Optimization of Quality Characteristics of Laser Cutting

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Abstract: **Laser cutting or laser machining is a very popular process for cutting of metallic sheets and plates now days. Generally the laser cutting process is termed as one of the advanced thermal process used to cut wide range of materials.In this process the molten material removed with the help of laser beam which is a mixture of gases supplied through laser generators with aid of pressurized gas which referred as assist gas.In this paper different approaches such as Taguchi method, statistical and mathematical models, and response surface methodology are used to evaluate the quality characteristics of laser cut components, such as heat affected zone (HAZ), surfaceroughness, kerf width. The main aim of this paper is to evaluate above mentioned quality characteristics by varying different input parameters such as laser power, speed, feed, pulsing frequency, gas pressure, duty etc**.

Keywords: *heat-affected zone (HAZ), laser cutting, surface roughnes, kerf qualitys*

I. INTRODUCTION

Sheet-metal cutting is the single largest, in terms of sales, global industrial laser application. CO_2 lasers dominate this application due to their good-quality beam combined to high output power. It is estimated that more than 40,000 cutting machines using CO2 lasers have been installed worldwide. With the aim of achieving greater competitiveness on the world market in the metal processing industry, it is necessary to meet the most stringent demands in terms of increased productivity, accuracy, quality of machined surfaces, reducing the consumption of materials and energy. To achieve these objectives, there is a broader use of technology of laser cutting of various materials. Laser cutting is classified as a typical thermal process that has special advantages over other known thermal processes due to the high quality and very smooth cut surface. To take advantage of this technology it is necessary for each processed material and thickness due to different thermal and structural properties, and different capabilities of absorption of laser radiation parameters to define the best process in terms of productivity and achieving the required quality

II LASER CUTTING PROCESS:

Laser cutting offers a high precision, CNC controlled method of cutting metallic, plastic, and thin ceramic components. It is a mechanized, thermal, non-contact process capable of cutting most materials with a high degree of precision and accuracy. There are two commonly used types of industrial cutting laser, CO_2 and Nd:YAG. These differ in that the wavelength of infrared light produced is 10.6μm for CO_2 lasers and 1.06μm for Nd:YAG lasers. Both these types of lasers produce the cut by focusing a beam of monochromatic light to a very small spot size by lenses and mirrors giving power densities in the up to 10^5 W/mm^2. This power density is sufficient to melt locally or even vaporize most materials. Once a through thickness zone of molten or vaporized material is generated (a keyhole), a jet of assist gas, delivered co-axially through the cutting nozzle, is used to eject this material from the kerf.

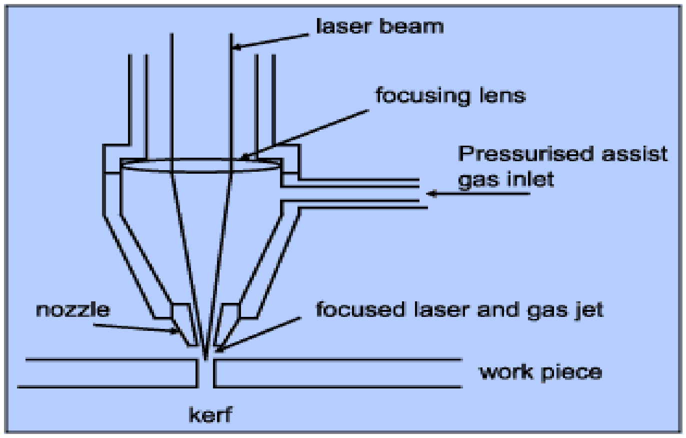

Fig. Laser cutting

The characteristics of the laser cutting process relate to the fact that the beam can be focused to a spot of less than 0.5mm diameter to achieve these very high power densities. The resulting cut edge is very square and the process is capable of cutting at very high speeds. The combination of an intensely concentrated heat source moving at high speeds also results in very little heat being transmitted to the surrounding material and, therefore, very little thermal distortion of part

III. LITERATURE REVIEW:

i Heat affected zone (HAZ)

A heat-affected zone (HAZ) is the portion of the base metal that was not melted during cutting/ but whose microstructure and mechanical properties were altered by the heat.

