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AN EXPERIMENTAL COMPARATIVE ANALYSIS FOR LASER ENGRAVING DEPTH OF CAST AND EXTRUDED ACRYLIC USING LASER MACHINING

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ABSTRACT

Laser beam machining (LBM) is one of the most widely used thermal energy based non-contact type advance machining process. The laser beam machining process has various types of micro-machining applications such as laser cutting, fine cutting, laser drilling, micro-drilling, precision machining, micro-fabrication, laser marking, and engraving, etc. The cutting process is carried out by moving a focused laser beam along the surface of the workpiece with constant distance, thereby generating a narrow typically some tenths of a millimetre cut kerf.

In recent years, researchers have explored a number of ways to improve the LBM process performance by analysing different factors that affect the quality characteristics of the LBM process such as kerf width, kerf taper, surface finish, etc. It is seen from the literature that the process performance of the LBM process can be improved considerably by the appropriate selection of laser beam process parameters. Hence, in this work, an attempt is made for a comparative study of the LBM process for different materials using the experimental method. This will give the ready reference to the process planner to choose an appropriate set of optimum solutions as per requirement. For this work, the experiments are carried out on the CO2 laser machine for various materials. The process parameters considered are assisting gas pressure, cutting speed, laser power, and pulse frequency. The quality performance measures are in terms of engraving depth.

Keywords: Laser beam machining, multi-objective optimization, Overall Evaluation Criteria.

I. INTRODUCTION

Laser beam machining, being a non-contact process, does not involve any mechanical cutting forces and tool wear. Laser beam machining is a thermal energy based cutting process, which is executed by moving a focused laser beam on the surface of the workpiece with appropriate scanning speed. Asist gas is supplied through a nozzle with pressure to remove the molten metal. Laser beam machining of sheet metals has always been a major research area for getting the improves quality of cut which depend on several factors such as laser type, laser power, pressure of assist gas, cutting speed, sheet material composition and its thickness, and mode of operation of laser beam. The materials which exhibit high degree of hardness or brittleness and passing through favourable thermal and optical properties such as low reflectivity, low thermal conductivity and diffusivity are well suited for laser cutting process. The process of laser cutting involved many parameters, which can be generally divided into two main categories—beam parameters and process parameters. Beam Parameters These are parameters that characterize the properties of the laser beam which include the wavelength, power, intensity and spot size, continue wave and pulsed power, beam polarization, types of beam, characteristics of beam, beam mode. These are parameters that characterize the properties of the laser beam which include focusing of laser beams, focal position and dual focus lens, process gas and pressure, nozzle diameter, stand-off distance and alignment, and cutting speed. The accuracy of LBM process is mainly based on a control parameter such as gas pressure, pulse frequency, cutting speed and laser power. Various authors done experimentation on improving response parameters of LBM by using one material. Very few authors were focused on parametric comparison for different materials.

II. LITERATURE REVIEW

Milos J. Madic and Miro slave R Radovanovic (1) worked on AISI 304 stainless steel identified the robust condition for minimization of Heat Affected Zone (HAZ) and burr height in Co2 laser cutting. The experiment was carried out on the basis of standard L27 Taguchi orthogonal array in which four laser cutting parameters such as laser power, cutting speed, assist gas pressure and focal position were arranged at three level. The result indicated that the focus position is most significant parameter affecting the Heat Affected Zone (HAZ) and burr height whereas effect of assist gas pressure can be neglected.

Abhimanyu and Satyanarayana (2) carried a work to optimize the cut quality of mild steel during the process of pulsed Co2 laser cutting with various input process parameters like cutting speed, laser power and material thickness the output parameters were chosen to be surface hardness and edge surface roughness. They finally deduced that RSM to be a most suitable method for the identifying and developing significant relationships between the input variables.

Prof. Rahul D Shelke and Mr. Umesh Kumar H. Chavan (3) has been worked on optimization of sheet metal cutting parameters of laser beam machine. In this experiment, Taguchi method was applied for the multiple performance characteristics of cutting operations. Analysis of various process parameters and on the basis of experimental results, analysis of variance and signal and noise ratio. The result indicate that the assist gas pressure is the most significant factor for SR during LBM meanwhile Laser Power and cutting speed are sub significant in influencing. Laser power is the most significant factor for the thickness during LBM.

