Optimization of Process Parameters of Co_2 Laser Cutting Process on Ss 304 Using Taguchi

K. Lokesh[1], N.Rajesh[2], R.Lokanadham[3]
[1, 2] Dept of Mech. Engg
[2]Assoc. Professor, Dept of Mech. Engg
[3]professor, Dept of Mech. Engg
[1, 2, 3] Chadalawada Ramanamma Engineering College, Tirupathi

Abstract- *SS 304 is the one of the important materials in the group of stainless steel. Type 304 stainless steel is a 300 series stainless steel austentic. It is defined as a chromium- nickel austenitic alloy. It wide applications in surgical instruments, home appliances, architectural applications, chemical containers, heat exchangers because of its slightly higher strength and wear resistance, so it is essential to estimate the optimum cutting parameters to machine it for desired output responses. Laser Beam Machining is widely used manufacturing technique utilized to perform cutting, engraving and welding operations on a wide variety of materials ranging from metals to plastics. In this paper optimal machining parameters such as cutting speed, gas pressure, pulse width in CO2 laser cutting of SS 304 are estimated for the maximum Material Removal Rate [MRR] and for minimum Kerf Deviation [KD] by using Taguchi analysis with help of DESIGN EXPERT minitab 15 software.*

Keywords- SS 304, Taguchi, CO2 laser cutting, Material Removal Rate [MRR], Kerf Deviation [KD].

I. INTRODUCTION

Laser cutting is a thermal based non-contact process capable of cutting complex contour with high precesion and high accuracy. It involves process of heating, melting and evaporation of material in a small well defined area and capable of cutting almost all materials. The word LASER stands for Light Amplification by simulated Emission of Radation. Stated that the demand for laser cutting process is increasing in the production industries like aerospace, automobile, ship building and nuclear industries because of the ability of laser to cut materials with attracting processing speed, high productivity and ability to cut materials with complex shapes

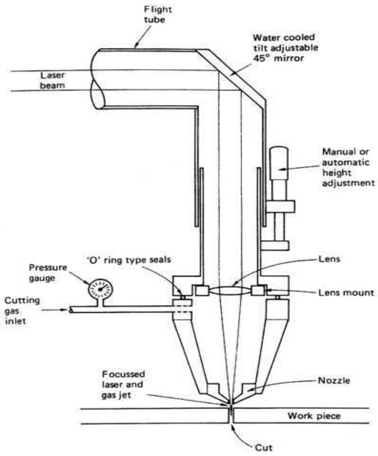

Fig.1 : Diagram of laser cutting

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 most commonly through optics. The laser optics and CNC (computer numerical control) are used to direct the material or the laser beam generated. A commercial laser for cutting materials at the material, which then either melts, burns, vaporizes away, or is involved a motion control system to follow a CNC or G-code of the pattern to be cut onto the material. The focused laser beam is directed 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.

II. METHODOLOGY

2.1 Experimental setup

From the literature survey of past researchers it is shown – that the material selection in manufacturing process is most important things as per process availability and customers requirement. There is number of material used in modern industry but steel have corrosion resistive property and high strength, so it is widely use in modern industry.

The material used to carry out experiment is SS304. In order to achieve the goal of this experimental work the cutting test were carried out in a TRUMPF- 3030- LEAN EDITION L20 CO2 LASER cutting machine at Sharp industries, Ambattur Industries, Ambattur.

Figure 2.1 Trumpf – 3030- Lean Edition L20 CO2 Laser

2.2 Full factorial design

Design of experiment: We have used factorial design, and used full factorial design. For a full factorial design, if the numbers of levels are same then the possible design N is

N=L N=9

Where L= number of levels for each factors

Table 2.2- Parameter and their levels

Process parameter	Process designation	Levels 1	Levels 2	Levels 3
Cutting speed [mm/min]	A	4	5	6
Gas Pressure [bar]	B	0.5	1	1.5
Pulse Width [ms]	C	0.2	0.3	0.4

2.3 Output Parameters

1. Metal Removal Rate [mg/min] $MRR = \frac{\text{Loss of Mass During Each Cut} \times \text{Cutting Speed}}{\text{Length of Each Cut}}$
2. Kerf deviation, KD[mm] KD=Maximum top kerf width-Minimum top kerf width

III. EXPERIMENTAL AND RESULTS

In these research laser cutting of SS 304 super alloy is carried out by using Trumpf- 3030 – Lean edition L20 CO2 Laser at by varying the input parameters.

