A critical linguistic assessment of the process parameters on the relative ranks of the yield parameters for nd: yag laser drilling

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ABSTRACT

Advances in manufacturing technology and the quest for smaller part geometry, have played the role of a curtain raiser for the new frontiers of machining process of metals. In this specific domain of precision manufacturing, the traditional machining methods have limited capabilities to meet higher accuracy, better surface finish and greater productivity related requirements from the customer. Micro machining is a ready solution towards the miniaturization of components and devices. The main problems during micro machining methods are to make a low heat affected zone and the controllability of other parameters to meet ever demanding process capability related requirements. High energy beam machining identifies a category of processes, each of which is capable of transferring a beam of such high energy intensity into metal cutting or drilling forces. It should be used to melt and vaporize a narrow zone of metals. This ability is useful for precision drilling, welding and cutting. Low power pulse Nd:YAG laser machining is now being used for these purpose often with the high level of precision in an economically viable manner. Thin strip cutting of metals through laser beam is one of the main applications in this area. This paper is focused on the cutting and drilling of the mild steel workpiece with lower thickness values and an attempt has been made to study the different process parameters in linguistic terms, which will affect relative ranks of the quality of the precision cutting and micro drilling of the metal specimen.

Keywords : Nd:YAG, micro drilling, linguistic terms, HAZ, .

INTRODUCTION

Laser beam machining is a method of cutting metal or refractory materials by localized melting and subsequently vaporizing the unintended material from the parent material with an intense beam of laser light from a laser source. The beam of light is used to manufacture small-diameter holes that can be spaced along a layout line to cut materials. Applications of LBM are limited to cutting, drilling or welding thin metals and materials. Laser beam machining (LBM) is one of the most extensively used thermal energy based non-contact type advance machining process which can be applied for wide variety of materials. It is perfectly suitable for geometrically complex profile cutting and making miniature holes in sheet metal. Among various type of lasers used for machining in industries, CO_2 and Nd: YAG lasers are the most established lasing materials.

Laser in short bursts has a power output nearly 10kw/cm^2 of beam cross section. The sum total of radiation is 7 kw/cm^2 on its surface. By focusing laser beam on a spot 1/100 of mm^2 in size, the beam will be concentrated in short flash to a power density of 10,0000 kw/cm^2. This is enough heat to melt and vaporize all high strength engineering materials and permits the fusion and welding of refractory substances and metals [1].

Nd:YAG (Neodymium-doped Yttrium Aluminium Garnet; Nd:$Y_3Al_5O_{12}$) is the type of the crystal that is utilized as a lasing medium for solid-state lasers. The dopant, triply ionized neodymium, typically substitutes the yttrium in the crystal structure of the yttrium aluminium garnet (YAG) due to their similar sizes. Traditionally the crystalline parent material is doped with around 1% neodymium by weight [2]. Laser operation of Nd:YAG was first achieved by Geusic et al. at Bell Laboratories in the year 1964 [3]. It has wide variety of applications in the manufacturing domain of etching, engraving, or marking of metals, metallic alloys and plastics. The prolific use of Nd:YAG lasers are reported in manufacturing for welding, cutting of different varieties of steels and alloys. For specific applications in automobile industry (cutting and welding of steel plates) the power levels of Nd:YAG lasers are typically within 1-5 kW range. Drilling operations of Super alloys for gas turbine parts employs pulsed Nd: YAG lasers. They are also utilized to make subsurface markings in transparent materials such as glass or acrylic materials [4]. Most of the early stages that defined cutting and drilling capability are based on ruby lasers. By the late 1960's some production application of cutting and drilling with ruby lasers were reported. By 1970's the development of CO_2 and Nd:TAG lasers had made them the leading contenders for material processing applications. By mid 1970's laser cutting and drilling had reached production status for a number of applications. Continued laser development has now made laser machining economically competitive with other machining methods. Laser machining is chosen for production not only because it offers technical advantages, but also, because it costs less in many cases. Industrially robust Nd:YAG lasers, for many years were limited to less than 1 KW of beam power and were mainly used in precision manufacturing and electronics industries. The availability in recent years, of initially 2 KW, then 4 KW and now high powers has enabled this laser to be used for a wider range of thickness and speeds which can be achieved for cutting, drilling and welding steels.

