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Parametric Analysis of Process Parameters of Laser Cutting Machine(Mazak Hyper Gear 510) By Using Anova Method On SS 304

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Abstract

Laser cutting is mostly a thermal process in which a focused laser beam is used to melt material in a localized area. A co-axial gas jet is used to eject the molten material from the cut and leave a clean edge. A continuous cut is produced by moving the laser beam or work piece and leave a clean edge. A particular characteristic of a laser cut is the formation of striations on the cut edge. These striations play an important part in laser cutting as they effectively control the edge roughness. 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 the present work an attempt has been made to study the effect of process parameters such as feed rate, input power and standoff distance on the quality of the machined surface using laser beam on mild steel and stainless steel. The quality of cut is assessed in terms of response parameters such as upper kerf width, lower kerfs width, taper of the cut surface and surface roughness. Design of experiments is implemented by using a full factorial design. The effect of the process parameters on response have been shown by means of main effect plots developed using ANOVA analysis. After Design of Experiment (DOE) by using full factorial method, the analysis will be carry by the ANalysis of VArience (ANOVA) method.

Keywords: CNC, ANOVA,DOE,SURFACE ROUGHNESS

Introduction

The Laser is basically a specialized light source that has properties that allow it to be focused into a small spot. The light intensity here is high enough that this allows the modification of materials by localized melting or vaporization. As the light output is highly controllable and consistent it can be used to produce high quality processing of materials, particularly cutting, drilling welding and marking.Laser sources of higher and higher beam quality are being made available at increasing power levels. However, choosing the optimum laser for an application may not be case of simply selecting the highest beam quality at the required power level. When the application requires a very fine cut with good edge quality a combination of good beam quality and a small spot size is required. Single mode fiber laser with its excellent beam quality is ideally suited for cutting thin section cutting (1-3 mm thick) at higher cutting speeds compare to a CO2 laser. The increase in cutting speed of the fiber laser is likely due to increased absorption with 1ìm radiation compared to 10.6µm. In thicker materials (>3 mm) where precision is not as important a more tolerant systems would use a larger spot size at somewhat lower beam quality. The wider kerf width produced using a larger spot size increases the volume of ejected material and also would generate cuts of good quality but at much reduced assist gas consumption. For thick sections materials multi-mode fiber lasers are better suited for the cutting process.

Experimental Procedure

In this investigation used material ss304 and three varying parameters feed speed, gas pressure and input power. Experiments are carried out using CNC laser cutting machine hyper gear 510, MAZAK by varying feed speed, gas pressure and input power for each material respectively. Anova carried out for identifies significant parameters.

2.1 Material specification: In this experiment use Stainless Steel 304 (3 mm thick) material.

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2.3 Design of experiment based on Taguchi method: In this investigation carried out by varying three control factors feed speed, gas pressure and input power on CNC laser cutting machine hyper gear 510, MAZAK at Martiaen engineering company, Unjha. A Control factors along with their levels are listed in Table 1. Full factorial design of experiments would require a large no. of runs; Hence Taguchi based design of experiment method was implemented. In Taguchi method Orthogonal Array provides a set of well-balanced experiments, and Taguchi's signal-to-noise. (S/N) ratios, which are logarithmic functions of the desired output, serve as objective functions for optimization. It helps to learn the whole parameter space with a minimum experimental runs. Taguchi replaces the full factorial experiments with a lean, less expensive, faster partial factorial experiment

Table 1. Control parameters and their levels

Machining Process Parameter	Level 1	Level 2	Level 3
Feed speed mm/min	0.5	0.6	0.7
gas pressure bar	2000	2100	2200
input power watt	1300	1500	1700

2.2 Specimen detail: L27 orthogonal array obtain based on the control factors. Total 27 nos. of experiments has been carried out and then cut a piece of 30 mm x 30 mm ss304 material.

