Comparative Analysis of Jobs to Identify Optimum Process Parameters of Laser Cutting Machine

Mr. Vishal J. Rana[1], Mr. Dharmang H. Patel[2], Mr. Jayesh D. Ramani[3], Dr. Vineet Goel[4]

[1]*M. Tech (Mechanical) Scholar, Bhagwan Mahavir College of Engineering & Technology, Surat, Gujarat, India*
[2]*Head of Mechanical Department, Bhagwan Mahavir College of Engineering & Technology, Surat, Gujarat, India*
[3]*Head of Mechanical Department, Tapi Diploma Engineering College, Surat, Gujarat, India*
[4]*Dean, Faculty of Engineering, Bhagwan Mahavir University, Surat, Gujarat, India*

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Abstract - *Laser cutting has emerged as a versatile and efficient technology for various industries, offering precise and rapid material processing capabilities. This study going into the critical analysis of laser cutting parameters and their impact on the cutting process, aiming to optimize precision and efficiency. By considering variables such as changing in standoff distance, changing in gas pressure, changing in cutting speed etc. This analysis shows how these parameters put influence on surface roughness, kerf width, production time and power consumption. Through comprehensive experimentation and data analysis, this research aims to provide insights into the most effective parameter settings for Mild Steel material and thicknesses, ultimately contributing to the advancement of laser cutting technology. The findings presented in this analysis can guide manufacturers, engineers, and researchers in making informed decisions for improved cutting outcomes and enhanced productivity in laser cutting applications.*

Key Words: Laser Cutting, Standoff Distance, Gas Pressure, Cutting Speed, Surface Roughness, Kerf Width, Production Time, Power Consumption, Mild Steel

1. INTRODUCTION

Laser cutting is basically a CNC cutting process in which a high-powered laser is used to cut through materials as per design data. In this process, a high-density light beam is generated by stimulating lasing material with an electrical discharge, within an enclosed container. Laser cutting has become an increasingly popular method for cutting materials such as metal, plastic, wood, and glass. A wide variety of industries, including automotive and medical device industries use laser cutting because it offers a high degree of accuracy and precision.

Industry have used the set process parameters like gas pressure, cutting speed, stand-off distance, etc. to manufacture a different job of different material in laser cutting machine. In this research work, the analysis of jobs were performed by changing the laser cutting parameters and try to optimize it, which could help the industry to improve its operation and processes. Optimization in process parameters of laser cutting machine will affect the surface roughness, power consumption, kerf width and production time of prepared job. By optimizing the process parameters, manufacturing plants can reduce the incidence of errors in e.g., configuring processes, increase product quality, reduce equipment and plant downtime. All the experiments were performed at Mausam Engineering, Surat in this research.

1.1 Laser Cutting Process

Laser cutting is a non-conventional machining process that uses a laser beam to cut material. The laser beam is focused onto the material and melts or vaporizes it, leaving a clean, precise cut. Laser Beam Cutting (LBC) has become the predominant method for cutting various types of sheet materials in industries today. This advanced technique offers the ability to cut a wide range of materials, including metals, composites, and ceramics.

By delivering thermal energy through a focused laser beam, the material is heated and subsequently cut. This unique process eliminates the need for mechanical cutting force, tool wear, and vibration, making LBC ideal for cutting even hard or brittle materials. The laser beam interacts with the electrons of the material, causing some of the energy to be absorbed. This absorption results in a localized increase in temperature, which can lead to melting, vaporization, or a change in the chemical state of the material.

In cutting, a pressurized gas is used to remove the molten material from the groove. The type of auxiliary gas employed depends on the material being cut. Inert gases are used to protect the surface from oxidation, while active gases (usually oxygen) generate an intense exothermal reaction, further increasing the temperature in the cutting area.

1.2 Specifications of Laser Cutting Machine

A machine used to prepare the different jobs of mild steel contains following specifications.

