to support the cutting process optimization concerning cyclic durability. Fatigue strength evaluation is performed with specimens cut out by high-power solid-state disk laser from sheets with thickness of 2, 4 and 6 mm made of Meta stable austenitic stainless steel type 304. Cyclic tests are carried out using a resonant pulsation testing system at test frequencies around 100 Hz at two different load modes, purely reversal load condition (R = -1) and tensile-tensile load condition (R = 0.1). In order to evaluate separately the effect of surface relief over the cutting kerf and burr in form of re- solidified drops, the fatigue specimens are tested at different surface conditions. [9]

3. METHODOLOGY:

Taguchi's method is a powerful technique for the design of a high quality system. It provides not only, an efficient, but also a systematic way to optimize designs for performance and quality. Furthermore, Taguchi parameter design can reduce the fluctuation of system performance and quality to the source of variation.
The methodology used**:**

- Identify the quality characteristics and select process parameters to be evaluated.
- Select the appropriate orthogonal array and assign these parameters to the orthogonal
- Conduct the experiments as per design matrix based on the arrangement of the orthogonal array.& Recording of responses Analyze the experimental results using the signal to noise(S/N) ratio.

4. EXPERIMENTATION:

4.1. Material for Experiment*:* Stainless Steel Grade SS 304 is used for this experiment. The chemical compositional ranges of grade 304 stainless steels are given below:

Table-1.
Chemical Composition Of SS 304

Elements	C	Mn	Si	P	S	Cr	Ni	N
%By weight	0.08 Max.	2.0 Max.	0.75 Max.	0.04 Max.	0.030 Max.	18.0-20.0	8.0-10.5	0.10 Max.

4.2. Profile Specification*:* The profile cut using the O2 laser. The 9 specimen of size 50*50 mm and 10mm fillets on each corner to cut from SS 304 sheet of 4mm thick.

4.3 Experimental Details*:* The experimentation has to carry out on make O2 fiber laser cutting machine having maximum laser power 1000 Watt.

1) **Selection of Process Parameters & Levels:** Process parameters and their ranges were determined by the Literature survey & by taking the review of experienced people working on laser cutting machine. Also surface roughness is to measure as a response.

Table-2.
Process Parameters with Levels

Sr. No.	**Parameter**	**Symbol**	**Unit**	**Levels**		
				1	**2**	**3**
1	Laser Power	A	Watt	800	900	1000
2	Cutting Speed	B	Mm/Min	1000	1500	2000

2) **Selection of Orthogonal Array**: Selection of an appropriate orthogonal array for the experiments is done on the basis of number of process parameters and its levels. As no. of parameters is 3 & no. of levels are 3, L9 orthogonal array is selected.

Table-3.
Orthogonal Array

Experiment no.	Process variables	
	Laser power(watt)	Cutting speed(mm/min)
1	800	1000
2	800	1500
3	800	2000
4	900	1000
5	900	1500
6	900	2000
7	1000	1000
8	1000	1500
9	1000	2000

5. RESULT AND DISCUSSION:

5.1 Surface Roughness:

Taguchi method of design of experiment is used to reduce the number of experiments, yet cover the entire parameter space with the help of a special design of orthogonal array. The results of such experiments are then transformed to a signal to noise(S/N) ratio to find out the deviation of the performance characteristics from the desired values. In this experiment, the desired characteristic for surface roughness is lower the better.

$$S/N = -10 \log [1/n \Sigma\ n\ i=1\ (yi^2)] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Table-4.
Average Surface Roughness Value and Their Corresponding (S/N) Ratios.

