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**Research Article**

# Experimental And Optimization Of Process Parameters On Laser Beam Machining To Minimize Kerf Taper, Surface Roughness And Dross Formation Of SS304

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**ARTICLE INFO**

**ABSTRACT**

Laser machining is a common industrial technique used to inexpensively cut a variety of materials. This study focuses on investigating the laser machining of SS304. Laser kerf width and cut edge quality were affected by process parameters such as cutting speed (V), assist gas pressure level (p), and laser power to determine how to set laser cutting parameters so that the material removal rate can be increased while accounting for practical process limitations associated with dross formation (P). For optimization, a statistical approach known as "Response Surface Methodology" (RSM) is applied. Using RSM, the effects of control factors (laser power, cutting speed, and assist gas pressure) and categorical factors (ferrous and non-ferrous material) were studied for different responses (surface roughness, Dross formation, kerf taper for straight profile) using An analysis of variance, also known as an ANOVA, was carried out to ascertain the relevance of the operating parameters on the performance qualities that were being taken into account. Further experimentation has been conducted to validate the performance of optimal parameters. The proper set of process parameters has been selected based on the findings of this investigation. To assess the influence of individual parameters on surface roughness, dross formation, and kerf taper, an ANOVA analysis was performed. Subsequently, a confirmation test was conducted to compare the projected wear rate value with the experimental data.

**Keywords:** CO2 Laser cutting, ANOVA, RSM, Kerf Geometry, Laser cutting parameters

## INTRODUCTION

Metal cutting using lasers is the most reliable technologyfor the production of industrial products. Laser beam cutting (LBC) ispopular for producing more intricate shapes in almost all materials. The commercial application of lasers involves different fields like medical, military, scientific research and industries [1].Based on wavelength the lasing mediumare classified assolid, liquid orgaseous. Ruby, Nd-Glass, Diode, He-Ne, $CO_2$, Nd-YAG, Argon ion, Dye, and Excimer lasers are the commercial lasers available for industrial material processing [2]. Due to their high powers, $CO_2$ and Nd: YAG areamong the most popular commercial lasers. The $CO_2$ laser is the earliest developed gas laser capable of producing high power in therange of 0.1 to 50kW and electrically more efficient in therange of 15–20% hence used in industries for processing thematerial [3].

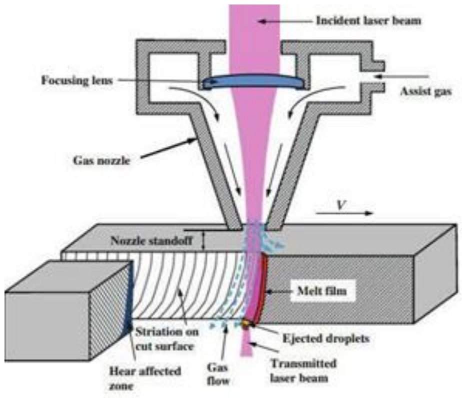



Figure1.Laser BeamCutting Process

Laser Beam Cutting (LBC) is the most common thermalenergy-basedunconventionaltwo-dimensional machining process, the desired profile is obtained either by moving the laser beam or workpiece platform controlled by a CNC system [4].There are many advantages over the other unconventional methods of cutting,like lower operating costs, higher cutting rates and producing complex geometries with exceptional quality,etc.Theme chan is min volves vaporization,melting,shearing and ablation. The laser cutting process is an advanced machining technique that uses heat. A high-density laser beam is directed at the workpiece in order to melt or evaporate it. The gas that comes out of the nozzle then blows away the molten material, leaving the cut area, or kerf, as shown in Figure 1. Non-metals like leather, ceramics, wood, and plastics are vaporised or sublimated. When the surface of the sheet metal is heated to boiling using the concentrated energy of the laser beam, the process is known as laser fusion cutting [5-8].