Results and Analysis

Table 2. Taguchi Orthogonal L27 Array and result of Surface Roughness for SS304

Trail no.	A laser power (P) (watt)	Gas pressure (p) (bar)	Feed speed (f) (mm/min)	Surface roughness (R_a) (μm)
1	1300	0.5	2000	3.59
2		0.6	2000	3.74
3		0.7	2000	2.96
4		0.5	2100	3.42
5		0.6	2100	3.95
6		0.7	2100	2.95
7		0.5	2200	3.40
8		0.6	2200	3.99
9		0.7	2200	3.27
10	1500	0.5	2000	2.41
11		0.6	2000	3.36
12		0.7	2000	2.18
13		0.5	2100	2.34
14		0.6	2100	3.42
15		0.7	2100	2.72
16		0.5	2200	2.81
17		0.6	2200	2.54
18		0.7	2200	2.35
19	1700	0.5	2000	3.42
20		0.6	2000	3.54
21		0.7	2000	3.61
22		0.5	2100	3.00
23		0.6	2100	3.42
24		0.7	2100	4.11
25		0.5	2200	3.78
26		0.6	2200	3.85
27		0.7	2200	3.88

Analysis Of Variance (ANOVA): Analysis of Variance (ANOVA) is a powerful analyzing tool to identify which are the most significant factors. It calculates variations about mean ANOVA results for the each response. Based on F-value (Significance factor value) important parameters can be identified. Table 3 ANOVA Table obtained by MiniTab15 software. ANOVA Table contains Degree of freedom (DF), Sum of Squares (SS), Mean squares (MS), Significant Factor ratio (F-Ratio) and Probability (P).

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Analysis of variance (ANOVA) for surface roughness

Total number of runs, n = 27

Total degree of freedom f_T = n-1 = 26

Three factors and their levels

Input power, A – A1, A2, A3

Gas pressure, B – B1, B2, B3

Feed speed, C – C1, C2, C3

Degree of freedom

Factor A – Number of level of factors, f_A = A-1 = 2

Factor B – Number of level of factors, f_B = B-1 = 2

Factor C – Number of level of factors, f_C = C-1 = 2

For error, Fe = $f_T - f_A - f_B - f_C$

= 26 – 2 – 2 – 2

= 20

T = Totals of all results = 88.01

$$\text{Correction factor C.F.} = \frac{T^2}{n} = \frac{(88.01)^2}{27} = 286.88$$

Total sum of squares

$$S_T = \sum_{i=1}^{n} y_i^2 \text{ - C.F.} = 295.11 - 286.88 = \mathbf{8.23}$$

The total contribution of each factor level

A1 = **3.59+3.74+2.96+3.42+3.95+2.95+3.40+3.99+3.27**
= **31.27**

A2 = **2.41+3.36+2.18+2.34+3.42+2.72+2.81+2.54+2.35**

= **24.13**

A3 = **3.42+3.54+3.61+3.00+3.42+4.11+3.78+3.85+3.88**

= **32.61**

B1 = 3.59+3.42+3.40+2.41+2.34+2.81+3.42+3.00+3.78
= **28.17**

B2 = 3.74+3.95+3.99+3.36+3.42+2.54+2.54+3.42+3.85

= **31.81**

B3 = 2.96+2.95+3.27+2.18+2.72+2.35+3.61+4.11+3.88

= **28.03**

C1 = 3.59+3.74+2.96+2.41+3.36+2.18+3.42+3.54+3.61

= **28.81**

C2 = 3.42+3.95+2.95+2.34+3.42+2.72+3.00+3.42+4.11

= **29.33**

C3 = 3.40+3.99+3.27+2.81+2.54+2.35+3.78+3.85+3.88

= **29.87**

Factor sum of squares

$$S_A = \left(\frac{A_1^2}{N_{A1}} + \frac{A_2^2}{N_{A2}} + \frac{A_3^2}{N_{A3}}\right) - C.F.$$

$$= \left(\frac{(31.27)^2}{9} + \frac{(24.13)^2}{9} + \frac{(32.61)^2}{9}\right) - 286.88$$

$$= 108.64 + 64.69 + 118.15 - 286.88$$

$$= 4.6$$

$$S_B = \left(\frac{B_1^2}{N_{B1}} + \frac{B_2^2}{N_{B2}} + \frac{B_3^2}{N_{B3}}\right) - C.F.$$

$$= \left(\frac{(28.17)^2}{9} + \frac{(31.81)^2}{9} + \frac{(28.03)^2}{9}\right) - 286.88$$

$$= 1.01$$

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Sc $= \left(\frac{C_1^2}{N_{C1}} + \frac{C_2^2}{N_{C2}} + \frac{C_3^2}{N_{C3}}\right) - C.F.$

$$= \left(\frac{(28.81)^2}{9} + \frac{(29.33)^2}{9} + \frac{(29.87)^2}{9}\right) - 286.88$$

