Parametric investigation in co2 laser cutting
Quality of hardox-400 materials

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Abstract

Laser cutting of hardox-400 materials is a popular process in several manufacturing industries This article presents a preliminary study to evaluate the effect of the processing parameters (laser power, Gas pressure, Nozzle diameter and cutting velocity) under the quality of the cut for several hardox-400materials. A plan of experiments was established considering CO2 laser cutting with prefixed processing parameters in several hardox-400 materials with same thickness. The objective was to evaluate the quality of the cut (presence of burr).

Key words: Hardox-400, laser cutting , kerfwidth

1. Introduction

Laser cutting of metals has become a reliable technology for industrial production. Currently, it is considered as a feasible alternative to mechanical cutting and blanking due to its flexibility and ability to process variable quantities of sheet metal parts in a very short time with very high programmability and minimum amount of waste. Laser cutting does not need special fixtures or jigs for the work piece because it is a non-contact operation. Additionally, it does not need expensive or replaceable tools and does not produce mechanical force that can damage thin or delicate work pieces. References give detailed descriptions of the laser phenomena and the mechanism of laser cutting of materials and Fig. 1 shows the typical laser cutting process. 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, narrow kerf width, small heat affected zone (HAZ), small metal deformation, perpendicular and sharp cut sides, square corners of cut edges and little or no oxide layer[1].

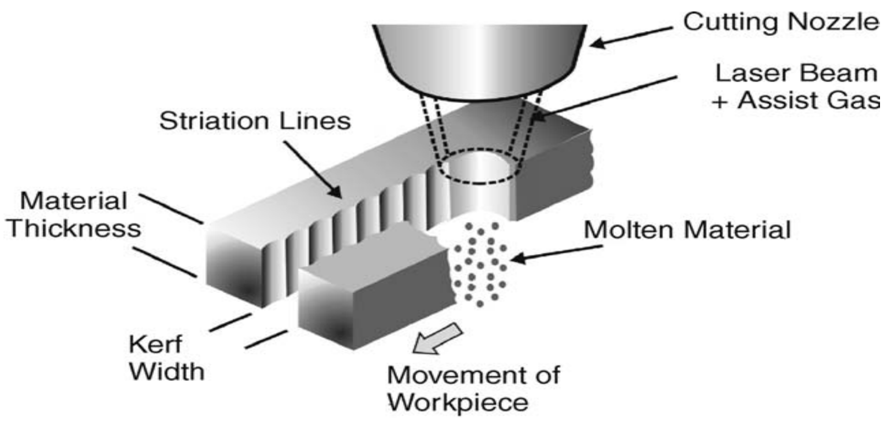

Figure.1: Schematic illustration for the process of co2 laser cutting of metals

- Laser cutting is a process in which the material is heated to its melting or vaporization temperature. Heating is achieved by concentrating the energy in a very small spot. This allows the cutting of almost all types of materials with thickness of up to 20 mm in the case of steel sheets without the need for very high levels of energy . There are different laser generators depending on the type of the laser-active material they use. Each type of laser creates a laser beam at a given wavelength. The CO2 generators are the most used for steel cutting with a wavelength 10.6 mm, whilst the Nd: YAG lasers generate a beam with a wavelength of 1.06 mm. In general, the Nd:YAG lasers wavelength is better absorbed by most of materials (copper, aluminum, precious metals, . . .). Steel, however, has acceptable absorption levels for the beam generated by CO2. This, added to the fact that these CO2 generators are more powerful and cheaper, explains why their use in industry is much more widespread. Once the beam has been generated, a lens system focuses the beam on a point with diameters of around 0.2 mm. The focusing of the beam allows for high energy densities to be reached, a typical value is about 1.4 _ 1010 W/m2. The high power density concentrated on the spot vaporizes almost all types of material (as long as there is a certain amount of beam absorption) [4].

2. Experimental procedure and operation Parameters

2.1 *Materia*l :*:* The base material used in this study was hardox-400 sheet 6 mmthick, whose chemical composition and mechanical properties are listed in Table 1. This hardox-400 .

