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State of Art of Laser Cutting Process

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ABSTRACT

LASER stands for Light Amplification by Stimulated Emission of Radiation. Laser beams are widely used for machining and other manufacturing processes such as cutting, drilling, micromachining, marking, welding, sintering, and heat treatment, of which laser cutting is one of the energy based unconventional process which is capable of cutting complex profiles in most of the materials with a high degree of precision and accuracy. The main objective of this paper is to review the research work carried out so far in the area of laser cutting process and also the experimental and theoretical studies on the influence of the process parameters like power, cutting speed, gas pressure, focus position etc on surface roughness, kerf width and heat affected zone (HAZ).

KEYWORDS: *Laser cutting process, Surface roughness, Kerf width and Heat affected zone (HAZ)*

I. INTRODUCTION

Laser cutting is a thermal based non-contact process capable of cutting complex contour on materials with high degree of precision and accuracy. It involves process of heating, melting and evaporation of material in a small well defined area and capable of cutting almost all materials. The word LASER stands for Light Amplification by Simulated Emission of Radiation). B.J. Ranganathan & G. Viswanathan [1] stated that the demand for laser cutting process is increasing in the production industries like aerospace, automobile, ship building and nuclear industries because of the ability of laser to cut materials with attractive processing speed, high productivity and ability to cut materials with complex shapes. Ahmet Hascalik and Mustafa Ay [2] mentioned that laser cutting is a non-contact operative method which does not need expensive or replaceable tools and does not produce any force that can damage the workpiece so that it can be used as an alternative to mechanical cutting processes. Arun Kumar Pandey and Avanish Kumar Dubey [3] said that different types of lasers available are solid lasers, liquid lasers and gaseous lasers among which solid state lasers like Nd:YAG and gaseous co2 lasers are mostly used for cutting because of their high power and suitable properties needed for the cutting of the material.of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper.

II. WORKING PRINCIPLE

The M. Madic et. al. [4] stated that laser cutting is a thermal, non-contact and highly automated process well suited for various manufacturing industries to produce components in large numbers with high dimensional accuracy and surface finish. They also stated that high power density beam when focused in a spot melts and evaporates material in a fraction of second and the evaporated molten material is removed by a coaxial jet of assist gas from the affected zone.

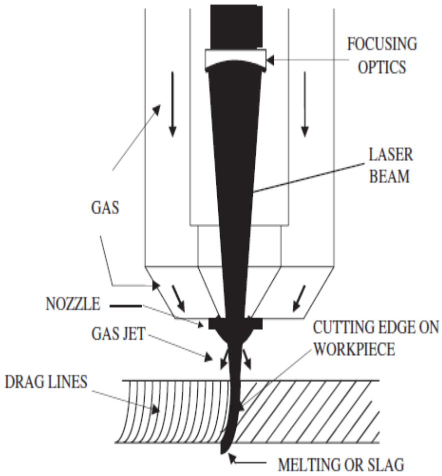

Figure 1. Schematic diagram of laser beam cutting [5]

III. PROCESS PARAMETERS

Laser cutting process has always been a major research area for getting the exceptionally good quality of cut like reduced surface roughness, kerf width and heat affected zone (HAZ). The quality of cut solely depends on the setting of process parameters like cutting speed, focal point, laser power, assist gas pressure etc.

3.1 Surface roughness

Surface roughness is an effective parameter representing quality of a machined surface. K.A. Ghany & M. Newishy [6] predicted that surface roughness value reduces on increasing cutting speed & frequency and decreasing laser power & gas pressure. Arun Kumar Pandey and Avanish Kumar Dubey [7] studied the effect of laser cutting of Titanium alloy sheet and observed that lower values of pulse frequency, higher values of cutting speed and moderate pressure of gas results in lesser surface roughness. A. Riveiro et. al. [8] found that good quality can be obtained by high cutting speed and high laser power. A. Stournaras et. al. [9] found that laser power and cutting speed were found to play the most important role on the cutting quality due to the fact that their combination determines the amount of heat that enters the cutting regime.