The ability of the laser to manufacture repeatedly quality drill holes with high aspect ratio at higher processing speed is an inherent advantage. However, the greater emphasis has to be laid on in ensuring the dimensional and qualitative attributes of the manufactured holes both from the geometrical (e.g. hole size, taper and aspect ratio etc.) and the metallurgical (e.g. heat affected zone, recast layer, micro cracking etc.) point of views. Contemporary literatures have amply revealed that the optimization of the laser parameters such as average power, pulse energy, pulse duration, pulse frequency, focal position etc. can possibly provide the means to minimize the geometrical and metallurgical defects as mentioned. Therefore, the current situation demands a great deal of effort to critically assess the parametric impact of the major process variables to attain best quality laser drilled holes.

EXPERIMENTAL SET UP

The materials used here is mild steel (carbon - 0.1 - 0.25%) of thickness 0.65 mm.

MACHINE

A CNC controlled SI Laser SLIP200 Nd:YAG laser machine with three axis control is used for drilling. The machine basically consists of a laser resonator and beam delivery unit, power supply unit, cooling unit and CNC controller for X,Y and Z axis movement.

The Specification of the machine is as per [table 1].

The surface morphology of the laser drilled holes as well as the spatter formation, was studied using a scanning electron microscope (SEM). The hole size measurements were performed using a optical microscope. After completion of the geometrical measurements, the laser drilled samples are sectioned using a wire cut EDM, mounted on the fixture and sequentially ground to the hole center.

EXPERIMENTAL PROCEDURE

The existing pulsed Nd: YAG laser system has been used to try out Micro

Model	SLP - 200
Average Power	200W
Pulse Energy @ 20 m s	50 J
Peak Power	7 kW
Pulse with the range	0.3 -20 m s
Pulse Repetition Rate	1 - 250 Hz
Work table Size	450 mm X 600 mm X 150 mm
Power Requirement	3 phase 440 V AC 20 Amps
Cooling Method	Chilled Water with external cooling facility

Table 1 : Specifications of the Laser System

Measurement range :	
Min. Value	0.01 μm
Maximum value	± 150 μm
Accuracy	2% value + 1 min value
Sample length Longer wave	0.03 inch
Shorter wave	2.5 μm (-3 d?)
Traverse speed	1 mms^{-1}
Power Supply	6 Nicd batteries, LR6,AA

Table 2 : Specifications of the surface roughness measuring instruments

drilling for mild steel samples. The sheets are 0.65 mm thickness for laser drilling operations.

For the experimentation Pulse Width, pulse repetition rate and the cutting speed are the key parameters identified to control the cutting operations and hence are considered for investigations.

The surface roughness measurements of the workpieces are done using Taylor Hobson Surtronic machine. The specifications of the surface measurement instruments are as following **[table2]**.

For measuring the surface roughness of the samples of thickness one 0.65 mm mounting fixture has been developed which consists of five slots for holding the samples cut by laser process [fig.1].

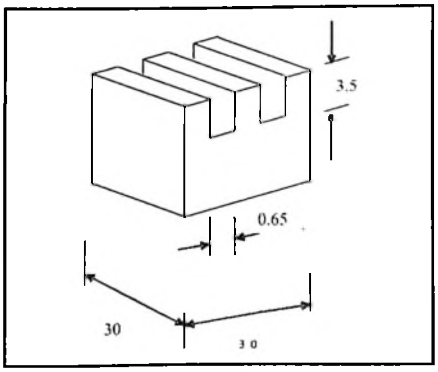

Fig.1 Mounting fixture for sectioning of samples in a Wire cut EDM for measuring the surface roughness of the samples of thickness 0.65 mm

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RESULTS

Experiment No. 1

Parameters	Values	Parameters	Values
Material	Mild steel	Length of the cut	2 cm
Thickness of the Workpiece	0.65 mm	Capacitor voltage	300V
Nozzle Height	1.6 mm		
Shielding Gas	Oxygen		
Gas flow pressure	3.5 kgf cmm^{-2}		
Cutting Speed	1 mms^{-1}		