Table 1: Chemical composition of hardox-400 Material

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C	Si	Mn	P	Cr	Mo	B
0.13	0.53	1.24	0.002	0.65	0.019	0.002

2.2 *Taguchi methodology based experiments* : These experiments were performed with a 3.5 kW CO2 (omada),To prevent the instability and damage caused by back reflections, the cavity is isolated by using a beam bender mirror with a multilayer coating that absorbs the back reflected laser beam. The laser beam was focused using a 127mm focal length lens except for the tests conducted to detect the influence of this parameter. For this purpose, lenses with 127 and 190.5mm were used. Tests were conducted in continuous wave (CW) and in pulsed mode. In CW mode, when the laser source delivers a constant power, the experiments were performed varying one factor at a time. The ranges of cutting parameter are summarized in Table 2. A commercial cutting head incorporating a conical converging coaxial nozzle with a 1.5 mm exit diameter was employed to supply the assist gas in a coaxial manner with the laser beam. In the tests conducted to reveal the influence of the nozzle exit on the quality of the cuts, nozzles with an exit diameter of 0 1.5 mm were also used. The distance from the lower part of the nozzle to the plate (also known as stand-off distance) was fixed at 1.5mm except for the tests conducted to reveal the influence of this parameter. Compressed air, nitrogen and oxygen at various pressures were used as assist gases. Based on experience for similar materials, oxygen and nitrogen are the most recommended gases for the experimentation. Most of the tests were performed using argon as assist gas except from the test performed to investigate the influence of the gas nature. In order to compare the results, the experiments were performed on unidirectional straight line cutting. On the other hand, the experiments conducted in pulsed mode were performed by means of one-factor-at-a-time experiments in a first stage. The ranges of cutting parameters are summarized in Table 3 Furthermore, a full factorial design (FFD) approach was also performed to efficiently screen out the key variables significantly affecting on the response variables .

Table 2 :control factors and theirs level use in experiments

Symbol	Factor	Unit	Level-1	Level-2	Level-3
A	Power	watt	1000	1500	2000
B	Gas pressure	Bar	0.5	0.6	0.7
C	Cutting speed	Mm/min	200	400	600
D	Pulse frequency	hz	20	25	30

Trial no	A Power	B Gas pressure	C Cutting Speed	D Pulse Frequency	Kerf width (mm)
1	1000	0.5	200	20	0.32
2		0.5	400	25	0.23
3		0.5	600	30	0.25
4		0.6	200	25	0.19
5		0.6	400	30	0.74
6		0.6	600	20	0.30
7		0.7	200	30	0.18
8		0.7	400	20	1.22
9		0.7	600	25	0.32
10	1500	0.5	200	25	0.85
11		0.5	400	30	1.04
12		0.5	600	20	0.24
13		0.6	200	30	0.85
14		0.6	400	20	1.06
15		0.6	600	25	0.48
16		0.7	200	20	0.97
17		0.7	400	25	1.11
18		0.7	600	30	0.36
19	2000	0.5	200	30	1.18
20		0.5	400	20	0.67
21		0.5	600	25	1.78
22		0.6	200	20	1.36
23		0.6	400	25	0.79
24		0.6	600	30	2.40
25		0.7	200	25	1.93
26		0.7	400	30	1.74
27		0.7	600	20	2.56

Table 3 : Plan of experiments

Trial no	A	B	C	D
1	1	1	1	1
2	1	1	2	2
3	1	1	3	3
4	1	2	1	2
5	1	2	2	3
6	1	2	3	1
7	1	3	1	3
8	1	3	2	1
9	1	3	3	2
10	2	1	1	2
11	2	1	2	3
12	2	1	3	1
13	2	2	1	3
14	2	2	2	1
15	2	2	3	2
16	2	3	1	1
17	2	3	2	2
18	2	3	3	3
19	3	1	1	3
20	3	1	2	1
21	3	1	3	2
22	3	2	1	1
23	3	2	2	2
24	3	2	3	3
25	3	3	1	2
26	3	3	2	3
27	3	3	3	1

Table 4 : Layout Using L_{27}

3. Result and discussion :

Kerf width measurements at the top and bottom surfaces of the sample indicated that the top kerf width was slightly larger than that at the bottom for most of the cutting conditions, which is indicative of the tapered nature of the laser cut as caused by loss of beam intensity, defocusing, or loss of gas pressure across the thickness of the cut. It was also observed that the kerf width slightly increased with an increase in cutting distance along the cut[5,6].

