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Experimental Investigation and Parametric Analysis of CO2 Laser cutting of Stainless Steel

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Abstract: Laser cutting is a popular unconventional manufacturing method used to cut various materials. The main objective of this work is to find the influence of the process parameters such as stand-off distance, power, gas pressure and speed on the responses like the kerf width, hardness and machining time for CO2 laser cutting of Stainless steel (AISI 314). The experiments were conducted based on Taguchi L9 orthogonal array and the results shows that kerf width decreases with increase in speed and power and kerf width increases with increase in gas pressure. The hardness gradually increases and then decreases with increase in speed and remains constant for a particular gas pressure and then results in sudden increase and decrease of hardness as the speed increases. Meanwhile the machining time increases with increase in power and speed whereas decreases with increase in gas pressure and stand-off distance.

Key words: CO2 Laser · Power · Speed · Gas pressure · Stand-off distance · Kerf width and machining time

INTRODUCTION

Laser cutting is popular unconventional manufacturing processes which cuts complicated shapes of various types of materials. In industries laser is used as an unconventional method for cutting and also welding. Laser cutting is non-contact method to achieve good precise cutting of complicated shapes. Also laser can be used to cut variety of materials like rubber, wood, ceramic, plastic and certain metals. The most commonly used types of laser are Nd: YAG and CO2 laser, in which CO2 laser dominates due to their good quality and high output power. CO2 laser has a wavelength of about 10.6µm due to this CO2 laser has high power output than Nd: YAG laser. Thus CO2 laser can be used for cutting aluminum and aluminum based alloys. In this paper, experiments have been done to investigate the effect of process parameters on kerf width and surface roughness.

B.J. Ranganathan & G. Viswanathan [2011] mentioned that because of the ability of laser to cut materials with comnplex shapes with high speed and productivity and used in production industries like ship building, aerospace, automobile and nuclear industries. Ahmet Hascalik and Mustafa Ay [2013] stated that laser cutting is a non-contact and a non-traditional machining process which does not produce any force which damage the workpiece. Arun Kumar Pandey and Avanish Kumar Dubey [2012] mentioned that of the different types of lasers available, Nd:YAG and CO2 lasers are widely used for cutting metals. M. Madic *et al*. [2015] stated that laser

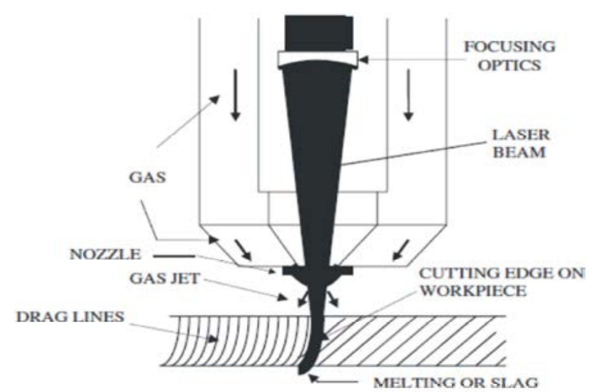

Fig. 1: Laser beam cutting [2015]

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cutting is a highly automated and non-contact thermal process which is used to produce components with high dimensional accuracy and surface finish. They also mentioned that high power density laser beam when focused in a spot melts and evaporates the material in a fractional second and the evaporated molten material from the zone is removed by a coaxial jet of assist gas.

Literature Review: R. Adalarasan *et al*. [2015] studied the application of pulsed CO2 laser cutting process on Al6061/SiCp/Al2O3 composite and investigated the influence of gas pressure, pulsing frequency, laser power and cutting velocity on the responses like kerf width and surface finish. They also found the optimal level of cutting parameters using a hybrid approach of grey based response surface methodology (GRSM). B. D. Prajapati *et al*. [2013], studied the effect of laser machine processing parameters such as laser power, gas pressure, cutting speed and thickness effect on surface roughness for on Mild steel and Hardox-400. They concluded that the cutting speed and work piece thickness play important role in surface roughness for both materials. H.A. Eltawahni *et al*. [2012] Investigated CO2 laser cutting of AISI316L stainless steel. Their aim is to relate the cutting edge quality parameters like kerf, surface roughness and also the operating cost to the process parameters like laser power, cutting speed, assist gas pressure, nozzle diameter and focus point position and found that the roughness value increases as the cutting speed increases and it decreases as the other parameters increases. They also found that kerf width increases as the laser power, pressure and nozzle diameter increase and it decreases as the cutting speed and focal position increases. Stournaras *et al*. [2009] conducted experiments on aluminum alloy AA5083, with the use of a pulsed CO2 laser. They observed that kerf width is mostly affected by laser power and cutting speed parameters. Furthermore, greater values of the assist gas pressure will result in a more effective removal of melted material. A. Riveiro *et al*. [2010] determined influence of processing parameters and optimal conditions for CO2 laser cutting of a aluminium alloy (2024-T3). Their results indicated that using high laser powers and focusing the laser beam slightly underneath the upper face or onto the surface of the workpiece, high material removal and good quality can be obtained. Patel and Sanghavi [2011] studied effect of process parameters such as feed rate, input power and standoff distance on the quality of the machined surface like kerf width and surface roughness using laser beam on mild steel and stainless steel. They found that of all the