## LITERATURE REVIEW

Vi Nguyen et al. (2022): This study compares Taguchi's method and Response Surface Methodology (RSM) for optimizing laser cutting parameters to achieve dimensional accuracy in stainless steel. They found that RSM provides more accurate results but Taguchi's method is faster and sufficient for many applications [1].
D. Pramanik et.al. (2022): This study investigates the effect of laser power and cutting speed on the quality of laser cutting SS41 and SUS304 stainless steel using a CO2 laser system. They analyze the kerf width, melting zone, and Heat Affected Zone (HAZ) to assess the cutting quality [2].
Prashant Kumar Shrivastava et al. (2022): This study focuses on optimizing kerf deviation, width, and taper for laser cutting Inconel-718 sheets. They use a hybrid approach combining regression analysis and a genetic algorithm to achieve significant improvements in these quality aspect [3].
Muhamad Nur Rohman et.al. (2022): This study uses a deep neural network (DNN) and an improved grey wolf optimizer (I-GWO) to predict and optimize dross formation during laser cutting of electrical steel sheet. They found that cutting in oil resulted in less dross compared to using alcohol or air [4].
A D Tura et.al. (2021): This study applies a genetic algorithm (GA) with response surface techniques to improve surface roughness in laser cutting SS304 stainless steel. They analyze the effects of nitrogen gas pressure, cutting speed, and focal point placement on surface roughnes 52].
Milos Madic D. Pramanik et.al. (2020): This study develops an optimization model for CO2 laser cutting of mild steel. The model considers factors like material removal rate, dross formation, kerf width, and surface roughness to find the optimal laser cutting parameters [6].
D. J. Kotadiya et.al. (2019): This study performs a parametric analysis of laser cutting parameters for a 5 mm stainless steel sheet. They investigate the effects of laser power, cutting speed, and gas pressure on surface roughness and found that laser power has the most significant influence [7].
R. Karthikeyan et.al. (2019): This study analyzes the effect of laser power, cutting speed, and gas pressure on kerf width and kerf ratio during laser cutting of mild steel. They found that laser power is the most crucial factor for minimizing kerf width [8].
Aniket Jadhav et.al. (2019): This study investigates the effect of laser power, cutting speed, and gas pressure on the surface roughness of laser-cut AISI 304 stainless steel. They determine that both laser power and gas pressure have a significant impact on surface roughness [9].
K. Rajesh et.al. (2019): This study investigates the influence of cutting speed, assist gas pressure, and laser power on kerf width and surface roughness during CO2 laser cutting of SS-304 stainless steel with nitrogen assist gas. They used an L27 orthogonal array and regression analysis to identify the most significant factors and develop a model to predict kerf width and surface roughness [10].
R.S. Barge1et.al. (2019): This article provides a general overview of laser beam machining (LBM) and the importance of optimizing process parameters for achieving desired output quality. It highlights the impact of

input parameters on cut quality and the need for advancements in minimizing the heat-affected zone and improving micromachining precision [11].
Dinesh Patidar et al. (2018): This study focuses on CO2 laser cutting of various steel grades. It explores the effects of the cutting process on material properties and the factors responsible for these changes. The authors discuss common optimization approaches used to minimize defects and the Heat Affected Zone (HAZ) during laser cutting. They emphasize the importance of microstructural analysis for understanding failure points and finishing requirements. The study also highlights various laser cut quality characteristics that can be optimized during single and multi-objective optimization processes [12].
R. S. Rana et.al. (2018):Similar to Dinesh Patidar et al. (2018), this study emphasizes the importance of laser cutting for high-strength steels and explores the impact of the process on material characteristics. It highlights the need to understand the factors influencing these changes[13].
M. Baluljeben et al. (2018): This study focuses on predicting surface roughness (Rq) during laser cutting of mild steel with oxygen assist gas. They investigate the influence of laser power and cutting speed and develop a model using ANOVA to predict surface roughness. The study identifies laser power and cutting speed as the most critical factors affecting surface roughness.[14].

### Focus of This Paper:Key Insights Revealed

This paper will investigate the optimization of laser cutting parameters for SS304 stainless steel, building upon the existing research on process control and quality characteristics. While Response Surface Methodology (RSM) has been established as a valuable tool for optimizing laser cutting, there is an opportunity to delve deeper into understanding the influence of laser cutting parameters on a wider range of factors. This research will explore how RSM can be used to optimize cutting speed for increased material removal rate while simultaneously minimizing dross formation, a crucial factor for process efficiency and material waste reduction. Additionally, we will consider the impact of laser cutting parameters on surface finish characteristics beyond just roughness, potentially including surface topography or adhesion properties, depending on their relevance to the targeted applications. By incorporating these aspects into the optimization process, this paper aims to establish a more comprehensive approach to laser cutting parameter selection for SS304, ultimately leading to improved process efficiency, material utilization, and product quality.

## MATERIAL AND METHODS

### Methodology of Experiment

There are many ways to improve the way a product, process, or operation is made. There are a variety of approaches one can take in order to achieve the best possible surface roughness, kerf taper anmd Dross. It is sometimes required to combine a large number of approaches in order to obtain statistically significant results can improve conclusions and suggestions. DOE is a very good way to find out what the effects of parameters are because it changes several parameters at once. When more parameters are investigated, it becomes necessary to create an increasing number of novel combinations. As the DOE is unable to manage each factor independently, it instead relies on numerical data. While using the one variable at a time (OVAT) method, just one parameter is modified at a time while all of the other parameters remain unchanged. This continues till the influence of a single parameter is determined.
It is a very accurate way to figure out what happens when you change the value of each parameter. It was found that reinforcement, load, and temperature had the most effect on the surface roughness, kerf taper anmd Dross. Using observations, Finding the optimal values for the process parameters required the optimization method. To find optimal range of parameter for the optimization research, an OVAT analysis was done.
ANOVA determined how each parameter affects output. Second-order regression equations are used for RSM. Three design points comprise a face-centered CCD:
(a) two-level factorial/fractional factorial design points;
(b) axial points (also known as star points) and
(c) centre points.
Six centre points are repeated to measure experimental error or pure error. The central composite design sample size is 2k + 2k + 6 for k parameters. 2k star points and 3 centre points are added to the 2k full factorial. k = 3 yields a 17-design-point block. 2k's design.