Sr. No.	Laser power	Cutting speed	SR (Ra)	SNRA
1	800	1000	6.5	-16.2583
2	800	1500	6.0	-15.5630
3	800	2000	5.2	-14.3201
4	900	1000	6.5	-16.2583
5	900	1500	5.1	-14.1514
6	900	2000	5.4	-14.6479
7	1000	1000	5.6	-14.9638
8	1000	1500	6.3	-15.9868
9	1000	2000	6.0	-15.5630

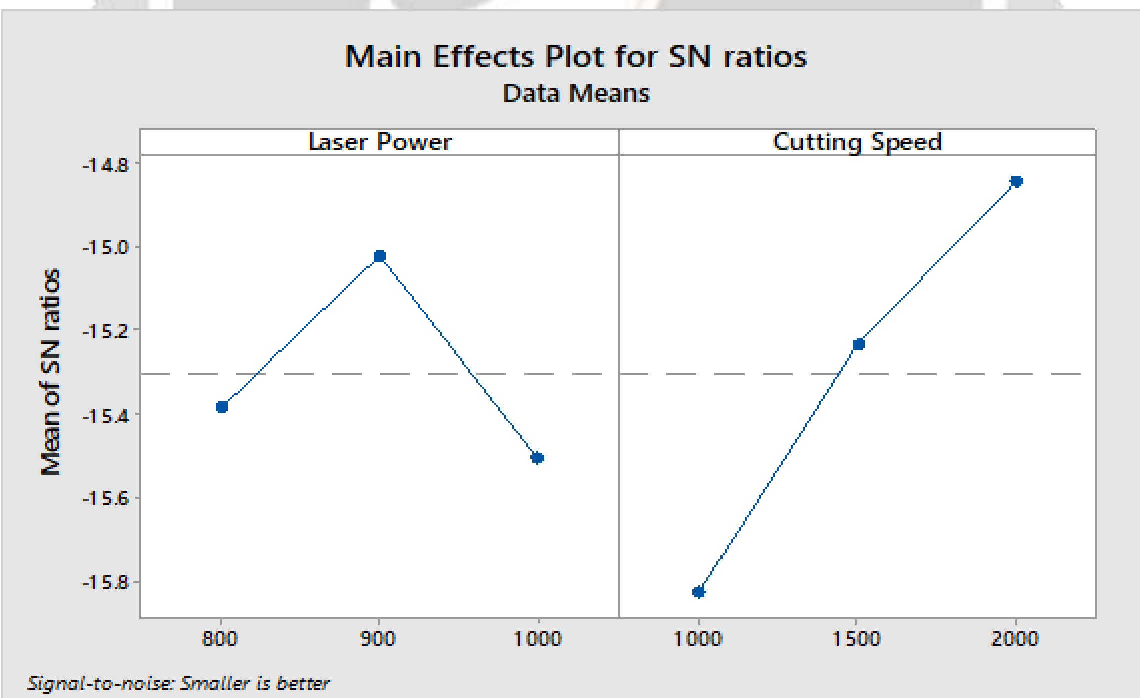

Chart-1: Signal to Noise Plot for Surface Roughness

Table-5.
Response Table for Surface Roughness S/N Ratios (Smaller Is Better)

Level	Laser Power(watt)	Cutting Speed(mm/min)
1	-15.38	-15.83
2	-15.02	-15.23
3	-15.23	-14.84
Delta	0.49	0.98
Rank	2	1

Table 4 Shows The Response Table Of Signal To Noise Ratios For Surface Roughness. Based On This Analysis, Low Surface Roughness Is Obtained At Laser Power 900 Watt, Cutting Speed 1500 Mm/Min The Optimal Combination From Table 5:

Laser Power = 900 Watt
Cutting Speed = 1500 Mm/Min

6. CONCLUSIONS:

- In this study, CNC laser cutting operation is done under various experimental conditions and the surface roughness was measured. 9 levels of experiments had been done. The input parameters are the laser power and cutting speed while the output parameter is surface roughness.
- The most effecting factors on surface roughness is cutting speed & laser power.
  The optimal combinations for SS 304 are:
  Laser power =900 watt,
  Cutting speed =1500 mm/min
- By the experimental data of taguchi method (DOE method) and SN ratio the optimum minimum value of surface roughness found that 5.100µm.

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