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A Review of Carbon Dioxide Laser on Polymers

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Abstract: **This paper presents an overview of laser machining process and investigates CO_2 laser cutting on polymers with various thickness. Laser Beam Machining is mainly used in many manufacturing industries. The highly collimated beam of a laser can be further focused to a microscope dot of extremely high energy density for cutting. Polymers are commonly used in automobile industries, medical, biotech devices, in the microelectronic and sensor industries for insulating layers in multi-level devices. Laser beam cutting can machine all common engineering polymers, the most common ones being polyamides, polycarbonate (PC) and polyester. In this literature review the various attempts made in CO_2 laser cutting of polymers is given.**

Keywords: Laser, Polymers, CO_2.

I. INTRODUCTION

Modern machining methods are established to fabricate difficult to machine materials such as high –strength, thermal- resistant alloys, various kinds of carbides, fiber-reinforced composite materials, satellites, and ceramics. Conventional machining methods of such materials produce high cutting forces that, in some particular cases, may not be sustained by the workpiece. Laser beam machining is light amplification by stimulated emission of radiation. A highly collimated, monochromatic, and coherent light beam is generated and focused to a small spot. A large variety of leather is available in the market, including solid state, ion and molecular types in either continuous wave (CW) or pulsed mode (PM) of operation. Laser is widely used in many industrial applications including plating, heat treatment, cladding, alloying, welding and machining.

II. PRINCIPLE OF LASER BEAM PRODUCTION

Laser works on the principle of Quantum theory of radiation. Consider an atom in the ground state (E_1) and when the light radition falls on the atom , it absorbs a photon of energy hv and goes to excited a states.(E_2) Normally the atoms in the excited state will not say there for long time. it comes to ground state by emitting photon of energy E=hv. Such emission takes place by one following two methods are Spontaneous emission and Stimulated emission.

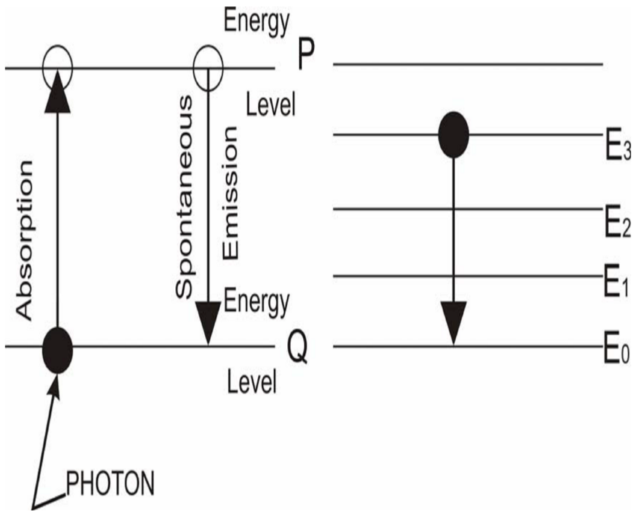

Figure 1. Energy level diagram

III. THE LASER CUTTING PROCESS

The process of laser cutting is a type of machining, which entails the interaction between the laser beam, cutting gas and work piece (Figure 1). The zone in which this process occurs is known as the cutting zone. The main task of the laser power in the cutting zone is to heat the material to the required temperature, thus turning the material from liquid to gaseous state. The cutting zone is a perpendicular surface that heats and melts by absorbing the laser beam. The molten zone progresses in the direction of cutting, which ensures a continuous cut. Many significant processes in laser cutting occur in this zone. The analysis of these processes provides valuable information about laser cutting. For example, it is possible to estimate the cutting speed and account for the formation of characteristic cutting marks.

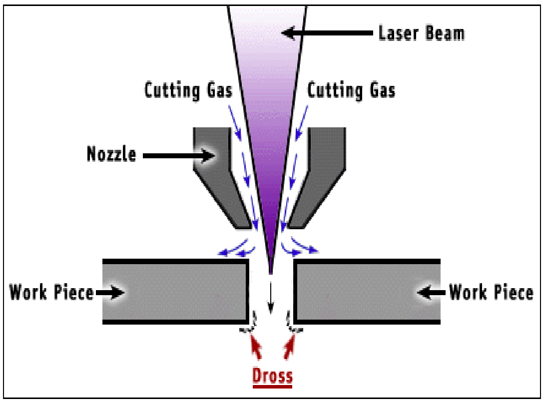

Figure 2: Laser cutting process

IV.PARAMETERS FOR LASER

TABLE 1: PARAMETERS TO BE CONSIDERED FOR LASER CUTTING

PROCESSING PARAMETERS	UNIT
Laser Power	W
Cutting Speed	mm/min, m/min
Type of Assist Gas	Oxygen, Nitrogen, Argon
Gas Pressure	Bar
Focal Length of lens	Mm
Focus Position Surface of work material	Mm
Nozzle Tip Distance	Mm
Nozzle Diameter	Mm
Material Thickness	Mm
Focal Diameter	Mm

