Experimentation and Parametric Analysis of Laser Cutting Process on Low Carbon Steel - A review

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Abstract: **Laser cutting process is a relatively new machining technique, which is extensively used in many industrial applications. Parameters which effect on quality of laser cutting are Laser power, Cutting speed, and Gas pressure. It's effect observe on Heat affected zone and Surface roughness. Laser cutting process on low carbon steel is rarely found in previous research work. This research includes Experimentation and Parametric analysis on Low carbon steel.**

Key words: **Laser cutting process, Low carbon steel**

I. INTRODUCTION

A laser is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. The initial foundation of the laser theory was laid by Einstein.

Components of a typical laser:

1. Gain medium
2. Laser pumping energy
3. High reflector
4. Output coupler
5. Laser beam

A laser consists of a gain medium, a mechanism to energize it, and something to provide optical feedback. The gain medium is a material with properties that allow it to amplify light by way of stimulated emission. For the gain medium to amplify light, it needs to be supplied with energy in a process called pumping. Light bounces back and forth between the mirrors, passing through the gain medium and being amplified each time. Typically one of the two mirrors, the output coupler, is partially transparent. Depending on the design of the cavity (whether the mirrors are flat or curved), the light coming out of the laser may spread out or form a narrow beam.

Cutting is the most widely practiced industrial application of laser among the machining operations. The advantages of laser cutting over other techniques are: flexibility, scope of automation, ease of control over depth of cut, cleanliness, noncontact processing, speed, amenability to a wide variety of materials (ductile/brittle, conductor/non-conductor, hard/soft), negligible heat affected zone. Following figure shows laser cutting process.

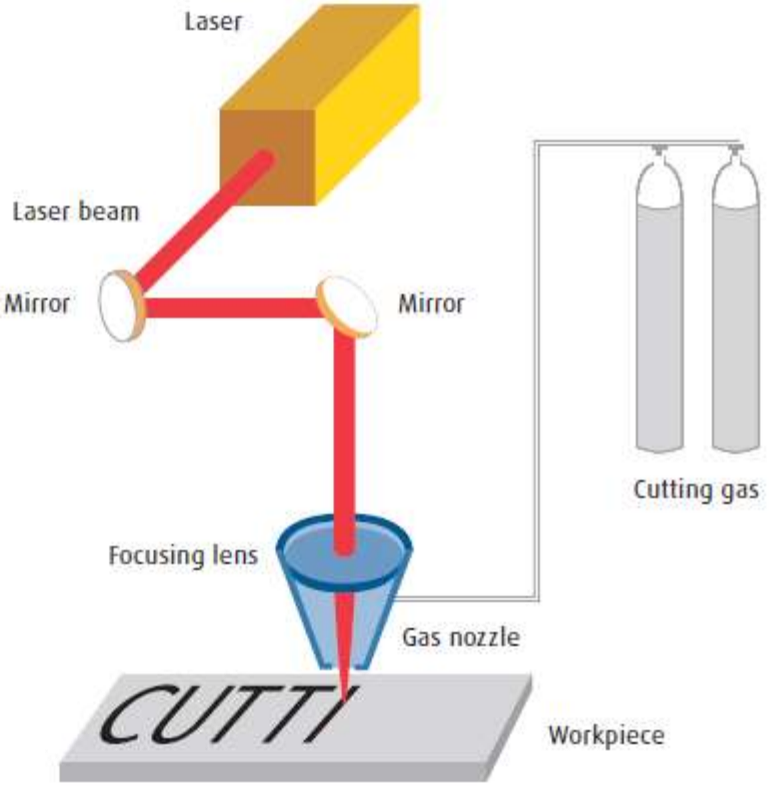

Figure 1: Schematic diagram of laser cutting process[8]

II. DIFFERENT MECHANISMS FOR LASER CUTTING

1. Vaporization Cutting,
2. Melting and Blowing (or Simply Melting),
3. Controlled Fractures,
4. Scribing and
5. Cold Cutting

1) Vaporization Cutting:
In vaporization cutting, the focused beam raises the surface temperature above the boiling point and generates a keyhole, which causes a sudden increase in absorptivity due to multiple reflections leading to quicker extension of the hole. This method is more useful in cutting materials that do not melt such as wood, carbon, and plastic.

2) Fusion Cutting (Melting and Blowing) :
In this process, a laser beam is used to melt the material and cutting is undertaken by blowing the molten material away with a sufficiently strong gas jet. This process requires only one tenth of the power for vaporization. If the gas (oxygen) reacts exothermically with the workpiece then another heat source is added to the process and is termed as reactive fusion cutting.

