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Influence of Cutting Parameters on Quality Characteristics during Fiber Laser Cutting of SS304” - A Review

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ABSTRACT: Fibre laser is a newer technology in laser cutting. Also, available at different power levels and very narrow spot size. Stainless Steel is widely used in industries throughout the world. It requires higher power due to the hardness and reflectivity. Therefore fibre laser are used for cutting Stainless Steel (SS-304).

The aim of this work is to study the influence of process parameters namely: laser power, cutting speed, assist gas pressure on cutting quality like kerf width and surface roughness. Design of Experiment (DOE) like full factorial method will be used to find the number of experimental runs to perform on the fibre laser machine. ANOVA analysis will be done to obtain the most significant factors on the response parameters as well as regression analysis was used to find the mathematical relation between process parameters and responses. Finally, validation will be done to find the deviation of statistical model with the experimental data.

KEYWORDS: Advance machining, Laser cutting, Ss304, Power, Fiber Laser, Cutting Speed, Gas Pressure,

I. INTRODUCTION

1.1 Introduction of Laser

The full form of laser is Light Amplification by Stimulated Emission of Radiation. Laser light is electro-magnetic wave in visible range. A laser consists of (1) laser medium source like atoms or molecules, (2) Pumping process for excite laser medium in to higher quantum mechanical energy levels, (3) Optical feedback that allow beam of radiation to pass through laser medium or bounce back through the laser medium. Now a day's lasers find applications in very field of engineering, medical ext.

Laser beam machining is non-conventional type machine, in which a laser beam is directed towards he work piece for machining. This uses thermal energy to remove or cutting the material from metallic corn on metallic surface. It cuts material with high degree of accuracy and precision. It involves heating, melting an evaporation of material in welled fined area and capable of cutting any type of material. Laser has many applications including military weapons to medical instruments. In industries lasers are used for cutting and welding. Laser can cut variety of materials like ceramic, rubber, plastic, metals, nonmetals ext. There are many types of laser machines available, but the most commonly used types are CO₂ and ND:YAG laser. The working principle of laser cutting is thermal, noncontact process suited for various manufacturing industries to produce desired product with high dimensional accuracy and surface finish. The laser beam produce high degree of temperature at focused point and it molten metal from material and molten material is removed by jet of assist gas from the heat affected zone.^[1]

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1.2 Types of laser beam machines

There are three main types of lasers in industry for laser cutting. 1-CO₂laser

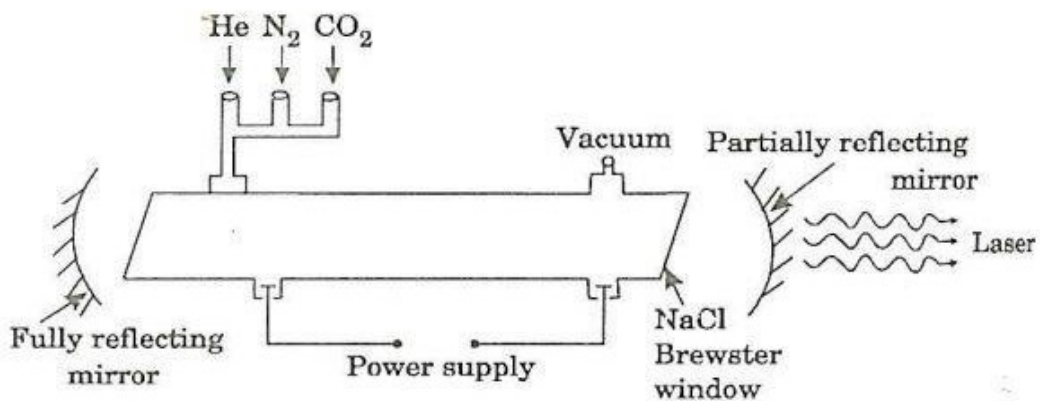
2- ND:YAG Laser

3- Fiber Laser

1.2.1 CO₂ Laser

Carbon dioxide lasers are used widely form machining applications, due to its ability to produce very high power and good efficiency.

Figure1.1: Schematic diagram of CO₂laser



The CO₂ laser produces a beam of infrared light with the principal wavelength bands centering round 9.4 to 10.6 micrometers.