### Experimental Machine Selection

All the experiments were conducted at Marathwada Auto Cluster, P-174, Waluj MIDC area, Waluj, Aurangabad, M.H., India. Marathwada Auto Cluster understands today's industrial requirements of productivity, efficiency and quality. Taking care of all the aspects MAC has installed a 3D laser Machine specially designed to meet needs of Industrial requirements of Marathwada region.

Figure 2. Laser BeamMachine

Table1. LBM Specifications.

| | |
|---|---|
| **Make & Model** | Prima Machines, Italy (Domino 400 CP) |
| **Work Area** | 3000 mm (X) X 1500mm (Y) X 400 mm (Z)<br>A-360° B+ 1350 |
| **Axis Speed** | The X and Y axes move at 100 m/min, and the Z axis moves at 50 m/min.<br>A, B 5400/s (1.5 rev per second) (1.5 rev per second) |
| **Laser source** | CO2 4000 w |
| **Cutting Capacity** | M.S. Max Thickness 20mm,<br>S.S. Max Thickness 12 mm,<br>Al Max Thickness 8mm |

## Selection of material

### Stainless Steel

The most widely used stainless steel is AISI 304. It has the widest range of applications and is used more often than any other stainless steel. It can be moulded and held in place quite well. AISI 304 may be deep drawn without intermediate tempering thanks to its consistent austenitic structure. This has made it the most popular grade for making drawn uncontaminated parts like sinks, pots, and pans. For these kinds of uses, "304DDQ" (Deep Drawing Quality) versions are often used. SS 304 can be easily bent or rolled into many different shapes for use in the industrial, scientific, and transportation fields. AISI 304 also has great qualities for holding things together. After joining thin pieces together, there is no need to heat them up after the weld. The austenitic structure also makes these grades very strong, even in cold temperatures.

The experiments are carried out on the SS304 the specimen shape is in the form of cuboids with a length 20 mm, width 20 mm and thickness 6 mm

Figure 3: SS304 Specimen

## RESULTS AND DISCUSSION

Most of the time, you look at the S/N ratio or main effectplotsof means to figure out how assist gas pressure, cutting speed and laser power affect the surface roughness, kerf taper and Dross formation of the output. Design expert software have been used for this purpose. ANOVA and a linear regression model were used to determine how each parameter impacts output response.

### RSM Experimentation

RSM generates second-order regression equations that relate response characteristics and process variables. by adding a third level, If, on the other hand, the quality factor is very important, you need to look at three level factors. We can fit a quadratic function with three levels. When we use four levels, we can also fit a cubic function. Using a software, the surface roughness (Ra), kerf taper (Kf) and Dross formation (Br) for each experimental run is calculated

RSM designs make it possible for us to estimate interaction effects and even quadratic effects, and as a result, they provide us with an understanding of the (local) shape of the response surface that is being investigated. An RSM issue involving three levels and three variables is said to have a CCD design if it has the highest efficiency possible. In addition, the number of needed runs is lower as compared to a system that utilises a central composite. The RSM CCD design allows for the investigation of the impact of input parameters and their interplay on output characteristics such surface roughness, kerf taper, and Dross production. The range of acceptable input parameters is displayed as a factor between its lowest and maximum values.

**Table 2**. Experimental matrix and Output response table

| Run | Factor | | | Response | | |
|---|---|---|---|---|---|---|
| | Cutting Speed (mm/min) | Gas Pressure (bar) | Laser Power (watts) | SR (Ra) | kerf taper (Degree) | Dross (mm) |
| 1 | 3500 | 9 | 3000 | 2.997 | 1.221 | 0.289 |
| 2 | 3500 | 8 | 2500 | 3.602 | 1.215 | 0.315 |
| 3 | 3500 | 7 | 3000 | 3.015 | 0.899 | 0.296 |
| 4 | 4500 | 6 | 2500 | 2.915 | 1.119 | 0.218 |
| 5 | 4500 | 9 | 2500 | 4.114 | 1.084 | 0.282 |
| 6 | 4500 | 8 | 2000 | 2.873 | 1.005 | 0.257 |
| 7 | 5500 | 9 | 2000 | 3.393 | 0.832 | 0.228 |
| 8 | 4500 | 8 | 2500 | 3.289 | 0.916 | 0.256 |
| 9 | 3500 | 9 | 2000 | 3.716 | 1.004 | 0.271 |
| 10 | 4500 | 8 | 2500 | 3.016 | 0.918 | 0.257 |
| 11 | 5500 | 7 | 3000 | 4.148 | 0.837 | 0.221 |
| 12 | 5500 | 9 | 3000 | 3.948 | 0.806 | 0.245 |
| 13 | 3500 | 7 | 2000 | 3.105 | 0.823 | 0.318 |
| 14 | 4500 | 8 | 3000 | 4.015 | 0.998 | 0.226 |
| 15 | 5500 | 8 | 2500 | 3.689 | 1.259 | 0.301 |
| 16 | 4500 | 8 | 2500 | 3.244 | 0.905 | 0.258 |
| 17 | 3500 | 9 | 2000 | 3.368 | 1.023 | 0.324 |

## Selection of an adequate model

Lack of fit test for surface roughness, kerf taper, and Dross to determine whether the model is adequate. For this test to demonstrate that the model is fit, it must reveal a little mismatch. To evaluate the fit of each polynomial model, the test for lack of fit compared residual error to replicated design point error. Residual error larger than pure error suggests that residuals may be reduced via improved modelling. According to Tables 3, 4, 5, there was no fit test for the SR, Kf, or Br. If the p-value is larger than 0.05, the model does not match the response data, but it may still be used with 95% confidence to predict the response parameter.