Mr. Amitkumar D Shinde and Prof.Pravin R Kubade (4) Performed the work investigation of effect of LAB process parameters on performance characteristics of stainless steel (SS304).In this they presents analysis of various process parameters and on the basis of experimental results, analysis of variance, F-test and S/N Ratio . They found that assist gas pressure is the most significant factor for SR during LBM. Meanwhile laser power and cutting speed are sub optimum surface roughness is LP2-CS2AGP2.The optimal parameter setting for the SR found (2400 – 900 -0.8). The parametric combination for optimum kerf width is LP1-CS3 – AGP3. The optimal parameter Setting for the kerf width found (2300 – 1000 – 0.9) .They concluded that the assist gas pressure and laser power plays a significant role in governing low SR &low kerf width.

K. Venkatesan and R. Ramanujam (5) Performed work on an experimental analysis of cutting forces and temperature in laser assisted machining of Inconel 718 using Taguchi method. This paper discussed about L9 orthogonal array, S/N ratio and ANOVA were adopted for finding the optimal process parameter for the performance measures of feed force (fx), thrust force (Fy) and cutting force (Fz).

Sandeep Kumar Singh and Sikander Swati Gangwar (6) has made effort for parametric analysis of cutting parameters for Laser Beam Machining based on central composite design. They found that in the theoretical study of Ra for mild Steel, Response Surface Methodology was employed to analyze the link between laser machining parameters with responses. The cutting parameters studied were cutting speed, Frequency and duty cycle.

Dubey and Yadava (7) have performed the multi-response optimization of laser beam cutting process of thin sheets (0.5 mm thick) of magnetic material using hybrid Taguchi method Response surface method.

Chirag Patel, Sandip Chaudhary and Parth Panchal (8) has studied the effect of various process parameters such as feed rate, input power and gas pressure up to 3 levels for each parameter by using laser beam on stainless steel for determining the quality of machined surface during each level. Full factorial design is being used for implementing the design of experiments.

Hence in this work the experiments are carried out on the CO2 laser machine for various materials like cast acrylic and extruded acrylic as they exhibit different properties for LBM process. The process parameters considered are assist gas pressure, cutting speed, laser power, and pulse frequency. The quality performance measures are in terms of engraving depth for both materials. For experimentation constant parameters are gas pressure and pulse frequency whereas variable parameters are cutting speed and laser power.

III. METHODOLOGY

1) **Selection of materials for LBM process.-** The selection of material was done by depending upon the physical properties of the material for laser cutting process. The cutting depth of a laser is directly proportional to the quotient obtained by dividing the power of the laser beam by the product of the cutting velocity and the diameter of the laser beam spot.

$$T \alpha \; p/vd$$

where *T* is the depth of cut, *P* is the laser beam power, *v* is the cutting velocity, and *d* is the laser beam spot diameter .For this work the cast acrylic and extruded acrylic sheets are used for experiments.

