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EXPERIMENTAL INVESTIGATION AND PROCESS PARAMETERS OF CO2 LASER CUTTING ON C45- MEDIUM CARBON STEEL

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ABSTRACT

Although metal cutting operations traditionally employ mechanical or manual processes, laser cutting can be a viable, effective, and cost-efficient option for metal fabrication. This project defines mathematical models of value changes for surface roughness (Ra, µm) and Kerf width (Kw, mm) during the experimentation of laser cutting on C45 medium carbon steel using oxygen as an assist gas. The width of laser kerf and quality of the cut edges are affected by process parameters are, laser power (P), cutting speed (V), Assist gas pressure(p). The experiment was designed and carried out the basic stand of the L27 orthogonal array and subsequently, the predictive model has been developed using multiple regression analysis, Analysis of variance (ANOVA) is then carried out to find the relative influence of process parameters on Ra and Kw. After comparing the simulated data with experimental data, the regression model shows the predicting Ra and Kw with more than 92% and 94% of accuracy for the given range of input parameters. It was observed that the Laser power had more effect on rather than cutting speed and gas pressure.

Keywords: *Laser cutting, surface roughness, kerf width, ANOVA, regression.*

I. INTRODUCTION

Among various advanced machining processes, laser cutting is one of the most widely used thermal-based processes applied for processing a wide variety of materials. In laser cutting the material is melted or evaporated by focusing the laser beam on the workpiece surface. It is a high energy-density process that works quickly on complex shapes, is applicable to any type of material, generates no mechanical stress on the workpiece, reduces waste, provides ecologically clean technology, and has the ability to do work in the micro range [1].

However, Co_2 Laser cutting system on surface characteristics of the cut section in the cutting stainless steel (SS) sheet (ASTM 304). In this study, cutting parameters laser power, cutting speed and gas pressure are analyzed and optimized with consideration of workpiece surface roughness and top kerf width.It was observed that the laser power had more effect on rather than cutting speed and gas pressure [2, 3]

Laser beam cutting may be applied for the miniaturization and ultra-precision cutting and/or finishing by appropriate control of different process parameters multi-objective optimization the kerf deviation, kerf width and kerf taper in the laser cutting of Inconel-718, The comparison of optimization results to experimental results shows an improvement of 88%, 10.63% and 42.15% in kerf deviation, kerf width and kerf taper, respectively [3, 4]

The nontraditional machining process is a substantially more effective way to machine this alloy. Laser cutting is an advanced thermal machining process that can be used as an alternative to mechanical cutting process.mathematical models of value changes for surface roughness (Ra, µm) and heat affected zone width (HAZ, mm) during high-alloyed steel 1.4828 laser cutting using oxygen as an assist gas. For the definition of appropriate mathematical models, multiple linear regression analysis is used,to obtain smaller values of the Ra parameter, one should strive as much possible towards higher cutting speed desired parameters.[5]

Therefore, in the current study C45- medium carbon steel is extensively investigated with a focus on modelling of Co_2 Laser cutting machine parameters like Laser power (P), Cutting speed (V), Gas pressure (p) as input parameters while Surface Roughness (Ra) and Kerf width (kw) are observed as output responses. ANOVA and regression analysis is performed for all output responses and optimal inputs are identified for each desired response parameter.

II. EXPERIMENTAL SETUP

The experiments were conducted on CNC laser cuttingMachine AMADA Quattro FANUC AF1000E. The process to analyze the effects of the predominant process parameters, i.e., Laser power, cutting speed, gas pressure during Laser cutting operation on the required machining characteristics i.e., surface roughness, kerf top with improved quality of products. The laser cutting experimental setup is shown in Figure 4.13. Experiments were conducted usinglaser cutting Machine for C-45 medium carbon steel as a specimen material. The specifications of laser cutting Machine used in the present study are given in Tables 4.

