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Experimental Investigation on AISI D3 Steel and Analysis of Process Parameters for CO_2 Laser Cutting Process

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ABSTRACT

CO_2 laser emit the infrared laser radiation with a wavelength of 10.6 µm and possess overall efficiencies of approximately 10 to 13 %. The laser active medium in a CO_2 laser is a mixture of CO_2, N_2 and He gases, where $CO_2$is the laser active molecules. The stimulation of the laser active medium is accomplished by electrical discharge in the gas. During the stimulation process, the nitrogen molecules transfer energy from electron impact to the CO2 molecules. The transition from energetically excited CO2 molecules to a lower energy level is accompanied by photon release leading to emission of a laser beam. Laser cutting is very well known manufacturing process used to cut various types of materials with good surface finish. AISI D3 steel is difficult to cut using laser with high speed rate, due to back reflection in these materials. The width of laser kerf and quality of the cut edges are affected by laser power, cutting speed, assist gas pressure and stand-off distance. The experiment was designed and carried out on the basis of standard L16 Taguchi's orthogonal array in which the four laser cutting parameters were arranged at three levels. The result shows that Kerf width (Kw) decreases with increase in power and stand-off distance and with decrease in assist gas pressure. Hardness value decreases due to machining. The width of laser cut or kerf, quality of the cut edges are affected by laser power, cutting speed, assist gas pressure, and stand-off distance between nozzle and the work piece material. From the analysis of mean values of variance, the significant laser cutting parameters were identified.

KEYWORDS: CO_2 Laser, CNC Machining, Hardness measuring machine, Kerf width

I.INTRODUCTION

Lasers that are capable of producing high power laser beams of high beam quality are suitable for cutting applications. The CO_2 and Nd: YAG lasers are the two laser technologies have for long been the workhorses for high power applications such as cutting. The CO_2 laser has gained considerable acceptance as a cutting tool because a very high power density can be achieved with such a laser and CO_2 lasers are available in high power levels. The CO_2 laser and Nd:YAG laser with output power capabilities of up to 8,000 W and 4,500 W respectively are now available for cutting applications. The CO_2 lasers with even higher output powers (up to 20,000 W) are power horses for welding and surface treatment applications.

Laser cutting is an unpredictable process which is characterized by various parameters and these parameters will decide the efficiency of the entire process in terms of productivity, cut quality and cost. Maximizing the productivity and cut quality along with minimization of the cost are the main particulars of manufacturers [1]. The optimal cutting parameters are set for achieving a desired goal. Improper selection of cutting parameters causes high manufacturing costs, low product quality and high waste and on the other hand, the suitable selection of these parameters results in enhancement of the end product quality [2]. Consequently, it has the more significance to precisely evaluate the relationship between laser cutting parameters and cutting performance through mathematical model and subsequently determinate the optimal or near-optimal cutting parameters through the use of optimization method.

II.LASER PRINCIPAL

A laser beam is produced in a glass tube with a mirror at both the ends. The laser gas is passed into the glass and spread by a turbine. The laser gas is a combination of carbon dioxide, nitrogen and helium. This combination of laser gas is usually known as a CO2 laser. There are a few other lasing gas combinations available and in use, but only for high powered industrial lasers, the CO2 mixture is the most commonly used. An external power source, such as the electrical power (DC power) or radio frequency (RF generator) that excite the atoms in the laser gas which release the excited atoms in the laser gas mixture. When the atoms of the laser get excite, the stimulated gas atoms give off a photon of 17 lights. This photon excites other atoms and gives more photons. This is in the form a chain reaction [3]. The photons produced moves between the two mirrors in the glass tube until a portion escapes through it partially reflective mirror. The laser beam is focussed onto the workpiece to be cut by matching the focal length of the laser beam to the depth of the cut result in high productivity and the best cut quality [4].