3) Controlled Fracture :
This approach is useful for cutting brittle material. During this process, laser beam heats a small volume of the surface causing it to expand and produce tensile stresses around the irradiated zone. If there is a crack in this space, it will act as a stress raiser, and cracking will continue in the direction of hot spot.

4) Scribing:-
During the process, a laser beam is used to weaken the structure by making a groove or line of holes following which it is mechanically broken.

5) Cold Cutting:-
This is the process of breaking the bond of organic materials by irradiating it with excimer laser working in the ultraviolet region. This process is useful in cutting plastic, machining of human hair, micro-surgery, and engineering with single cells, tumor surgery, etc.

III. LITERATURE REVIEW

Various researchers are working on laser cutting process to cut various materials. They are working on various parameters.

A.M. Orishich et. al[1] discuss on the fiber and CO2 laser were compared from the viewpoint of two laser-cutting methods: the oxygen-assisted cutting of low carbon steel and fusion cutting of stainless steel with a neutral assistant gas. The absorbed laser energy was measured in respect to the unit of the removed material volume at the cutting parameters correlating to the minimal roughness of the cut surface. They discusses on the potentiality of the method of absorbed laser energy measurement by the value difference at the cut channel inlet and outlet. The absorption coefficient means the integral coefficient which includes also the laser power absorbed at multiple reflections in the cut channel. The measurement process is schematically shown in following figure.

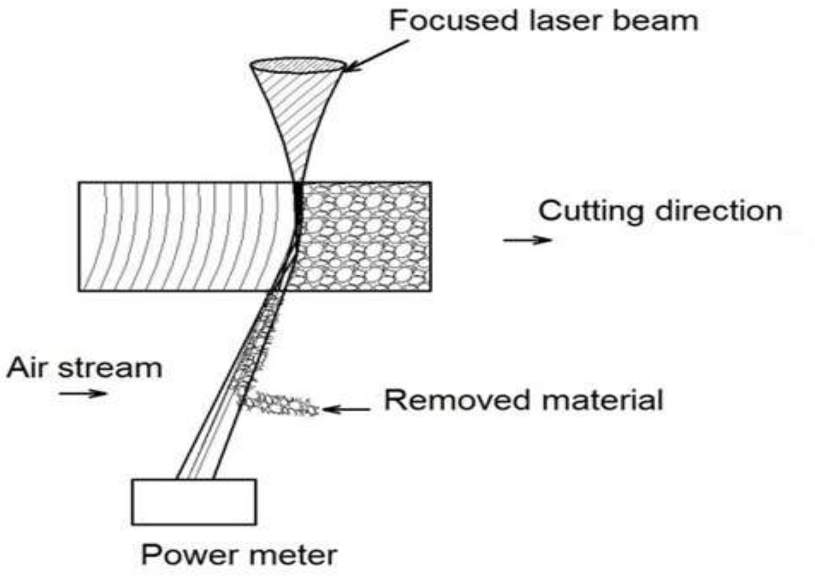

Figure 2: Schematic diagram of the absorption coefficient measurement[1]

In the fusion-cutting of stainless steel, the specific energy E is different when the cut surface roughness is minimal. The optimal speed corresponding to the minimal roughness coincides with the maximal speed. The lower value of this speed in the CO2 case correlates with the higher value of the specific absorbed energy *E*. This conflicting result may be caused by the technique of the laser-beam absorption coefficient in the cut channel when the absorbed power is measured is the difference between the power value at the channel inlet and outlet. This approach neglects the beam power part which strikes the sheet surface normally and might be reflected. This part of the beam must heat the metal up to the melting point and initiate the cut channel formation.

Erica Librera[2] discussed on laser cutting which provides various advantages such as high flexibility in terms of process parameters and cut material type as well as possibility to obtain complex geometry in different dimensions with high precision. Differences are visually appreciated, measured 2D roughness values of different CO2 and fiber laser cutting conditions are very similar. Recently, a greater diffusion of 3D surface profilometry devices is present. These devices allow areal surface roughness parameters to be defined, which are potentially suitable to better quantify the laser cut quality. This work points out the use of a focus-variation microscopy to acquire 3D surfaces and evaluate analytically the surface quality of laser cut edges using areal surface roughness parameters.

In this paper the differences between two laser cutting technologies in terms of the cut-edge quality have been investigated. The reliability of the standard roughness measurements and possibilities addressed which is arising from use of new 3D topography measurement technologies.

