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Optimization of Laser Beam Machining Process Parameters of MS E250 material

M. M. Sayyad[1], Ravindra L. Karwande[2], Md. Irfan[3]

[1,]PG Student, Department of Mechanical Engineering,

[2]'Asso. Prof. Mech. Engineering Dept., MSSCOET, Jalna.

[3,] Research Scholar, Dr. BAMU, Aurangabad

Abstract- *Laser beam machining (LBM) is one of the nontraditional thermal energy based non-contact type machining process where material removal takes place by melting and vaporization, is used for almost whole range of engineering materials. Experiments are carried out using L9 orthogonal array by varying laser power, cutting speed and gas pressure for MS E250 material. The results showed that the gas pressure and cutting speed are the significant parameters affecting the surface roughness, whereas the influence of the laser power is much smaller. In Taguchi method L9 orthogonal array has been selected. The analysis of variance (ANOVA) has been used to determine effect of each parameter*

Keywords: *LBM, Process parameters, SR, Optimization.*

1. INTRODUCTION

In modern technology laser has become an important tool. Laser machining is a non-contact process and the attractive characteristics of laser machining include narrow low thermal distortion, generates no mechanical stress on the work piece like conventional machining process, high precision, high machining rate, ecologically clean technology and superior surface finish. The basic principle involves generation of high intensity beam of infrared light. This beam is focused onto the surface of work piece which the material and establishes localized melt throughout the depth of the sheet.

Laser cutting is a technology that uses a laser to cut materials, and is typically used for industrial manufacturing applications. . 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. The focused laser beam directed at the material, which then either melts, burns, vaporizes away, or is 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. The laser cutting process mainly depends on the cutting parameters to achieve maximum metal removal rate and to minimize the surface roughness, This research is an attempt to find the link between laser cutting parameters and surface roughness, to improve surface quality.

2. EXPERIMENTATION

A. Methodology of Experiment

There are several optimization techniques to develop product, process or operation. Various techniques can be applied to optimize laser process. Sometimes different techniques are required integrate to get statistically significant results, which can lead to better conclusions and recommendations. Some extensively used methods in developing a process or a product are Build Test Fix (BTF), Design of Experiment (DOE) and One Variable at a Time (OVAT), BTF is very primitive and unorganized approach. It is iterative method of developing a process focused on improvement from last experiment. DOE is highly efficient method of investigating the effect of parameters as it varies multiple parameters at once. As more parameters are investigated, more number of new combinations is required. DOE cannot control individual parameters and more relies on statistical data. In one variable at a time (OVAT) approach, variation is done with one variable at a time and other parameters are kept constant until the effect of one parameter is studied.

It is highly precise method to study effect of each parameter at different levels. Laser power, cutting speed and gas pressure were identified as most predominant parameters affecting the LBM. Based on the observation, Taguchi method has been used to optimize the process parameters. OVAT analysis has been conducted to find out effective range of parameters for optimization study. L9 orthogonal array (OA) has been selected from available designs. Standard notation for OA is given below

OA = Ln (Xm)

Where n= number of experiments, X= number of levels and m= number of parameters under study. From available designs for 3 levels 3 parameters, OA with least number of experiments required to conduct (L9) has been selected. ANOVA has been conducted to find out contribution of each parameter in the output. Minitab 19 software has been used for analysis.

B. Experimental Machine Selection

All the experiments were conducted at **Vaishali Laser LLP** Gut No. 70, Plot No. 1/A Wadgaon, Waluj MIDC area, Waluj, Aurangabad, M.H., India.

Figure 1. Laser Beam Machine

Brand	SIL
Laser Source	Up to 1000W
Laser Wavelength	1080nm
Laser type	Fiber Laser
X axis Stroke	2050 mm
Y Axis Stroke	3050 mm
Z Axis Stroke	250 mm

Table 1. LBM Specification.

C. Selection of material

MS E250A

- High tensile strength.
- High impact strength.
- Good ductility and weldability.
- A magnetic metal due to its ferrite content.
- Good malleability with cold-forming possibilities.

Not suitable for heat treatment to improve properties

Chemical composition of Sisal material is shown in Table 2

Table 2 Chemical Composition of MS E250A material.