V. LITERATURE REVIEW:

K.C.P.Lum et.al [1] investigated the laser processing of medium density fiberboard sheet varying it thicknesses from 3-60mm. The bigger the nozzle diameter, the lower the gas pressure cutting was done by continuous wave cutting and pulse wave cutting was used in that kerf width values obtained had also been also very similar to that achieved using CW for all thickness of MDF, pulsing was very effective. Associated quality of cut was evidenced by the low surface roughness values. Burn out was also minimal, even for angular profile cut of small internal angle.

Paulo Davin et.al [2] studied the Laser cutting of thermoplastics materials such as polyethylene (PE), polycarbonate (PC), polymethymethacrylate (PMMA), polyvinyl chloride (PVC), thermoset plastic that include epoxy and phenolic resins experiment was carried out with CO_2 laser cutting system that consisting of 40 kw continuous wave that excited by high frequency. The geometric form used for the CO_2 laser cutting polymer / composites and quality of laser cutting was evaluated by heat affected zone (HAZ) was studied under microscopy , High PC was next found more, EPOXY+GF was less, PMMA has very less, PH+AF no burr. Dimension of HAZ for EPOXY+GF , PH+AF has high, PC was moderate, PMMA was less, PP was absent, it was evident that HAZ increase with the laser power and decrease with the laser power and decrease with the laser power and decrease with the cutting velocity. The thermo set plastics present the cut surface deteriorated burn out –high dimension of HAZ, consequently poor workability. Laser cutting workability of the polymers/ composite under investigation was as follow: PMMA very high, PC high, PP high/medium and thermoset plastic reinforced lower.

F. Caiazzo et.al [3] investigated CO_2 laser cutting process of three polymers that were polyethylene (PE), polypropylene (PP), polycarbonate (PC) in three different thickness ranging from 2 to 10 mm. The measurement of roughness taken on cut edges and faces was much better in the PP than that of PE. The workability of three polymers concluded are PC high, PP medium-high, PE lower.

I.A. Chouhury et.al [4] Studied CO_2 laser cutting of three polymeric materials namely polypropylene (PP), polycarbonate (PC), polymethacrylate (PMMA). The quality of cut was found to be good compared to PP and PC. The dimension of HAZ for all polymers investigated were directly proportional to the laser power and inversely proportional to cutting speed and compressed air pressure. The effect of laser beam on the HAZ was more significant than the effect of cutting speed and compressed air pressure. Surface roughness was inversely proportional to laser power, cutting speed and compressed air pressure. Effect of cutting speed and compressed air pressure on the surface roughness were more significant than the effect of laser power. The surface Quality and workability of polymeric material by laser cutting appeared to be moderate for PC and PP and very good for PMMA.

J. Paulo Davim et.al [5] Studied CO_2 laser cutting on PMMA materials. Applications of thermoplastics PMMA were used in many cases for lenses, light pipes, outdoor signs, light pipes, light covers, etc. The HAZ increased with the laser power and decreases with the cutting velocity. The PMMA present low dimension of HAZ without burr. The surface roughness increases with a decrease in laser power and an increases of cutting velocity. The PMMA in complex 2D cutting present the dimension of HAZ between 0.12 to 0.37 mm, without burr and low surface roughness.

Mustafa kurt et.al [6] Studied the effect of the co_2 laser cutting parameters such as gas pressure, cutting speed and laser power on the dimensional accuracy and measurement surfaces roughness of engineering plastic (PTFE and POM) materials, the material which was being extensively used in industries. The maximum deviation of POM from the nominal value was 0.89 mm. The maximum deviation of PTFE from nominal value was 1.2 mm. Laser cutting indicated that low speed results in good surface roughness and low striation frequency at cutting edges. The effect of gas pressure on desired dimensions can be negligible. Both POM and PTFE materials had dimensional, diameter and surface quality error tendency inspite of different materials properties. The good surface quality obtained with low frequency. The form error value increased as the gas pressure and laser power increased.