**Table 3** Lack of fit test for Surface roughness

| **Source** | **Sum of Squares** | **df** | **Mean Square** | **F-value** | **p-value** | |
|---|---|---|---|---|---|---|
| Linear | 0.013 | 11 | 1.204E-003 | 0.91 | 0.6327 | |
| 2FI | 8.313E-003 | 8 | 1.039E-003 | 0.79 | 0.6687 | |
| Quadratic | 4.092E-003 | 5 | 8.185E-004 | 0.62 | 0.7124 | Suggested |
| Cubic | 3.179E-004 | 1 | 3.179E-004 | 0.24 | 0.6724 | Aliased |
| Pure Error | 2.645E-003 | 2 | 1.322E-003 | | | |

**Table 4** Lack of fit test for Kerf Taper

| **Source** | **Sum of Squares** | **df** | **Mean Square** | **F-value** | **p-value** | |
|---|---|---|---|---|---|---|
| Linear | 0.060 | 10 | 6.026E-003 | 1.84 | 0.3393 | |
| 2FI | 0.042 | 7 | 6.061E-003 | 1.85 | 0.3301 | |
| Quadratic | 0.025 | 4 | 6.290E-003 | 1.92 | 0.3092 | Suggested |
| Cubic | 0.000 | 0 | | | | Aliased |
| Pure Error | 9.818E-003 | 3 | 3.273E-003 | | | |

**Table 5** Lack of fit test for Dross

| **Source** | **Sum of Squares** | **df** | **Mean Square** | **F-value** | **p-value** | |
|---|---|---|---|---|---|---|
| Linear | 0.013 | 11 | 1.204E-003 | 0.91 | 0.6327 | |
| 2FI | 8.313E-003 | 8 | 1.039E-003 | 0.79 | 0.6687 | |
| Quadratic | 4.092E-003 | 5 | 8.185E-004 | 0.62 | 0.7124 | Suggested |
| Cubic | 3.179E-004 | 1 | 3.179E-004 | 0.24 | 0.6724 | Aliased |
| Pure Error | 2.645E-003 | 2 | 1.322E-003 | | | |

"Lack of Fit Tests": Want to selected model to have insignificant lack of fit.

## Analysis of variance (ANOVA)

ANOVA analyses the outcomes. The F-value compared model and residual variance (sum of square ratio). If variance values are closed, the model or factor is less likely to affect output response (an F-value near to 1) Significant process variables for the response parameters have p-values below 0.05.

**Table 6**ANOVA result for Surface roughnss

| Source | Sum of Squares | df | Mean Square | F-value | p-value | |
|---|---|---|---|---|---|---|
| Model | 2.70 | 9 | 0.30 | 6.17 | 0.0127 | Significant |
| A- Reinforcement(%) | 0.035 | 1 | 0.035 | 0.73 | 0.4226 | |
| B- Load (N) | 0.16 | 1 | 0.16 | 3.34 | 0.1105 | |
| C- Temperature (watts) | 0.042 | 1 | 0.042 | 0.87 | 0.3831 | |
| AB | 5.408E-003 | 1 | 5.408E-003 | 0.11 | 0.7486 | |
| AC | 0.063 | 1 | 0.063 | 1.30 | 0.2913 | |
| BC | 0.069 | 1 | 0.069 | 1.42 | 0.2719 | |
| $A^2$ | 1.58 | 1 | 1.58 | 32.41 | 0.0007 | |
| $B^2$ | 0.18 | 1 | 0.18 | 3.78 | 0.0930 | |
| $C^2$ | 0.074 | 1 | 0.074 | 1.53 | 0.2563 | |
| Residual | 0.34 | 7 | 0.049 | | | |
| Lack of Fit | 0.11 | 5 | 0.021 | 0.18 | 0.9441 | Non Significant |
| Pure Error | 0.23 | 2 | 0.12 | | | |
| Core Total | 3.04 | | | | | |

If the Model F-value is more than 6.17, then the model is statistically significant. The possibility that such a huge "Model F-Value" was created purely by chance is just 1.27 percent.
Unfortunately, we can't tell fit from mistake since the "Lack of Fit F-value" is just 0.19. A "Lack of Fit F-value" of this magnitude is 94.41% likely to be attributed to random chance. We can tolerate a little size difference. The results the model predicts must be reliable.