Figure.1 Laser cutting machine setup

Table.1 Specifications of Laser cutting machine

MODEL	SPECIFICATIONS
Model	AMADA (Quattro) Japan.
Laser continuous rated output	1000 W
Maximum cutting size	1,250mm * 1,250mm (X and Y axis)
Z-axis traveling	100mm (Zaxis)
Cutting feed rate	2000mm/min (X and Y axis)
Accuracy	±0.01 mm
Max. cutting sheet Thickness	6 mm

Table.2 Chemical composition of the c-45 carbon steel

C %	Si %	Mn %	P %	S %	Cr %	Ni %
0.42-0.50	0.40	0.50-0.80	0.045	0.45	0.40	0.40

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Table.3Machining variables and their levels used in the experimentation

Symbol	Cutting Parameters	Unit	Level 1	Level 2	Level 3
LP CS GP	Laser power cutting speed V (mm/min) O2 assist gas pressures(Bar)	[W] [mm/min] [Bar]	600 1400 0.3	800 1700 0.4	1000 2000 0.5

III. MEASUREMENT OF RESPONSE PARAMETERS

The three response parameters measured after machining of laser cutting are surface roughness and kerf width.

3.1Surface Roughness

The surface roughness was measured by using a portable surface roughness tester (MitutoyoSurftest SJ-210). An average of three measurements was used as a response value in each machinedslot.

3.2 Kerf width

Kerf is defined as the width of material that is removed by a cutting process. It was originally used to describe how much material was removed by the tool. In the present study, the kerf width of each specimen is measured by using Profile projector.

IV. MODELING AND VALIDATION

In this present study laser cutting of experiment is carried out and ANOVA and multiple regression modeling are done to predicted the Ra and Kw in context of input parameters. Figure 3 and figure 4 shows the main effect plots for Ra and Kw using Minitab 17 software.

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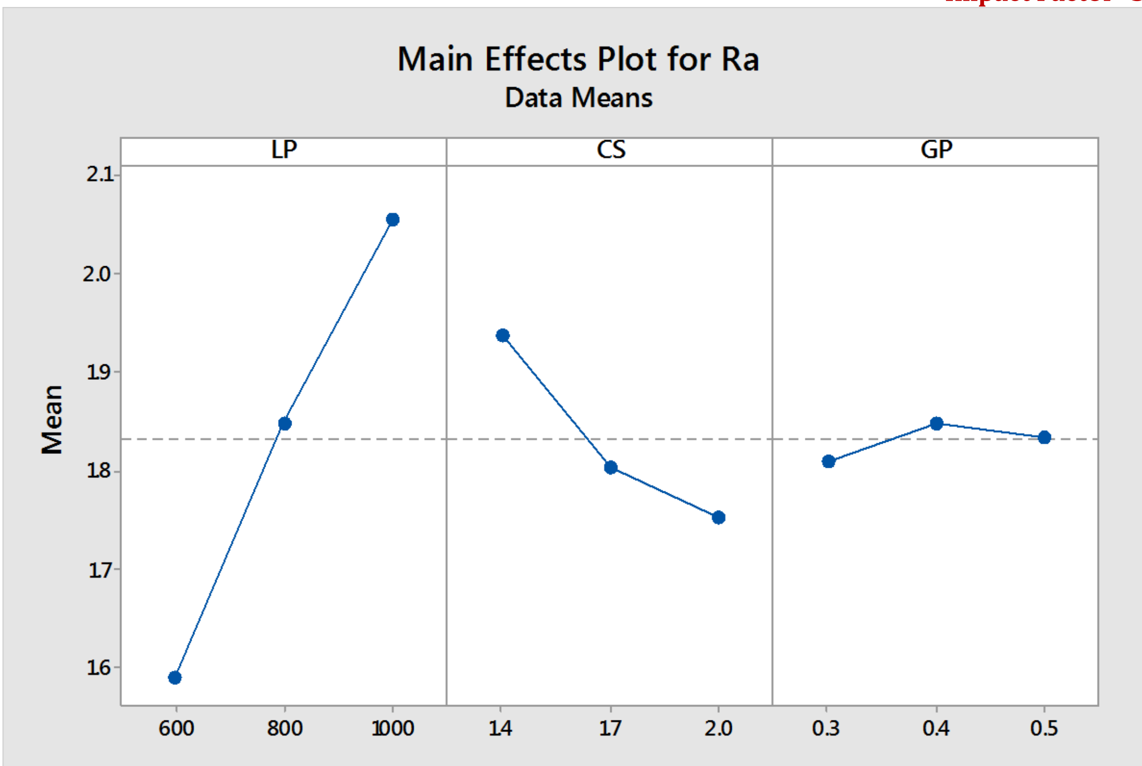

