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Review on Effects of Process Parameters on Surface Roughness, Kerf Width and Material Removal Rate In CO_2 Laser Cutting Machine For SS 410

KEYWORDS: process parameter, laser cutting, optimization, taguchi

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ABSTRACT this paper is about the literature review of laser cutting. There are few process parameter controls the laser cutting and laser machining. This paper is about the process parameter and material already investigated by different author. The design of experiment methods used by different author and the analysis or optimization done by different author is listed here.

I. INTRODUCTION

Laser (light amplification by stimulated emission of radiation) is a coherent and amplified beam of electromagnetic radiation. The key element in making a practical laser is the light amplification achieved by stimulated emission due to the incident photons of high energy. A laser comprises three principal components, namely, a gain medium, a device for exciting the gain medium (amplifying state), and optical delivery /feedback system. For example, in CO2 laser, a gain or laser medium CO2, an optical resonator or cavity with two mirror (one is fully reflective and another partial reflective) and, an energizing or pumping source that supplies energy to the gain medium to activate CO2 into amplifying state. Additional provisions of cooling the mirrors, guiding the beam and manipulating the target are also important. The laser medium may be a solid (e.g. Nd:YAG or neodymium doped yttrium– aluminium– garnet), liquid (dye) or gas (e.g. CO2, He, Ne).

1.3 PRINCIPLE OF LASER CUTTING PROCESS:

Laser-beam machining (LBM) removes material by melting, ablating, and vaporizing the work piece at the point of impingement of a highly focused beam of coherent monochromatic light (Fig. 1.1). The electromagnetic radiation operates at wavelengths from the visible to the infrared. The principal lasers used for material removal are the Nd:glass (neodymium:glass), the Nd:YAG (neodymium:yttrium– aluminum–garnet), the ruby and the carbon dioxide (CO2). For pulsed operation, the power supply produces short, intense bursts of electricity in to the flash lamps, which concentrate their light flux on the lasing material. The resulting energy from the excited atoms is released at a characteristic, constant frequency. The monochromatic light is amplified during successive reflections from the mirrors. The thoroughly collimated light exits through the partially reflecting mirror to the lens, which focuses it on or just below the surface of the work piece.

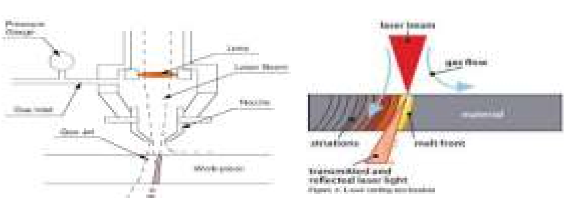

Figure: 1.1 Laser-beam machining

II.LITRETURE REVIEW

Stournaras A. et al. [1] ,use taguchi approach to solve the low coupling of the laser radiation with high reflectivity material as aluminium alloys (AA5083 with 2 mm thickness sheet), is processed in pulsed mode (8,9 and 10 Hz). They determine the contribution of each individual parameter to cutting quality and use regression analysis to develop an empirical model. They found laser power and cutting speed play significant role on the cutting quality, the pulsing frequency and the assist gas pressure also important for the surface roughness.

Riveiro A. et al. [2] have studied processing parameters and optimal conditions for CO2 laser cutting of an aluminium–copper alloy (2024-T3) (3 mm thickness sheet) have been determined under CW and pulsed mode, which opens a new sort of material to be cut by existing CO2 laser cutting. They proper take care of beam back- reflection. With the help of full factorial design (FFD) approach they screen out effectively the key variable significantly affecting on the response variables and investigated the interdependence of processing parameters on them. Experiment conducted by varying the pulse frequency, laser power and gas pressure, remaining parameters ware kept constant. Best result obtained under high laser power, high frequency and moderate duty cycle. When processing in pulsing mode two clear processing regimes were detected depending on the pulse frequency; processing at low frequencies (f<100 Hz) induces an intense recoil pressure on the molten material. Nevertheless, removal induced by the assist gas predominates using high frequencies (f >100 Hz).The high relevance of the assist gas on the cut quality was pointed out.