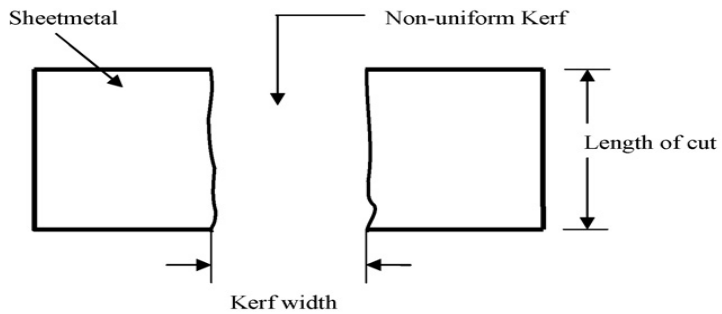

Figure. 2. kerf width of cutting metal

Cutting speed and laser power has important role in achieving desire kerf width in cutting of hardox-400.here I have got results on different laser power 1000,1500 and 2000.

3.1 Effect of laser power at 1000w

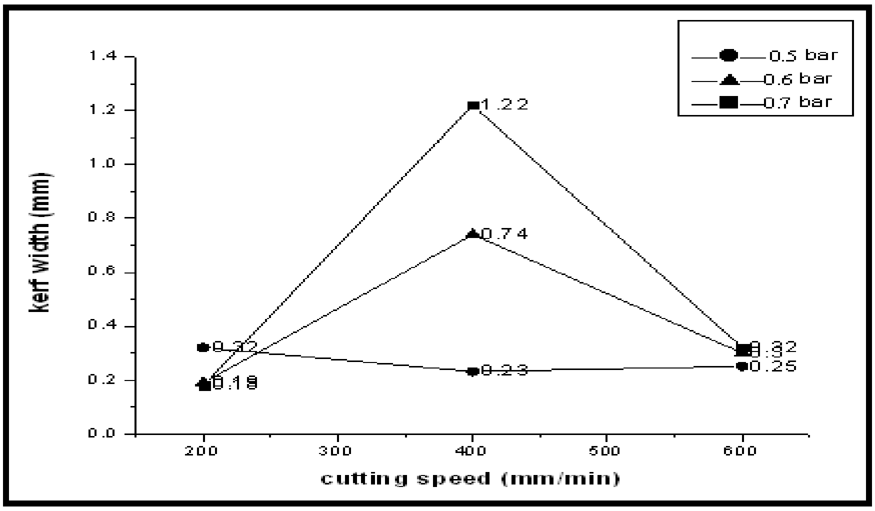

Figure.3 :graph of cutting speed Vs kerf width with laser power 1000 watt

In above figure in which cutting speed Vs. kerf width at three different gas pressure with constant laser power 1000 watt indicated. when gas pressure 0.5 bar in which cutting speed increase 200 to 400 mm/min then kerf width is decrease from 0.32 mm to 0.23 mm similarly cutting speed 400 to 600 mm/min then after slightly decreses form 0.23 mm to 0.25 mm. . In gas pressure 0.6 bar in which cutting speed increase 200 to 400 mm/min then kerf width is increase from 0.19 mm to 0.74 mm similarly cutting speed 400 to 600 mm/min then after kerf width decrease form 0.74 mm to 0.30 mm. . in gas pressure 0.7 bar in which cutting speed increase 200 to 400 mm/min then kerf width is increase from 0.18 mm to 1.22 mm similarly cutting speed 400 to 600 mm/min then after kerf width decrease from 1.22 mm to 0.32 mm.