**Table 7**ANOVA result for Kerf taper

| Source | Sum of Squares | df | Mean Square | F-value | p-value | |
|---|---|---|---|---|---|---|
| Model | 0.20 | 9 | 0.066 | 5.8 | 0.037 | significant |
| A- Reinforcement(%) | *0.016* | *1* | *0.016* | *0.81* | *0.3983* | |
| B- Load (N) | *0.061* | *1* | *0.061* | *3.03* | *0.1254* | |
| C- Temperature (watts) | *0.015* | *1* | *0.015* | *0.77* | *0.4088* | |
| AB | *0.017* | *1* | *0.017* | *0.85* | *0.3874* | |
| AC | *2.349E-003* | *1* | *2.349E-003* | *0.12* | *0.7423* | |
| BC | *0.043* | *1* | *0.043* | *2.17* | *0.1845* | |
| $A^2$ | *0.019* | *1* | *0.019* | *0.94* | *0.3651* | |
| $B^2$ | *8.706E-003* | *1* | *8.706E-003* | *0.43* | *0.5311* | |
| $C^2$ | *0.066* | *1* | *0.066* | *3.28* | *0.1130* | |
| Residual | 0.14 | 7 | 0.020 | | | |
| Lack of Fit | *0.10* | *4* | *0.025* | *1.86* | *0.3194* | Not significant |
| Pure Error | *0.040* | *3* | *0.013* | 1 | | |
| Core Total | *0.34* | 16 | | | | |

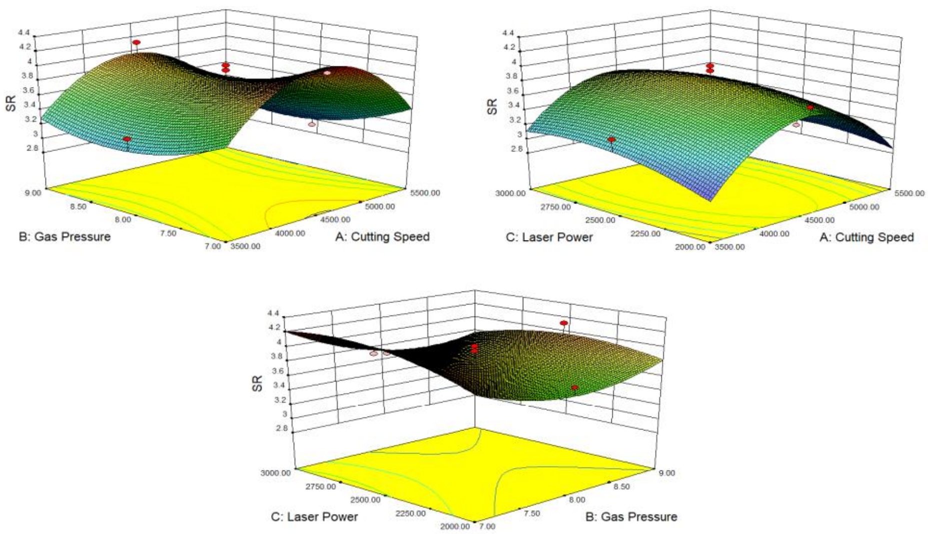
**Table 6** ANOVA result for Dross

| Source | Sum of Squares | df | Mean Square | F-value | p-value | |
|---|---|---|---|---|---|---|
| Model | 0.016 | 9 | 1.744E-003 | 3.77 | 0.0470 | Significant |
| A- Reinforcement(%) | *7.611E-004* | *1* | *7.611E-004* | *1.64* | *0.2405* | |
| B- Load (N) | *3.489E-003* | *1* | *3.489E-003* | *7.54* | *0.0287* | |
| C- Temperature (watts) | *1.852E-007* | *1* | *1.852E-007* | *4.003E-004* | *0.9846* | |
| AB | *1.201E-004* | *1* | *1.201E-004* | *0.26* | *0.6261* | |
| AC | *2.101E-004* | *1* | *2.101E-004* | *0.45* | *0.5220* | |
| BC | *4.753E-003* | *1* | *4.753E-003* | *10.27* | *0.0150* | |
| $A^2$ | *3.286E-004* | *1* | *3.286E-004* | *0.71* | *0.4272* | |
| $B^2$ | *6.283E-003* | *1* | *6.283E-003* | *13.58* | *0.0078* | |
| $C^2$ | *8.301E-004* | *1* | *8.301E-004* | *1.79* | *0.2223* | |
| Residual | 3.239E-003 | 7 | 4.627E-004 | | | |
| Lack of Fit | *2.934E-003* | *5* | *5.869E-004* | *3.85* | *0.2188* | Non Significant |
| Pure Error | *3.047E-004* | *2* | *1.523E-004* | | | |
| Core Total | 0.019 | 16 | | | | |

## Development of regression model

Using Expert Design v13 software, a regression model Inputting experimental parameters into the regression equation, one may predict the values for the SR, Kf, Br at all levels of the research parameters. A graph also shows that the values of output response predicted and those that response measured match up. With the help of design expert v13 software, a mathematical model for cutting speed, gas pressure and laser beam is made, and regression analysis is used to get a predicted value for SR, Kf, Br.