= 0.05

$$S_e = S_T - (S_A + S_B + S_C)$$

$$S_e = 8.23 - (4.6 + 1.01 + 0.05)$$

= 2.57

Mean square (Variance)

$$V_A = \frac{S_A}{f_A} = \frac{4.6}{2} = 2.3$$

$$V_B = \frac{S_B}{f_B} = \frac{1.01}{2} = 0.505$$

$$V_C = \frac{S_C}{f_C} = \frac{0.05}{2} = 0.025$$

$$V_e = \frac{S_e}{f_e} = \frac{2.57}{20} = 0.1285$$

Variance ratio

$$F_A = \frac{V_A}{Ve} = \frac{2.3}{0.1285} = 17.89$$

$$F_B = \frac{V_B}{Ve} = \frac{0.505}{0.1285} = 3.92$$

$$F_C = \frac{V_C}{Ve} = \frac{0.025}{0.1285} = 0.194$$

$$F_e = \frac{V_e}{Ve} = \frac{0.1285}{0.1285} = 1$$

Percentage contribution

$$P_A = \frac{S_A}{S_T} = \frac{4.6}{8.23} = 0.5589 = 55.89\%$$

$$P_B = \frac{S_B}{S_T} = \frac{1.01}{8.23} = 0.1227 = 12.27\ \%$$

$$P_C = \frac{S_C}{S_T} = \frac{0.05}{8.23} = 0.000607 = 0.060\ \%$$

$$P_e = \frac{S_e}{S_T} = \frac{2.57}{8.23} = 0.3122 = 31.22\%$$

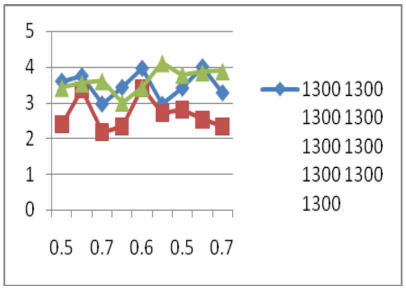

Chart: 1

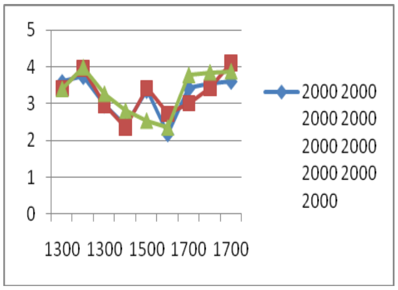

Chart: 2

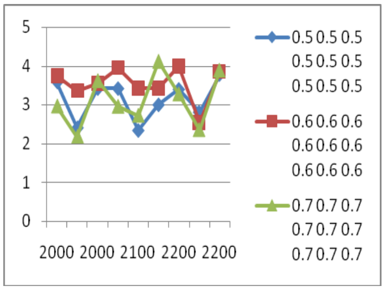

Chart: 3

Chart 1, the input power is take constant and feed speed & gas pressure are varying.

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Chart 2, the feed speed is take constant and input power & gas pressures are varying.

Chart 3, the gas pressure is take constant and input power & feed speed are varying.

Conclusions

Above analysis shows the percentage contribution of individual parameters on surface roughness in laser cutting.

- The percentage contribution of input power is 55.89 %,
- The percentage contribution of gas pressure is 12.27 %,
- The percentage contribution of feed speed 0.06 %
- The percentage contribution of the error is 31.78 %. Error is caused due to human error, machine error or any error in the surface tester.

Here, the percentage contribution of input power is maximum, so the input power is most affected parameter in laser machining process.

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References

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