3.2 Effect of laser power at 1500w

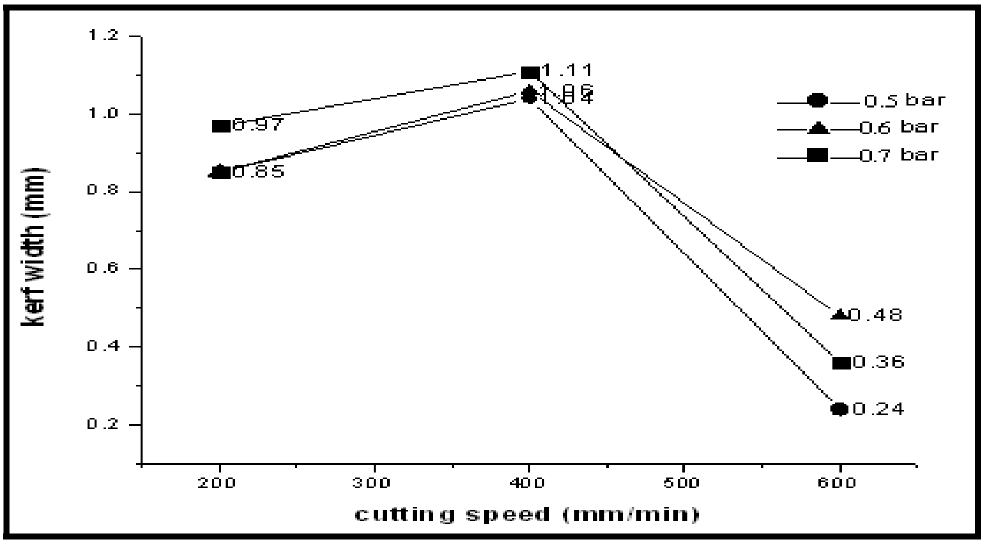

Figure.4 graph of cutting speed Vs kerf width with laser power 1500 watt

In above figure in which cutting speed Vs. kerf width at three different gas pressure with constant laser power 1500 watt indicated. when gas pressure 0.5 bar in which cutting speed increase 200 to 400 mm/min then kerf width is increase from 0.85 mm to 1.06 mm similarly cutting speed 400 to 600 mm/min then after decreses form 1.06 mm to 0.24 mm. . In gas pressure 0.6 bar in which cutting speed increase 200 to 400 mm/min then kerf width is increase from 0.85 mm to 1.06 mm similarly cutting speed 400 to 600 mm/min then after kerf width decrease from 1.06 mm to 0.48 mm. . in gas pressure 0.7 bar in which cutting speed increase 200 to 400 mm/min then kerf width is increase from 0.97 mm to 1.11 mm similarly cutting speed 400 to 600 mm/min then after kerf width decrease from 1.11,mm to 0.36 mm.

3.3 Effect of laser power at 2000w

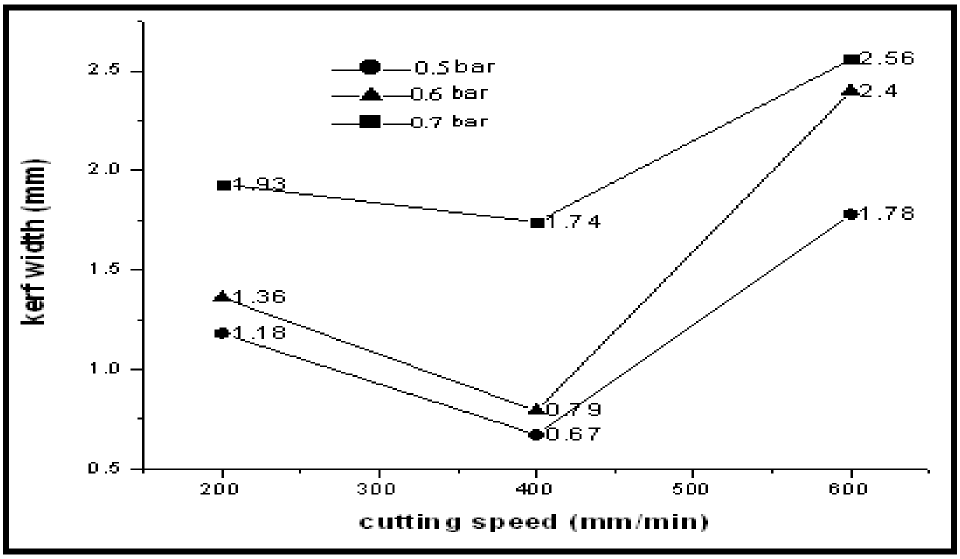

Figure.5 graph of cutting speed Vs kerf width with laser power 2000 watt

In above figure in which cutting speed Vs. kerf width at three different gas pressure with constant laser power 2000 watt indicated. when gas pressure 0.5 bar in which cutting speed increase 200 to 400 mm/min then kerf width is decrease from 1.18 mm to 0.67 mm similarly cutting speed 400 to 600 mm/min then after increses form 0.67 mm to 1.78 mm. . In gas pressure 0.6 bar in which cutting speed increase 200 to 400 mm/min then kerf width is decrease from 1.36 mm to 0.79 mm similarly cutting speed 400 to 600 mm/min then after kerf width increase from 0.79 mm to 2.40 mm. . in gas pressure 0.7 bar in which cutting speed increase 200 to 400 mm/min then kerf width is decrease from 1.93 mm to 1.74 mm similarly cutting speed 400 to 600 mm/min then after kerf width increase from 1.74,mm to 2.56 mm.