1.2.2 ND:YAG Laser

Y₃Al₅O₁₂ is a crystal that is used as a lasing medium for solid state lasers. The dopant, triply ionized neodymium, Nd (III), typically replaces a small fraction of the yttrium in the host crystal structure of the yttrium aluminum garnet (YAG), since the two ions are of similar size.[1] It is the neodymium on which provides the lasing activity in the crystal, Nd:YAG laser rod Nd:YAG (neodymium-doped yttrium aluminum garnet; Nd: in the same fashion as red chromium ion in ruby lasers. Laser operation of Nd:YAG was first demonstrated by J.E. Geosocial. At Bell Laboratories in 1964. Nd:YAG lasers are optically pumped using a flash tube or laser diodes. These are one of the most common types of laser, and are used for many different applications Nd:YAG lasers typically emit light with a wavelength of 1064nm, in the infrared. However, there are also transitions near 946, 1120, 1320, and 1440nm. Nd:YAG lasers operate in both pulsed and continuous mode. Pulsed Nd:YAG lasers are typically

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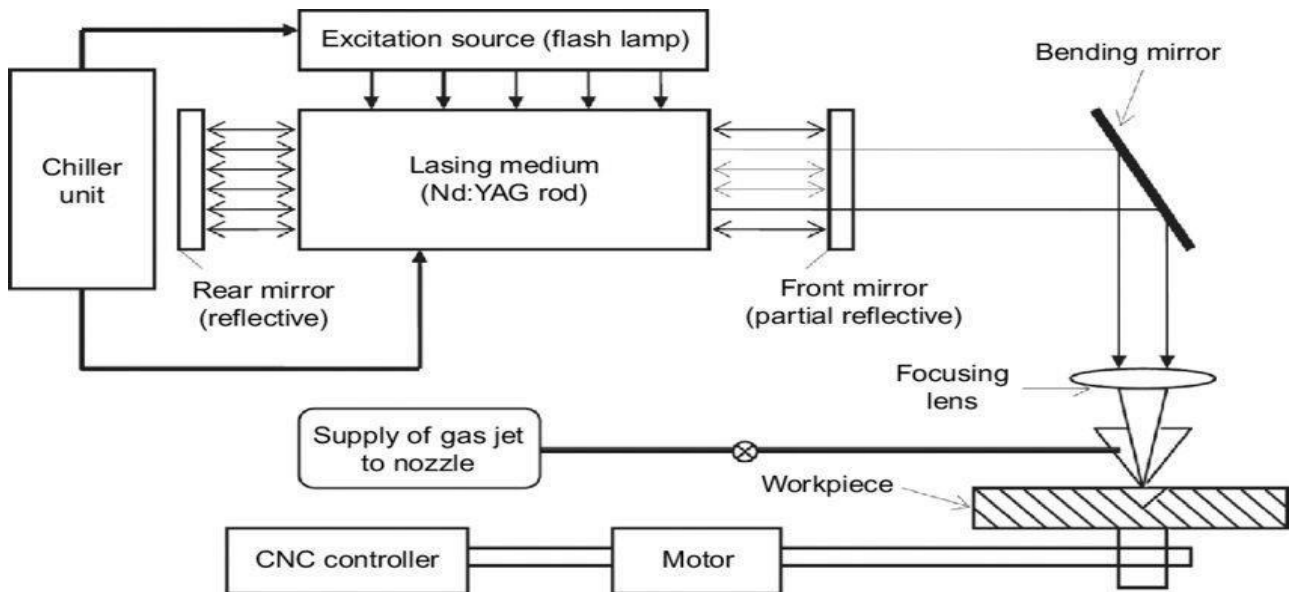


Figure1.2: Schematic diagram of ND:YAG laser^[1]

1.2.3 Fiber Laser

Fiber optics are made possible by a principle of total refraction, resulting in guiding of light inside a medium with higher index of refraction than surrounding medium. Swiss physicist Jean-Daniel Colladon and French physicist Jacques Babinet conducted an Experiment to guiding light inside a thin stream of water in 1842, proving this principle. Unclad optical fibers were first used in 1930 medical instrument used to look inside otherwise inaccessible parts of the body. Early fiber optic communications were limited with attenuation inside an optical fiber. First use ful fibers for communications were made in 1970.

Fiber lasers are sub type of solid state lasers. Optical fibers with different dopants inside core, mainly rare earth metal ions, serve as gain media. Mirrors are needed to form optical resonator. Dichroic dielectric mirror can be used in simple laboratory setups of fiber lasers but fiber Bragg gratings are used in most industrial products. Fiber lasers are mostly pumped by one or several diode lasers.