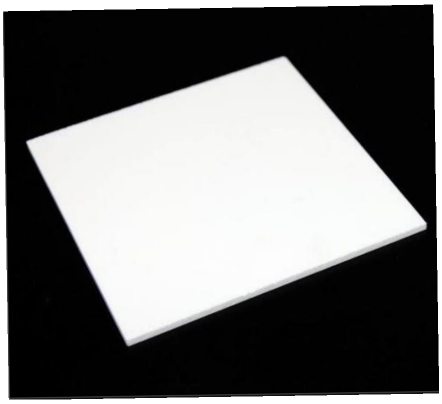

Fig. 1 Photo of Cast Acrylic sheet

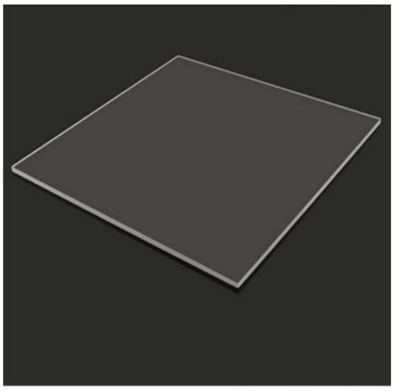

Fig 2 Photo of Extruded Acrylic sheet

2) Selection of Laser cutting Machine- The LBM is generally used for cutting the materials like non metal Acrylic, soft wood, Cardboard, cloth, Leather, Plastic, rubber, Paper, wool engraving G. This machine is made by Trilok Lasers Pvt. Ltd .The usage of this machine is an on cloth, leather, plush, Paper, Glass &other non-metals. In this 60W Power is to be used for an operation. This is knife edge type and model is 'TIL6090' . The 60W Power and 220V in single phase is the input to the machine. This machine is having cutting accuracy up to 99.9%. The total Power for this is 1000 W. The wavelength of Laser is 10.6mm for the operation. Machine table having height of 3 ft 6". The operating temp of the machine is 20-35. Working speed of this is up to 1.500 mm/sec. 0.6 MPa air supply is used for this. The character volume is of 1mm and only 1 punching head is used in this.

Fig 3 Laser Machine

3) Experimentation by changing process parameters on different materials-The process parameters considered are assist gas pressure, cutting speed, laser power, and pulse frequency. The quality performance measures are in terms of engraving depth for both materials. For experimentation constant parameters are gas pressure and pulse frequency whereas variable parameters are cutting speed and laser power.

IV. EXPERIMENTAL ANALYSIS

The numbers of experiment are carried out to analyze depth behavior of cast and extruded acrylic material by the input parameters are laser speed, laser power etc. and response parameters are laser engraving depth. Other parameters like gas pressure and laser frequency are kept constant throughout the experiments. The design matrix for performing experimentation along with recorded response parameters for cast and extruded acrylic is given in Table 1.The depth of laser engraving has been measured using the digital micrometer.

Table 1. The depth of laser engraving for cast and extruded acrylic

Sr. No	Laser Speed (mm/sec)	Laser Power (Watt)	Engraving Depth(mm)	
			Cast Acrylic	Extruded Acrylic
1	50	30	0.480	0.430
2	50	60	0.700	0.530
3	50	90	0.750	0.610
4	100	30	0.220	0.060
5	100	60	0.390	0.130
6	100	90	0.440	0.200
7	150	30	0.190	0.020
8	150	60	0.300	0.120
9	150	90	0.340	0.140
10	200	30	0.120	0.010
11	200	60	0.200	0.090
12	200	90	0.230	0.130

V. RESULTS AND DISCUSSION

The discussion on results obtained by experimental analysis is carried out to reach the conclusion. The difference in result for engraving depth is compared at different laser power and cutting time for laser beam machining process. The results for one power are compared to other power. The depth of engraving is going to increase by increasing power and decreasing speed. Comparing depth behaviour of cast and extruded acrylic material at different power and speed interval. The engraving depth of the acrylic material is directly depending on the power and inversely proportional to speed of laser cutting. The following graphs shows the depth behaviour of cast and extruded acrylic material at laser power and cutting time for laser beam machining process.

5.1. Laser engraving depth at Cutting Speed= 50 mm/sec

Table 2. The depth of laser engraving for cast and extruded acrylic at speed=50 mm/sec

Sr.No	Laser Speed (mm/sec)	Laser Power (Watt)	Engraving Depth(mm)	
			Cast Acrylic	Extruded Acrylic
1	50	30	0.480	0.430
2	50	60	0.700	0.530
3	50	90	0.750	0.610

