iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 **Issue:** XII **Month of publication:** December 2024

DOI: https://doi.org/10.22214/ijraset.2024.66035

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue XII Dec 2024- Available at www.ijraset.com

An Investigation on the Laser Abrasive Jet Machining of glass using Taguchi L27 arrays

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Abstract: Nowadays, it might be challenging to machine materials that are difficult to cut. The main issues with machinability are high cutting powers, poor surface quality, and short tool lives. Traditional machining techniques have been shown to be less efficient and time- consuming. Nowadays, it might be challenging to machine materials that are difficult to cut. Nowadays, researchers are choosing hybrid machining techniques to solve these issues. The laser-assisted machining approach has drawn attention recently among other techniques. The cutting of difficult-to-cut materials with the aid of lasers can improve the machinability of those materials. Heat assistance is provided by a low power CO2 laser, and a HYBRID non- conventional machining technique is created by combining CO2 laser machining with an abrasive jet approach. In the aforementioned study, two unconventional machining techniques are used to evaluate the process variables, performance traits for a better material removal rate, and surface roughness. This work summarises the machining process for the machining of challenging materials using laser assistance.
Keywords: Hybridmachining, CO2laser, Abrasivejetmachining, hybridnon conventional machining

I. INTRODUCTION

The laser assisted machining (LAM) method have various specific conditions, machining input and out variables, input parameters of laser, work substrate material properties. So, realizing and examine such properties and its influence over each process parameter is essential for the optimization to geta better output response. Prominent behavior has been noticed in the contortion nature on surface of the work and resistance offered in between tool and chip interface but there is a need to investigation contortion surface nature when heated at higher temperature and rise in strain rate[1].The significance of laser process parameters using ANOVA it is noticed as, working distance that is stand off distance will influence on top kerf surface deviation as it has maximum F-value among the other power and feed of laser process parameters [2]. Heating the workpiece with a CO_2 laser is a significant factor that can be utilized to heat borosilicate glass it reduces surface roughness and cutting forces. With a relatively low power laser, a small portion of the work piece can be immediately heated helping to increase the rate at which fragile materials like glass are removed from milling operations to the micron level [3]. The amount of material removal by machining to certain depth were studied, laser is used as assistance with conventional machining. 900°Cthepreheatingtemperature of inconel metal, a heat shield is provided in between the conventional machining and laser machining tools, the high temperature strength Inference drawn from the results compared with conventional machining, input and output parameters measurements, assisted machining with laser protected with heat shield while machining can be used to obtain a better product[4].Multiple machining optimizations for abrasive air jets(AAJM) Response surface methodologyis used to examine non-traditional machining for machining hybrid fibre reinforced polymer composites. [5]. Through the investigation process parameters of machining by laser. Micro- channels were established with small average values of surface roughness can be attained at the proper laser power when the workpiece is at proper tool location andheatassisted to certain strain point, at low feed rate, and at high axial depth of cut, only if the tool withstands the cutting forces[6]. Traditional machining techniques for spherical optics are typically time-consuming and expensive. One potential step forward is to use CO_2 laser radiation in unusual machining processes like laser ablation to achieve greater efficiencies and faster speeds. The majority of the laser energy used in thefight was used to burn through the material. According to the findings of the experiments, pulse stability had a significant impact on how quickly surface roughness increased in the future. [7]. Edge chipping was improved when the preheating temperature, spindle speed, and inclination perspective of the workpiece were increased in laser aided milling (LAMill). the preheating temperature inversely related the cutting energy,the strength of silicon nitride inversely related to pre heating temperature. as a result, the surface finish is superior, cutting tool will have better tool life as there is minimum damage [8]. Materials surface behavior have the same chemical compositiondoes not change even after machining withlaser.