F. Schneider et.al [7] studied the laser cutting in both single-pass and multi-pass process layer–wise removal of material in direction of the top side of the work piece till after several passes the groove reaches the bottom side completely. Heat accumulation was reduced by a cooling break between subsequent passes, repeated absorption of radiation with low intensity at the edge of the beam and escaping vapour. Cutting of FRP with ns-pulsed CO_2 laser radiation in the KW – range was performed to achieve high cutting rates and small HAZ. To avoid accumulation of heat in the work piece, processes with effective assistant gas flow had to be developed. In multi-pass processing of CFRP with 2.1 thickness the width of the HAZ was reduced.

Bai Hua Zhou et.al [8] studied the capability of low power laser to perform task other than marking. The effect of speed change on the depth of cut was less significant at low speed. In the cutting process the melted or evaporated materials must leave the narrow kerf that will block the laser beam and consequently reduces its intensity. At high depth of cut and low work piece speed the blocking effect reduces the effectiveness of the laser power increase. Cutting of pine wood, particle board, and rubber produces more smoke than wood during the cutting process. The smoke blocks the laser beam and reduces laser beam intensity. When compared with theoretical and experimental to the rubber material, the quality of the laser process was accepted, vaporized materials blown away from the kerf, but the laser cutting process caused a lot of smoke. The increase in cutting depth does not change linearly with increase input energy. The deeper the cutting depth, the more energy was produced.

P. Bamforth et.al [9] presented the CO_2 laser cutting optimization with the aid of 3D transient finite difference model. Laser cutting processes were often dominated by thermal effects and are readily modelled. The positional accuracy of the CW cutting system had also been shown to lack the ability to cut the lace. Process tolerances in the CW process mean that increases in HAZ volume of up to 10.2 times were achievable with only modest positional error.

Avanish Kumar Dubey et.al [10] investigated the design of experiments based studies on LBC process so far had been mainly aimed at the optimization of the single quality characteristic at a time. It has found the linear parameters are significant for both the models. Pulse width, cutting speed, square effect of pulse width, and interaction effect of pulse frequency and cutting speed have been obtained as significant factors for KW. The MRR has been found to be significantly affected by cutting speed, pulse width, pulse frequency, and square effect of cutting speed.

Islam Shyha [11] investigated the the CO_2 laser trimmg of the fibre reinforced plastics. The results showed that the material Removal Rate increased with the cutting speed and not on laser beam power or gas pressure settings. The surface quality was mainly dependent on the cutting speed of the laser beam. Kerf width reduces and the cutting speed increased.

AA Shaikh FM Varsi [12] studied the effect of depth of cut for single pass cutting on CO_2 laser. They considered the cutting parameters as laser power (p) from 0 to 100% of maximium capacity 25 watt, cutting speed (v) from 0 to 100% of maximum capacity of 42 ips (1066mm/sec). They observed the generated of depth of cut by allowing for single pass cutting. It was observed that the depth of cut decreased as the cutting speed increased; using a predictive method it was found that the experimental values coincide with the predicted values.

VI. CHARACTERISTIC OF LASER

Material Removal Technique: Heating , melting and vaporization of material by using high intensity of laser beam

Work Material: All Materials except those have high thermal conductivity and high reflectivity.

Tool: Laser beam wave length ranges of 0.3 to 0.6 µm

Pulse duration: one million second.

Medium: Atmosphere

Material removal rate: 6 mm^3/min

VII. ADVANTAGES

- Heat affected Zone is small around the machined surface.
- Process can be easily automated.
- Laser beam can be sent to long distance without diffraction. It can also be focused at one point there by generating large amount of heat.
- Beam configuration and size of exposed area can be easily controlled.
- There is no tool wear.
- Unlike conventional machining there is no direct contact between tool and work piece.
- Soft materials like rubber and plastics can be machined.
- Cutting of complex shapes is easy.
- Two or more cuts simultaneously
- Remote cutting over long stand-off distances.

VIII. DISADVANTAGES

- Intial investement is high
- Operating cost is also quite high
- Highly skilled operators are needed.
- Rate of production is low.
- Life of flash lamp is short.
- Overall efficiency is extremely low (10 to 15%).

IX. CONCLUSION

- The laser process is widely in many manufacturing sectors .
- The laser cutting of polymers is can be implemented in industries.
- High Accuracy of products can be cut, welded with precision dimension.
- Reduces tooling costs and reduced set up-times.
- Low power laser cutting can be used to cut polymeric materials and other non- metallic materials.
- High power laser cutting can be used to cut steels, and metals.

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