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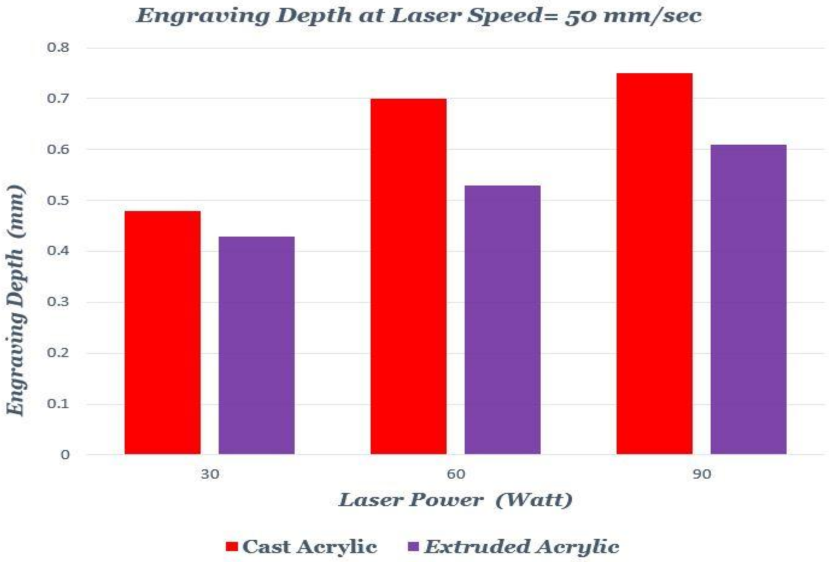

Fig.4 Laser engraving depth at Cutting Speed= 50 mm/sec

From above graphs, it is seen that the engraving depth is depends on the laser power. The graph shows the depth behaviour at laser speed 50 mm/sec and laser power 30 Watt, 60 Watt and 90 Watt respectively. The maximum depth can be obtained at laser speed 50 mm/sec and laser power 90 Watt. From graph it is observed that for cast acrylic depth obtained is more as compared to extruded acrylic. The depth of laser engraving goes on increasing as power goes on increasing.

5.1.2 Laser engraving depth at Cutting Speed= 100 mm/sec

Table 3. The depth of laser engraving for cast and extruded acrylic at speed=100 mm/sec

Sr.No	Laser Speed (mm/sec)	Laser Power (Watt)	Engraving Depth(mm)	
			Cast Acrylic	Extruded Acrylic
1	100	30	0.220	0.060
2	100	60	0.390	0.130
3	100	90	0.440	0.200

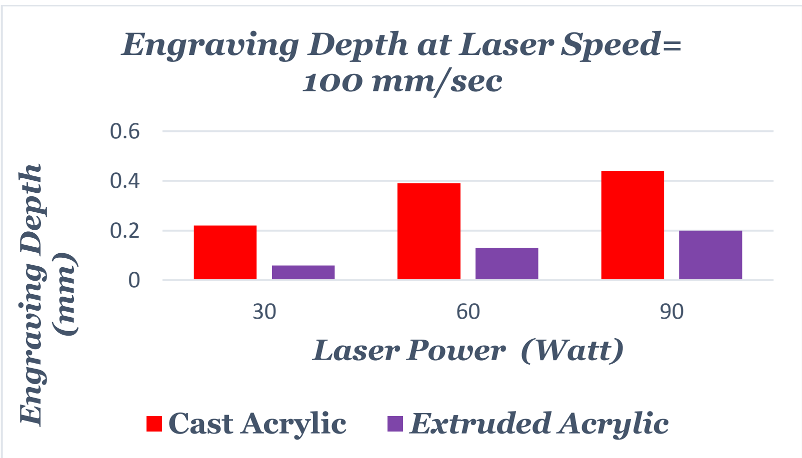

Fig.5 Laser engraving depth at Cutting Speed= 100 mm/sec

From above graphs, it is seen that the engraving depth is depends on the laser power. The graph shows the depth behaviour at laser speed 100 mm/sec and laser power 30 Watt, 60 Watt and 90 Watt respectively. The maximum depth obtained at laser speed 100 mm/sec and laser power 90 Watt is 0.440 mm.