Surface Roughness (SR);

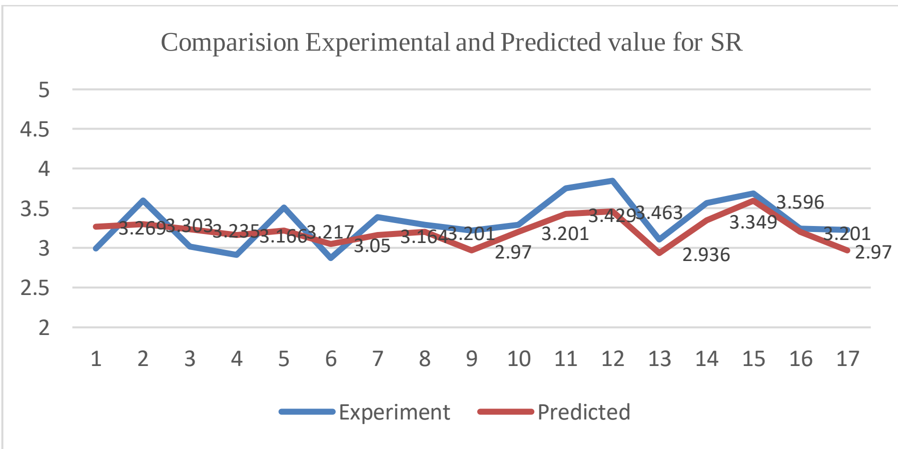



**Graph1:**3D plotsfor theSurface roughness

**Table 7**Regressionmodel summary forSR

| | | | |
|---|---|---|---|
| Std.Dev. | 0.22 | $R^2$ | 0.881 |
| Mean | 3.44 | Adjusted$R^2$ | 0.7442 |
| C.V.% | 6.42 | Predicted$R^2$ | 0.5903 |
| | | AdeqPrecision | 8.222 |

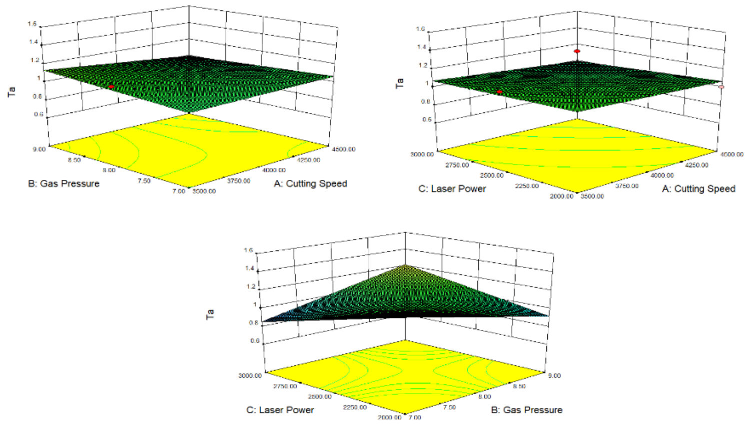
R2 describes the extent to which input parameters account for the variance in output/predicted response. Thus, the greater the R2, the more variance can be described by the input parameters, and the better the model. Nevertheless, the issue with R2 is that it remains constant or increases when additional factors are added, even if they have no correlation with the output response. Adjusted R2 is used to alleviate this issue. Modified R2 penalises the addition of parameters that do not enhance the model. Adjusted R2 values are always larger than or equal to R2 values.




**Graph:2** The comparison between experimental and predicted value of SR

Less than 10% difference was detected between the SR values computed using the regression equation and the experimental results for each encounter. Thus, we may assert that the established regression equation is valid. Graph 2 illustrates the experimental and expected values computed using the regression equation. CCD design and ANOVA statistical analysis provide.

Kerf Width (Kf):Kerf taper is a unique and unpleasant geometric characteristic of laser beam machines. It is the angle that, under standard conditions, runs from 0.1° to 2 and is measured in degrees.




**Graph:3**3D plotsfor thekerf taper

**Table8** Regression model summary for kerf taper

| | | | |
|---|---|---|---|
| Std.Dev. | 0.12 | $R^2$ | 0.2763 |
| Mean | 1.05 | Adjusted$R^2$ | 0.1093 |
| C.V.% | 11.71 | Predicted$R^2$ | -0.3321 |
| PRESS | 0.36 | AdeqPrecision | 4.714 |