3.1 Obtain results are shown in table:

Table 3.1 : Experimental results of Full factorial Method

Cutting Speed [mm/min]	Gas Pressure [bar]	Pulse Width [m/s]	Machining Time [sec]	MRR [mg/min]	Weight [g]	Kerf Deviation [mm]
4	0.5	0.2	0.33	0.344	0.860	0.928
4	1	0.3	0.33	0.364	0.910	0.988
4	1.5	0.4	0.33	0.368	0.920	1
5	0.5	0.3	0.33	0.430	0.860	0.988
5	1	0.4	0.33	0.435	0.870	1.044
5	1.5	0.2	0.33	0.445	0.890	0.998
6	0.5	0.4	0.33	0.516	0.860	0.996
6	1	0.2	0.33	0.522	0.870	0.984
6	1.5	0.3	0.33	0.528	0.880	0.835

3.2 Chemical Composition of SS 304

Element	Percentage [0\0]
Chromium	18 [0\0]
Nickel	8[0\0]
Carbon	0.08 [0\0]

3.2 .1 Experimental Procedure

1. Selection of objectives and variables of machining.
2. Selection of experimentation setup such as machine tool, cutting tool and cutting parameters ranges [cutting speed, gas pressure, pulse width].
3. Measuring material removal rate.
4. Writing the Observation table [MRR].
5. Observation sheet: Selected range of parameters and response entered in the Design Experts minitab software, and generate the observation sheet in the run order.
6. Data collection and analysis: According to the observation sheet analysis, optimization is done in Taguchi and the outputs [graphs, equations and optimized parameter ranges] are generated.

Fig.3.2 : Workpiece after machining

3.4 Model graphs plotted for MRR

The model graphs for Material Removal Rate [MRR] with respect to significant cutting speed ,gas pressure, pulse width Fig.3.3, Fig. 3.4 and Fig. 3.5 respectively. The Material Removal Rate [MRR] increases with increases in cutting speed. The Material Removal Rate [MRR] is increasing to increasing in gas pressure. The Material Removal Rate [MRR] increasing to increasing in pulse width.

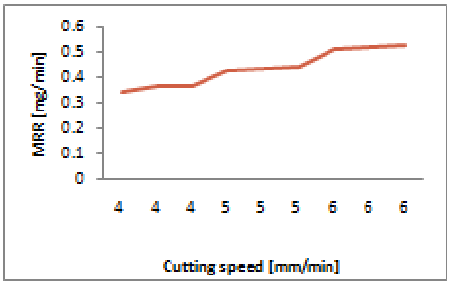

Fig.3.3 : Graph between Cutting speed and Metal removal rate [MRR]

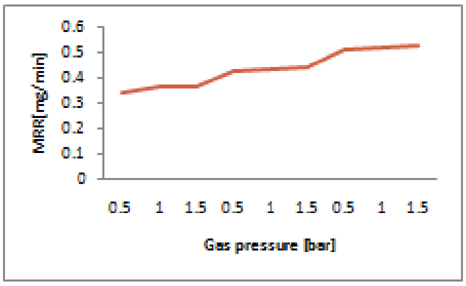

Fig.3.4 : Graph between Gas pressure and Material removal rate [MRR]

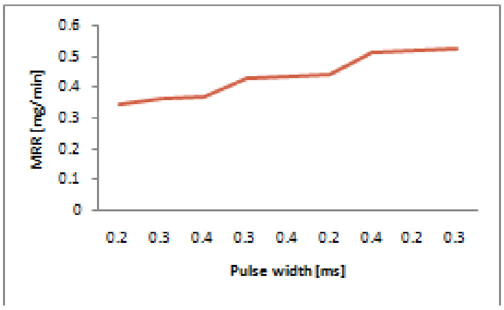

Fig.3.5 :Graph between Pulse width and Material removal rate [MRR]

3.5 Model graphs plotted for Kerf deviation

The model graphs for Kerf deviation [KD] with respect to significant factors cutting speed, gas pressure, pulse width are given in the Fig 3.6,3.7 and Fig 3.8 respectively. The Kerf Deviation [mm] increases with decreases in cutting speed. The Kerf Deviation [mm] is increasing with decreasing in gas pressure. The Kerf Deviation [mm] is increasing with decreasing in pulse width