Fig.2 main effects plots for surface roughness Ra

ANOVA ofsurface roughness

Table.4 Results of ANOVA for Ra

SOURCE	DF	SEQSS	ADJ SS	ADJ MS	F	P	%Contribution
LP	2	0.97496	0.97496	0.487478	55.12	0.000	73.77
CS	2	0.16296	0.16296	0.081344	9.20	0.001	12.33
GP	2	0.00696	0.00696	0.003478	0.39	0.680	0.52
ERROR	20	0.17687	0.17687	0.008843			13.38
TOTAL	26	1.32147					

The result of Ra generated through Minitab is shown in table 2. laser power is the most prominent factor affecting the Ka with a Percentage of contribution is 73.77 % followed by cutting speed with a % of contribution is 12.33 % and Gas pressure has negligible influence on Ra % contribution is 0.52 % as illustrated in the table.

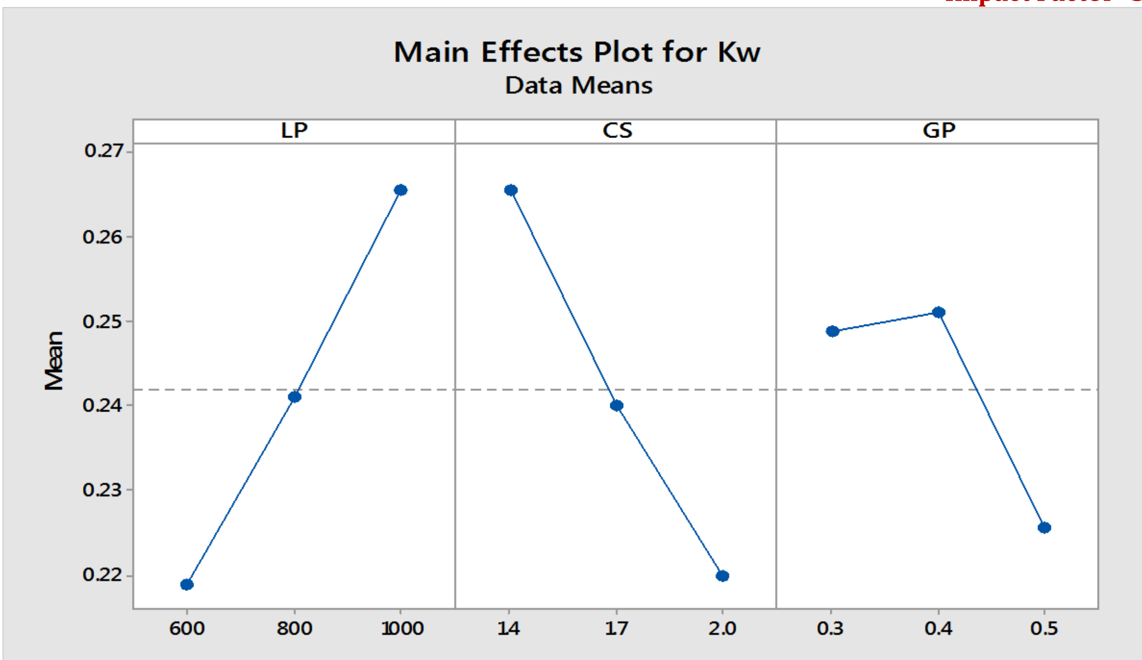

Figure.3 Main Effect plot for Kw

ANOVA of kerf width

Table.5 results of ANOVA for Kw

SOURCE	DF	Seq SS	adj SS	Adj MS	F	P	%Contribution
LP	2	0.009807	0.009807	0.004904	32.61	0.000	38.00
CS	2	0.009385	0.009385	0.004693	31.21	0.000	36.36
GP	2	0.003607	0.003607	0.001804	12.00	0.000	13.97
ERROR	20	0.003007	0.003007	0.000150			11.65
TOTAL	26	0.025807					

The result of Kw generated through Minitab 17 is shown in table 3. the effect of laser power is the most prominent factor affecting the Kw with a Percentage of contribution is 38.00 %, followed by cutting speed with a % of contribution is 36.36 % and Gas pressure has negligible influence on Kw % of contribution is 13.97 % as illustrated in the table.

