# OPTIMIZATION OF INPUT PARAMETERS ON SURFACE ROUGHNESS DURING LASER CUTTING - A REVIEW

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***Abstract: There are many factors responsible for the performance of the laser cutting process. Identification of the effective factors that significantly affect the cut quality is important. In recent years the researchers have explored the number of ways to improve the quality of cutting in the different lasers. This paper reviews the research work carried out so far in the area of Fiber Laser cutting process. Several optimization techniques used for the determination of optimum laser cutting condition have been critically examined. This works aim that the effect of laser machine processing parameters, such as the laser power, cutting speed, and gas pressure on measured surface roughness for the laser cutting of stainless steel. The main objective was to identify the most common process parameters and cut quality characteristics. The performance of laser cutting process mainly depends on laser parameters.***

***Keywords: Laser cutting process, Fiber Laser, Gas pressure, Cutting Speed, and Laser Power.***

## I. Introduction

### A. Laser

Laser (Light Amplification by Stimulated Emission of Radiation) is a coherent and amplified beam of electro-magnetic radiation [10].

### B. Laser Cutting Process

Laser cutting is a common manufacturing process employed to cut many types of materials. Materials which may be cut included ferrous metal, non ferrous metal, stone, plastic, rubber and ceramic. Laser cutting works by directing a high power pulsed laser at a specific location on the material to be cut. The energy beam is absorbed into the surface of the material and the energy of the laser is converted into the heat, which melt or vaporize the material. Additionally gas is focused or blown into the cutting region to expel or blow away the molten melt and vapor from cutting path.

There are several advantage of laser cutting over mechanical cutting, since the cut is performed by the laser beam, there is no physical contact with the material therefore contaminates cannot enter or embed into the material. Laser cutting can produce high quality cut, complex cut, cut several part simultaneously, produce clean cutting edge which require minimal finishing as well as low edge load during cutting which will reduce distortion [9].

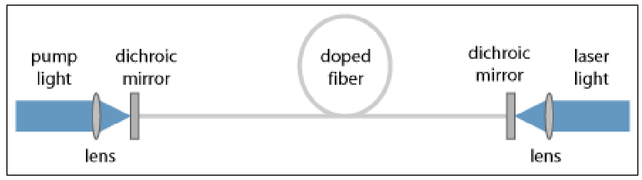


Figure 1: Scheme of a simple fiber laser

### C. Fiber Laser Cutting

For a Fiber Laser the gain medium is an Ytterbium doped glass fiber, with the excitation energy being provided by laser diodes, operating around 950nm, coupled by various schemes into the core of the doped fiber. The laser beam wavelength is typically in range 1.07$\mu$m to 1.09$\mu$m. obviously the physical dimensions of the gain medium for the Fiber Laser are very different from other laser types. A Nd:YAG rod might be 200mm, a $CO_2$ discharge around 2m, but the gain fiber in a Fiber Laser will be 10's of meters long.

The reflectors used in the Fiber Laser are physically very different from traditional lasers. Typically the mirror will be formed from a dielectric coating on substrate; which will be transmissive at the laser wavelength for the output coupler. For the Fiber Laser, Bragg Gratings written into the core of a fiber are used. These Fiber Bragg Gratings (FBGs) consist of periodic refractive index variations. The longitudinal period of the grating determines the wavelength of the reflected light, and the magnitude of the variation controls the reflected percentage [11].

#### C..1 Advantages of Fiber Laser

The advantages of the Fiber Laser for Industrial applications can be summarized as follows:

1. Good reliability and lifetime.
2. High stability of laser output leading to consistency of processing.
3. Small size of overall unit.
4. Generally longer warranty than standard lasers.

  

5. Option of air cooled or water cooled up to a few hundred watts output power.
6. Lower price than equivalent power traditional laser.
7. Integrated damage protection against back reflection issues.
8. Control software offering full functionality and ability to be integrated into system level controllers.
9. Fault diagnostics for improved warning or alarm identification.
10. End of life warning for tracking diode lifetimes.
11. Reliable, stable and linear power monitor integrated to laser.
12. Single sourcing for laser and process tools (cutting head, welding head or galvanometer based scanners).
13. Ability to increase processing performance of reflective materials through periodic enhancements to laser peak power [11].

