PARAMETRIC OPTIMIZATION OF CO_2 LASER MACHINING ON POLYPROPYLENE-A Review

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ABSTRACT

This Paper presents effect of CO_2 laser machining on Polypropylene material. Polypropylene (pp), also known as polypropene, is a thermoplastic polymer used in a wide variety of applications including packaging and labelling, textiles etc. CO_2 Laser machining is thermal energy based non-contact type advance machining. Currently, machine operators use "trial and error" approach to set-up laser cutting parameters in order to achieve the desired surface roughness. The setting up of laser cutting parameters is repetitive due to trial and error process. This report gives an effect of CO_2 laser cutting parameters (laser power, cutting speed, stand-off distance etc.) on the cut quality parameters (heat affected zone, surface waviness, kerf taper ratio etc.). The Taguchi method has been used in order to obtain optimum machine parameters.

Keyword: - *CO2 Laser, Polypropylene, Optimization, Control Parameters, Response Parameters.*

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1. INTRODUCTION

CO_2 laser emits an invisible infrared beam of a single wavelength in the form of a small, intense beam. Specifically, CO_2 emits photons at 10.6µm and 9.6µm. The laser gases for CO_2 lasers normally contain a mixture of helium, nitrogen, and carbon dioxide. Some laser types also require small amounts of CO, H2 or Xe in the laser gas mixture because of dissociation of gas molecules. The beam for a CO2 Gas Laser produces a very high temperature that may be used for engraving, cutting, drilling, marking, welding and in various medical applications such as dermatology and as a medical tool for producing clean cuts with little bleeding.
The basic mechanism of laser cutting is extremely simple and can be summarized as follows:1). A high intensity beam of infrared light is generated by a laser.2). This beam is focused onto the surface of the work piece by means of a lens.3). The focused beam heats the material and establishes a much localized melt (Generally smaller than 0.5mm diameter) throughout the depth of the sheet. 4). The molten material is ejected from the area by a pressurized gas jet acting coaxially with the laser beam materials this gas jet can accelerate the cutting process by doing chemical as well as physical work. For example, Carbon or mild steels are generally cut in a jet of pure oxygen. The oxidation process initiated by the laser heating generates its own heat and this greatly adds to the efficiency of the process. This localized area of material removal is moved across the surface of the sheet.

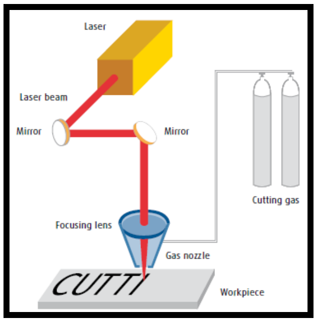

Fig. Laser Beam Machining

2. Literature survey

Joao M.P. Coelhoa, Manuel A. Abreua [1] discussed That Engineering parameters predicted by the model were applied to cutting superposed high- and low-density polyethylene and polypropylene samples, transparent and white, with thicknesses between 10 and 100 mm. Input parameters - cutting speed -20m/s and laser power-2.7kW and its Output is successfully modeled.

F. Caiazzo, F. Curcio[2] has investigated This work investigates the application of the CO2 laser cutting process to three thermoplastic polymers, polyethylene (PE), polypropylene (PP), and polycarbonate (PC) in different thicknesses ranging from 2 to 10 mm. Input parameters - Laser power, cutting speed, type of focusing lens, pressure and flow of the covering gas, thickness of the samples.Output- kerf widths on top and bottom, thicknesses, the melted transverse area, the melted volume per unit time and surface roughness values (*R*a).

K.F.Tamrin, Y.Nukman [3] It is found that low laser power and high cutting speed are necessary. However, supplied air pressure has different effects on cut quality of all thermoplastics. Input parameters - Laser power of 200W, high cutting speed of 0.4 m/min and low compressed air pressure of 2.5 bar. Output- HAZ.

N. Aboulfotoh Ali, H. A. El- flaah [4] Plastic, paper, glass and texture exhibit high absorption at 10.6 µm and require moderate power level of 1-20 W. The experimental results show that the cutting quality varies with the kind of the materials and cutting speed. Input parameters- CUTTING SPEED, LASER POWER. Output- KERF WIDTH.

Bai Hua Zhou, S.M. Mahdavian [5] For all materials like plastic, wood, particle board, and rubber the cutting results show that the increase in cutting depth does not change linearly with increasing input energy. The deeper the cutting depth, the more energy is being used. The results of cutting experiments have been compared with the prediction of a theoretical model that follows the same trends. Input parameters - Material properties and cutting speed.Output- Depth of the cut.

Joao M.P. Coelho, Manuel A. Abreu [6] The methods applied to the determination of the transmission and absorptance showed that for thicknesses lower than 200 µm polyethylene samples has a high degree of transparency to that wavelength. Polypropylene samples demonstrated similar characteristic for thicknesses lower than 100 µm. This transparency is characterized by absorptances lower than 20% and transmittances higher than 80%. Input parameters - Transmittance, Reflectance and Absorptance. Output- Attenuation length and the complex refractive index.