Crystal structure of the base materials remains crystalline and that of laser radiated surface if found to be amorphous structure, continuous CO_2 laser and fibre lasers appear to bethe most reasonable options to process natural granite, Complex geometrical shapes without cracks on the cutting edge on natural stones can be machined with having 150um widthresolidified layer,[9] a threshold energy level called line energy was studied for drilling oflaminates made of Ti/CFRP/Ti for higherCO_2 laserfrequency smaller heat effected zone width and MCI damage factorwas observed [10]. Variation of the process parameters, behavior of output parameters is studied which shows improvement in kerf width size and selection of suitable work materials forlaser machining will play amajor role, process parameters determination is essential for machining brittle materials to study environmental impact and novel manufacturing techniques. [11]. In the present work laser is being used has a assistance for machining brittle materials glass as one of the source other source is being abrasive jet another mechanical approach for machining brittle material glass both are focused at same location sequentially, hence it is a combination of two non conventional machining process which are non contact type of material removal mechanism, so it can be stated as hybrid machining process.is on a CNC controller X–Y router table . The Material removal rate is by impact and erosion in abrasive jet machining, melting and evaporation by low power continuous CO_2 laser, partially Laser removes the material by ablation, it

Using an electronic balance with a resolution of 0.0001mg and a digital readout, the samples were meticulously weighed both before and after the machining process. The machining process was carried out on with a 1mm diameter hole of material E38 having hardness number 58 is abrasive jet nozzle tool was used as the cutting tool. According to Patel and Tandon (2015), MRR was calculated as the weight loss in the work material per unit time and stated in Eq.1

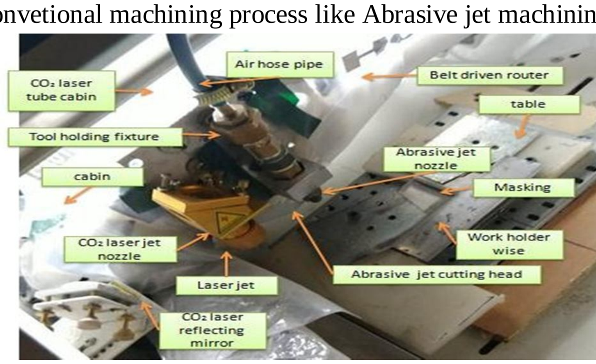
$$MRR = \frac{w1-w2}{w1} \text{ g/min,..} \qquad \text{Eq.1}$$

Table:1 Chemical composition of sodalime glass

Chemical Composition	wt.%	Formula	Melting point	Density in g/cm^3	Thermal conductivity in W/mK	Refractiveindex
Silicon dioxide	71–74	SiO_2	1710	2.65	6.8	1.544
Sodium dioxide	12–16	Na_2O	1132	.27	***	***
Calcium oxide	6–8	CaO	2713	3.34	****	**
Magnesium Oxide	3–5	MgO	2852	3.6	45-60	1.7355
Aluminium dioxide	0.5–1.5	Al_2O_3	2072	3.937	30	1.77

II. EXPERIMENTATION

In the present work an attempt has been made to machining with a low power CO_2 laser which is non contact type non conventional machining process with another nonconvetional machining process like Abrasive jet machining having an abrasivesizeofthe



Fig(1):Experimentalsetup

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The abrasive jet machining conducted M sand as abrasive particle, M-Sand of300 micron size was used as a tool assisted with compressed air media as abrasive jet tool,the CO_2 laser continuoussource which is of low power usually utilized for engraving purpose commercially available with computer controlled router, is used for machining the work material, the work material is of soda-lime glass. The jet of air coming out of the compressor is circulated to mixing chamber containing the abrasives and mixture, abrasive irregular shaped sharp edged M-sand micron size is directed towards the workpiece by the abrasive jet nozzle. The workpiece is mounted and is stationary placed on the table with wise , the speed, power can be controlled by the software

Chemical composition of sodalime glass will show the refractive index1.5 to 1.77 range indicates the incident light having laser power will effect the material surface there by inducing the plastic deformation over the surface by melting and evaporation as the temperature is around nearly 320degree for 30 watt power.

Table 2:Process parameter and levels.