Laser cutting is a thermal cutting process in which a cut kerf (slot) is formed by the heating action of a focused traversing laser beam of power density on the order of 10^{4} W mm^{-2} in combination with the melt shearing action of a stream of inert or active assist gas. The focused laser beam melts the material throughout the material thickness and a pressurized gas jet, acting coaxially with the laser beam, blows away the molten material from the cut kerf. The basic principle of laser cutting is shown in figure 13 and the terms related to the cutting process are illustrated in figure1

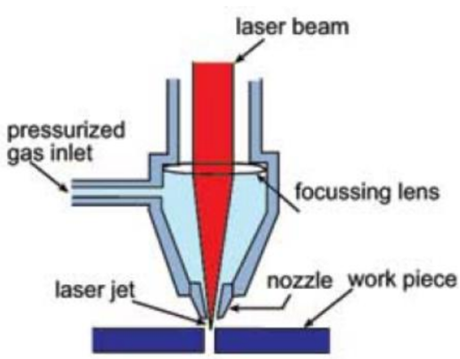


Figure 1: Basic principal of Laser Cutting

The terms used in Laser cutting process of work piece.

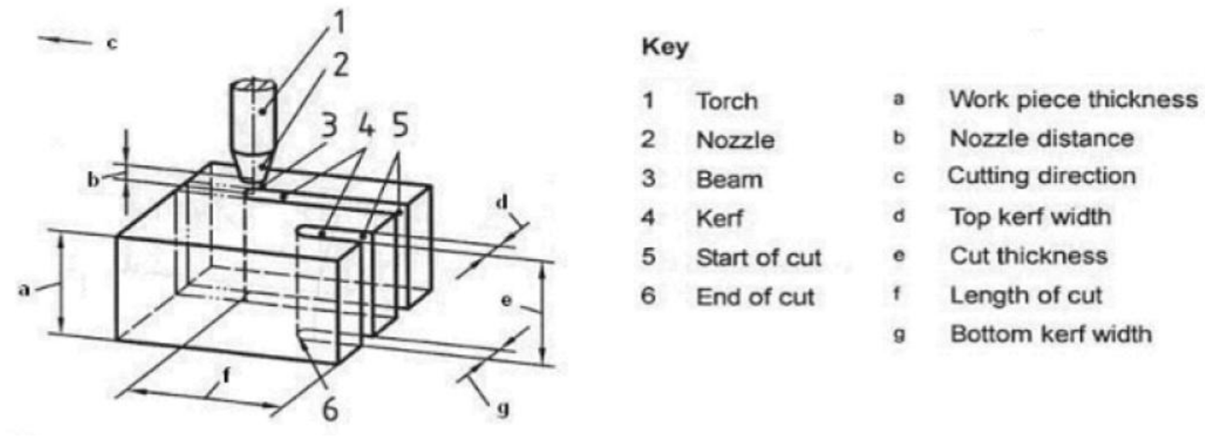


Figure 2: Term related to the cutting process of workpiece

III.LITERATURE REVIEW

Prof.Dhawal.et.al[5]investigated optimization of CO2 laser of stainless steel machining by experimental analysis using the material considering the input parameters of Power (700-900W), Thickness(2-8mm), Cutting Speed(800-3000m/min) and Gas Pressure(7-10 kpa).They found that the output parameters are kerf width and HAZ(heat affected zone) and found the kerf width increases with increase in pressure, power with the reduction of speed. **Shang-Liang Chen [6],**investigated CO2 laser cutting performance on 3 mm thick mild steel plate with assistant-gas pressures of up to 10 bar. A co-axial cutting nozzle able to withstand pressures of up to 12 bar was designed and set up. Experiments were performed with this high-pressure coaxial nozzle. The cutting edges were examined to provide information on cutting quality. The results show that an acceptable-quality cutting region does not exist for pure oxygen cutting, but that good cutting cannot be obtained at an assistant-gas pressure of over 4 bar with 3 mm thick mild-steel plate. For inert-gas cutting, dross under the cut kerf was formed with most of the cutting parameters. An almost clean cut was found with an argon gas pressure of 10 bar at a cutting speed of 25 mm/s. For the laser cutting of 3 mm thick mild steel plate it is advised that oxygen cutting is still the best, although argon and nitrogen may be used instead. Air is inferior to these gases as an assistant gas. **Mayank N Madia& Prof. Dhaval M Patel [7]**, studied the Laser cutting characteristics including power level and focal length are investigated in order to obtain surface roughness with maximum cutting speed. The surface roughness is investigated for a laser power range of 1000-1500Wand focal length 122-132, gas pressure 7 bar constant for brass materials.**Prof.E.FallahiSichani .et.al [8]** has examined on plasma formation in CO2 fusion laser cutting of stainless steel by considering the input parameters of Power(4Kw), Thickness(6mm),Cutting Speed(1.26- 2.94m/min), Gas pressure (18bar). He found that the output parameters are Kerf Width &HAZ(heat affected zone) which results in increase of cutting speed &heat transfer from melt pool to assist gas. **K.A. Ghany& M.Newishy[9]** predicted that surface roughness value reduces on increasing cutting speed & frequency and decreasing laser power & gas pressure. Arun Kumar Pandey and Avanish Kumar