Compound	Value	Compound	Value
C	0.22	**Cr**	1.50
Si	0.40	**Cu**	0.70
Mn	1.50	**Mo**	0.80
S	0.045	**V**	0.51
P	0.014	**Fe**	Remaining

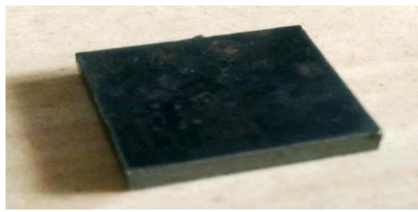

Figure 2. MS E250A and a test specimen

3. RESULTS AND DISCUSSION

To get complete understanding of effects of input parameters laser power, cutting speed and gas pressure on output SR, you usually assess signal to noise ratio or main effects plot for means. For this purpose, Minitab 19 statistical software has been used. Modeling of SR has been done. ANOVA has been conducted to find out effect of each parameter on the SR and linear regression model has been established to predict the values of SR.

A. Experimental Result

Table 4 shows the L9 OA with measurement of SR for runs one to nine.

Table 3 L9 orthogonal array with response characteristic.

Experiments	Inputs Factors			Output Responses	
Trial No.	**Laser Power**	**Cutting Speed**	**Gas Pressure**	**SR**	**S/N Ratio**
1	700	1200	1.1	5.98	-15.5340
2	700	1300	1.2	6.25	-15.9176
3	700	1400	1.3	6.78	-16.6246
4	800	1200	1.2	8.15	-18.2232
5	800	1300	1.3	9.12	-19.1999
6	800	1400	1.1	6.15	-15.7775
7	900	1200	1.3	8.97	-19.0558
8	900	1300	1.1	7.18	-17.1225
9	900	1400	1.2	6.04	-15.6207

The S/N ratio values are calculated with help of Minitab 19 software. It can be seen that variation in S/N ratio is minimum for all experiment.

B. Main Effects of SR

Figure 2 shows the main effects plot from S/N ratios.

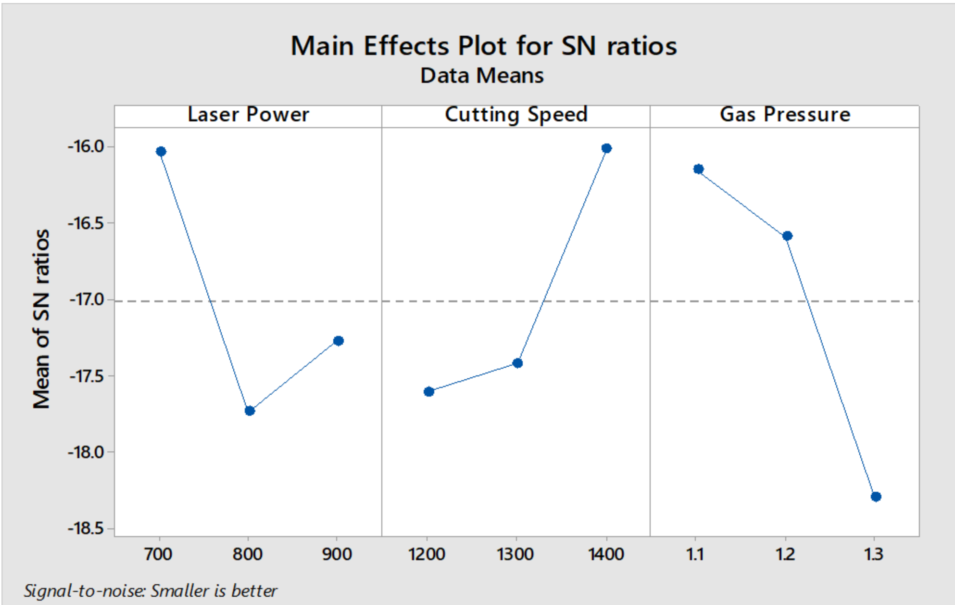

Figure.2 Main Effects Plot for S/N Ratio

A higher S/N ratio with better characteristics was used and was calculated with the help of the Minitab19 software for the experimental tests. The values of the complete S/N ratio are S/N ratio for the first test. It is observed that the optimum Surface Roughness was in the highest values of the in the response graph. The optimal input parameters were Laser Power 700 watt (level 1), Cutting speed 1400 mm/min (level 3) and Gas Pressure 1.1 bar (level 1).