Fig. 2: Stainless steel workpiece after laser cutting

parameters input power is the most predominant parameter that affects the cut quality like kerf width and surface roughness using ANOVA. Milos Madic and Miroslav Radovanovic [2012] developed mathematical models using Multiple Regression Analysis (MRA) and Artificial Neural Network (ANN) for the surface roughness in CO2 laser cutting of mild steel. They compared experimental results and models of laser cutting parameters such as cutting speed, laser power and assist gas pressure on surface roughness. They concluded that ANN model for CO2 laser cutting and optimized the process parameters on the basis of the desired surface quality, productivity and actual operating costs. Prof. Dhaval P. Patel and Mrugesh B. Khatri [2012] investigated CO2 laser cutting process for Stainless Steel (S.S) and Mild Steel (M.S) and found that Kerf width generally increases with increase in assist gas pressure and laser power and decrease in cutting speed. Milos Madic *et al*. [2013] observed that higher cutting speed, lower assist gas pressure and intermediate laser power produces minimal surface roughness. Arun Kumar Pandey and Avanish Kumar Dubey [2012] studied the effect of laser cutting of Titanium alloy and observed that higher values of cutting speed, moderate pressure of gas and lower values of pulse frequency results in lesser surface roughness.

Experimental Procedure: A CO2 laser cutting system with power of 4 kW and wavelength of 10.6 ìm was used to cut 3 mm thick Stainless steel plate. Based on the literature, the parameters to be investigated were four, namely the assist gas pressure, cutting speed, laser power and stand-off distance. The work piece after cutting process is as shown in the Figure 2 and the parameters were varied on 3 levels is shown in Table 1 and the L16

Table 1: Input Parameter level

Parameters / Levels	Level 1	Level 2	Level 3	Level 4
Laser Power (W)	1800	2000	2200	2400
Cutting Speed (mm/s)	3500	4000	4500	5000
Assist Gas Pressure (Bar)	6.5	7	7.5	8.5
Stand-Off Distance (mm)	0.7	0.9	1.1	1.3

Table 2: Taguchi L9 Orthogonal array

Experiments	Laser Power	Cutting Speed	Gas Pressure	Stand Off Distance
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	1	4	4	4
5	2	1	2	3
6	2	2	1	4
7	2	3	4	1
8	2	4	3	2
9	3	1	3	4
10	3	2	4	3
11	3	3	1	2
12	3	4	2	1
13	4	1	4	2
14	4	2	3	1
15	4	3	2	4
16	4	4	1	3

Table 3: Response Values of the Experiments

Experiments	Machining time Secs	Kerf width mm	Mean hardness HRC
1	2.312	1.035	65.25
2	5.398	0.86	89.75
3	3.687	0.405	93.5
4	4.283	0.305	74.75
5	2.596	0.435	82
6	4.95	0.46	71.5
7	3.605	0.56	84.75
8	2.544	0.485	82.5
9	4.409	0.51	59.75
10	4.545	0.525	72.75
11	4.816	0.57	92.75
12	3.501	0.53	81.75
13	4.908	0.62	86.25
14	4.318	1.06	68.5
15	3.908	0.8	60.75
16	4.498	0.54	63.75

orthogonal array used is presented below in Table 2. Laser cutting process is a major research area for getting kerf width and surface roughness. The responses from Table 3 is analysed with the input process parameters and following the graphs are obtained.