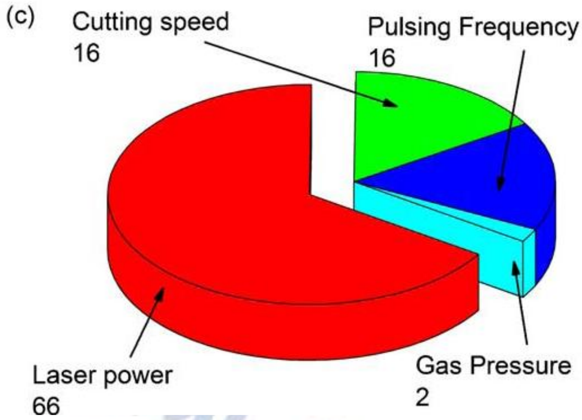

Figure. 2. Effect of each parameter on surface roughness [8]

Milos Madic and Miroslav Radovanovic [10] in their graph illustrated that surface roughness decreases with increase in cutting speed and increases with increase in assist gas pressure

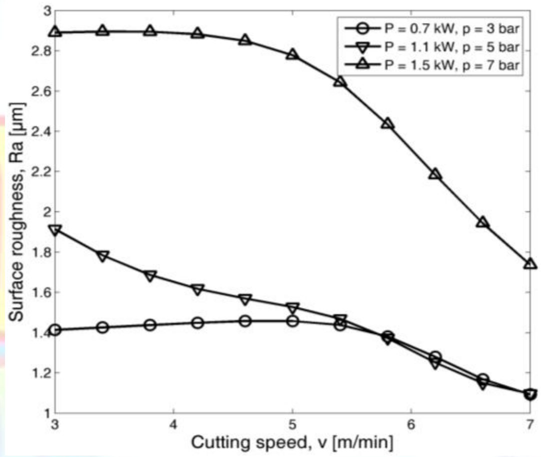

Figure 3. Surface roughness vs Cutting speed [10]

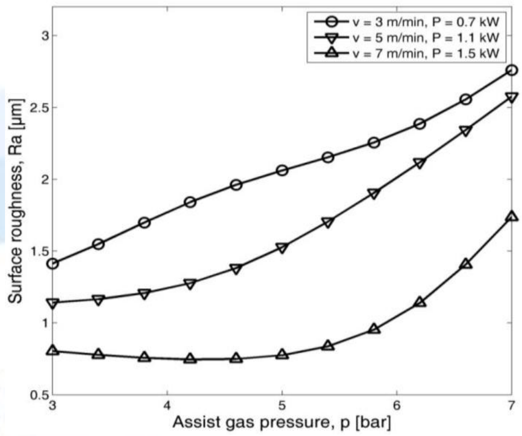

Figure 4. Surface roughness vs Assist gas pressure [10]

Thawari, G. et al. [11] observed that surface roughness value reduces with increase in cutting speed and frequency and decrease in laser power and gas pressure. N. Rajaram et. al. [12] in their work concluded that high powers and lower feed rates gave good surface roughness. Milos Madic et. al. [13] observed that the cutting speed should be kept at the highest level (7m/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.

Sundar et al. [14] concluded the following: decrease in assist gas pressure shows a good decrease in surface roughness; higher cutting speed produces low surface roughness; there is a direct relation between the laser power and the surface roughness and the effect of laser power was more significant at low levels of laser power; and the effect on stand-off distance on surface roughness was very less significant.

3.2 Kerf width

Kerf is a groove or a slit or a notch usually the lower and upper part of the cut is usually not parallel, it will be narrow at the bottom than the top. Kerf width is measured along the whole cut line of the width as shown in Fig 5. It is the difference of starting width of the top profile to the ending width of the top profile. This same applies to the bottom surface. [14]

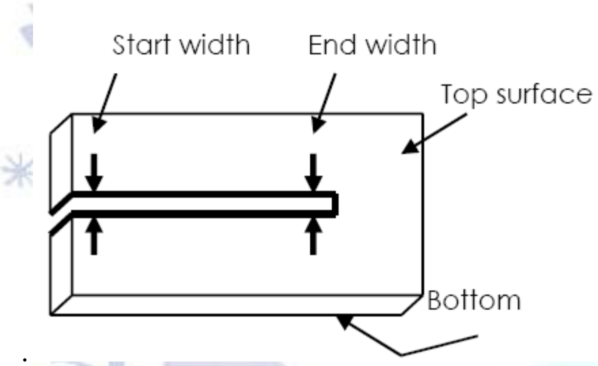

Figure 5. Kerf width measurements [14]

Dhaval P. Patel and Mrugesh B. Khatri [15] identified that kerf width generally increases with increase in assist gas pressure and laser power and decrease in cutting speed. Ghany, K.A. & Newishy [16] observed that increase in the frequency reduces the kerf width.