Fig -1: Laser Cutting Machine

Table -1: Specification of Laser Cutting Machine

PARAMETERS	RANGE
Model Number	MT-3015
Cutting Material	M.S., S.S, G.I., AL
Application	Metal Cutting
Capacity	2 KW
Machine Type	Open Body
Machine Dimension	5000 * 3300 * 2000 mm
Working Area	3000 * 1500 mm
Phase	3 Phase
Screen	17-inch LCD
CNC System	Cypcut
Transmission mode	Rack and Pinion
Weight	4.5 ton
Worktable max. weight capacity	1000 kg
Rated Voltage	380 V
Cutting thickness range	14 mm
X- Axis travel distance	3030 mm
Y- Axis travel distance	1520 mm
Z- Axis travel distance	105 mm
Max. cutting speed	100 m/min

2. LITERATURE REVIEW

Laser cutting of aluminum alloy AlMg3, steel St37-2, and stainless steel AISI 304 was successfully performed within the tested range of parameters. Overall cut quality was good with limited imperfections. Kerf geometry was mainly affected by material type, thickness, and gas pressure. Narrower kerfs were obtained at smaller thicknesses. AlMg3 showed the widest kerfs due to its high reflectivity. Surface roughness was primarily influenced by material type and the interaction of material with cutting speed. AlMg3 exhibited the roughest cuts while AISI 304 had the smoothest. Increasing speed improved roughness for steel but worsened it for aluminum alloy. For AlMg3, low speed and high pressure is preferred. For St37-2, high speed and pressure worked best. And for AISI 304, high speed with moderate pressure gave the highest quality. [1]

The recent up gradation of newer and high strength materials has 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. There are different operating parameters which will affect different mechanical properties of the material to be cut and also quality of the cutting. These parameters are operating power, cutting speed, assist gas type, and assist gas pressure, focal point, stand-off distance and also material specific properties. [2]

Laser cutting is a non-contact, thermal process used to cut materials with high precision and accuracy. It uses a focused laser beam to melt and vaporize material along the cut path. Common laser cutting machines use CO_2 or Nd: YAG lasers. Process parameters like laser power, cutting speed, gas pressure and focus position affect cut quality. Important quality characteristics are surface roughness, heat affected zone (HAZ) and kerf width. Lower laser power and higher cutting speed reduce roughness. Higher gas pressure increases HAZ width. Laser power and cutting speed have significant effects on quality. Increasing power and decreasing speed reduces roughness. Kerf width increases with power and decreases with speed. For HAZ, results are mixed. Some studies show HAZ reduces with speed and increases with power. Others show opposite trends depending on material. [3]

Laser cutting is a thermal, non-contact process used for cutting complex profiles in materials with high precision. CO_2 lasers operate at 10.6 µm wavelength while Nd: YAG lasers operate at 1.06 µm. Important process parameters are laser power, cutting speed, and gas pressure and nozzle design. Key quality characteristics are surface roughness, heat affected zone (HAZ) and kerf width. Increasing laser power and decreasing cutting speed reduces surface roughness. Higher gas pressure increases HAZ width. Smaller nozzle diameter gives narrower kerf. Lower power and higher speed increased roughness. [4]

One of the main problems with laser cutting equipment is related to the wrong setting of cutting parameters. The mismatching of these parameters leads to a loss of cut surface quality, which is hardly re-established. This loss of quality is usually related to a burr problem. Thus, this study is aimed to improve and optimize this process using a fiber laser equipment. Three important laser cutting parameters were studied in order to investigate their importance in the cut surface quality: radiation power, cutting speed and gas pressure. So, this paper provides the work on the stainless-steel material. From this paper, it was concluded that the values recommended by the machine's manufacturer are not the optimum to get the best quality because, with less radiation power and higher cutting speed values, the laser cutting process will be optimized, allowing as well the reduction of power consumption and increase in productivity. [5]

3. DESIGN OF SAMPLE JOB

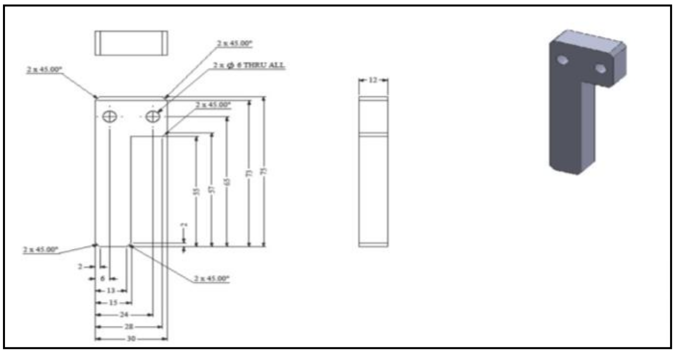

Fig -2: Design of Job

Figure 2 represents the detailed drawing of selected job which can be used to manufacture different pieces by changing the process parameter in laser cutting process.