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5.1.3 Laser engraving depth at Cutting Speed= 150 mm/sec

Table 4. The depth of laser engraving for cast and extruded acrylic at speed=150 mm/sec

Sr.No	Laser Speed (mm/sec)	Laser Power (Watt)	Engraving Depth(mm)	
			Cast Acrylic	Extruded Acrylic
1	100	30	0.190	0.020
2	100	60	0.300	0.120
3	100	90	0.340	0.140

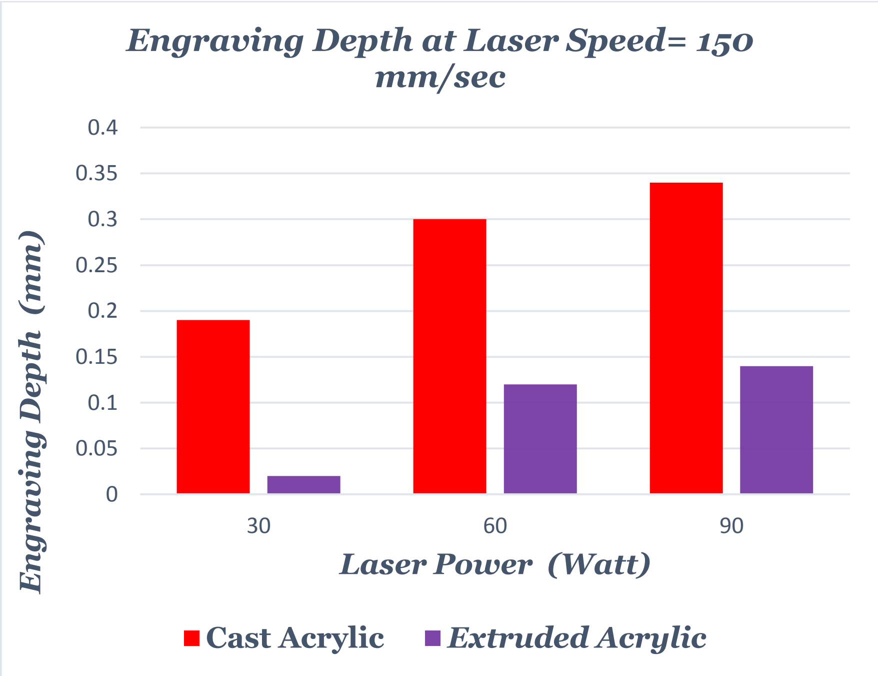

Fig.6 Laser engraving depth at Cutting Speed= 150 mm/sec

From above graphs, it is seen that the engraving depth is depends on the laser power. The graph shows the depth behaviour at laser speed 150 mm/sec and laser power 30 Watt, 60 Watt and 90 Watt respectively. Very less depth is obtained at laser speed 150 mm/sec and laser power 30 Watt for extruded acrylic. From graph it is observed that for cast acrylic depth obtained is more as compared to extruded acrylic.

5.1.4 Laser engraving depth at Cutting Speed= 200 mm/sec

Table 5. The depth of laser engraving for cast and extruded acrylic at speed=200 mm/sec

Sr.No	Laser Speed (mm/sec)	Laser Power (Watt)	Engraving Depth(mm)	
			Cast Acrylic	Extruded Acrylic
1	100	30	0.120	0.010
2	100	60	0.200	0.090
3	100	90	0.230	0.130