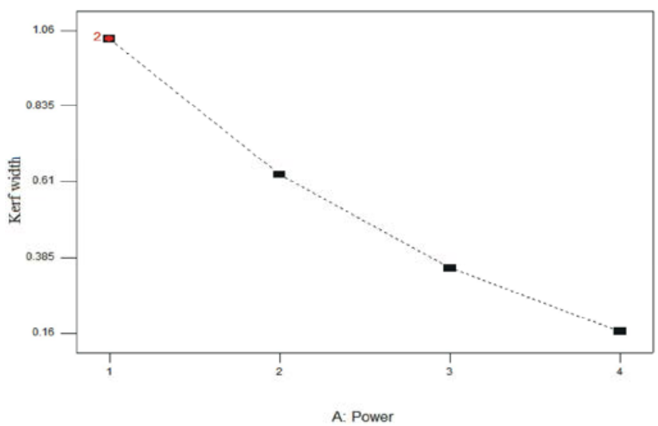

Fig. 3: Kerf width Vs Power

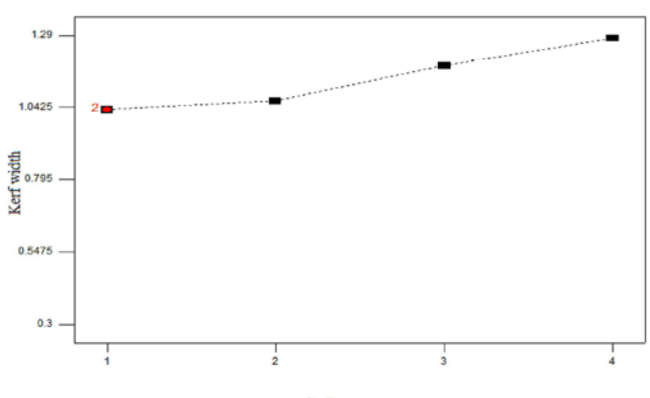

Fig. 4: Kerf width Vs Speed

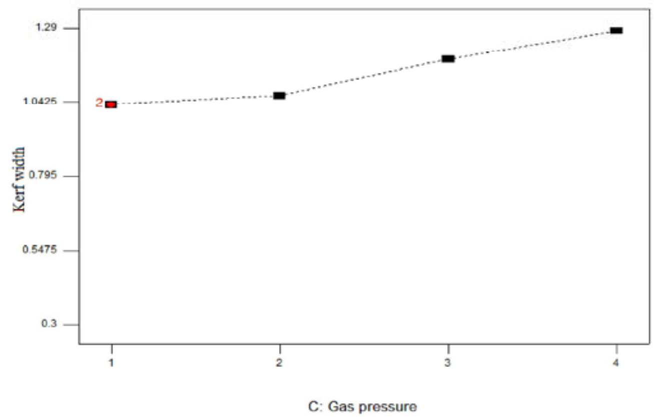

Fig. 5: Kerf width Vs Gas Pressure

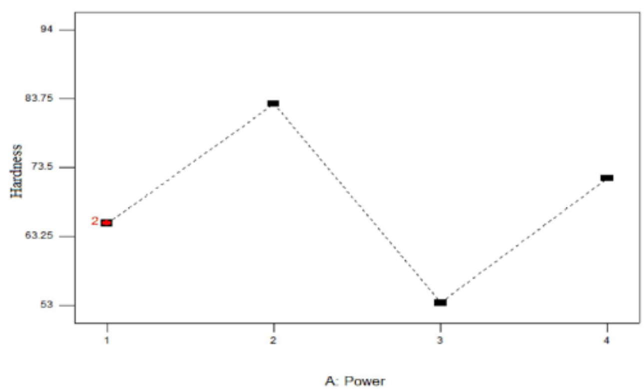

Fig. 6: Kerf width Vs Gas Pressure

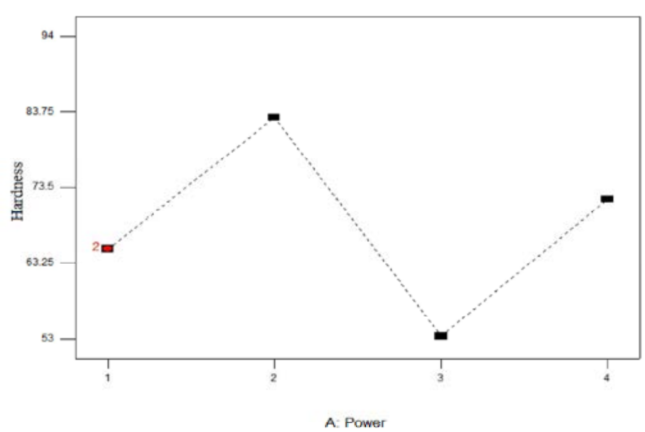

Fig. 7: Hardness Vs Power

RESULTS AND DISCUSSION

Kerf Width: The responses from Table 3 is analysed with the input parameters and following the graphs are obtained From Figure 3 and 4 it observed that as the value of power and speed increases, the kerf width decreases. From Figure 5 it is known that with increase in gas pressure kerf width increases wheares kerf width gradually increases with increase in stand of distance and decreases at the certain point as shown in Figure 6.