4. PREPARATION OF DATA SETS

By varying the values of process parameters of Laser Cutting Machine, variations are obtained in the values of surface roughness, kerf width, production time and power consumption. So, optimum values can be gained by varying the values of parameters which can help the industry to increase its production rate, reduction in power consumption, more accurate production in terms of dimensional stability and reduction in the surface roughness.

Following parameters were considered in the research for variation to make different samples on laser cutting machine.

1. Standoff distance 2. Gas Pressure 3.Cutting Speed

Other parameters are used as same for all jobs. To vary the above-mentioned parameters, 27 data sets were prepared before manufacturing of job by laser cutting machine in which total 6 data sets were prepared by varying the single process parameter, 12 data sets were prepared by varying any two process parameters, 8 data sets were prepared by varying all three process parameters and 1 data set (Set No.-27) was directly taken on which industry works.

Table -2: Data Set

S.N. (Data Set)	Standoff Distance (mm)	Cutting Speed (m/min)	Gas Pressure (bar)
1	***1 mm***	1.35 m/min	0.75 bar
2	***0.6 mm***	1.35 m/min	0.75 bar
3	0.8 mm	***2 m/min***	0.75 bar
4	0.8 mm	***0.9 m/min***	0.75 bar
5	0.8 mm	1.35 m/min	***0.85 bar***
6	0.8 mm	1.35 m/min	***0.65 bar***
7	***1 mm***	***2 m/min***	0.75 bar
8	***0.6 mm***	***0.9 m/min***	0.75 bar
9	***1 mm***	***0.9 m/min***	0.75 bar
10	***0.6 mm***	***2 m/min***	0.75 bar
11	***1 mm***	1.35 m/min	***0.85 bar***
12	***0.6 mm***	1.35 m/min	***0.65 bar***
13	***1 mm***	1.35 m/min	***0.65 bar***
14	***0.6 mm***	1.35 m/min	***0.85 bar***
15	0.8 mm	***2 m/min***	***0.85 bar***
16	0.8 mm	***0.9 m/min***	***0.65 bar***
17	0.8 mm	***2 m/min***	***0.65 bar***
18	0.8 mm	***0.9 m/min***	***0.85 bar***
19	***1 mm***	***2 m/min***	***0.85 bar***
20	***1 mm***	***2 m/min***	***0.65 bar***
21	***1 mm***	***0.9 m/min***	***0.85 bar***
22	***1 mm***	***0.9 m/min***	***0.65 bar***
23	***0.6 mm***	***2 m/min***	***0.85 bar***
24	***0.6 mm***	***2 m/min***	***0.65 bar***
25	***0.6 mm***	***0.9 m/min***	***0.85 bar***
26	***0.6 mm***	***0.9 m/min***	***0.65 bar***
27	**0.80 mm**	**1.35 m/min**	**0.75 bar**

5. MANUFACTURING OF DIFFERENT JOBS

After finalize the mentioned data sets in table 2, jobs were prepared on laser cutting machine according to design with M.S. material having thickness of plate of 10 mm. All the parameters were entered as per table 2 in Cypcut software of laser cutting machine.

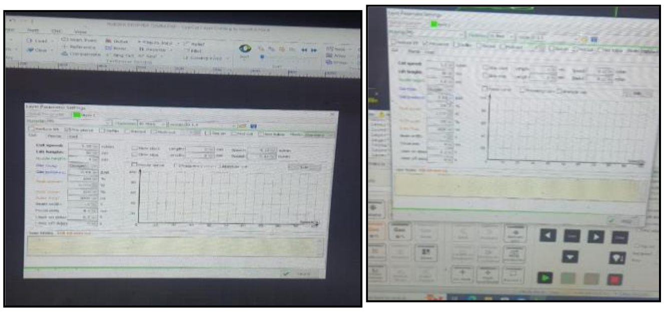

Fig -3: Setting of Process Parameters in Cypcut Software

Fig -4: Manufacturing of Jobs on Laser Cutting Machine

6. MEASUREMENT OF PROPERTIES

Different properties like production time, kerf width, power consumption and surface roughness were measured to identify the optimum value of data set.

6.1 Production Time:

Production time for manufacturing of all jobs was measured with the help of stop-watch during manufacturing of job at industry.

6.2 Power Consumption:

Power consumed during manufacturing of individual job is calculated with the help of power clamp meter in which voltage and current was measured. After that to calculate the power consumption, both are multiplied together.

$P = VI$

Where, P = Power Consumption, W

V = Voltage, V

I = Current, A

6.3 Kerf Width:

Kerf width describes the amount of taper formed between top and bottom surface of job which was measured with vernier caliper.