Dubey studied the effect of laser cutting of Titanium alloy sheet and observed that lower values of pulse frequency, higher values of cutting speed and moderate pressure of gas results in lesser surface roughness. N. Rajaramet. al. in their work concluded that high powers and lower feed rates gave good surface roughness. Dhaval P. Patel and MrugeshB.Khatri identified that kerf width generally increases with increase in assist gas pressure and laser power and decrease in cutting speed. Ghany, K.A.& Newishy observed that increase in the frequency reduces the kerf width.

IV.EXPERIMENTATION

The experimental studies were performed using CNC Laser cutting machine (MT-LY150 MT-LY200). The composition of AISI D3 steel work-piece material used for experimentation in this work is given in Table 1.

Table 1 Chemical composition of AISI D3 steel (wt %)

Material	C	Cr	Mn	Mo	V	Si	Ni
AISI D3	2.05	11.10	0.589	0.042	0.055	0.498	0.065

Table 2CNC Laser machine details are shown below

Model type	MT-LY150	MT-LY200
Max laser power	150W	200W
Laser wave-length	10640nm	10640nm
Cutting thickness	$\leq$0.7mm	$\leq$2mm
Max cutting speed	3000mm/min	4000mm/min
Min.line width	0.15mm	0.15mm
Repeat positioning accuracy	$\pm$0.08mm	$\pm$0.10mm
Working area(mm)	1300X2500mm(made to order)	1300X2500mm(made to order)
Control system	Professional software	Professional software
Total power consumed	$\leq$12KW	$\leq$12KW
Power supply	220v/50 60hz	220v/50 60hz
Cooling mode	Water cooling	Water cooling
Main parts	Water chiller; exhaust fan.o2 device.	Water chiller; exhaust fan.o2 device.

4.1 Design of Experiments: Taguchi technique is a powerful statistical technique for analyzing and optimizing the process parameters. The Taguchi analysis uses orthogonal arrays from design of experiments theory to study the influence of a large number of variables on responses with small number of experiments. As per the review of the literature, the selected parameters to be investigated were four, namely the laser power, the cutting speed, the stand-off distance, and the pressure of the assist gas.

Table 3 Level of parameters

Level & Parameter	Level 1	Level 2	Level 3	Level 4
Power (watt)	150	170	180	200
Speed (mm/min)	3000	3300	3600	400
Pressure (bar)	6.5	7	7.5	8.5
SOD (mm)	0.7	0.9	1.1	1.3

The success factor any experiment is basically based on how well that experiment has been designed. The design of experiments ensures the following benefits:
Identifies the relationships between cause and effect of the reality.

a. Facilitates the understanding of interactions among the factors in the experiment.
b. Finds the levels at which the controllable factors are to be fixed.
c. Minimizes the experimental error.
d. Improves the robustness of the design.