Yilbas[17] examined the effects of laser output power and cutting speed at the workpiece surface on the resulting kerf size. Fig 6 shows the variation of kerf width with cutting speed and laser output power. Kerf width Increases with increase in laser power and decreases with increase in cutting speed.

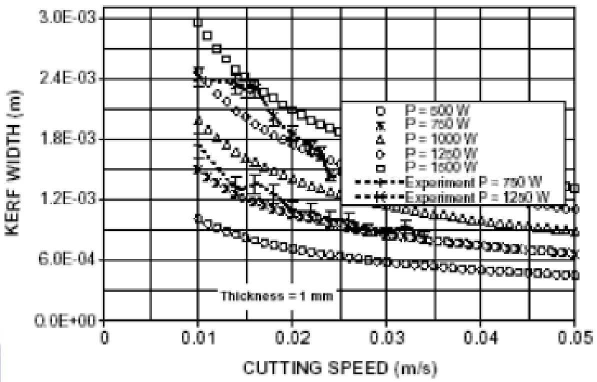

Figure 6. Variation of the kerf width with cutting speed [17]

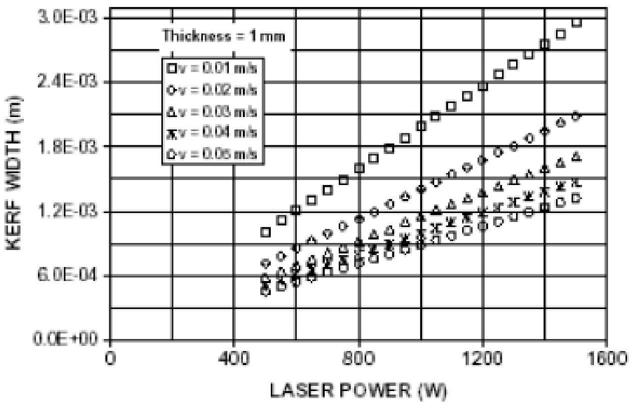

Figure 7. Variation of the kerf width with laser output power [17]

Arun Kumar Pandey et. al. [18] carried out laser cutting of Titanium alloy sheet and found that pulse width and assist gas pressure have been found the significant factors for kerf taper.

3.3 Heat Affected Zone (HAZ)

The thermal heat of laser cutting produces a heat affected zone (HAZ) next to the cut edge. The heat affected zone is the part of the material whose metallurgical structure is affected by heat but is not melted. Rajaram et al. [11] investigated the combined effects of the laser power and cutting speed on the size of HAZ in CO2 laser cutting of 4130 steel. It was found that an increase in the cutting speed and a decrease in the laser power resulted in a decrease in the width of HAZ. Sheng et al. [18] showed that the HAZ increases with increasing laser power. On the other hand, it was found that the HAZ decreases with increasing cutting speed

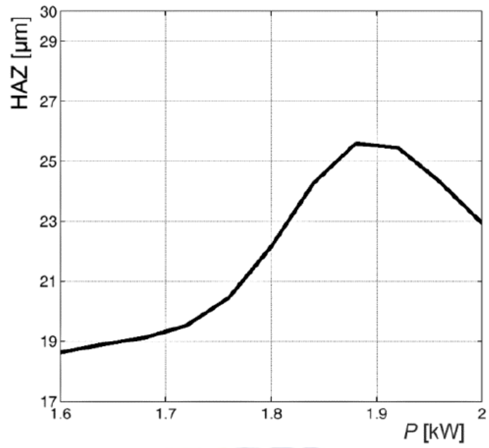

Figure 8. Effect of the laser power on the width of HAZ [18]

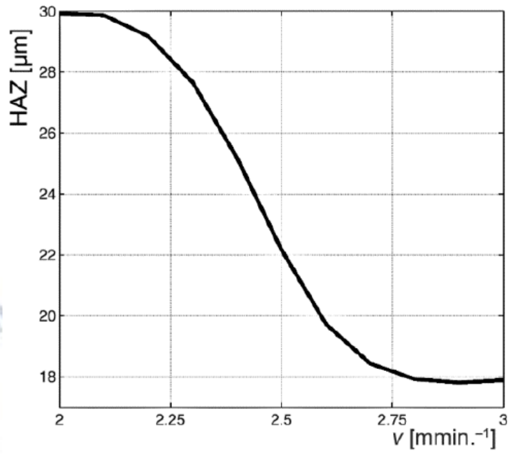

Figure 9. Effect of the cutting speed on the width of HAZ [18].

