An Experimental Analysis of Fiber Laser Cutting On Stainless Steel-304

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Abstract--- Fiber Laser Cutting is non-conventional machining process in which laser is generated and highly intense laser impinge onto the surface of the material to cut. Fiber laser cutting is newly developed process which is modified from simple laser cutting. Due to using fiber optics there is less power loss as compared to the laser cutting. Nitrogen and oxygen gases are used as the assist gas. This paper enlightens on analysis of operating power, focal point and cutting speed on the performance parameters such as surface roughness, kerf width and bending force while using oxygen as the assist gas.
Keywords: – Fiber laser cutting, Stainless Steel- 304, Oxygen Gas, Response Surface Method.

I. INTRODUCTION

The first laser was invented in 1960. It was an optical pumped laser using a ruby crystal as gain medium. Since then the technology have been in constant development. In 1967 laser cutting was demonstrated for the first time. This was done using a focused CO_2 laser and an assist gas jet. (Wandera, 2010) It wasn't until 1978 that the first flatbed laser cutting machine was introduced for commercial use. This machine was actually a punch/laser cutting machine, where the cutting head was a stationary unit and the work piece could be moved in the x-y directions using numerical controls. The year after (1979) Trumpf (German laser machine manufacturer) introduced a 500-700 W CO_2 laser cutting machine (Trumpf, 2012).

The increasing laser beam quality and laser power is of high interest for the manufacturing industry, since these factors are highly influencing the obtainable quality of the work piece and allowable material thickness.

A. *Working Principle Of Fiber Laser Cutting*

An almost parallel laser beam, which is usually invisible, is generated in the laser source and directed to the cutting head by mirrors, where it is concentrated (focused) by a lens to a small spot (Fig. 1). Depending on the process, t h e spot is placed on t h e surf ace of t h e work piece or on the material to be cut.

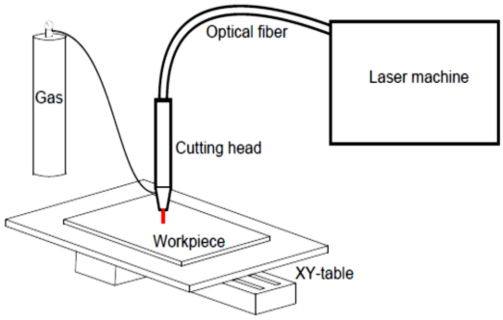

Fig. 1: Example of a Laser Cutting Setup Consisting of a Laser Machine, Optical Fiber, Cutting Head, Gas, Work Piece and a XY-Table.

The intense light beam quickly heats up the work piece and melts the material. The assist gas (also called: cutting gas) is applied to protect and cool the focusing lens and to remove the molten metal from the cut kerf at the same time. There are two cutting processes, depending on the type of assist gas used:

When cutting with oxygen, the material is burned and vaporized after being heated up to ignition temperature by the laser beam. The reaction between the oxygen and the metal actual y creates additional energy in the form of heat, which supports the cutting process. These exothermic reactions are the reason why oxygen enables penetration of thick and reflective materials when it is used as a cutting gas.

II. LITERATURE REVIEW

A. B.Adelmann, R. Hellmann [1] reveals that the position of the focus has the highest influence on the strength from the results of the optimization by design of experiments. The position of the focus has the most important influence on the strength and the velocity has almost no influence in the analyzed interval. To measure the flexural strength, a 3-point bending test machine (Thuemler) is used.

B. B.S.Yilbas, S.S.Ahktar, C.Chatwin[2] reveals It is found that the high conductivity of bronze increases the cooling rates within the cutting section, which influences the thermal stress field in the cutting region. Laser hole cutting in bronze is carried out and the thermal stress formed in the cutting section is examined using a finite element code. The cut geometry and microstructural changes in the cutting section are examined using optical microscope, scanning electron microscope (SEM), and energy dispersive spectroscopy (EDS).

The maximum residual stress is in the order of 200 MPa, which is almost uniformly distributed along the whole edges. The high residual stress region extends almost 0.0025 m along the hole circumference in the substrate material.

C. A.G.Malikov, A.M.Orishich, V.B.Shulyatyev [3] reveals Surface roughness dependence on the cutting parameters has been investigated experimentally for the laser-oxygen cutting.

Two conditions for minimum surface roughness have been established: (i) the laser energy per unit material volume removed should be constant; (ii) the laser power per unit thickness of cut sheet should be constant. The kerf width and sheet thickness ratio have been determined experimentally.

D. Cihan Karatas, Omer Keles, Ibrahim Uslan, Yusuf Usta [4] reveals that beam waist position has significant effect on the kerfs size and as the work piece thickness reduces. The relative location of beam waist position varies for the minimum kerf width. The micro cracks are found in the solidified material at the cutting surface, which is due to non-uniform and rapid cooling of the solidified material at the surface. The measurements are composed with the experimental findings. SEM and optical microscopy are conducted to examine the cutting surfaces. The minimum kerf width is obtained when focus setting becomes similar to the nominal focal length of the focusing lens particularly for thin work pieces.

E. Avanish Kumar Dubey, Vinod Yadava [5] reveals the quality of laser cut kerfs mainly depends on appropriate selection of process parameters.

Assist gas pressure and pulse frequency significantly affect the kerf quality in the operating range of process parameters.

The multi-objective optimization of kerf quality such as kerf deviation and kerf width using Taguchi quality loss function has been done for pulsed laser cutting of thin sheet of aluminum alloy.

F. B.S. Yilbas [6] found that laser output power and oxygen gas pressure have significant effect on the percentage of kerf width variation.