Table 2 : Parametric Values of experiment No. 1

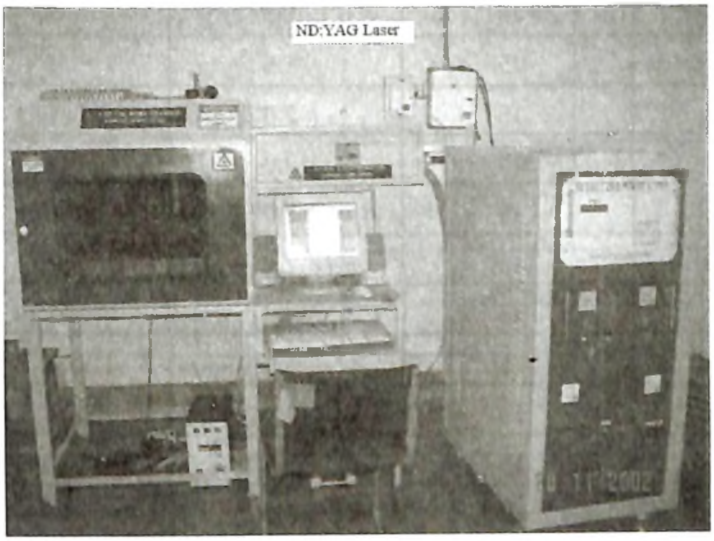

Fig. 2 : NdYag Laser Machining Set up at BIT Mesra

CONCLUSIONS

The entire investigation becomes lot more simpler if the values of the major process control parameters are expressed in linguistic terms and the values of the yield parameters are expressed in terms of the their relative ranks. One can easily reveal the fact [table 4] that when the cutting speed is high the surface roughness is of higher relative ranking. The highest relative ranking of surface roughness is obtained when the laser cutting speed is high and pulse width pulse rate is low [Sl. No.4 of table 4].

REFERENCES

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Table 3 : Influence of pulse repetition rate, pulse width and speed on the surface roughness values of the laser drilled hole

Sl. No.	Pulse rate (Hz)	Pulse Width(ms)	Speed (mms-1)	Ra (μ inches)	Ranks of Ra
1	10	1.5	1	131.00	13
2	10	1.5	1	131.17	12
3	10	1.5	2	221.50	3
4	10	1.5	3	409.00	1
5	10	2.0	1	150.45	10
6	10	3.9	1	236.67	2
7	15	1.5	1	110.40	24
8	15	1.5	2	157.00	7
9	15	1.5	3	156.33	9
10	15	1.5	3	156.83	8
11	15	2.0	1	114.83	21
12	15	2.0	1	114.83	20
13	15	2.0	2	187.17	5
14	15	2.0	2	187.67	4
15	15	2.0	3	185.33	6
16	15	3.9	1	117.33	19
17	15	3.9	1	117.83	18
18	15	3.9	2	146.33	11
19	15	3.9	3	112.33	23
20	15	3.9	3	112.83	22
21	20	1.5	1	102.50	26
22	20	1.5	2	122.17	17
23	20	1.5	2	122.17	16
24	20	1.5	3	127.33	15
25	20	1.5	3	127.33	14
26	20	2.0	1	101.43	27
27	20	3.9	1	110.23	25P

Analysis of Results

It has been found that for pulse width and pulse rate remaining constant the surface roughness of the laser cut part increases appreciably from 131 μ inch to 409 micro inch with the increase of laser cutting speed **[Sl. No. 1-4] [table 3].**

Table 4 Linguistic assessment of the influence of pulse repetition rate, pulse width and speed on the relative ranks of the surface roughness values

Sl. No.	Pulse rate (Hz)	Pulse Width(ms)	Speed (mms-1)	Ranks of Ra	Ra (μ inches)
1	Low	Low	Low	13	131.00
2	Low	Low	Low	12	131.17
3	Low	Low	MODERATE	3	221.50
4	Low	Low	HIGH	1	409.00
5	Low	MODERATE	Low	10	150.45
6	Low	HIGH	Low	2	236.67
7	MODERATE	Low	Low	24	110.40
8	MODERATE	Low	MODERATE	7	157.00
9	MODERATE	Low	HIGH	9	156.33
10	MODERATE	Low	HIGH	8	156.83
11	MODERATE	MODERATE	Low	21	114.83
12	MODERATE	MODERATE	Low	20	114.83
13	MODERATE	MODERATE	MODERATE	5	187.17
14	MODERATE	MODERATE	MODERATE	4	187.67
15	MODERATE	MODERATE	HIGH	6	185.33
16	MODERATE	HIGH	Low	19	117.33
17	MODERATE	HIGH	Low	18	117.83
18	MODERATE	HIGH	MODERATE	11	146.33
19	MODERATE	HIGH	HIGH	23	112.33
20	MODERATE	HIGH	HIGH	22	112.83
21	HIGH	Low	Low	26	102.50
22	HIGH	Low	MODERATE	17	122.17
23	HIGH	Low	MODERATE	16	122.17
24	HIGH	Low	HIGH	15	127.33
25	HIGH	Low	HIGH	14	127.33
26	HIGH	MODERATE	Low	27	101.43
27	HIGH	HIGH	Low	25	110.23

As it happens in the conventional machining process the productivity of cutting has inverse relationship with the surface finish of the product. If pulse width increases keeping the values of the pulse rate and cutting speed constant it is found that the surface roughness appreciable rises to a great extent **[sl. 5-6][table 3]**.