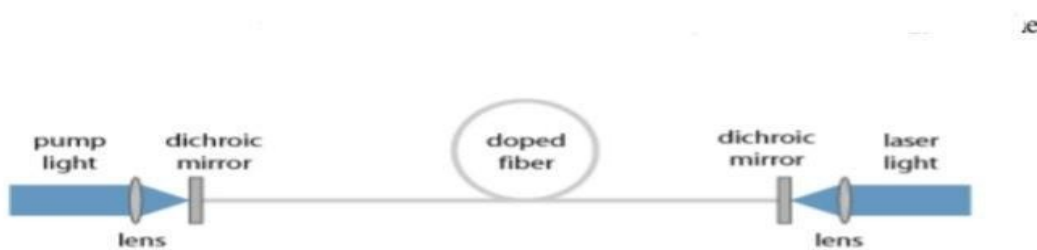


Figure1.3: Schematic diagram of Fiber laser^[5]

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1.3 Laser Cutting

Laser cutting is widely used manufacturing process used to cut many type so materials. During laser cutting, a high power laser beam is directed towards the material. The Energy of laser converted into heat and it melt the material. The molten metal is blow away with the help of assist gas. The precision levels and edge quality achieved with laser cutting machines are better than traditional cutting methods, as the laser beam will not wear during the laser cutting process. Laser cutting technology also enables us to cut complex shapes without the need for tooling and at a similar or faster speed than other cutting methods. The fact that laser cutting technology offers reduced contamination of the work piece presents certain advantages over traditional mechanical cutting techniques.

Laser cutting also allows us to cut small diameter holes with complex detail and good edge quality in either sheet, plate, tube or box section. Laser cutting is a technology that uses a laser to cut materials and is typically used for industrial manufacturing applications, but is also starting to be used by schools, small businesses and hobbyists. Laser cutting works by directing the output of a high-power laser, by computer at the material to be cut. The material the neither me its, burns, vaporizes or is blown away by a jet of gas leaving an edge with a high quality surface finish. Industrial laser cutters are used to cut flat sheet material as well as structural and piping materials. There are two cutting process depending upon assist gas used.

1. When cutting with oxygen, there action between oxygen and the metal create Additional energy in form of heat, which beneficial for cutting process.
2. When cutting with inert gas (nitrogen or argon), material got melted solely by laser power and blown out by kinetic energy of assist gas jet. As these gases are non reactive with metal, no additional heat is generated, so the laser power required is higher than oxygen assisted laser cutting.

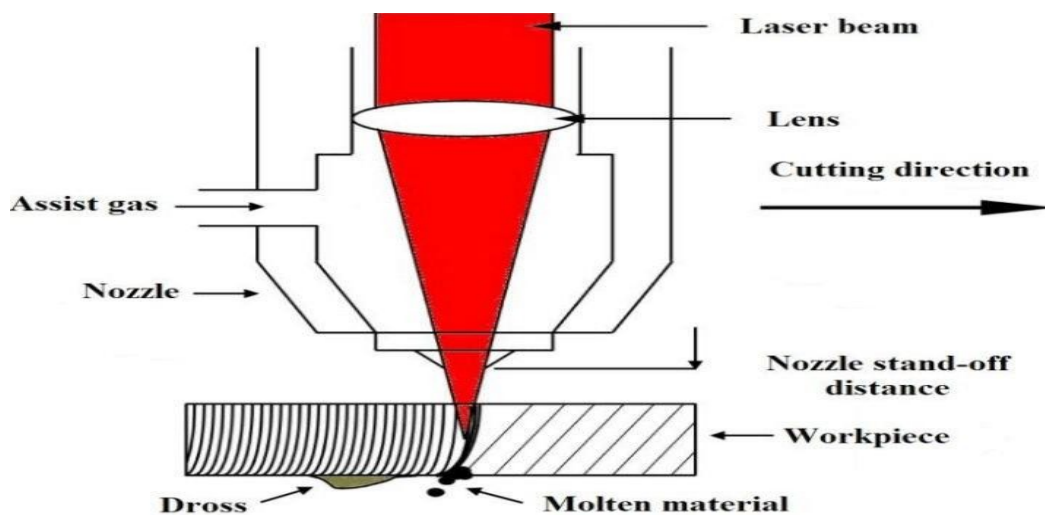


Figure1.4: Schematic diagram of laser cutting^[12]

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II. LITERATURE REVIEW

2.1 Literature Review

1. Priyanka Joshi and Amit Sharma [1] laser cutting of Aluminum alloy (Al 6061-T6) thin sheet has been carried out using pulsed Nd-YAG laser to investigate the dimensional accuracy of the kerf geometry and zone of the metal surgical changes in the sheet metal. These responses are quantified inter MS of kerf taper and heat affected zone for the study. The taper in the kerf and heat affected zone are the functions of our laser cutting parameters namely: lamp current, pulse width, pulse frequency and cutting speed and different settings of these laser cutting parameters are utilized to analyze their poses. In order to analyze the experimental results.

