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Laser Cutting of Composite Materials

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Abstract— **En353 as many industrial applications used in different industries like railways, Machine tools, Automobile industries etc. The composition of EN353 steel is carbon, Silicon, Molibdenam, Sulpher, Phosphorus, Nickel Chromium and Molibdenam. As Laser machining process is very quick machining process and micro hole can be produced by laser machining so during machining of EN353 steel Laser machining process can be adopted. The effects of the different Machining parameters during EN353 steell cutting, Material Removal Rate (MRR) is consider as response 1 and discussed with the help of different graphsThe response surface methodology (RSM) is adopted for optimization the machining parameters for maximum MRR.**

Keywords: **Ytterbium Fiber Laser, metal cutting operations, Response surface Method, Non Conventional Machining**

I. INTRODUCTION

Sometimes for machining the EN353 steel conventional machine process can not be used because in conventional machining process there is more tool wear, less life time of tool due to direct contact between tool and work piece, less dimensional accuracy etc. Different nonconventional machining processes such as abrasive water Jet Machining, Electrochemical Machining, Electric Discharge Machining, Wire Electric Discharge Machining, etc. have shown their scope of applications towards the machining of 5mm thick EN353 steel but these processes have also their own limitations and still remain machining problems like low material removal rate, high surface roughness and poor dimensional accuracy, more time consumption etc.

Flemming Ove et al have explained in their paper that the first results of proof-of-principle studies applying a new approach for laser cutting with high brightness and short wavelength lasers will be presented. In the approach, multi beam patterns are applied to control the melt flow out of the cut kerf resulting in improved cut quality in metal cutting. The beam patterns in this study are created by splitting up beams from two single mode fiber lasers and combining these beams into a pattern in the cut kerf. The results are obtained with a total of 550 W of single mode fiber laser power. Burr free cuts in 1 mm steel and aluminum and in 1 and 2 mm AISI 304 stainless steel is demonstrated over a wide range of cutting rates. The industrial realization of this approach is foreseen to be performed by either beam patterning by diffractive optical elements or multi beam fiber laser arrangements. [1]. Tsai and Chen [2] proposed an explanation for why the focused Nd:YAG laser is used to scribe a groove-crack on the surface of substrate and the defocused CO_2 laser is used to introduce thermal stress. An excimer laser was used to study the basic mechanism roughening the surface of silicon carbide by Tonshoff and Kappel [3]. Tsai and Li [4] stated that the under water laser drilling quality of LCD glass and alumina substrates is much better than that from laser drilling in air.

II. YTTERBIUM FIBER LASER SYSTEM

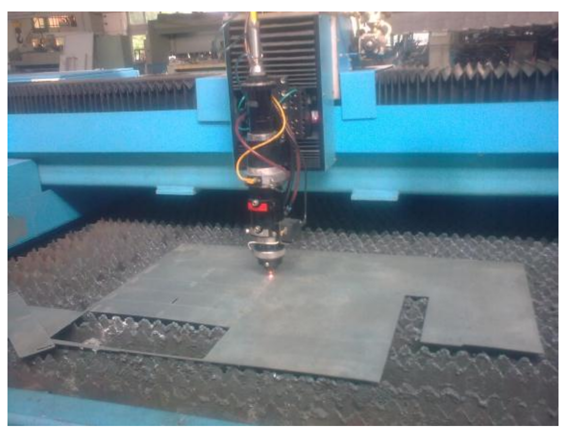

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Figure 1. Metal pieces cut from 5 mm thick EN353 steel sheet by ytterbium Fiber Laser of 1000kW

A Ytterbium laser machine YLR 1000 with CNC system RP 3015 was used for experiments. Table 1 represents the detail specification of Ytterbium laser machine YLR 1000.

III. EXPERIMENTAL PLANNING

Table 1 represents the machining parameter limits and their Levels with codes

Table- 1 Machining parameters limit, and their levels with codes

Sr.No.	Machining Parameters	Symbol	Units	Level				
				-2	-1	0	1	2
1	Laser power (W)	x_1	Watt	400	500	700	900	1000
2	Modulation frequency(Hz)	x_2	Hz	600	700	800	900	1000
3	Gas pressure (bar)	x_3	bar	1	2	3	4	5
4	Cutting speed (m/min)	x_4	m/min	0.5	0.7	0.9	1.1	1.3
5	Pulse width (%)	x_5	%	75	80	90	95	100

IV. EXPERIMENTAL RESULTS

Following Table- 2, shows the experimentally obtained results for. Material Removal Rate.

Table- 2 Plan for CCD; different controlling parameters andresults

Run	x_1	x_2	x_3	x_4	x_5	MRR, g/s (Response1)
1	-1	-1	-1	-1	1	1.228
2	1	-1	-1	-1	-1	1.229
3	-1	1	-1	-1	-1	1.230
4	1	1	-1	-1	1	1.638
5	-1	-1	1	-1	1	1.638
6	1	-1	1	-1	1	1.047
7	-1	1	-1	-1	1	1.048
8	1	1	1	-1	-1	1.049
9	-1	-1	-1	1	-1	1.047
10	1	-1	-1	1	1	1.047
11	-1	1	-1	1	1	1.048
12	1	1	-1	1	-1	12.047
13	-1	-1	1	1	1	1.229
14	1	-1	1	1	1	1.228
15	-1	1	1	1	-1	1.230
16	1	1	1	1	1	1.638
17	-2	0	0	0	0	1.638
18	2	0	0	0	0	1.638
19	0	-2	0	0	0	1.639
20	0	2	0	0	0	1.640
21	0	0	-2	0	0	1.641
22	0	0	2	0	0	2.047
23	0	0	0	-2	0	1.048
24	0	0	0	2	0	1.049
25	0	0	0	0	-2	1.228
26	0	0	0	0	2	1.229
27	0	0	0	0	0	1.230
28	0	0	0	0	0	1.229
29	0	0	0	0	0	1.365
30	0	0	0	0	0	1.445
31	0	0	0	0	0	1.228