3.4 main effects of input parameter on kerf width

In below figure we have plotted main effects of kerf width for laser power, gas pressure , cutting speed , pulse frequency in graph shown that in which laser power increase 1000 watt to 2000 watt then kerf width increases . in gas pressure increase 0.5 bar to 0.7 bar then kerf width increase near to mean line. in cutting speed in which increase 200 mm/min to 400 mm/min then kerf width increase upto mean line but cutting speed 400 mm/min to 600 mm/min then kerf width is minor increase to mean line. in pulse frequency increase upto 20 hz to 30 hz then initially minor decrease below mean line then after increase as initial position**.**

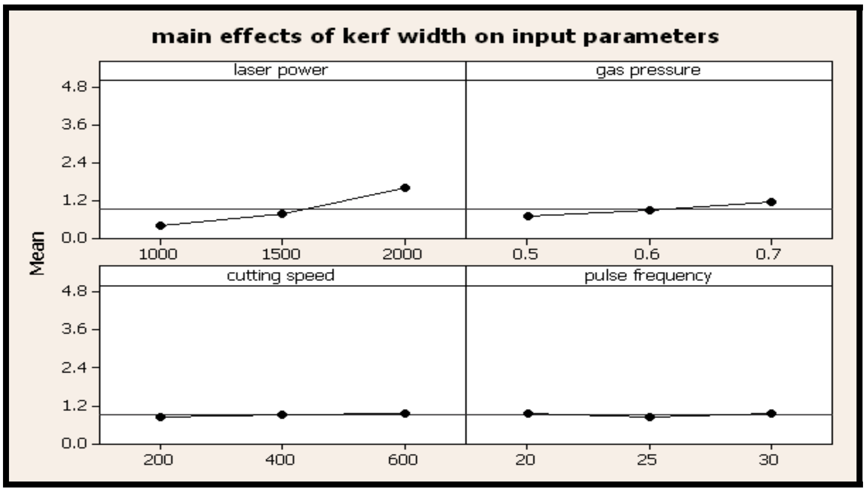

figure.6: Main effects of kerf width on input parameters

4. Conclusion :

kerf width has important role for achieving desire cutting quality .various process parameter affects kerf width during laser cutting by removing the material and kerf width is defined as the width of cutting slot of material. variation of kerf width power, cutting speed, gas pressure and pulse frequency. After the experiment performed that it can be noticeable that at lower laser power 1000 watts ,medium gas pressure 0.6 bar and cutting speed decreasing upto 200 mm/min pulse frequency 25 (Hz) then got minimum kerf width. At higher lasr power 2000 awtts , high gas pressure upto 0.7 bar ,higher cutting speed 600 mm/min and pulse frequency 20 (Hz) in order to get maximum kerf width so optimum results for kerf width was indicate in result table below.

Table.5 : Result Table

sr no	Power (watt)	Gas pressure (bar)	Cutting Speed (mm/min)	pulse frequency (Hz)	kerf width (mm)
1	1000	0.6	200	25	0.19
2	2000	0.7	600	20	2.56

5 References:

[1] Narendra B. Dahotre • Sandip P. Harimkar "Laser Fabrication and Machining of Materials" ISBN 978-0-387- 72343-3 .

[2] W.M. Steen, J.N. Kamalu, in: M. Bass (Ed.), Laser Cutting, Laser Materials Processing, vol. 3, North Holland, New York, 1983, pp. 17–111.

[3] Rajaram N., Sheik-Ahmad J. and Cheraghi S. H., "CO_2 laser cut quality of 4130 steel", International Journal of Machine Tools & Manufacture Volume 43 (2003)

[4] N. Rajendran, M.B. Pate, The effect of laser beam velocity on cut quality and surface temperature, American Society of Mechanical Engineers, Heat Transfer Division 104 (1988) 121–127.

[5] Amit Sharma, Vinod Yadava .Optimization of kerf quality characteristics during Nd: YAG laser cutting of nickel based superalloy sheet for straight and curved cut profiles. Optics and Lasers in Engineering 48 (2010) 915–925

[6] Avanish Kumar Dubey, Vinod Yadava .Optimization of kerf quality during pulsed laser cutting of aluminium alloy sheet . journal of materials processing technology 204(2008) 412–418