V. DEVELOPED MULTIPLE REGRESSION MODELS

The mathematical model has been prepared for Ra and Kw using Multiple Regression Analysis to predict the Ra and Kw. Therefore regression tool software MINITAB 17 has been used to find the value of regression coefficients, The developedMultiple Regressionmathematical models for surface roughnessand kerf width are shown in equation (1), and (1), respectively and the R-Sq values for regression model is 92.72% and 94.22%

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Ra = 1.42 + 0.00350 LP - 2.31 CS + 3.76 GP - 0.000001 lp2 + 0.444 cs2 - 2.67 gp2 + 0.000153 lp cs - 0.00383 lp gp + 0.917 cs gp (1)

Kw = 0.409 - 0.000288 LP - 0.248 CS + 1.031 GP + 0.000000 lp2 + 0.0309 cs2 - 1.389 gp2 + 0.000153 lp cs + 0.000250 lp gp - 0.1389 cs gp (2)

VI. COMPARISON OF RESULTS

Table 3 shows the results of experimental Ra and kw and predicted Ra and kw using second regression model and figure 5 and 6 shows the comparison of results

Table 6 Experimental and predicted results of Ra and Kw

Exp. trial	Natural Factors			Experimental Results		predicted results	
	Laser Power [W]	Cutting Speed [mm/min]	Gas Pressure [bar]	Ra [µm]	Kw [mm]	Ra [µm]	Kw [mm]
1	600	1400	0.3	1.62	0.28	1.5	0.24
2	600	1400	0.4	1.65	0.26	1.59	0.25
3	600	1400	0.5	1.86	0.24	1.63	0.22
4	600	1700	0.3	1.53	0.23	1.33	0.21
5	600	1700	0.4	1.63	0.22	1.45	0.21
6	600	1700	0.5	1.57	0.23	1.51	0.18
7	600	2000	0.3	1.36	0.17	1.24	0.19
8	600	2000	0.4	1.31	0.14	1.39	0.18
9	600	2000	0.5	1.62	0.16	1.48	0.15
10	800	1400	0.3	1.98	0.29	1.74	0.24
11	800	1400	0.4	2.04	0.3	1.75	0.25
12	800	1400	0.5	1.81	0.26	1.71	0.23
13	800	1700	0.3	1.74	0.28	1.58	0.22
14	800	1700	0.4	1.86	0.24	1.61	0.23
15	800	1700	0.5	1.61	0.22	1.6	0.2
16	800	2000	0.3	1.74	0.18	1.49	0.21
17	800	2000	0.4	1.76	0.22	1.56	0.21
18	800	2000	0.5	1.92	0.24	1.57	0.18
19	1000	1400	0.3	2.15	0.28	1.89	0.24
20	1000	1400	0.4	2.23	0.26	1.82	0.26
21	1000	1400	0.5	1.81	0.29	1.7	0.24
22	1000	1700	0.3	2.13	0.27	1.74	0.23
23	1000	1700	0.4	2.08	0.29	1.7	0.24
24	1000	1700	0.5	1.91	0.25	1.61	0.22
25	1000	2000	0.3	2.04	0.24	1.67	0.23
26	1000	2000	0.4	1.92	0.25	1.66	0.23
27	1000	2000	0.5	1.94	0.26	1.59	0.2