Miroslav RADOVANOVIC [7] For optimization purpose statistical and regression analysis were used as well as Taguchi optimization method. Experiment planning according to the Taguchi method so that wider experimental range is covered and empirical data modeling by means of artificial neural networks provides an efficient approach for accurate modeling of laser cutting process.Input parameters - Laser power, cutting speed, feed, and gas pressure.Output- Kerf width, surface roughness, HAZ and dross formation.

M. Lakshmi Chaitanya, A. Gopala Krishna[8] The most prominent performances of LBC, namely HAZ and Ra were enumerated. Primarily, from the experimental details, RSM was used to model the mathematical equations for the selected performance responses. The central composite rotatable factorial design was used extensively to diminish the number of experimental values. Subsequently, the validated mathematical models of RSM were used by NSGA-II to find the multiple sets of optimal solutions. Input parameters - Laser power, pulse frequency, gas pressure and pulse width.Output- Heat Affected Zone (HAZ) and surface roughness (Ra).

A.A. Cenna (2001) [9] The model developed uses the energy balance equation to predict various parameters in laser cutting of composite materials. The developed model successfully predicts the cut quality parameters such as kerf width at the inlet and at the exit and angle of the cut surfaces. It also predicts the transmitted energy loss through the kerf. Input parameters - Spatial distribution, interaction time, absorption coefficient and the thermal properties of the material.Output- kerf width at the entry and at the exit, material removal rate and energy transmitted.

C. Dowding (2015) [10] The maximum peel resistance force delivered by the 0.6mm diameter spot size was significantly greater than any achieved using the larger spot diameters tested. The peak peel performance recorded for 1.0, 1.4 and 2.00mm all sit along a linear trend, which is not adhered to by the 0.6mm result. It is proposed that the high irradiance possible using the 0.6mm diameter laser spot caused a more substantial bond. Input parameters - Laser Power, Traverse Velocity and Spot Size.Output- Peel resistance force.

K.F. Muhammad (2014) [11] The purpose of this research is to find the most optimum set of parameters of CO2 laser beam cutting (LBC) to cut an acrylic sheet. Parameters to be optimized are gap distance, cutting speed, laser power and temperature of the surrounding. Input parameters - Stand-off distance, cutting speed and laser power.Output- Surface Roughness, Kerf Taper Angle, Heat Affected Zone and Kerf Width.

Tony Hoult [12] Laser cutting speeds for thin polypropylene films were much higher using a shorter 10.2 μm wavelength than the typical 10.6 μm wavelength. Very marked cut speed differences were observed that depended on the orientation of the BOPP film. A possible explanation for the higher laser cutting speeds is based on the molecular structure of polypropylene. Input parameters - Laser wavelength.Output- Cutting speed.

Ruben Phipon (2012) [13] Using Genetic Algorithm, minimum Kerf taper obtained is 0.14695° which is 0.313° less in magnitude than experimentally measured value. Also, minimum surface roughness predicted using GA is 1.2625μm which is 0.3375μm better in value compared to the experimental measured value. The average percentage prediction error of GA is found to be 3.35% for kerf taper and 4.02% for surface roughness. Input parameters - Oxygen pressure, pulse width, pulse frequency and cutting speed.Output- kerf taper and surface roughness.

Shilpesh Rajpurohit (2013) [14] A large amount of thermal energy is conducted into the matrix and a large heat affected zone (HAZ) is produced by the heat generated during the process. This ultimately causes matrix recession, matrix decomposition and/or delamination. Therefore the use of lasers for the processing of GFRP is regarded as critical due to the large material damage by the heat. Input parameters - Laser power, cutting speed, gas pressure. Output- Heat affected zone, surface roughness, kerfwidth, taper angle.

A A Shaikh (2014) [15] It was found that depth of cut of Acrylic increases with increase in power whereas depth of cut decreases with increase in speed. The value of average error obtained as 4.5% which shows close convergence of predicted model from the actual one. The variation of predicted model from the actual one may be due to the evaporation of material and getting settled back during the experiment. Input parameters - Varying pressure and traverse speed.Output- Depth of cut.

Ario Sunar Baskoro(2011) [16] From the RSM analysis, in laser CO2 cutting for gypsum it is found that power and number of layer have significant effect to make depth of cut deeper, while the speed has no significant effect to increase the depth of cut. Input parameters - Speed, current, voltage, number of pass, number of layer and compressed air, Output- Depth of cut.

R.J.Ajudiya (2015) [17] The laser speed is increase the width of slot is decrease with constant power level because as the speed of laser head is increase the interaction time between laser spot and the material is decrease so due to less time of interaction less amount of material is evaporated. Similarly as the numbers of overlapping lines are increase the width of slot is increase with particular power levels. Here as the numbers of overlapping lines are increase then the numbers of laser passes over the material is also increase so width is increase due to expansion of heat affected zone at the edges. Input parameters - Power and traverse speed of head.Output- Material removal and the depth of cut.

3. CONCLUSIONS

The polypropylene samples, transparent and white, with thicknesses between 10 and 100 mm are successfully cut by cutting speed -20m/s and laser power-2.7kW.Low laser power and high cutting speed are necessary for PP cutting. However, supplied air pressure has different effects on cut quality of all thermoplastics. Appropriate Input parameters are Laser power of 200W, high cutting speed of 0.4 m/min and low compressed air pressure of 2.5 bar. Output- HAZ.

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