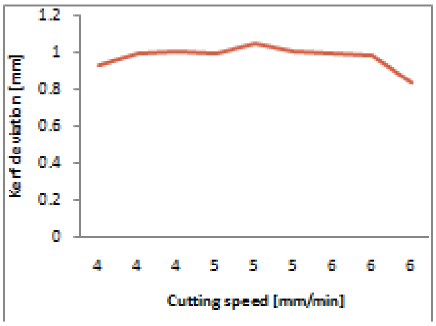

Fig.3.6 : Graph between Cutting speed and Kerf Deviation

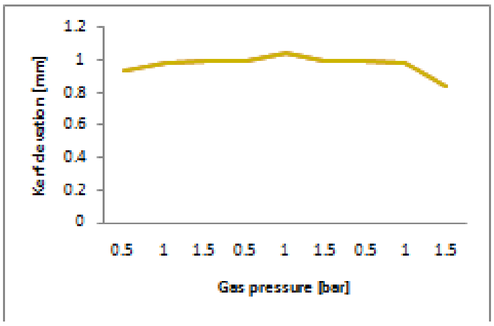

Fig.3.7 : Graph between Gas pressure and Kerf Deviation

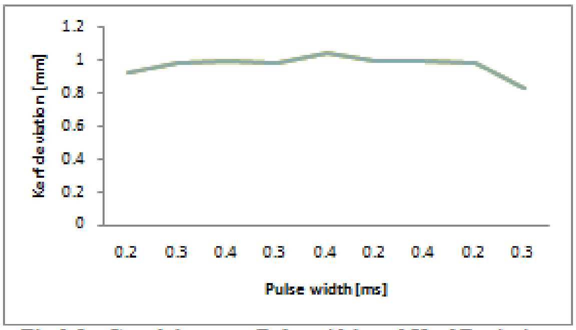

Fig.3.8 : Graph between Pulse width and Kerf Deviation

3.6 Taguchi Design

Identify the control factors and their levels.

Table 3.1 : Parameter and their levels

Factors	Levels 1	Levels 2	Levels 3
Cutting speed [mm/min]	4	5	6
Gas Pressure [bar]	0.5	1	1.5
Pulse Width [ms]	0.2	0.3	0.4

The design matrix is formed by using Taguchi full factorial design [L9 Orthogonal array]. It is given by the table 3.2 for levels 1,2,3 and parameters x1,x2,x3.

Table 3.2 : L9 Orthogonal Array

S.No	X1	X2	X3
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	3
5	2	2	1
6	2	3	2
7	3	1	2
8	3	2	3
9	3	3	1

3.5 Conducting the Matrix Experiment

In accordance with the above OA, were conducted with factors and their levels as mentioned in table 3.1. The experimental layout with the selected values of the factors is shown in Table 3.3. Each of the above 9 experiments were conducted 3 times to account for the variations that may occur due to the noise factors.

Table 3.3 : OA with Control Factors

Experiment No	Control factors		
	Cutting Speed [mm/min]	Gas Pressure [bar]	Pulse Width [ms]
1	4	0.5	0.2
2	4	1	0.3
3	4	1.5	0.4
4	5	0.5	0.3
5	5	1	0.4
6	5	1.5	0.2
7	6	0.5	0.4
8	6	1	0.2
9	6	1.5	0.3

3.6 Experimentation of Data

The Following are the experimental results of the work carried out.

3.6.1 Experimental Details

Since the objective function is Larger-the-better type of control function, was used in calculating the S/N ratio. The S/N ratios of all the experiments were calculated and tabulated as shown in Table 3.4.

Table 3.4 : Tabulated S/N ratios

Experiment No.	S/N Ratio [dB]
1	-9.26883
2	-8.77797
3	-8.68304
4	-7.33063
5	-7.23021
6	-7.03280
7	-5.74701
8	-5.64659
9	-5.54732

Taguchi Analysis: MRR [mg/min] versus Cutting speed, Gas pressure, Pulse width

Response Table for Signal to Noise Ratios
Larger is better

Level	Cutting speed [mm/min]	Gas pressure [bar]	Pulse width [ms]
1	-8.910	-7.449	-7.316
2	-7.198	-7.218	-7.219
3	-5.647	-7.088	-7.220
Delta	3.263	0.361	0.097
Rank	1	2	3