Lamikiz A. et al. [3] have discussed on CO_2 laser cutting for high strength steels(AHSS) and parameters that most influence the cutting of sheet metal have been studied. The results have, demonstrate very different behaviors between the thinnest and thickest sheets, whilst the variation of the cutting parameters due to the influence of the material is less relevant. They found that good quality cuts at a large range of speeds (ranging from 2000 to 7000 mm/ min) have been obtained for the 0.7 and 0.8 mm sheets. Furthermore, a 200 W power is enough to cut these sheets with a cutting speed up to 4000 mm/min. In all the experiments, both in the case of the thin and the thick sheets, the optimum focal position has been established near the under surface of the sheet. In

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the experiments where the laser beam has been focused on the surface of the sheet and even above the sheet, the results show poor quality in cutting areas. In their study they found that high strength steel cutting is perfectly viable, and most considerations valid for mild steel can be applied to achieve optimum cutting conditions.

Eltawahni H.A. et al. [4] had studied the, CO_2 laser cutting of stainless steel of medical grade AISI316L (3mm thickness). Design of experiment (DOE) was implemented b y applying Box–Behnken design to develop the experiment layout and mathematical models were developed to determine the relationship between the process parameters and the edge quality features. They tried to found the cutting edge quality parameters namely: upper kerf, lower kerf, the ratio between them, cut section roughness and operating cost to the process parameters such as laser power (1, 1.25 and 1.5 kW), pressure (10,12.5 and 15 bar),cutting speed (1,2 and 3 m/min), nozzle diameter (1,1.5 and 2 mm) and stand of distance (-4,-3 and -2 mm). Then, an overall optimization routine was applied to find out the optimal cutting setting that would enhance the quality or minimize the operating cost. The ratio increases as the laser power, nitrogen pressure and nozzle diameter increase, and it decreases as the cutting speed and focal position increases. The roughness value increases as the cutting speed increases and it decreases as the other parameters increases. However, the nozzle diameter has no significant effect on the roughness. The optimal cutting setting for AISI316L was laser power of 1.49 kW, cutting speed between 1538 and 1661 mm/min, a focal point position of 2.02 mm, nitrogen pressure of around 11.4 bar and nozzle diameter of 1.5 mm if the quality is important.

Wang J. [5] presented analysis and optimization of CO_2 laser cutting process for metallic coated sheet steels, GALVABOND. The study reveals that visual examination indicates that when increasing the cutting rate to as high as 5000 mm/min, kerfs of better quality could be achieved. Experimental setup used, material thickness (0.55, 0.8, 1.0mm) assist gas (O2), pressure (200,500,800 KPa), laser power (400, 500, 600, 700 W), cutting speed (2, 2.5,3 and 3.5 m/min). Some kerf characteristics such as the width, heat affected zone and dross in terms of the process parameters ware also discussed. It had shown that the energy efficiency ranges from as low as 5% to about 24% under the test conditions. High cutting speed and low laser power are favoured from the energy efficiency point of view and this condition also gives small size of HAZ.

N. Rajaram et al., [6] studied the effect of laser power and feed rate on kerf width, surface roughness, striation frequency and the size of heat affected zone (HAZ) on 1.27 mm, 4130 steel using 2kW laser machine. They vary power from 0.7-1.3 kW and feed rate 29.6-55 mm/s and other parameter ware kept constant. They found at low power and high cutting speed continuous through cut not done, whereas at 900 to 1300 W continuous cut obtained. Result shows decrease in kerf width occurs with an increase in feed rate for powers from 900 to 1300 W. As power and feed rate increases kerf width also increases same behavior is also found in surface roughness. Striation frequency is less dependent on laser power but it increases as the cutting speed up to critical level (approx. 46mm/s) and then decrease. HAZ mostly effected by laser power and increases with it and as speed increases the layer of HAZ decrease because less time for high power interaction. Regression model for laser power and feed rate on the quality characteristic ware developed.

Pratik et al., [7] had cut mild steel (3 mm) using CO2 laser by varying power (1.0 – 1.4 kW), feed rate (2400-3600 mm/min), and stand of distance (SOD, 1.0-1.5 mm) using full factorial design. They measure upper and lower kerf width taper angle, surface roughness and performed ANOVA. Results suggest that as feed rate increase upper and lower kerf width decrease, while it increases with laser power. The effect of SOD on upper kerf is not significant, while for lower kerf width it decreases as SOD increases. Surface roughness decreases with increases in feed rate. It also decreases with increase in laser power intensity.