Taguchi‘s OA technique chooses a fraction of the combinations out of the full factorial design. If we take this study, the number of input parameters chosen were 4 and the number of level are 3. For a full factorial design the number of trials to be performed is 3^4= 81, but OA for the same design chooses just set of combinations L_9 and L_{27} out of these 81 trials. One can choose L_9 for lesser resolution, and L_{27} for higher resolution. This proposed experiment is designed using Taguchi‘s L_9 OA technique. The experimental design table for L_{16}OA is shown in Table 4

Table 4 L16 Orthogonal Array

EXPERMENT NO.	POWER	SPEED	PRESSURE	STAND OF 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	1	2
14	4	2	3	1
15	4	3	2	4
16	4	4	1	3

4.2 Machining Operation:

CO_2 laser cutting machine is used cut AISI D3 Steel to perform experiments. The size of specimen is shown below and dimension of workpiece is 300x300x2 mm. the specimen were made up of linear cut of 10 mm in length for measuring kerf width and with a radius of 25mm as shown below.

Figure 3 Machining operation

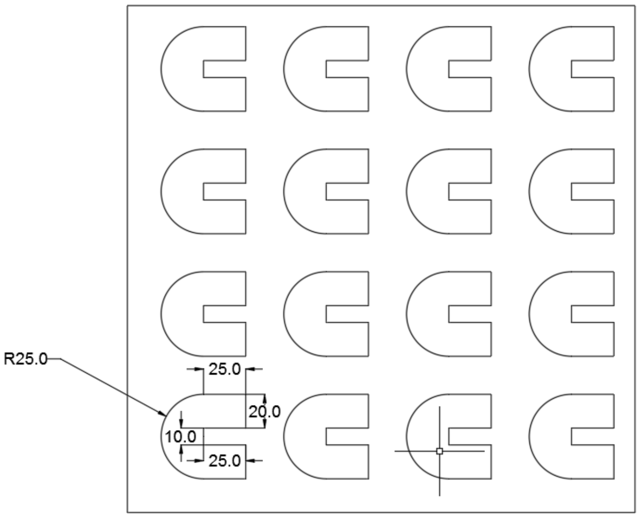


Figure 4 The work piece after cutting process is shown

V. RESULT AND DISCUSSION

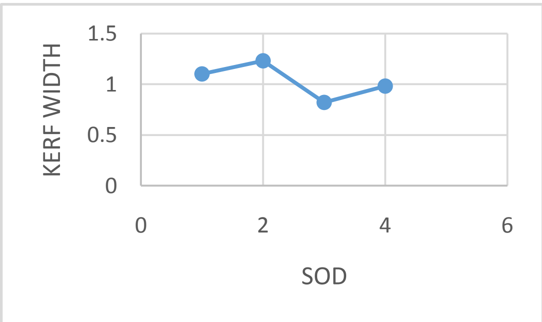
In below table shown the analyzed response using hardness testing machine.

Table 5 Response values of experiments

TIME	KERF WIDTH	MEAN HARDNESS
2.121	1.031	66.25
5.115	0.913	90.21
3.221	0.381	94.66
4.12	0.403	75.62
2.86	0.289	83.30

5.1	0.432	69.98
3.42	0.486	86.35
2.88	0.613	81.32
4.101	0.412	58.47
4.883	0.572	77.36
4.694	0.577	96.7
3.290	0.563	89.43
5.3	0.581	86.44
4.601	1.12	68.9
3.49	0.88	61.35
4.632	0.6	64.25

The width of a saw cut, which depends on Several factors: the width of the saw blade; the set of the blade'steeth; the amount of wobble created during cutting; and the amount of material pulled out of the sides of the cut.