Slno	Symbol	Process parameter	Unit	levels		
				1	2	3
1	A	Speed	mm/sec	2	4	6
2	B	Laserpower	watt	10	20	30
3	C	Standof Distance	mm	1	2	3
4	D	Speedof Abrasivejet	mm/sec	2	4	6

Process parameters speed of the laser, laser power, stand of distance from the nozzle tip to work piece distance areselected for the laser test setup and out of various process parameters of AJM the abrasive size taken as constant, flow of the abrasive jet 6 bar pressure maintained constant, the flow of air is maintained constant

Table3:Taguchi L27 array with test results of MRR

Sl no	Speed of CO2 laser	Power of CO2 laser	oD of CO2 Laser headnozzle	SoD of abrasive jet machining nozzle	MRR
1	2	10	1	2	9.44E-03
2	2	10	2	4	8.13E-03
3	2	10	3	6	7.92E-03
4	2	20	1	4	9.52E-03
5	2	20	2	6	9.47E-03
6	2	20	3	2	9.69E-03
7	2	30	1	6	9.65E-03
8	2	30	2	2	1.27E-02
9	2	30	3	4	9.66E-03
10	4	10	1	2	8.97E-03
11	4	10	2	4	7.95E-03
12	4	10	3	6	6.08E-03
13	4	20	1	4	8.73E-03
14	4	20	2	6	6.70E-03
15	4	20	3	2	8.97E-03
16	4	30	1	6	8.93E-03
17	4	30	2	2	8.96E-03
18	4	30	3	4	8.69E-03

19	6	10	1	2	7.59E-03
20	6	10	2	4	7.27E-03
21	6	10	3	6	6.99E-03
22	6	20	1	4	7.92E-03
23	6	20	2	6	7.09E-03
24	6	20	3	2	7.70E-03
25	6	30	1	6	7.86E-03
26	6	30	2	2	8.87E-03
27	6	30	3	4	7.96E-03

Taguchi is DOE technique which will give array of experiments to be conducted for optimizing the put response, taghuchi we taken array l_{27}as shown in Table 3 and results are analyzed byANOVA,one wayANOVAtechnique is used for the study.

By the regression analysis it is found that MRR for soda lime considering various process parameters of both non conventional machining set up laser speed(A),laser power(B), stand of distance of laser (C) and stand of distance of AJM
(D). the percentage contribution of laser speed is more 38% as the laser traversing speed will give initial surface deformation by thermal effect and the laser power will contribute22% as the power will also melt the material surface, The next speed of the abrasive jet machining was maintained while the CO2 laser heated the workpiece.

Table4: RegressionanalysistestresultsofMRR

	Source	DF	SeqSS	AdjSS	AdjMS	F	P	% Contribution
MRR	A	2	16.36	16.36	8.1799	21.96	0	38.10145
	B	2	9.46	9.46	4.7299	12.7	0	22.03177
	C	2	1.74	1.74	0.8702	2.34	0.125	4.052355
	D	2	8.674	8.674	4.337	11.64	0.001	20.20122
	Residual Error	18	6.704	6.704	0.3725			
	Total	26	42.938					

For A1-B3-C1-D1 the optimum results were obtained from regression analysis result is as shown in figurefor lowspeed 30 watt power minimum stand off distance that is 2mm wewill get the optimum results as shown in Fig 2.

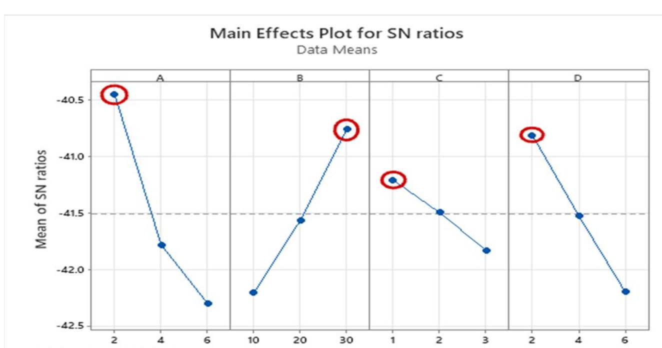

Fig 2:S/N ratio of Mean for MRR values

III. CONCLUSION

1) The largest value of the output response S/N ratio is found at the combination A1-B3-C1-D1 ratio for the factors A, B,C and D, respectively. Therefore, A1- B3-C1-D1 is the optimal parameter combination
2) By ANOVA, the results of % contribution for groove machining by the CO_2 laser feed is more as that of other process parameters

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