Paulo Davim et al. [19] conducted an experimental study for CO2 laser cutting of polymeric materials and observed that the HAZ increases with increase cutting speed as shown in Fig 8.

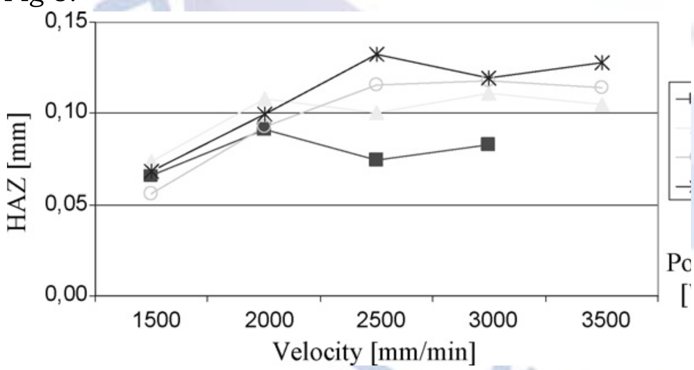

Figure 10. Dimension of HAZ (mm) of PMMA in function of cutting velocity for several power laser [19]

Dhaval P. Patel and Mrugesh B. Khatri [15] conducted experimental investigation on CO2 laser cutting of mild steel and stainless steel and identified that size of HAZ reduces with an increase in cutting speed.

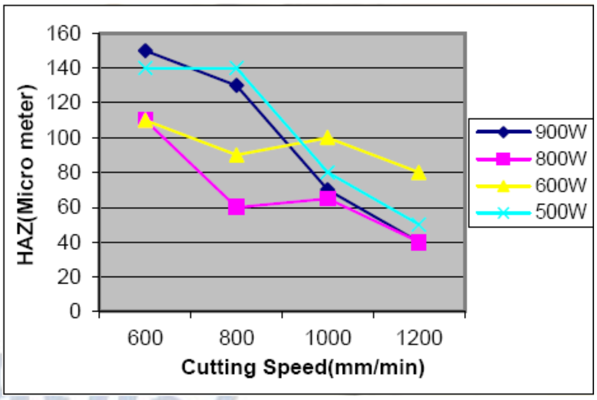

Figure 9 HAZ Vs Cutting speed [15]

Hanadi G. Salem et. al. [20] HAZ width increases with increasing the laser power and decreases with increasing scanning speed and gas pressure.

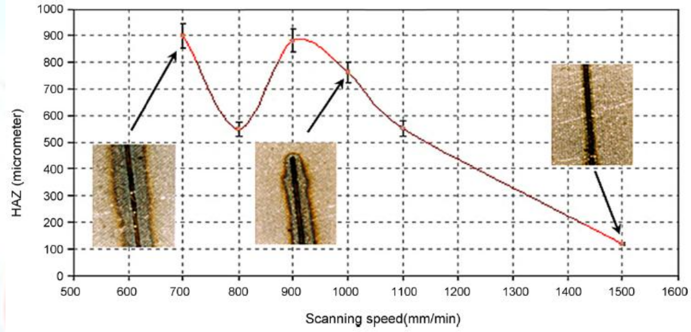

Figure 10. HAZ vs Speed [20]

Hocheng and Pan [21] found out that the section area of HAZ (A) increased with decrease in traverse speed and increase in laser power. Also HAZ decrease with increase in gas pressure.

IV. Conclusion

The work presented here is an overview of research work carried out in laser cutting process. From the above discussions it can be concluded that :

1. Laser cutting process is capable of cutting complex profiles in most of the materials with a high degree of precision and accuracy.
2. The performance of laser cutting process depends on the input process parameters like laser power, cutting speed, assist gas pressure etc and also on the important performance characteristics like surface roughness, HAZ and kerf width.
3. This paper just presents an overview of the recent experimental investigations in laser cutting of various engineering materials concerned with cut quality like surface roughness, HAZ and kerf width and identifies the most common process parameters and cut quality characteristics

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