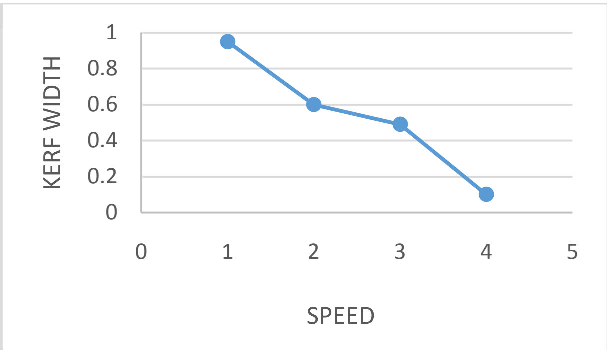
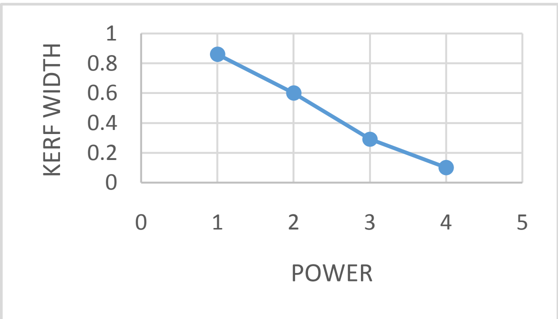


Fig. 5Kerfwidth vs SOD

Fig. 6Kerfwidth vs SPEED



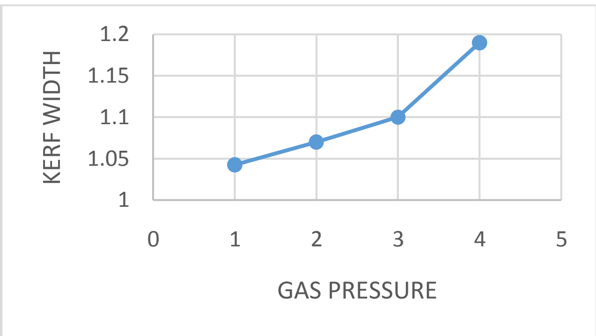


Fig. 7Kerfwidth vs POWER

Fig. 8Kerfwidth vs GAS PRESSURE

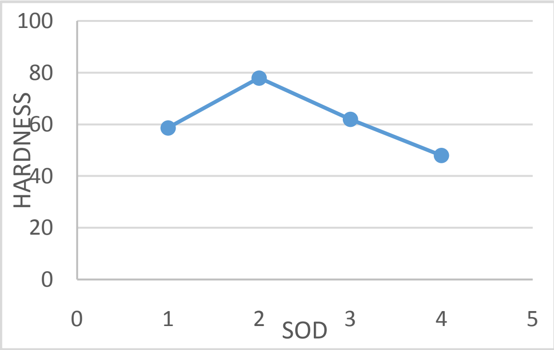
From the above graph of kerf width it is observed that

1. The power increases, the value of the kerf width gradually decreases.

2. The value of the speed increases which results in reduction of kerf width gradually

3. The assist gas pressure increases the value of the kerf width increases. Thus the pressure of assist gas should be low for minimizing the kerf width.

4. The stand of distance increases the, value of the Kerf width gradually increases and decreases at the certain point.



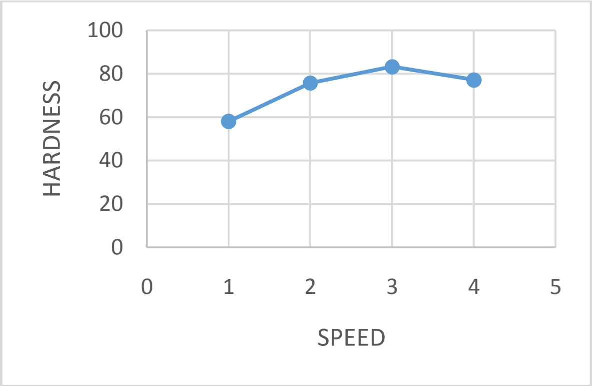
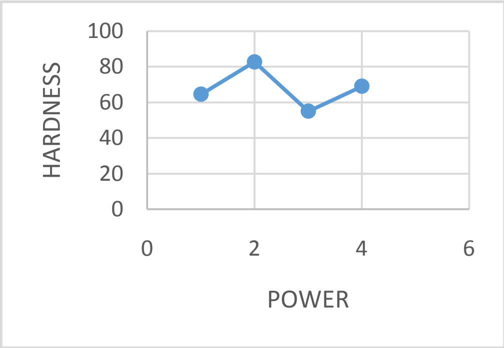