The preferred operating experimental setting of laser cutting parameters has been found as: Lamp current at 260amps, pulse width at 4ms, pulse frequency at 10Hz, and cutting speed at 20mm/min.

2. Mirotslav Ravanovic and Predrag Dasic [2] studied that laser cutting is preliminary used for cutting of mild and alloy steel. Surface quality is very important parameter of laser cutting that ensures an advantages on other cutting process.

The main conclusion of this paper is, when we cut the material with laser, the standard roughness increases along with the sheet thickness, but decrease with increase in laser power.

By cutting with laser power of 800watt, standard roughness is 10um for sheet thickness of 1mm, 20um for 3mm, and 25um for 6mm thick sheet

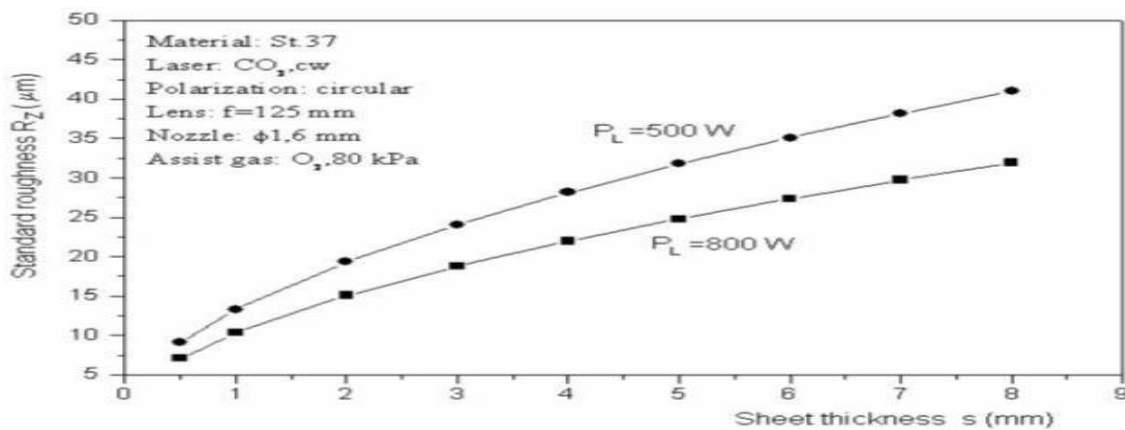


Figure 2.1: Sheet thickness vs. Surface roughness

3. M.Madic, M.Radanovich and B.Nedic[3] This paper is about cutting of mild steel in industrial application. In this research work mechanical model is prepared for estimating the surface roughness of mild steel based on cutting parameters. Functional dependence between laser cutting parameters, their interaction and surface roughness is complex and nonlinear. Minimum R2/R1 is about to correspond to assist gas pressure of 3 bar and cutting speed of 9m/min. Reaction between R1 and R2 is nonlinear and can be expressed by second degree polynomial.

4. Jetro Pocurni and John Powell[4] They reached to the conclusion that as material thickness increase, laser cutting efficiency decreases. A thinner section fiber laser cut more efficiently than CO2 laser and at thicker section CO2 laser cut more efficiently than fiber laser. Argon as assist gas, the difference in cutting efficiency between CO2 laser and fiber laser is reduced.

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5. Vipulk.Shah, Hardik j. Patel and Dr.Dhaval Patel[5] From the study of this paper, they found that fiber laser is an adequate process to cut sheet metal with good surface finish with less time. Study says that oxygen gas pressure is found the most significant effect on surface roughness and kerf width. Laser power has also effect on surface roughness and kerf width. Value of surface roughness and kerf width is increase with increase in laser power. Reason behind this is high power intensity the material removal rate from the work piece.
6. A.F.M. Tahir and E.A. Rahim[6] The ultra-high strength material was under experiment and they found the relationship between input parameters and cutting quality of high strength steel. They found that laser power and cutting speed were greatly responsible for cutting quality and mechanical property of material, whereas assist gas pressure does not significantly affect the output. High power density produces poor cutting quality and incomplete cutting was observed due to insufficient heat affected zone.