Milos Madic et al.,[8] presented,Taguchi method for optimization of surface roughness in CO2 laser cutting of mild steel (2 mm ,S355JG3 (EN)) using cutting speed (3-7 m/min), laser power (0.7-1.5 kW) and oxygen as assist gas pressure (3-7 bar) were considered in the experiment using Taguchi's L25 orthogonal array. They found cutting speed and assist gas pressure are the most significant parameters affecting the surface roughness variation, whereas the influence of the laser power is much smaller. It was observed that the cutting speed should be kept at the highest level (7 m/min), assist gas pressure at the lowest level (3 bar), while laser power should be kept at an intermediate level (0.9 kW) for obtaining minimal surface roughness.

Eltawahni H.A. et al, [9] studied cutting edge quality parameters and to find out the optimal cutting conditions for ultra-high performance polyethylene (UHPP). They applied DoE by implementing Box-Behnken design and ANOVA analysis, validated their result with mathematical model. The effects of process parameters (laser power (800-1450 kW), cutting speed (700-1750 mm/min), focal point position (-1 to -7 mm)), on each response were determine. Some major findings are:
The upper kerf decreases as the focal position and the cutting speed increase, and it increases as the laser power increases. The lower kerf increases as the laser power and focal position increase, and it decreases as the cutting speed increases. The ratio decreases as the focal position and laser power increase, and it increases as the cutting speed increases. The focal position has the main effect on the ratio.

Caiazzo F. et al., [10] studied the application of CO_2 laser cutting of polymeric materials, polyethylene (PE), polypropylene (PP) and polycarbonate (PC) in order to provide potential future industrial users of this technology. They studied with optimum power levels and cutting velocities as well of the quality of the surfaces. In their experiments they tested different thicknesses ranging from 2 to 10 mm and process parameters examined were: laser power, range of cutting speed, type of focusing lens, pressure and flow of the covering gas, thickness of the samples. Furthermore, the values of kerf widths on top (Lsup) and bottom (Linf) thicknesses, the melted transverse area, the melted volume per unit time and surface roughness values (Ra) on cut edges were measured. They have reported that, for all the three plastic, the high cutting speeds are not always synonyms with good process efficiency, the laser cutting workability under investigation is as follow: PC high, PP high/medium and PE lower. focusing lens, pressure and flow of the covering gas, thickness of the samples. Furthermore, the values of kerf widths on top (Lsup) and bottom (Linf) thicknesses, the melted transverse area, the melted volume per unit time and surface roughness values (Ra) on cut edges were measured.

III. MATERIAL SELECTION
Steel AISI 410 or SS410.Plate Thickness as 6 mm.
CHEMICAL COMPOSITION:

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Grade	C	Mn	Si	P	S	Cr	Mo	Ni	Al
410	0.18	0.52	0.31	0.03	0.016	11.80	0.067	0.0020	0.013

Table 3.1: Chemical Composition.

MECHANICAL PROPERTIES:

Grade	Tensile Strength (MPa) min	Yield Strength 0.2% Proof (MPa) min	Elongation (% in 50mm) min	Hardness
				Rockwell B (HRC) max
410	517	310	25	85

Table 3.2: Mechanical Properties.

PHYSICAL PROPERTIES:

Grade	Density (kg/m3)	Elastic Modulus (GPa)	Mean Co-eff of Thermal Expansion (μm/m/°C)	Thermal Conductivity (W/m.K)	Melting point
			20-200°C	At 100°C	
410	7.65	200	10.5 x 10 -6	14.4-24.9	1482-1532°C

Table 3.3: Physical Properties.

APPLICATION OF MATERIAL:

Furnace parts, Micrometer parts, Tray supports, Caps and vaporizers in petroleum fractionating towers ,Lining for reaction chamber, Coal screens ,Fishing tickles ,Keys, Lamp brackets ,Rules and tapes ,Wall screens ,Steam turbine buckets, Blades

IV. CONCLUSION

From the above literature survey we find that there are many researches done on optimization techniques for process parameter for surface roughness and kerf width . But I found that there are very few researches done on SS 410 so we want to do research on this material. We like to use D.O.E as RSM for analysis.

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