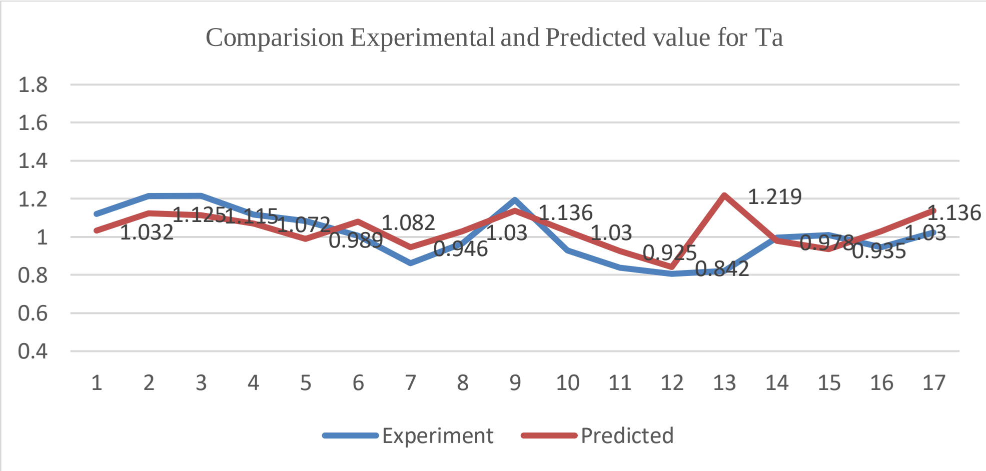
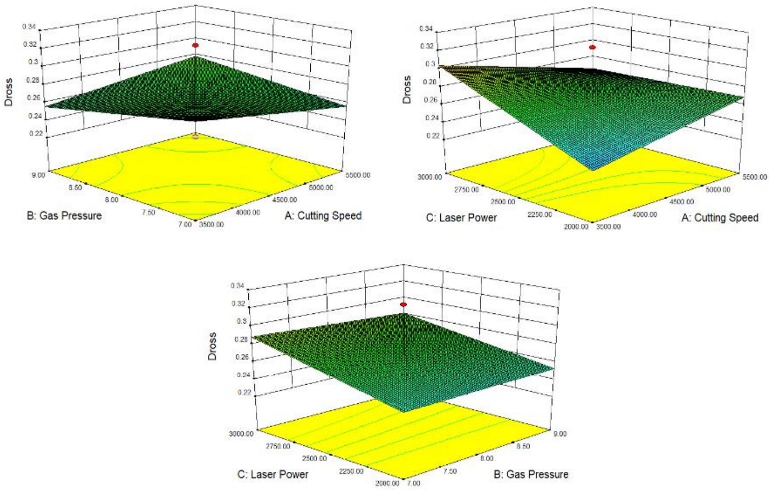



Figure The comparison between experimental and predicted value of kerf taper

Dross formation (Bf):Dross is the residual softening that remains adhered to the face of the cut edge after the cutting activity has concluded. For some beam/material combinations, dross is insignificant, such as when a $CO_2$ laser is used to cut steel. Yet, when cutting heavier steel pieces, dross may function as a retardant.




**Graph:5**3D plots*for t*heDross

**Table9** Regression model summary for Dross

| | | | |
|---|---|---|---|
| Std.Dev. | 0.034 | $R^2$ | 0.3940 |
| Mean | 0.27 | Adjusted$R^2$ | 0.0304 |
| C.V.% | 12.79 | Predicted$R^2$ | -0.4414 |
| PRESS | 0.028 | AdeqPrecision | 4.384 |

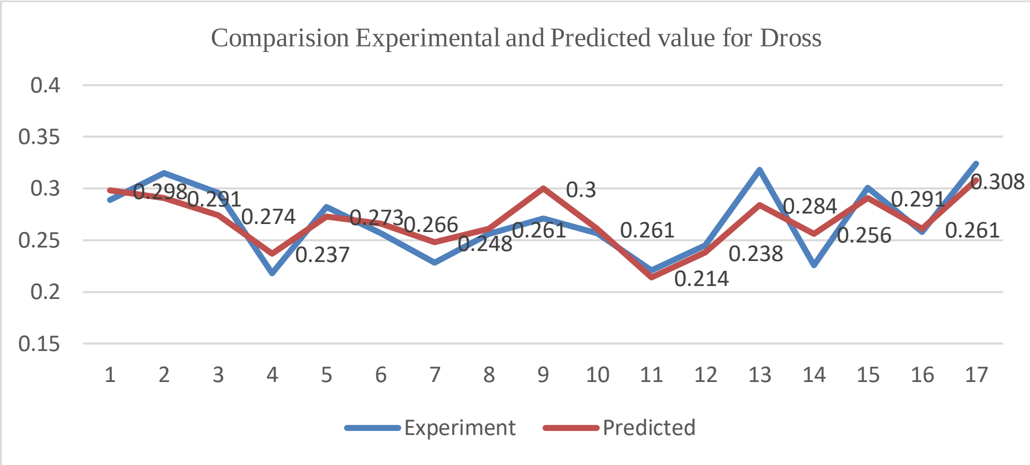



**Figure 4**. Thecomparisonbetweenexperimental andpredictedvalueofDross

## Confirmation experiment

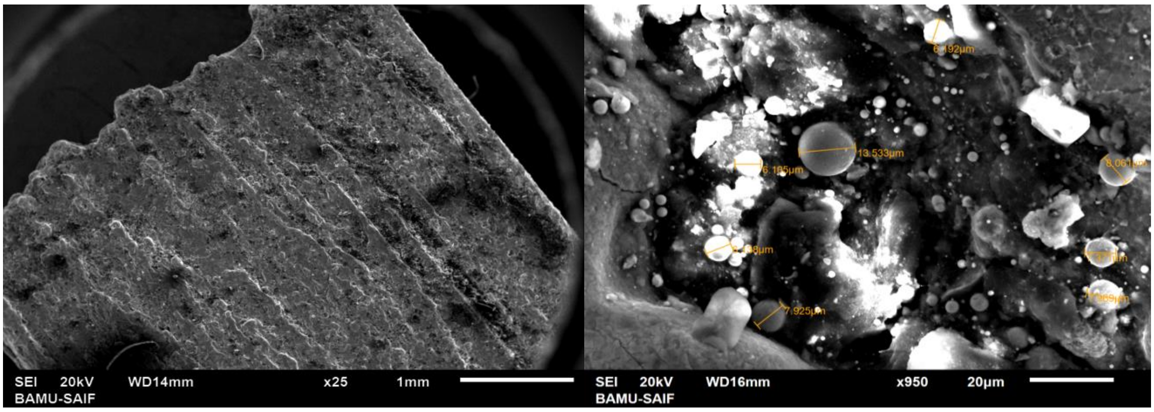
Using the identical experimental setup for the Cutting speed, Gas pressure, and Laser power, a confirmation test is conducted to ensure that the desired result was attained. Table 10 displays the outcomes of the Confirmation experiment with regard to output response.Table;10 Confirmation experiment result