Tam et al. [1] in this research Taguchi method to study laser cutting process for 4.5 mm thick mild steel sheet (S/N) ratio of overall figure of merit was considered as quality function.

Lim et al. [2] this paper represents Taguchi robust design to study the width of cut, heat affected zone during laser cutting of "quad flat number (QFN) Lead packages" using diode pumped solid state laser (DPSSL). In these cutting parameters are laser current, laser frequency and cutting speed.

Mathew et al.[3] this study presents parametric studies on pulsed ND YAG laser cutting of fiber reinforced plastic (FRP) composite sheet 2mm thick. A central composite design (CCD) with uniform precision was used for the experimental design and second order response surface model for heat affected zone and kerf taper developed. In this cutting parameters are speed, pressure, pulse energy, pulse duration, pulse repetition rate.

Araujo et al. [4] in this experiment the microstructure in heat affected zone during laser cutting of AA2024 by a continuous CO_2 laser beam investigated. micro structural changes of the heatof laser machined Al 2024 T3 have been analyzed after fatigue test and related to macroscopic properties to carry out aeronautic requirements and quality specifications. They investigated that α-liquid phases were present in the heat affected zone.

Duan et al. [5] in this paper laser high power cutting process and formulation of the geometry of the heat affected zone was considered. They considered the effect of various laser process parameters, multiple reflections, and inert gas pressure on the geometry of the cut sections. They showed that the shape of the cutting section was strongly dependent on the cutting speed, laser power, and focal position; however, assisting gas pressure had slight effect on the cut geometry.

Dell'erba et al. [6] in this experiment backreflected beams entering into the laser cavity can damage the laser cavity, cavity optics or beam delivery optics. Second, the high thermal conductivity of aluminum that tends to produce a large heat affected zone due to the high heat conduction losses.

Kar and Migliore [5] this study presents that while cutting of aluminum T6 and 7075 – O by using air ,cut edges were oxidized and exhibited higher tendency of recast formation being more uneven in profile. Parts obtained by CO_2 laser cutting exhibit large heat affected zone.

Chryssolouis [8] Steen in this researchPulsed Nd:YAG laser cutting becomes an excellent cutting process because of high laser beam intensity, low mean beam power, good focusing characteristics, and narrow heat affected zone.

Grum and Zuljan [9] in this experiment heat affected zone after laser cutting was examined. They introduced a factorial analysis among the variables of laser cutting parameters to identify the most affecting parameter on the geometrical characteristics of the cut.

J.Wang [10] in this paper experimental investigation is presented which analyses the CO_2 laser cutting process for difficult-to-cut metallic coated sheet steels, which are called GALVABOND. A laser-material interaction is carried out to study the energy efficiency involved and to understand the cutting process. Kerf characteristics such as the width, heat affected zone (HAZ) and dross in terms of process parameters are then discussed. the relationship between the cutting speed and laser power for good quality cuts is established. From the study with high cutting speeds, it is found that the size of HAZ generally increases with an increase in laser power, but reduces with an increase in cutting speed. In many cases, varying the cutting speed in the lower region did not result in a significant change in the size of the HAZ and in some cases lower cutting speeds even caused a reduced HAZ size.

Jana Petru et al.[21] this study measurement and evaluation of the width of the heat-affected zone is carried out for Hayness 188 which is cobalt-nickel-chromium-tungsten alloy having excellent high temperature strength with very good resistance to oxidizing environments up to 1095 °C. In this experiment Winbro Delta gas CO2 laser operating in continuous mode is used.

ii Surface roughness

Surface roughness, often shortened to roughness is a component of surface texture. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth.

Lim et al. [2] In this experiment Taguchi method was applied to study the surface roughness obtained during high speed laser cutting of stainless steel sheets.

Almeida et al. [2] in this paper factorial design approach was applied to determine the effects of pulse energy, overlapping rate and type of assist gas on the surface roughness on the dross formation during Nd: YAG laser cutting of pure titanium and titanium alloy (Ti 6Al4V)

Rajaram et al. [13] in this experiment laser cutting of 4130 steel was studied, they showed that low feed rates have good surface roughness and low striation frequency at the cutting edges.