Serkan Apay and Behcet Gulenc[3] used Surface coating operations which is important place in metal technologies. The work of surface coating operations is to improve and enhance the inferior properties of a surface through its modification. The low-carbon AISI 1015 steel was coated with cobalt-base alloy Stellite 6 welding wire by microlaser welding. After coating, the microstructures of the coated surface cross-sections were examined. The microstructure, hardness and wear resistance of the surface-alloyed layer were investigated using optical microscopy, scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), X-ray diffraction analysis and pin-on-disk tests. The Stellite coating alloy to the diffusion from chrome and cobalt AISI 1015 steel was examined by means of the line analysis method and element mapping analyses.

AISI 1015 low-carbon steel was coated with cobalt- base Stellite 6 alloy welding wire by using microlaser welding. Structural steels can be coated with Stellite alloys by the method of microlaser welding in one pass under normal atmospheric conditions without taking any measure and without a pre-annealing thermal process.

G. R. Fayaz and A. Ebrahimi [4] used model to multilayer laser solid freedom fabrication process for material properties of low carbon steel 1015 for workpiece and cobalt which allow stellite 21 with 1.5wt.% nano CeO2 as the powder particles. Transient heat transfer and mass transfer equations in laser solid freeform fabrication process are solved by Finite Element Method (FEM). In this approach, the geometry of the deposited material, temperature and thermal stress fields across the process area are predicted. For each layer the clad height is computed. The results for powders with and without nano CeO2 are compared. For a specific point and time, the stress due to heat expansion and contraction is obtained. The addition of nano CeO2 into the power, the maximum stress and the melt pool temperature increase but the crack formation decreases.

H.A. Eltawahni[5] discussed laser cutting is a popular manufacturing process utilized to cut various types of materials economically. The width of laser cut or kerf, quality of the cut edges and the operating cost are affected by laser power, cutting speed, assist gas pressure, nozzle diameter and focus point position as well as the work-piece material. CO2 laser cutting of stainless steel of medical grade AISI316L has been investigated.

Design of experiment (DOE) was implemented by applying Box–Behnken design to develop the experiment lay-out. The aim of this work is to relate the cutting edge quality parameters namely: upper kerf, lower kerf, the ratio between them, cut section roughness and operating cost to the process parameters which are mentioned above. Then, an overall optimization routine was applied to find out the optimal cutting setting that would enhance the quality or minimize the operating cost. To determine the relationship between the process parameters and the edge quality features mathematical models were developed. Also, process parameters effects on the quality features have been defined.

R. Adalarasan et.al[6] proposed the second generation metal matrix composites (MMCs) which find wide applications in aerospace and automotive industries. For cutting these advanced materials and obtaining a good surface texture is challenge. The present study reports the application of non-contact type (thermal energy based) pulsed CO2 laser cutting process on Al6061/SiCp/Al_2O_3 composite. The process parameters in laser cutting influence the kerf width, surface finish and cut edge slope. These quality characteristics were observed for the various combinations of cutting parameters like laser power, pulsing frequency, cutting speed and assist gas pressure. The cutting trials were designed according to Taguchi's L18 orthogonal array and a hybrid approach of grey based response surface methodology (GRSM) was disclosed for predicting the optimal combination of laser cutting parameters. A substantial improvement in the surface finish was observed in the responses obtained with the optimal setting of parameters. The atomic force microscopy (AFM) images and P-profile graphs of the cut surface were also observed to study the surface finish and texture.

H.A. Eltawahni et. al[7]] proposed laser process parameters influence greatly the width of kerfs and quality of the cut edges. This article reports experiments on the laser plywood-cutting performance of a CW1.5kWCO_2 Rofin laser, based on design of experiments (DOE). The laser was used to cut three thicknesses 3,6 and 9 mm of plywood panels. The process factors investigated are: laser power, cutting speed, air pressure and focal point syyposition. The aim of this work is to relate the cutting edge quality parameters namely: upper kerf (UK), lower kerf (LK), the ratio between upper to lower kerfs and the operating cost to the process parameters mentioned above. Mathematical models were developed to establish the relationship between the process parameters and the edge quality parameters, and special graphs were drawn for this purpose. Finally, a numerical optimization was performed to find out the optimal process setting at which both kerfs would lead to a ratio of about 1 and at which low cutting cost take place.

CONCLUSION

Laser cutting is the most widely practiced industrial application among the machining operations. The advantages of laser cutting over other techniques are: flexibility, scope of automation, ease of control over depth of cut, cleanliness, noncontact processing, negligible heat affected zone etc. Parameters which affect on quality of laser cutting are Laser power, Cutting speed, and Gas pressure. The values of these parameters were higher in previous work. By using suitable optimization method reducing values of these parameters.

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