Fig. 9HARDNESSvs SOD

Fig. 10HARDNESS vs SPEED



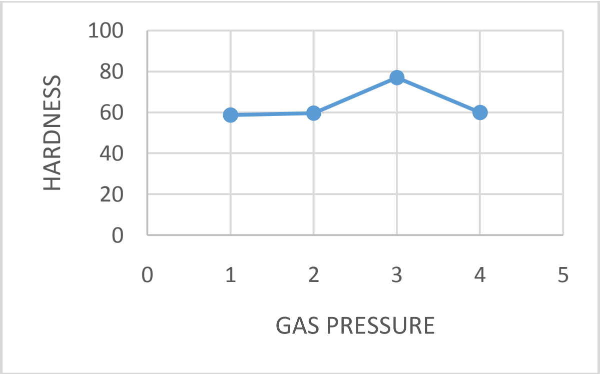


Fig. 11HARDNESSvs POWER

Fig. 12HARDNESS vs GAS PRESSURE

We observed from the graph that,

• Power increases, the value of the surface hardness has both sudden increase and decreases to a certain level of point.

• The value of the speed increases, the value of the surface hardness gradually increases and after a certain point it starts to decrease.

• Gas pressure increases, the value of the surface hardness remains constant for a particular gas pressure and then results in sudden increase and decrease of hardness.

• The value of the Stand of distance increases the value of, the surface hardness suddenly increases and then gradually decreases to a certain level.

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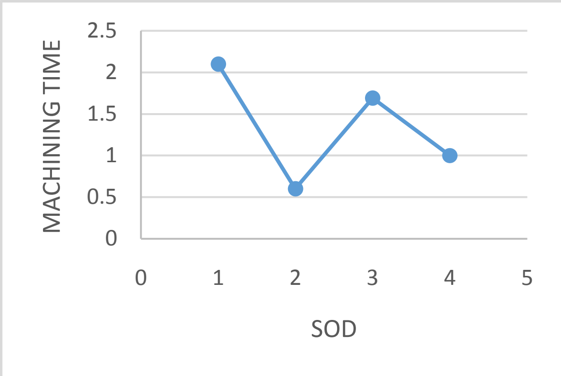


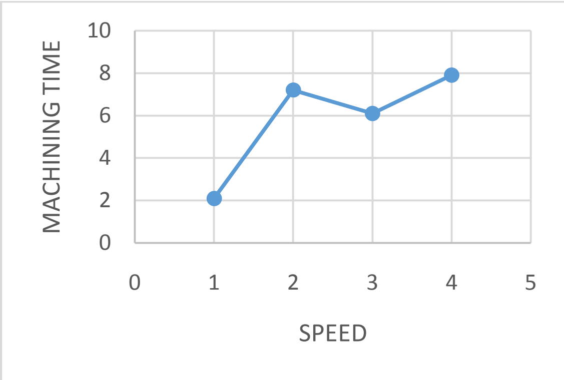
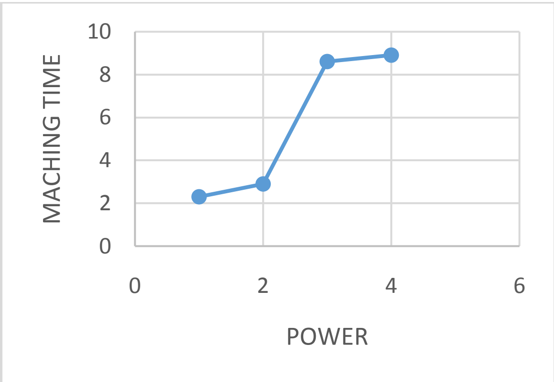