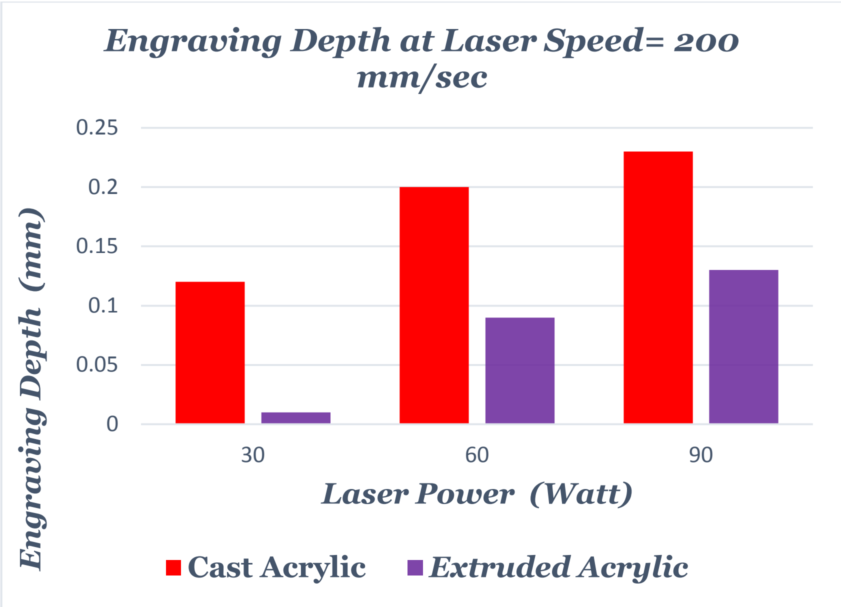

Fig.7 Laser engraving depth at Cutting Speed= 200 mm/sec

From above graphs, it is seen that the engraving depth is depends on the laser power. The graph shows the depth behaviour at laser speed 200 mm/sec and laser power 30 Watt, 60 Watt and 90 Watt respectively. The maximum depth can be obtained at laser speed 200 mm/sec and laser power 90 Watt. From graph it is observed that for cast acrylic depth obtained is more as compared to extruded acrylic. The depth of laser engraving goes on decreasing as laser speed goes on increasing.

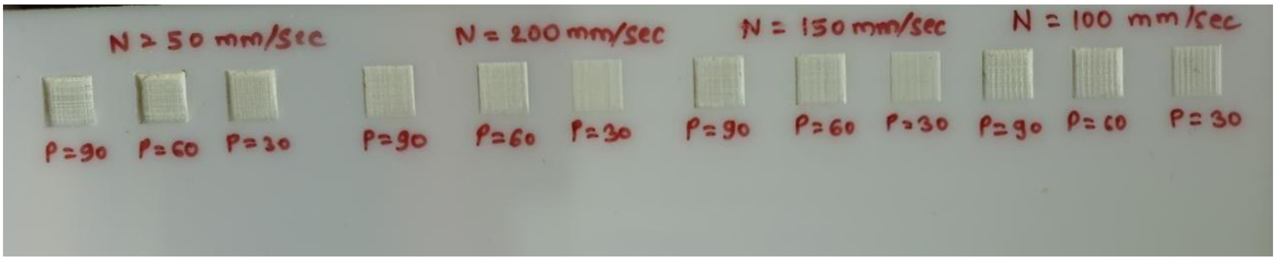

Fig.8 Laser engraving depth for cast acrylic

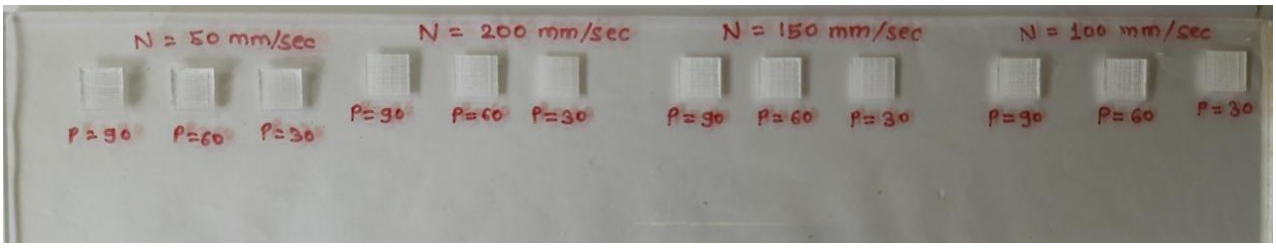

Fig.9 Laser engraving depth for extruded

VI. CONCLUSION

The present study investigates the depth of laser engraving for different laser speed and laser power. As per this study, were made following conclusions. In this study, process parameters were kept constant and the effect of response parameters were studied by using variation in laser speed and laser power. Depth of laser engraving is directly proportional to laser power and inversely proportional to laser speed. laser engraving depth obtained for cast acrylic is more as compared to extruded acrylic.

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