## II. Literature Survey

**Mayank N Madia, Prof. Dhaval M Patel**, "Effect of focal length on surface roughness of 1mm thin brass sheet by using assist gas O2". In this research they studied the Laser cutting characteristics including power level and focal length are investigated in order to obtain surface roughness with maximum cutting speed. The surface roughness is investigated for a laser power range of 1000-1500W and focal length 122-132, gas pressure 7 bar constant for brass materials. This paper is studied the effect of focal length on surface roughness 1 mm thin brass sheet using an oxygen as assist gas. The cutting cross section was measured surface roughness. The variation was analyzed with laser power and focal length. They use plasma detector sensor for predetermined cutting speed. The full factorial method is used for cutting speed and surface roughness. In this study they use full factorial three level design method used to optimize the process parameter. So from this article they found that Focal length is most significant factor for surface roughness of brass sheet. Improper focal length affects the surface roughness and cutting speed [1].

**K. Abdel Ghany, M Newishy**, "Cutting of 12mm thick austenitic stainless steel sheet using pulsed and CW Nd:YAG laser". In this article the work aims to evaluate the optimum laser cutting parameters for 1.2 mm austenitic stainless steel sheets by using pulsed and CW Nd:YAG laser beam and nitrogen or oxygen as assistant gases, each one separately. For cutting stainless steel by pulsed and CW Nd:YAG laser, it was shown that the laser cutting quality depends mainly on the laser power, pulse frequency, cutting speed and focus position. Increasing the frequency and cutting speed decreased the kerf width and the roughness of cut surface, while increasing the power and gas pressure increased the kerf width and roughness. Comparing with oxygen, nitrogen produced brighter and smoother cut surface with smaller kerf, although it did not prove to be economical. In CW mode, the speed can be increased to more than 8 m/min with equivalent power and gas pressure (limited by the laser system). Pulsed mode was also not economical, especially in limited frequency laser systems, where the pulse overlap should be controlled by both frequency and speed. In CW, the speed can be increased to the maximum system limit [2].

**B.D. Prajapati et. al.** "Parametric investigation of CO2 laser cutting of mild steel and hardox-400 material". In the present research, the effect of laser machine processing parameters such as laser power, gas pressure, cutting speed and thickness effect on measured response such as surface roughness. The experiment was designed according to Taguchi L27 orthogonal array with three different level of each input parameter. For result interpretation, analysis of variance (ANOVA) was conducted and optimum parameter is selected on the basis of the signal to noise ratio, which confirms the experimental result. The result indicated that cutting speed and work piece thickness play important role in surface roughness. Cutting speed and thickness of plate have high contribution on surface roughness for both materials. Laser power had less effect for surface roughness might be due to small variation in their level. Gas pressure had higher effect for cutting of mild steel and for hardox-400 had less effect. The S/N ratio suggests the optimum parameter setting for selected operating rage of experiment [3].

**A. Riveiro et. al.** "The role of the assist gas nature in laser cutting of alluminium alloys" have been studied that the process relies on the removal of the melted material with the aid of a pressurized assist gas. Among the main variables controlling the process, the assist gas type is an essential factor. This gas is normally chosen taking into account the material to be processed and the required cut quality. While the effect of the utilization of different assist gas is perfectly studied in cutting steels, the influence of the assist gas type during laser cutting of aluminum alloys is not well studied. This work presents a study on the influence of different assist gases (argon, nitrogen, oxygen and air) on the edge quality and its surface chemistry during laser cutting of a typical Al-Cu alloy. After investigation the Results indicate a clear influence of the assist gas nature on the finishing characteristics. Formation of oxides and nitrides were observed to modify the cut quality and cutting speed. Oxygen, nitrogen and compressed air react to a greater or lesser extent with the molten material generating a large amount of oxides and/or nitrides. This largely affects the cutting speed and cut quality of the obtained cuts. On the other hand, argon was arisen as the more efficient assist gas to obtain best quality results and with the higher efficiency. Then, from the point of view of quality and efficiency argon is the best choice for processing Al-Cu alloys [4].