C. ANOVA Result

ANOVA, the ratio between the variance of the cutting parameter and the error variance is called Fisher's ratio (F). It is used to determine whether the parameter has a significant effect on the quality characteristic by comparing the F test value of the parameter with the standard F table value at the P significance level. If the F test value is greater than P test the cutting parameter is considered significant. Relevance of the models is tested by analysis of variance (ANOVA). It is a statistical tool for testing the null hypothesis for planned experiments, in which several different variables are studied simultaneously. ANOVA is used to quickly analyze the variances in the experiment using the Fisher test (F test). ANOVA table shown the result of the ANOVA analysis. ANOVA analysis makes it possible to observe that the value of P is less than 0.05 in the three parametric sources. It is therefore clear that laser power, cutting speed and gas pressure of the material have an influence on the MS E250A. The last column of cumulative ANOVA showed the percentage of each factor in the total variance that indicates the degree of impact on the outcome. Table 3 shows results obtained from analysis of variance

Table 4 ANOVA Result.

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% Contribution
Laser Power	2	3.4526	1.72630	20.16	0.047	27.11
Cutting Speed	2	3.3529	1.67643	19.58	0.049	26.33
Gas Pressure	2	5.7573	2.87863	33.62	0.029	43.79
Residual Error	2	0.1713	0.08563			
Total	8	12.7340				

It shows table 4 that the Laser Power (27.11%), Cutting Speed (26.33%), the and the Gas Pressure (43.79%) have major influence on the Surface Roughness. Contribution of Gas Pressure (43.79%) is highest among all three parameters hence it is most dominating parameter while Laser Power is least affecting parameter.

D. Development of Regression Model for SR

Regression model has been developed using Minitab software. Substituting the experimental values of the parameters in regression equation, values for SR have been predicted for all levels of study parameters. Graphical representation also shows that a predicted and experimental value of SR correlates with each other.

Regression Equation –

$$SR = 0.77 + 0.00530 \text{ Laser Power} - 0.00688 \text{ Cutting Speed} + 9.27 \text{ Gas Pressure}$$

Table number 4 gives comparison between experimentally measured and predicted SR by developed mathematical equation

Difference between SR values calculated using regression equation and experimental values for each experience found less than 10%. Hence, we can say that the regression equation developed is valid..

Sr. No.	Experimental value	Predicted value	Error %
1	5.98	6.42	6.85
2	6.25	6.66	6.15

3	6.78	6.89	1.59
4	8.15	7.87	3.55
5	9.12	8.11	9.78
6	6.15	5.57	8.42
7	8.97	9.33	3.85
8	7.18	6.79	5.74
9	6.04	6.54	7.64

Table 4 Experimental and Predicted Values of SR

E. Confirmation Experiment Result

Table 5 shows the difference between value of SR of confirmation experiment and value predicted from regression model developed.

Parameter	Model value	Experimental value	Error %
Surface Roughness (Ra)	5.04	5.51	9.23

Table 5 Confirmation Experiment Result

Confirmation experiment is conducted by keeping parameters at optimum levels suggested by Taguchi method and the SR value obtained has been compared with value predicted by the regression model keeping the parameters at same levels. It can be seen that the difference between experimental result and the predicted result is 9.23%. This indicates that the experimental value correlates to the estimated value.

4. CONCLUSIONS

This study covers the observations about the Surface Roughness over the MS E250A material by the process of Laser Beam Machine for the different input parameters to thoroughly study over the effect of Laser beam machining process on the MS E250A material. Throughout the experimentation I got some results as under.

The combination of laser cutting parameters i.e. cutting speed, laser power and gas pressure were planned by L9 Orthogonal Array Taguchi method , based on the results obtained and derived analysis the following can be concluded.

1) The optimal solution obtained for SR based on the combination of laser cutting parameters and their levels is (i.e. laser power 700W, Cutting speed 1400 mm/min, and Gas pressure 1.1 bar).
2) ANOVA results indicate that cutting speed plays prominent role in determining the surface roughness.

The contribution of Laser power, Cutting speed and Gas pressure to the quality characteristics surface roughness Ra is 27.11%, 26.33% and 43.47% respectively.

3) Cutting speed and Laser Power are the most significant parameters majorly affecting the surface roughness whereas the Gas Pressure is much smaller.
4) The optimal cutting parameters are determined using Taguchi methods match with the experimental values by minimum errors i.e 9.23% for SR
5) Through the developed mathematical models, any experimental results of surface roughness with any combination of laser cutting parameters can be estimated.

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