Hardness: Hardness has sudden increase and decrease with increase in power as shown in Figure 7. From Figure 8 it is observed that as the speed increases the value of the surface hardness gradually increases and

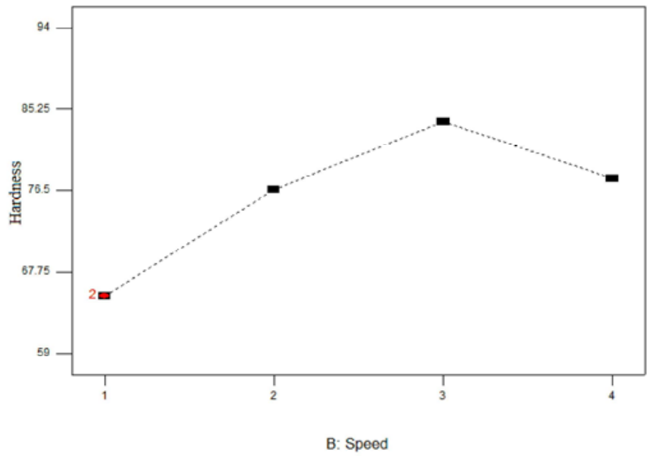

Fig. 8: Hardness Vs Speed

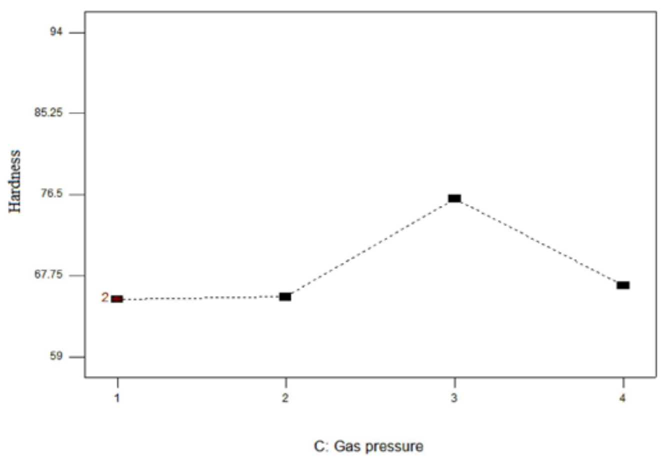

Fig. 9: Hardness Vs Gas Pressure

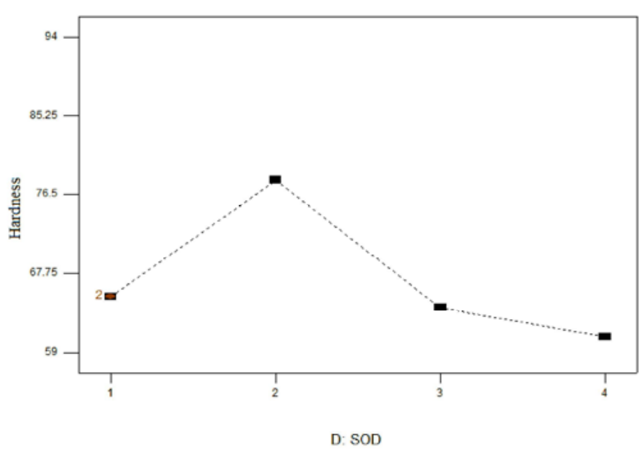

Fig. 10: Hardness Vs SOD

after a certain point it starts to decrease. From Figure 9 it is clear that the as the gas pressure increases, the hardness remains constant to some extent and then results in sudden increase and decrease of hardness. When the value of the stand of distance increases the value of the hardness suddenly increases and gradually decreases as shown in Figure 10.