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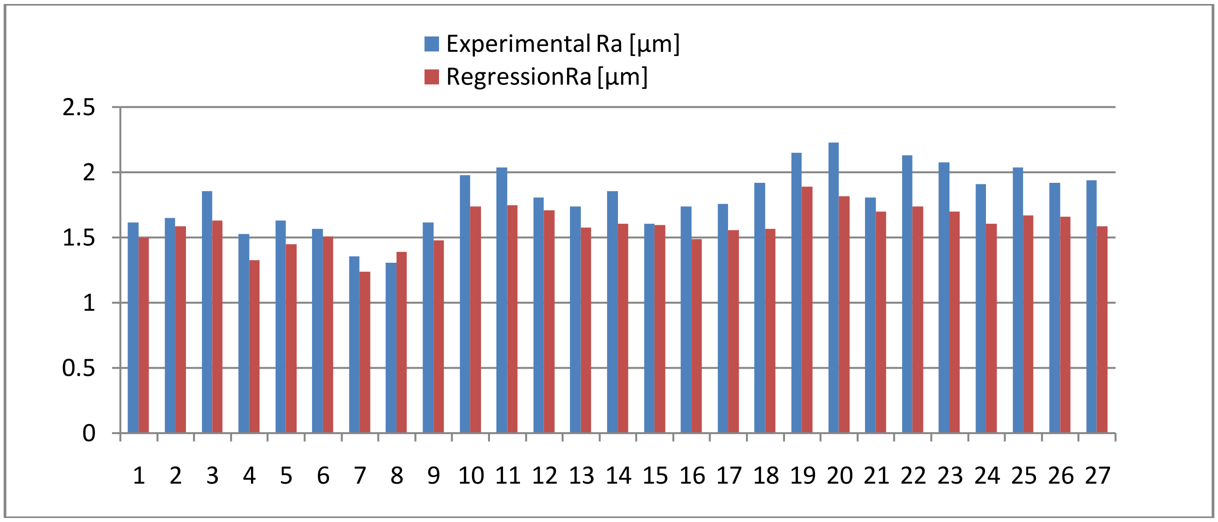