A.Riveiro et al. [6] this study presents the role of assist gas for laser cutting of aluminum alloys, the experiments shows that compare to air when assist gas is used velocity gets doubled. Assist gasses used for laser cutting can be termed as inert or reactive gases. The assist gases used generally are oxygen and nitrogen for aluminum and its alloys nitrogen is used as assist gas. When high quality edges are required nitrogen is used in case of carbon and stainless steels.

Caizzo et al. [14] in this research laser cutting of polymeric plastics was examined, they measured the kerf width and surface roughness of the cut edges and the cutting conditions were optimized through fuzzy mathematical programming.

Lobo et al. [15] this paper presents influence of laser processing parameters on particulate generated during cutting of mild steel sheets. They showed that particle diameter in the dross was directly related to the process quality measures and of the cut edge surface finish.

Wandera et al. [16] this study presents laser cutting of thick section stainless steel and medium section aluminum. They showed that low surface roughness was achieved with the focal point position inside the work piece showing the need for wider kerf for better melt ejection in thick section metal cutting. in addition to this there was reduction in surface roughness with increased assist gas pressure due to the gas dynamics inside the narrow cut kerf.

Chen and Yao [17] in this experiments the laser cutting was carried out at cutting speeds both below and above the oxygen reaction front velocity and showed that striation depth and surface roughness decreased with cutting speeds and increased with gas pressure across the entire cutting speed ranges(15-50 mm/s)

Kaebernick et al.[18] in this paper increase of striation depth thus surface roughness with increasing gas pressure was observed

Radovanovic and Dasic [19] in this research it was observed that surface roughness increases along with sheet thickness, but decreases with increase in the laser power when laser cutting of mild steel.

Neimeyer et al [20]. this study presents that the average surface roughness may be best at high cutting speed and low assist gas pressure. They confirmed that the work piece thickness showed little effect on the cut surface quality. It was conducted that the profiles of the cut surfaceof the top and bottom edges yield the same values for average surface roughness despite the significant visual difference in the striation pattern.

iii Kerf quality

The kerf normally produced by laser cutting its quality and its dimensions such as kerf width ,kerf taper mainly depends mainly on appropriate selection of process parameters. Generally minimum kerf width with accurate and uniform kerf is the main requirement now days.

Avinash Kumar Dubey et al. [8] in this paper optimization of kerf qualities namely kerf width and kerf deviation is experimentally investigated during Nd: YAG laser cutting of aluminum alloy sheet of 0.9 mm thickness. Taguchi quality loss function is used for optimization purpose. They studied that assist gas pressure and pulse frequency significantly affects the kerf quality characteristics in the operating range of process parameters.

B.S. Yiblas [22] In this experiment laser cutting of thick mild steel sheet is carried out, the input process parameters are laser power, cutting speed, and assist gas pressure which is oxygen used in this case. Effects of these selected input process parameters on percentage kerf width are examined by factorial analysis method. Thermal efficiency of the process and liquid layer thickness is formulated; also optical microscopy is used to study the cutting defects and kerf size variations. It was investigated that laser power and gas pressure have significant effects on percentage of kerf width variation.
Cihan Karatas [23] in this paper CO_2 laser cutting of HSLA- steel which is hot rolled and pickled is considered and effect of beam waist position on work piece surface and work piece thickness on striation formation is examined.,for modeling of kerf width lump parameter analysis is used. It was found that beam waist position has significant effect on kerf size and as the work piece thickness reduces, the relative location of beam waist position varies for the minimum kerf width.

IV SUMMARY:

The quality characteristics which discussed in paper are most important related to final product and they are strongly depend on the type of assist gas used for cutting and input parameters such as laser power, speed ,feed etc. work piece material has not significant impact on this quality characteristics. Selection of assist gas for different materials is important in case of laser cutting because assist gas react chemically with the material due to which certain reactions like oxidation takes place which results in poor quality characteristics in the final product.

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