Response Table for Means

Level	Cutting speed [mm/min]	Gas pressure [bar]	Pulse width [ms]
1	0.3587	0.4300	0.4370
2	0.4367	0.4403	0.4407
3	0.5220	0.4470	0.4397
Delta	0.1633	0.0170	0.0037
Rank	1	2	3

Main Effects Plot for S/N ratios

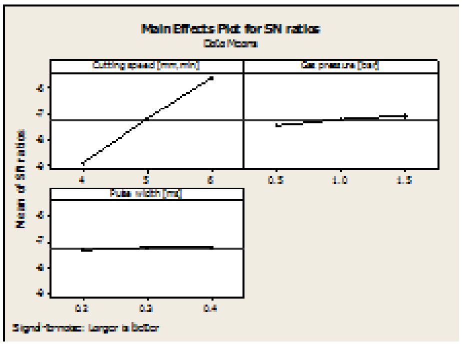

Fig.1. charts showing between parameters levels vs

Main Effects Plot for Mean

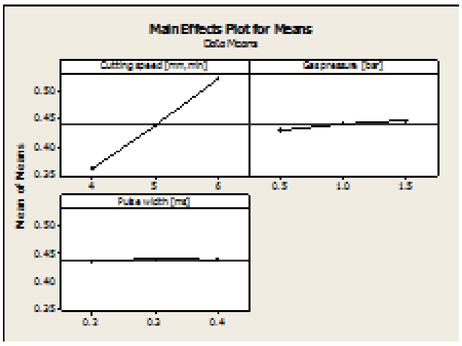

Fig.2. charts showing between parameters vs Mean

3.7 Experimentation of Data

The Following are the experimental results of the work carried out.

3.7.1 Experimental Details

Since the objective function is Larger-the-better type of control function ,was used in calculating the S/N ratio. The S/N ratios of all the experiments were calculated and tabulated as shown in Table3.5

Table 3.5 Tabulated S/N ratios

Experiment No.	S/N Ratio [dB]
1	0.64904
2	0.10486
3	0.00000
4	0.10486
5	-0.37401
6	0.1739
7	0.03481
8	0.14010
9	1.56627

Taguchi Analysis: Kerf deviation, versus Cutting speed, Gas pressure, Pulse width

Response Table for Signal to Noise Ratios
Smaller is better

Level	Cutting speed [mm/min]	Gas pressure [bar]	Pulse width [ms]
1	0.25130	0.26290	0.26884
2	-0.08392	-0.04302	0.59200
3	0.58039	0.52789	-0.11307
Delta	0.66431	0.57090	0.70506
Rank	3	2	1

Response Table for Means

Level	Cutting speed [mm/min]	Gas pressure [bar]	Pulse width [ms]
1	0.9720	0.9707	0.9700
2	1.0100	1.0053	0.9370
3	0.9383	0.9443	1.0133
Delta	0.0717	0.0610	0.0763
Rank	2	3	1

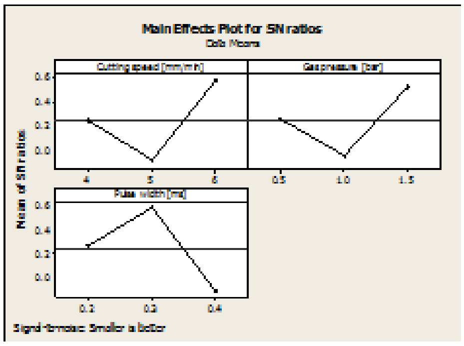

Fig - 1 charts showing parameters levels vs S/N ratio

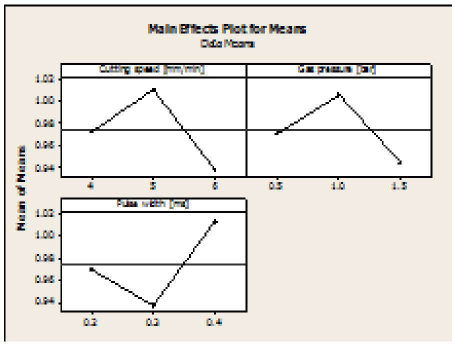

Fig -2 Charts showing parameter levels vs means

3.7.2 Full Factorial Analysis

A full factorial analysis consists of conducting experiments taking into account all the possible combination of the factors and their levels. As far as the following experiments are concerned the factors i.e; cutting speed, gas pressure, pulse width were considered at 3 different levels as shown in Table 3.6. These with the results of the fractional that was conducted using Taguchi method.