6.4 Surface Roughness:

The value of surface roughness was measured by surface roughness tester.

All the measured properties according to data set number is mentioned below.

Table -3: Measured Properties of Jobs

S.N. (Data Set)	Time (sec)	Power (W)	Kerf width (mm)	Surface roughness (micron)
1	30	10.80	0.10	5.057
2	29	10.50	0.18	4.370
3	27	8.10	0.18	5.811
4	33	14.00	0.14	6.115
5	29	7.80	0.10	6.340
6	30	7.68	0.20	5.420
7	28	6.42	0.64	5.810
8	32	9.90	0.14	11.670
9	31	9.54	0.20	5.550
10	28	8.96	0.08	6.120
11	29	9.30	0.20	12.320
12	30	10.98	0.14	6.570
13	32	9.36	0.12	10.410
14	31	9.28	0.26	5.490
15	30	6.08	1.26	8.250
16	37	6.63	0.38	7.500
17	28	7.00	0.22	6.510
18	35	9.20	0.28	13.700
19	29	6.52	0.96	8.420
20	27	9.96	0.40	4.750
21	36	9.76	0.18	14.20
22	36	9.54	0.12	15.050
23	27	6.12	0.14	12.340
24	29	9.10	0.10	3.090
25	35	8.76	0.28	24.090
26	33	12.06	0.08	6.320
27	30	7.75	0.12	11.100

7. ANALYSIS OF JOBS

According to the variation in process parameters like cutting speed, stand-off distance and gas pressure, values of properties i.e. production time, power consumption, kerf width and surface roughness were recorded in the table 3. After measuring all the properties, comparative analysis was carried out to determine the optimum process parameters while making a job on laser cutting machine. Analysis was performed for four different measured properties by making a graph of all properties against the job number.

7.1 Production Time Analysis:

To improve the productivity on laser cutting machine, it is necessary that production time should be as less as possible. From measured data of production time on 27 jobs, minimum time was obtained for job number of data set 3, 20 and 23.

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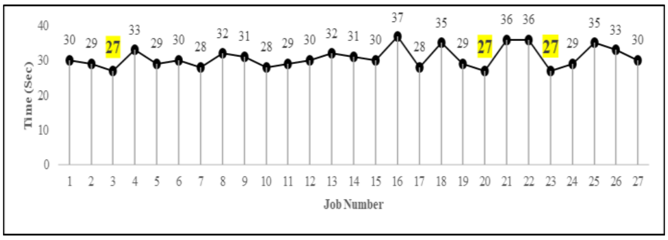

Chart -1: Analysis of Production Time

Optimum data sets are mentioned below which consumes minimum time of 27 second to prepare a job on laser cutting machine.

Table-4: Optimum Data Set for Minimum Production Time

Job No.	Standoff Distance (mm)	Cutting Speed (m/min)	Gas Pressure (bar)
3	0.8 mm	***2 m/min***	0.75 bar
20	***1 mm***	***2 m/min***	***0.65 bar***
23	***0.6 mm***	***2 m/min***	***0.85 bar***

7.2 Power Consumption Analysis:

If consumption of power is reduced while making a job on laser cutting machine then it should be beneficial for an industry. From measured data of power consumption on 27 jobs, minimum power was consumed for job number 15.

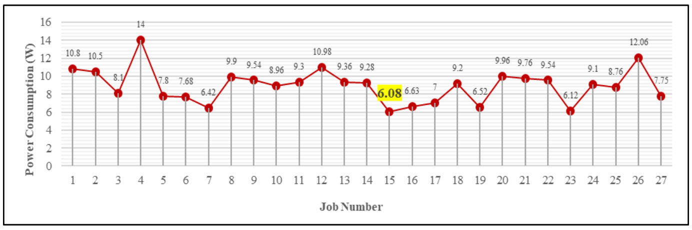

Chart -2: Analysis of Power Consumption

Optimum data set is mentioned below which consumes minimum power of 6.08 W to prepare a job on laser cutting machine.

Table-5: Optimum Data Set for Minimum Power

Job No.	Standoff Distance (mm)	Cutting Speed (m/min)	Gas Pressure (bar)
15	**0.8 mm**	**2 m/min**	**0.85 bar**

7.3 Kerf Width Analysis:

It is necessary that after manufacturing of job on laser cutting machine, dimensions of jobs should be match with design. But generally slight taper is taking place between top and bottom surface of job due to cutting of piece with high temperature laser. From measured data of kerf width for 27 jobs, minimum kerf width was generated for job number 10 and 26 having value of 0.08 mm.