A factorial analysis is carried out to identify the main effects and interactions of the parameters. Thermal efficiency of cutting and liquid layer thickness is formulated. Optical microscopy and scanning electron microscopy (SEM) are carried out to examine the cutting defects and the kerf size variation.

G. H.A. Eltawahni, N.S.Rossini, M.Dassisti, K.Alrashed, T.A.Aldaham, K.Y.Benyounis and A.G.Olabi, "Evaluation and optimization of laser cutting parameters for plywood materials", Optics and Lasers in Engineering 51 (2013) 1029–1043 in 2013 [10] used ACW 1.5 kW CO_2 Rofin laser with a linear polarized beam angled at 45° provided by Mechtronic Industries Ltd. A focusing lens with a focal length of 127 mm was used to perform the cut. Therefore compressed air was supplied coaxially as an assist gas with different pressures. Furthermore, the compressed air system was used to remove smoke and fumes generated by the laser cutting operation. The nozzle used has a conical shape with nozzle diameter of 1.5 mm. The stand-off-distance was kept to 0.5 mm. The upper and lower kerf width ''responses'' were measured using an optical microscope with digital micrometers attached to it with an accuracy of 0.001mm, which allows measurement in both X-axis and Y-axis. An average of three measurements of both kerf widths was recorded for all runs.

They conclude that the focal point position has the major role in influencing the average upper kerf width and the latter decreases as the focal position increases. Moreover, the upper kerf decreases as the cutting speed and air pressure increase, and it increases as the laser power increases. The laser power and cutting speed have the main effect on the average lower kerf width and the latter decreases as the cutting speed increases while it increases as the laser power increases. The focal point position and the laser power have the principal role in affecting the ratio between upper kerf widths to the lower kerf width.

III. OBJECTIVE

Finding out the effect of operating power, focal point and cutting speed on the performance parameters such as surface roughness, kerf width and bending force while using oxygen as the assist gas.

A. *Experimental Set-Up*

Material to be used as work piece: - Stainless Steel-304

Variable input parameters: - Operating Power (W), Focal Point (mm), Cutting Speed (mm/min.).

Experiment has to be done on Future X Laser Cutting Machine

B. *Response Surface Method is used for DOE.*

It is used to examine the relationship between one or more response variables and a set of quantitative experimental variables or factors.

Factor	Level 1	Level 2	Level 3
Operating Power (W)	800	900	1000
Focal Point (Mm)	+3	0	-3
Cutting Speed (Mm/Min)	5000	6000	7000

Table 1 Factors with levels

From above experiment effect on output parameter: - SR, KW and BF are found.

Sr No.	WS	WB	A	SR	MRR	Kerf
1	900	0	6000	3.945	0.269	0.36
2	900	3	5000	3.81	0.303	0.36
3	1000	0	7000	3.598	0.284	0.37
4	800	-3	6000	4.145	0.24	0.38
5	900	-3	7000	4.1	0.29	0.4
6	1000	3	6000	3.348	0.299	0.4
7	800	3	6000	4.364	0.276	0.33
8	800	0	7000	4.321	0.283	0.39
9	1000	0	5000	3.646	0.267	0.36
10	800	0	5000	4.156	0.237	0.32
11	900	0	6000	3.945	0.269	0.36
12	900	3	7000	3.89	0.28	0.37
13	900	0	6000	3.945	0.269	0.36
14	900	0	6000	3.945	0.269	0.36
15	900	0	6000	3.945	0.269	0.36
16	1000	-3	6000	3.901	0.252	0.32
17	900	-3	5000	4	0.208	0.31

Table 2 Result table

Equations for output parameters from the results obtained:-

Equation for S.R (Surface Roughness)

Surface Roughness = (+3.64779) + (7.87500E-005 * (A)) + (0.55842 * (B)) + (5.16375E-004 * (C)) – (6.43333E-004 * (A) * (B)) – (5.32500E-007 * (A) * (C)) – (1.66667E-006 * (B) * (C))

Equation for KW (Kerf Width)

KW = (-0.28878) + (5.17500E-004 * (A)) + (0.051250 * (B)) + (8.05000E-005 * (C)) + 9.16667E-006 * (A) * (B)) – (7.25000E-008 * (A) * (C)) – (8.75000E-006 * (B) * (C))

Equation for BF (Bending Force)

BF = (-0.61934) + (9.37500E-004 * (A)) – (0.055417 * (B)) + 1.57500E-004 * (C)) + (1.08333E-004 * (A) * (B)) – (1.50000E-007 * (A) * (C)) – (6.66667E-006 * (B) * (C))

Where, A= Cutting Power,
B= Focal Point and
C= Cutting Speed.

IV. CONCLUSION

- Surface Roughness is affected by the combination of operating power, kerf width and the cutting speed. With all of them having maximum values highest is the roughness and with all of them having value minimum is the roughness.
- Kerf width is largely affected by operating power, kerf width and cutting speed.
- As increasing cutting power kerf width increases and same way as increasing focal point and cutting speed kerf width decreases and vice-versa.
- Bending force is largely affected by cutting power and focal point.
- As increasing cutting power required bending force to bend the material increases and same way as increasing focal point and cutting speed required bending force to bend the material decreases and vice-versa.

V. FUTURE SCOPE

For the future work more different parameters such as perpendicularity, kerf taper, upper and lower kerf width, crack formation, and stria formation can be used for analysis on different work piece materials as bronze, aluminium and its alloy, mild steel, plywood, ceramics etc. Also, effect of other process parameters such as gas pressure, beam diameter, focus diameter, stand-off distance on material surface roughness, kerf width and required bending force to bend the material can be found out. Equation relating all the output parameters in terms of input parameters can be found out.

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