V. MATHEMATICAL MODELING AND PROCESS OPTIMIZATION

Mathematical models for MRR

The developed mathematical model based on RSM for correlating the MRR with various predominant laser machining process parameters as considered in the experimental design as follows,

$$YMRR = 0.1.3404 + 0.0719.x1 - 0.0250.x2 + 0.1702.x3 + 0.0893.x4 - 0.0548.x5 - 0.0609.x1.x2 + 0.0279.x1.x3 + 0.3528.x1.x4 - 0.1855.x1.x5 - 0.0171.x2.x3 - 0.4905.x2.x4 + 0.6821.x2.x5 - 1.1908.x3.x4 - 0.3218.x3.x5 - 0.2510.x4.x5 + 0.2621.x12 + 0.2848.x22 + 0.4895.x32 + 0.6942.x42 - 0.1512.x52 \quad \ldots\ldots(1)$$

Analysis of variance (ANOVA) and Model fitment Test

Table- 3 Results of analysis of variance for MRR

Source of variation	d.o.f.	Sum of squares	Mean square	F-value	P-value
		MRR (Eqn. 1)	MRR (Eqn. 1)	MRR (Eqn. 1)	MRR (Eqn. 1)
Second-order terms	20	3.1550	0.1577	6.1847	0.0026
Lack of fit	6	0.2144	0.0357	-	-
Experimental errors	4	0.0406	0.0101	-	-
Total	30	3.4101	-	-	-

From Table 3, it is clear that the laser power, modulation frequency, gas pressure, cutting speed,

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pulse width are significantly influencing for on Material Removal Rate (MRR). P-value for response 1 i.e. MRR is less than 0.05. The F-test values for response 1 i.e. MRR at 95% confidence level are 6.1847. The value of R^2(adj) for MRR are 0.77. These values are above the average value and developed second order models fits the data, therefore, the data for the response 1 i.e. MRR are well fitted in the developed second order models.

VI. PARAMETRIC ANALYSIS ON MACHINING CHARACTERISTICS OF YTTERBIUM FIBER LASER

Effect of process parameters on MRR

A 2-D plots is shown in Fig. 6.1 which shows the combined effects of N_2 gas pressure and wait time on MRR. This 2-D plot is drawn with the experimentally obtained results during Ytterbium fiber laser machining of EN353 Steel-MMC at constant 700 Watt laser power, 800 Hz modulation frequency and 87.5 % pulse width. From Fig. 3, it is clear that the MRR is high at low nitrogen gas pressure zone i.e. 15 to 17 bar and low wait time zone i.e. 0.1 to 0.15 s. Again from 2-D plot Fig. 3, it is also clear that MRR is high at high gas pressure and high wait time i.e.20 bar and 0.3s respectively. MRR is less at moderate gas pressure and moderate wait time. The experimental results reveal that comparatively low gas pressure and low wait time are found to be favorable for higher MRR because due to less wait time, there will be less heat losses from the drill area and due to high metal vaporization MRR increases.

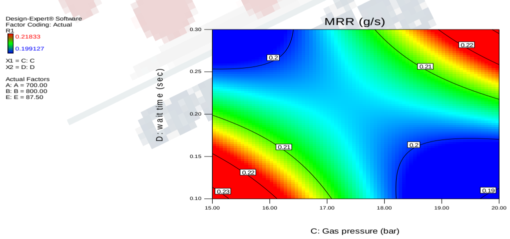

Fig.2 Response surface plot of MRR with variation of wait time and gas pressure of Al/5wt%Al2O3-MMC

Table-5 Optimal values of process parameters for maximized MRR

Experimental validity search on MRR				
Process parameters	Actual values of parame-tric combination	Value obtain-ed from Eqn.1	Value obtain-ned from experi-ment	Error
Laser power (W)	526	3.7964	3.8014	0.005
Modulation frequency (Hz)	863			
Gas pressure (bar)	4.99			
Cuttingspeed(m/min)	0.54			
pulse width (%)	80.13			

VII. CONCLUSIONS

The Ytterbium fiber laser has a capability to perform successful quality to cut 5 mm thick EN353 steel. The Ytterbium fiber laser process parameter can be possibly controlled for effective cutting of 5 mm thick EN353 steel. Based on the machining of 5mm thick EN353 steel by Ytterbium fiber laser the following outcome can be concluded on the basis of the developed mathematical model as follows: The optimal value of MRR is at Laser power 526 kW, modulation frequency 863 Hz, gas pressure 4.99 bar, cutting speed 0.54 m/min and pulse width 80.13%. At this combinations of machining parameters the difference between the value obtained from equation 1 and and actual experimental result is very less. i.e. the error is 0.005

REFERENCES

[1] Flemming Ove Olsen, Klaus Schuett Hansen, and Jakob Skov Nielsen (2009), Multibeam fiber laser cutting, Journal of Laser Applications, Volume 21, Issue 3, 2009, pp-133

[2] Tsai, Chwan Huei., and Chen Hong-Wen, (2003) Laser cutting of thick ceramic substrates by controlled technique, Journal of Materials Processing Technology, Vol-136, pp166-173

[3] Tonshoff (1) H.K.; and Kappel H; (1998), Surface modification of ceramics by laser machining; Ann of CIRP, Vol. 47(1), pp.471-474.

[4] Tsai, Chwan Huei, and Li Chang-Cheng; (2009) Investigation of underwater laser drilling for brittle substrate, Journal of Materials Processing Technology, Vol.209, pp 2838-2846