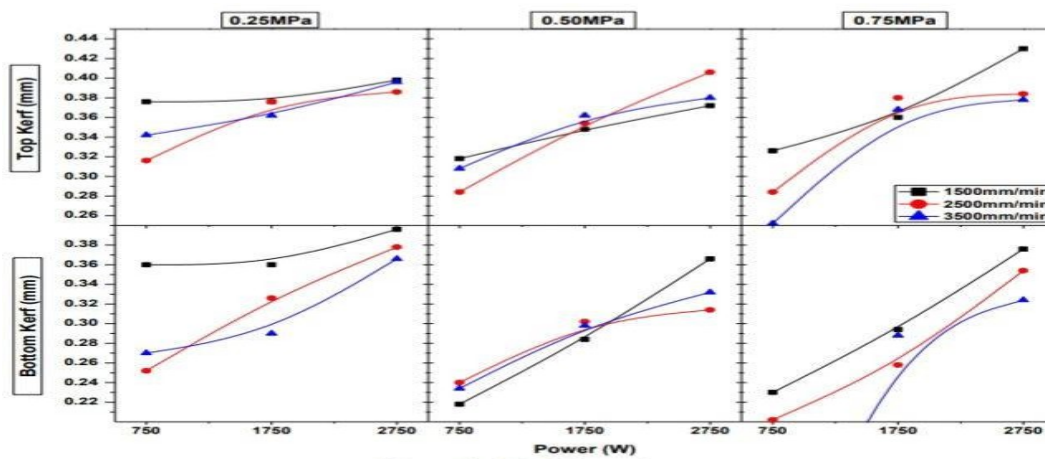


Figure 2.2: Power vs. kerf width

7. Anil P. Varkey, Dr.Shajan Kuriakose and V. Narayanan[7] The study is carried on titanium Grade-5 alloy. The conventional cutting method is not useful on this material because of its poor thermal conductivity, low elastic modulus and high chemical affinity. They found that the titanium alloy sheet can easily cut by CO₂ laser. The parameters for experiment are cutting speed, laser power and assist gas pressure. They found that laser power and cutting speed has influence on cut quality. Cutting speed affects surface roughness and laser power affects kerf taper significantly.
8. B.S. Yibas and Farhan Ashraf [8] The material Ti-6Al-4V Alloy, Steel 304, Inconel 625, Alumina was under the experiment. The percentage of kerf width, size variation due to laser output power and cutting speed are examined. They also examined the life cycle assessment of the laser cutting process. They found that increasing laser power or reducing cutting speed results in increase of percentage of kerf width and size.
9. Vishal Solanki and Mayank Madia[9] They studied the effect of cutting speed, gas pressure and laser power on quality of laser cut on super duplex stainless steel and Titanium alloy grade-2 by using fiber laser. They used ANOVA analysis and reached to conclusion that laser power is most significant factor for surface roughness of super duplex alloy stainless steel and Titanium grade-2. Good quality cut can be produced at cutting speed of 4000mm/min and laser power at 900Watt and gas pressure of 12bar for titanium grade-2, the optimum parameters are, cutting speed at 4000mm/min, laser power 950Watt and assist gas pressure at 12bar.

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10. A.K Dubey and Vinod Yadava[10] They used Aluminum alloy sheet for experiment. Process parameter are cutting speed, laser power and Assist gas pressure. The analysis is done for kerf quality. They found that, the optimum levels of process parameters for minimum kerf deviation and kerf width for cutting aluminum alloy sheet of 0.9 mm thickness is: gas pressure at 8.0kg/cm², pulse Wide that 1.2ms, pulse frequency at 28Hz, and cutting speed at 17.5mm/min. Assist gas pressure and pulse frequency significantly affect the kerf quality in the operate in grange of process parameters.

The kerf deviation and kerf width have been reduced up to 0.01 and 0.2250mm, respectively against the initial value of kerf deviate on and kerf width as 0.04 and 0.2625mm, respectively. The multiple S/N ratio at any conditions has been improved by 2.0493dB

11. Dhruval J. Kotadia, Anjal R.Patel and D.H.Pandya [11] The analyst is for SS304 material was done using laser cutting. And they found that the optimized value of parameters found as power 500W, gas pressure 15 bar and cutting speed 2000mm/min for the minimum value of surface roughness 4.39939 m and top kerf width 283.688m. Based on these results, the optimal cutting condition, at which the surface roughness and top kerf width were minimized and both the delayed cutting phenomenon was estimated to improve both the quality of the cut section and the cutting efficiency.

III. CONCLUSION

1. Many literature papers have been studied and survey has been completed
2. The experiment material stainless steel 304 has been selected
3. Plate thickness has been decided, and is 1mm, 2mm and 3mm
4. The setup of fiber laser machine has been identified at JC METAL FAB, Sachin-surat.
5. Process parameters as well as number of experimental runs has been decided.
6. Experiments have been conducted at the site.

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