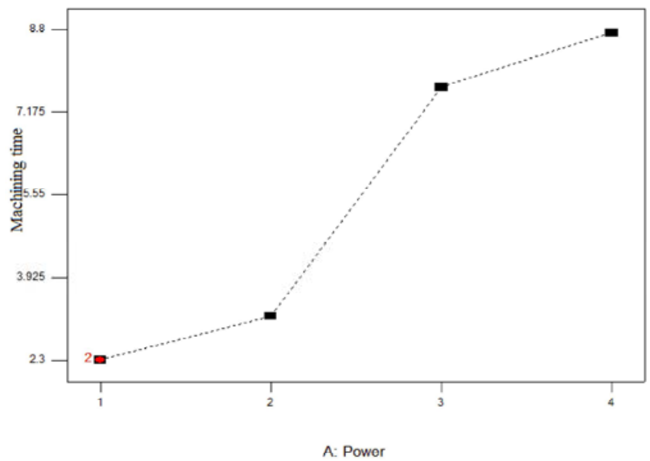

Fig. 11: Machining time Vs Power

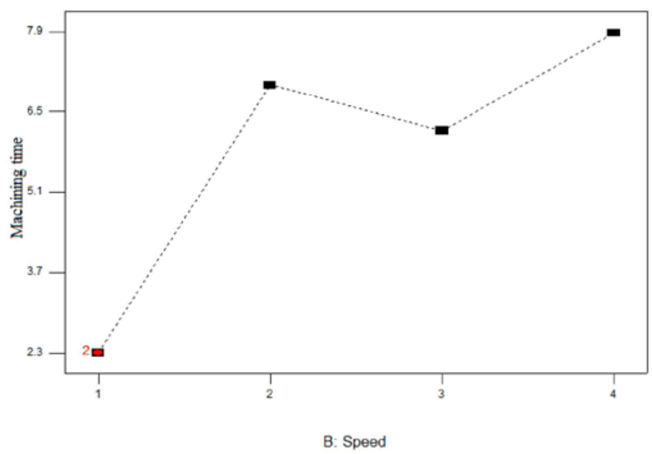

Fig. 12: Machining time Vs Gas Pressure

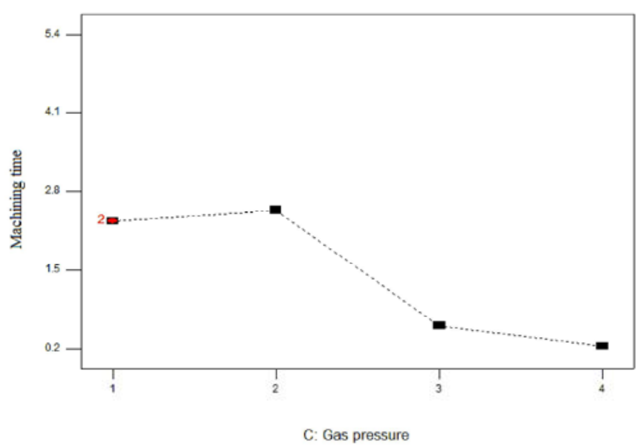

Fig. 13: Machining time Vs Speed

Machining Time: From the Figure 11 and Figure 12 it is found that when the power and speed increases the value of the machining time also gradually increases. Whereas the machining time gradually decreases with increase in gas pressure as shown in Figure 13. Also It is found that the machining time suddenly decreases and then increases with increase in SOD as shown in Figure 14.

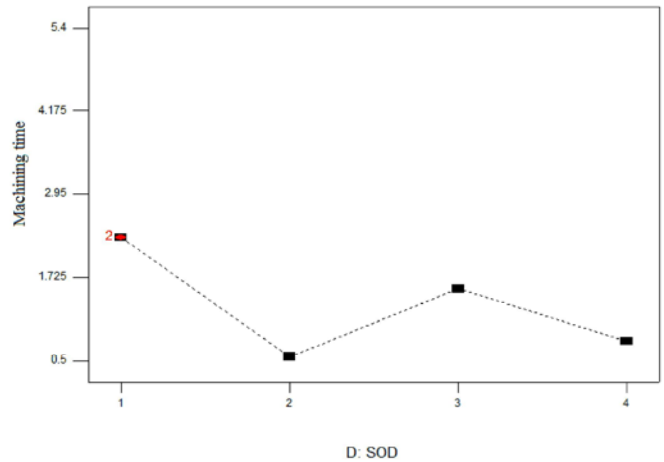

Fig. 14: Machining time Vs Stand off Distance

CONCLUSION

Laser cutting an energy based unconventional process which is capable of cutting complex profiles in most of the materials. The performance characteristics of laser cutting process like kerf width and surface roughness depends on the input process parameters like stand-off distance, laser power, assist gas pressure and cutting speed. From the experimental analysis the following conclusions were made.

- Increase in value of power results in gradual decreases in kerf width, machining time simultaneously increases for every point and there is a sudden increment and decrement in hardness value.
- Machining time and kerf width are inversely proportional, since increase in the value of speed decreases their values and hardness gradually increases and all of sudden decreases.
- There is a increment in the value of hardness and kerf width, when the value of pressure increases and machining time reduces. At some point hardness remains constant and reduces.
- Stand of distance have an similar impact on all kerf width, machining time and hardness. Since both increment and decrement happens when SOD increases.
- It is observed that the assist gas pressure has less effect on kerf width and surface roughness as compared with other parameters like stand-off distance, laser power and cutting speed.

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