Figure.4 Comparison of Ra results

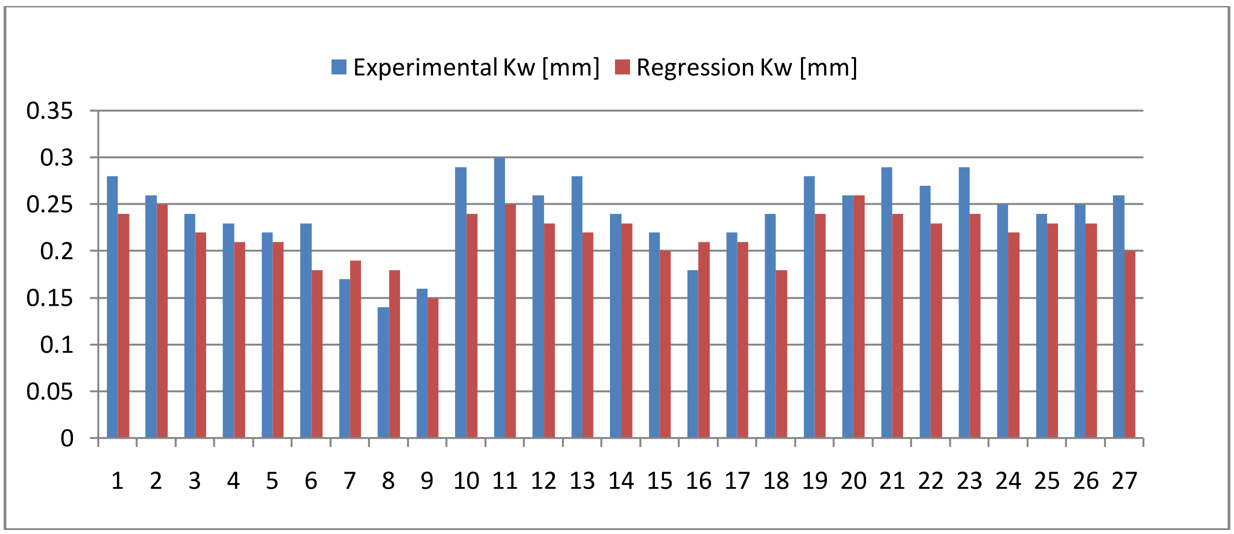

Figure.5 Comparison of Kw results

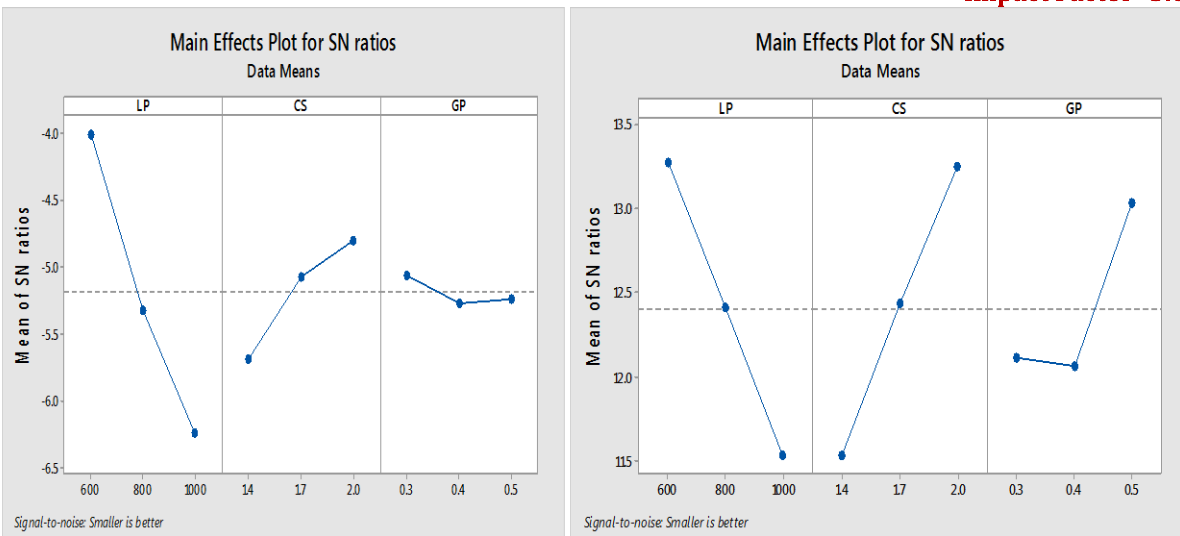

Figure.6 Signal to Noise ratio plot for Ra and Kw

Table 7 Validation of Performance Results

PARAMETER	**OPTIMUM CONDITION**
RA	LASER POWER- 600 CUTTING SPEED-2.0 GASS PRESSURE- 0.3
KW	LASER POWER- 600 CUTTING SPEED-2.0 GASS PRESSURE- 0.5

VII. CONCLUSION

The complete analysis of influence process parameters the machining was performed with laser cutting on medium carbon steel. The cutting parameters selected during experiments were laser power, cutting speed and gas pressure, while the response parameters taken is surface roughness and kerf width. Multiple regression model using MINITAB 17 has been developed from experimental data to predict the Ra and Kw.

VIII. SURFACE ROUGHNESS

- From the ANOVA table, it is found that laser power laser power is the most influential factor followed by cutting speed and gas pressure.
- Based on the experimental results, through Regression, it is found surface roughness increase in the laser power and cutting speed.
- From the main effect slots, it is found that the minimum surface roughness is obtained at Laser power 600watts, cutting speed 2000 mm/min and gas pressure 0.3 bar.
- Regression analysis was successfully applied to prediction accuracy of surface roughness is 92.72%.

IX. KERF WIDTH

- From the ANOVA table, it is found that laser power laser power is the most influential factor followed by cutting speed and gas pressure.
- Based on the experimental results, through Regression, it is found surface roughness increase in the laser power and cutting speed.

- From the main effect slots, it is found that the minimum kerf width is obtained at Laser power 600 watts, cutting speed 2000 mm/min and gas pressure 0.5 bar.
- Regression analysis was successfully applied to kerf width with the prediction accuracy is 94.22%.

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