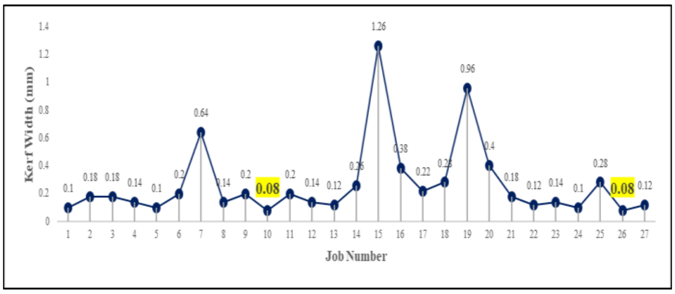

Chart -3: Analysis of Kerf Width

Optimum data sets are mentioned below which generates minimum kerf width of 0.08 mm.

Table-6: Optimum Data Set for Minimum Kerf Width

Job No.	Standoff Distance (mm)	Cutting Speed (m/min)	Gas Pressure (bar)
10	***0.6 mm***	***2 m/min***	0.75 bar
26	***0.6 mm***	***0.9 m/min***	***0.65 bar***

7.4 Surface Roughness Analysis:

After making a job on laser cutting machine, it is necessary that it provides the smoother surface i.e. jobs having lower surface roughness value for better finishing of a product. From measured data of surface roughness for 27 jobs, minimum roughness was obtained for job number 24 with 3.090 micron.

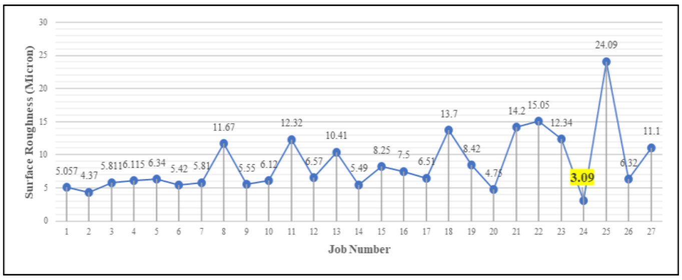

Chart -4: Analysis of Surface Roughness

Optimum data set is mentioned below which generates minimum value of surface roughness of 3.09 micron.

Table-7: Optimum Data Set for Minimum Roughness

Job No.	Standoff Distance (mm)	Cutting Speed (m/min)	Gas Pressure (bar)
24	***0.6 mm***	***2 m/min***	***0.65 bar***

7.5 Comparative Analysis of All Properties

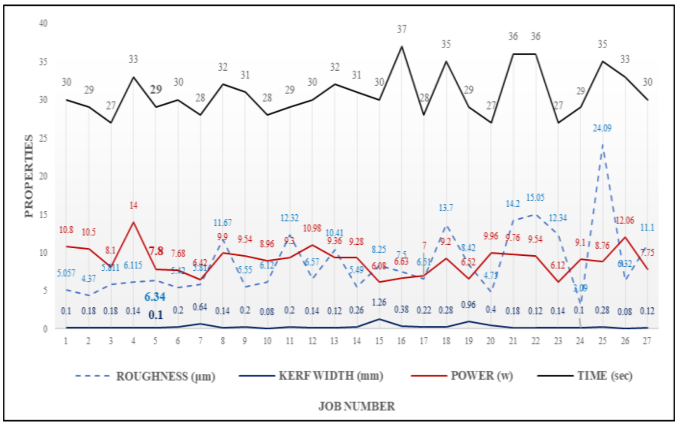

Chart -5: Comparative Analysis of All Properties

8. CONCLUSIONS

The research provides the optimum data set of jobs made up of mild steel for which value of surface roughness, production time, power consumption and kerf width will become minimum. Selection of data sets will be depended on industry according to its objective to reduce mentioned parameter.

From table 3; when the cutting speed is increased, then time for making a job is decreased. From table 4; power consumption is become optimum when cutting speed and pressure of gas have their larger value. Consumption of power is decreased by increasing the cutting speed and gas pressure. From table 5; kerf width has minimum value when the stand-off distance is decreased in both cases. From table 6; if value of cutting speed increased, gas pressure and standoff distance decreased then, job having the minimum value of surface roughness which ultimately improves the surface finish of the product.

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