Table 3.6 Full factorial Experiment Matrix

Experiment No	Cutting speed [mm,min]	Gas pressure [bar]	Pulse width [ms]	MRR [mg/min]	Kerf Deviation [mm]
1	4	0.5	0.2	0.344	0.928
2	4	1	0.3	0.364	0.988
3	4	1.5	0.4	0.368	1
4	5	0.5	0.3	0.430	0.988
5	5	1	0.4	0.435	1.044
6	5	1.5	0.2	0.445	0.998
7	6	0.5	0.4	0.516	0.996
8	6	1	0.2	0.522	0.984
9	6	1.5	0.3	0.528	0.835

3.7.2 Comparison of full factorial analysis with Taguchi parameter design:

It is evident from the results of the full factorial analysis shown in Table 3.7 the best characteristics obtained were at MRR cutting speed 6 mm/min, gas pressure 1.5 bar, pulse width 0.4 ms and Kerf Deviation obtained were at cutting speed 5mm/min, gas pressure 1 bar, pulse width 0.4

ms. From Taguchi parameter design the optimum parameter levels obtained were also same. Thus, it can be noted that Taguchi parameter design will also give accurate results with lesser number of experiments to be performed.

Table 3.7 : Optimum values of factors and their levels

Parameter	Optimum value	
	MRR	Kerf Deviation
Cutting speed [mm/min]	6	5
Gas pressure [bar]	1.5	1
Pulse width [ms]	0.4	0.4

IV. CONCLUSIONS

The experimental work involves analysis of Metal Removal Rate [MRR] and Kerf Deviation [KD] in TRUMPF-3030-Lean Edition L20 CO_2 Laser cutting of SS 304 with Taguchi leads to the following conclusions.

1. There is common impact of cutting speed, gas pressure, pulse width on MRR. MRR increases with increase in cutting speed, gas pressure, pulse width.
2. There is common impact of cutting speed, gas pressure, pulse width on Kerf deviation. Kerf deviation increases with decreases in cutting speed, gas pressure, pulse width.
3. Optimum cutting parameters to maximum MRR are cutting speed=6 mm/min, gas pressure= 1.5, pulse width 0.4.
4. Optimum cutting parameters to minimize Kerf deviation are cutting speed=5 mm/min, gas pressure= 1, pulse width 0.4.
5. This confirmation study results indicate that the predicted values obtained by the mathematical model agree with the actual values.
6. This confirmation study results show that a dross-free cut can be observed along the Kerf edge of the sheet.
7. This study indicates the application feasibility of the proposed optimization technique for continuous improvement of laser cutting in the manufacturing industry.

V. ACKNOWLEDGEMENT

1. Dr. Reddy Babu, Prof. Dept. of Physics, Chadalawada Ramanamma Engineering College, Tirupati for providing proflometer to measure the kerf deviation. The authors express their greatful thanks to Dr. Reddy Babu.
2. Sharp Industries, Chennai for providing laser machining setup.

REFERENCES

[1] K.Rajesh,UV Muralikumar, Effect of process parameters on machinability characteristics of CO2 laser process used for cutting SS 304 stainless steels, Material Today: procedding, Volume 98 ,July 2019.

[2] Dhrupal J KOTADIYA Jayadeep M Kapopara, Parametric analaysis of parameter for laser cutting, Material Today: Procedding, Volume 5[2],5384-5390,2018.

[3] A.Prathibian, M.Chandrasekharan, Optimization of CO2 laser cutting of stainless steel for curved profile, Material Today, Volume 5, 14531-14538’2018.

[4] Mr.Umang Patel, Naveet K.Prajapati, Optimiziation of process parameters of CO2 laser cutting process on SS 304, International Journal for technological research in engineering, Volume 5,Issue 9,2347-4718 2016.

[5] Xiaoqing wang, Xibing Gong, Powder bed laser additive manufacturing of Inconel 718 parts, Engineering Manufacture, volume 231[11],1890-1903, 2017.

[6] LV Shanjin, Wang Yang, An investigation of pulsed laser cutting of titanium alloy sheet, Optices and lasers in engineering, volume 44[10], 1067-1077,2006.

[7] Roy, N:Kuar, A.S:Mitra, Submerged pulsar Nd: Yag laser beam cutting of super alloy experimental investigation, Volume 35[1-4], 151-171, 2016.