**Arindam Ghosal et. al.** "Response surface method based optimization of ytterbium fiber laser parameter during machining of Al/Al2O3-MMC". This paper presents the investigated results on machining of Al/Al2O3-MMC by ytterbium fiber laser. The effects of the different parameters on the response characteristics are explained. A comprehensive mathematical models for correlating the interactive and higher-order influences of various machining parameters such as laser power, modulation frequency, gas pressure, wait time, pulse width on the machining performance criteria e.g., metal removal rate and tapering phenomena has been developed for achieving controlled over fiber laser machining process. The response surface methodology (RSM) is employed to achieve optimum responses i.e., minimum tapering and maximum material removal rate. The parameters wait time and modulation frequency is identified as the most significant and significant parameters for MRR. The material removal rate increases with increase of N2 gas pressure [5].

**Pradipkumar S. Chaudhary, Prof. D. M. Patel**, "Parametric effect fiber laser cutting on surface roughness in 5mm thick mild steel sheet (IS-2062)". 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 and Cutting Speed is most significant factor for Surface Roughness of Mild Steel 5mm thickness sheet [6].

**Avanish Kumar Dubey, Vinod Yadava**, "Optimization of kerf quality during pulsed laser cutting of aluminium alloy sheet". In laser beam cutting (LBC) process, the cut quality is of great importance. The quality of laser cut kerf mainly depends on appropriate selection of process parameters. Uniform kerf with minimum kerf width is of today's demand. It has been found that the kerf width during LBC is not uniform along the length of cut and the unevenness is more in case of pulsed mode of LBC. Till date, no experimental study has been done for kerf unevenness or kerf deviation along the length of cut. In present paper, two kerf qualities such as kerf deviation and kerf width have been optimized simultaneously using Taguchi quality loss function during pulsed Nd:YAG laser beam cutting of aluminium alloy sheet (0.9 mm-thick) which is very difficult to cut material by LBC process. Assist gas pressure and pulse frequency signiïňĄcantly affect the kerf quality in the operating range of process parameters. The kerf deviation and kerf width have been reduced up to some level, respectively against the initial value of kerf deviation and kerf width. The multiple S/N ratio at any conditions has been improved [7].

**Prof D. M. Patel, Dipesh Patel**. "Parametric Analysis of ytterbium: fiber laser cutting process". In this report they mainly focus on cut quality and the cut quality mainly decided by surface roughness, kerf width, and perpendicularity. The experiment was carried out on 5mm thickness M.S. plate by varying the parameter like; laser power, gas-pressure, and cutting speed. The factorial design was used for design of experiment. As per the studied they conclude that cutting speed and gas pressure is effective process parameters [8].

## III. Conclusion and Discussion

The work presented here is an overview of recent works of laser cutting process and future directions. From above discussion it can be concluded that :

1. Laser cutting process is a powerful method for cutting complex profiles and drilling holes in wide range of workpiece materials. Apart from cutting and drilling, laser cutting process is also suitable for precise machining of micro-parts. The micro-holes of very small diameters (up to 5 mm) with high aspect ratio (more than 20) can be drilled accurately using nanosecond frequency tripled lasers.
2. The performance of laser cutting process mainly depends on laser parameters (e.g. laser power, wavelength, mode of operation), material parameters (e.g. Type, thickness) and process parameters (e.g. feed rate, focal plane position, frequency, energy, pulse duration, assist gas type and pressure). The important performance characteristics of interest for laser cutting process study are HAZ, kerf or hole taper, surface roughness, recast layer, dross adherence and formation of micro-cracks.
3. The laser cutting process is characterized by large number of process parameters that determines efficiency, economy and quality of whole process and hence, researchers have tried to optimize the process through experiment based, analytical, and AI based modeling and optimization techniques for ïňĄnding optimal and near optimal process parameters but modeling and optimization of laser beam cutting with multi-objective, and with hybrid approach are non-existent in the literature.
4. This paper presents an overview of recent experimental investigations in laser cutting of various engineering materials concerned with cut quality. The main objective was to identify the most common process parameters and cut quality characteristics. The reviews show that cutting condition (laser power, cutting speed, feed, and gas pressure) for studying the cut quality. The cut quality includes surface roughness, kerf, HAZ.
5. Most experimental studies have been performed with using single assist gas. No one researcher used the combine assist gas for laser cutting process. So now we will doing experimental work with using different material or combine assist gas by adopting Taguchi experimental design.

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