| Parameter | Experimental value | Predicted value | Error % |
|---|---|---|---|
| SR (Ra) | 2.821 | 3.083 | 8.49 |
| Kerf taper (degree) | 0.806 | 0.842 | 4.27 |
| Dross (mm) | 0.209 | 0.219 | 4.54 |

The confirmation experiment is undertaken with the parameters set to the optimal levels advised by the design expert v13 programme, and the resultant SR, Kf, and Br values are compared to the value predicted by the regression model. For SR, Kf, and Br, the experimental result deviates from the expected result by 8.49%, 4.27%, and 4.54%, respectively. This indicates a correlation between the experimental value and the estimated value.

## WornSurface (SEM)Analysis

Scanning Electron Microscope images are taken at central Facility, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad.
SEM images of worn surfaces of specimens were taken at different concentrations of sizes.



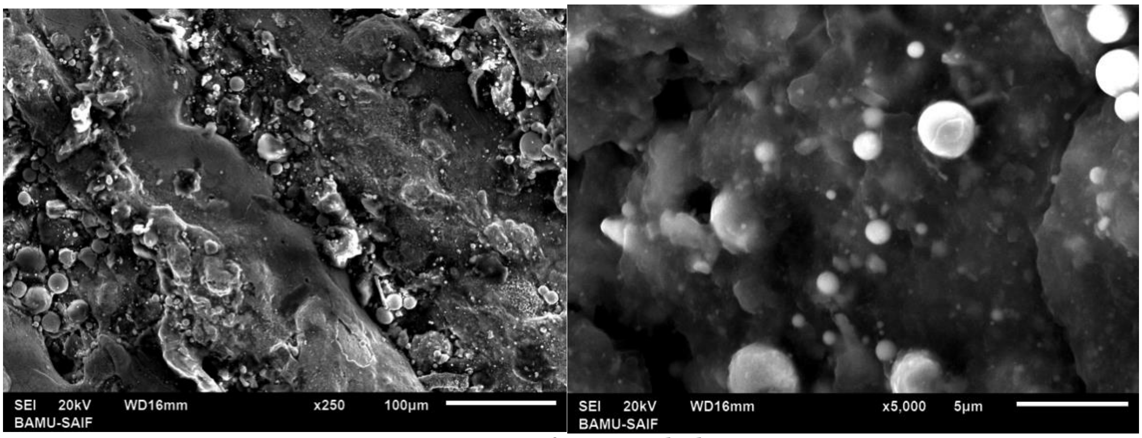


Figure:2 Surface Morphology

## CONCLUSIONS

This research examines the Surface Roughness, kerf taper, and Dross over the SS304 material by the Laser Beam Machine process for the varied input parameters to investigate the influence of Laser beam machining on the SS304 steel material. During the testing, I obtained the following results:.

1. The optimal solution for SR is (Cutting speed 4500 mm/min, Gas pressure 7.0 bar, and Laser power 2000W), for Kerf taper (Cutting speed 5500 mm/min, Gas pressure 9.0 bar, and Laser power 3000W), and Dross (Cutting speed 5500 mm/min, Gas pressure 7.0 bar, and Laser power 2500W).The optimal cutting parameters are determined using RSM methods match with the experimental values by minimum errors i.e 8.49% for SR, 4.27% for Kerf taper, 4.54% for Dross.
2. Using the provided mathematical models, any experimental data for surface roughness, kerf taper, and Dross may be calculated for any combination of laser cutting settings.
3. The precision of these models may be improved by increasing the number of experiments conducted on wide domains of process variables. Model development might incorporate additional interactions..
4. Optimization of RSM models are discussed. Optimal process parameters are known to reduce kerf taper (Ta), average surface roughness (Ra), and heat impacted zone (HAZ) individually or as a combined multi-objective optimization issue with equal and varied weights.
5. This is due to more number of experiments taken in RSM to get better fit.
6. The models have been found to be accurately representing both to the kerf taper, surface roughness, dross formation and heat affected zone values with respect to experimental results.
7. The validation studies demonstrate that RSM determines the best parameter set more accurately. The RSM approach is thus suggested for determining the best parameter settings.

## FUTURE SCOPE

1. Experimentation on different materials with varied combinations of input parameters.
2. Adoption of alternative methodologies for analysis and optimization.
3. Study of the micro hardness of the surface.
4. Exploration of alternative techniques for optimizing process parameters using the same experimental data.
5. Further examination of machine conditions concerning the range of process variables. Quantification of noise associated with the employed machinery is also necessary for a comprehensive understanding.

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