Fig. 13TIME vs SOD

Fig. 14TIME vs SPEED



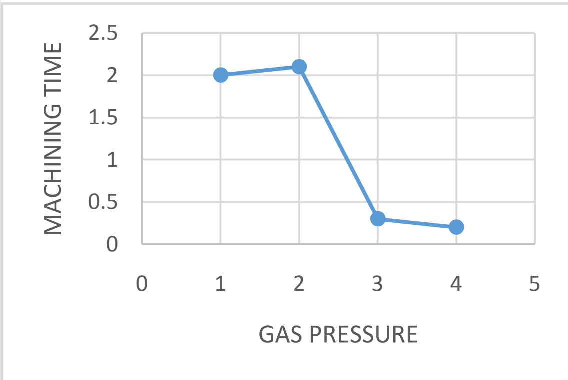


Fig. 15TIME vs POWER

Fig. 16TIME vs GAS PRESSURE

It is shown that from the graph above given are

• Power increases the value of the machining time also gradually increases from point to point to a certain level.

• The value of speed increases, the value of the machining time gradually increase and decreasein nature.

• The value of the gas pressure increases the value of the machining time gradually decreases to a certain level

• The SOD increases the value of the machining time suddenly decreases and then increases to a certain point.

VI.CONCLUSION

The experiment presented here is an overview of research work carried out in laser cutting process. From theabove discussions it can be concluded that:

Increase in value of power results in gradual decreases in kerfwidth, machining time simultaneouslyincreasesfor every point and there is a sudden increment and decrement in hardness value.

Machining time and kerfwidth are inversely propotional,since increase in the value of speed decreasestheirvalues, and hardness gradually increases and all of sudden decreses.

There is a increment in the value of hardness and kerfwidth, when the value of pressure increases andmachining time reduces.At some point hardness remains constant and reduces.

Stand of distance have an similar impact on all kerfwidth, machining time and hardness Since both incrementand decrement happens when SOD increases.

REFERNCES

[1] John C., “Laser processing of engineering materials”. 1st edition 2005, Elsevier Butterworth Heinemann.

[2] B.S. Yilbas., F. Al-Sulaiman., C. Karakas., M. Ahsan., “Laser cutting of multilayered kevlar plates” Journal of Materials Engineering and Performance, Vol. 16, No. 6, pp. 663-671, 207

[3] William., Jyothimoy., Mazumdar., “Laser material processing” Springer 4th edition.

[4] Huang Q, Hagstroem J, Skoog H, Kullberg G. “Effect of laser parameter variation on sheet metal welding”. J Join Mater 1991;3(3):79–88.

[5]Dhaval P. Patel, Mrugesh B. Khatri, ―Optimization of High Power Co2 Laser Machining Centre‘s Machining Parameters byExperimental Analysis, International Journal of Engineering Research and Applications (IJERA), Vol. 2(Issue 2), 2012, 1190-1196.

[6] Ahmet Cekic.et.al(2014)- 25th DAAAM International Symposium on Intelligent Manufacturing and Automation,DAAAM2014Definition of Mathematical Models of High-Alloyed Steel 1.4828 inCO2 Laser Cutting.

[7] A.M. Orishich,A.G.Malikov,V.B.Shulyatyev,*, A.A. Golyshev-Experimental comparison of laser cutting of steel with fiber andCO2lasers on the basis of minimal roughness 8th International Conference on Photonic Technologies LANE 2014

[8]Jun Hu, Zhuoxian Zhang, Jingwen Luo, Xiaojun Sheng. ―Simulation and experiment on standoff distance affecting gas flow in lasercutting‖ , journal of Applied Mathematical Modeling, Vol 35, 2011, 895–902.

[9]Sivarao, Ammar, T.J.S.Anand, Shukor, ―Stochastic Modeling and Optimization of Laser Machining by Response SurfaceMethodology‖ ,International Journal of Engineering & Technology, Vol 10(04), 13-21.

[10]MilosMadic, MiroslavRadovanovic and LaurentiuSlatineanu, ―SurfaceRoughness Optimization In Co2 Laser Cutting By Using Taguchi Method", U.P.B. Sci. Bull., Vol. 75(Iss. 1), 2013, 97-106.

[11] H.A. Eltawahni ,M.Hagino , K.Y.Benyounis , T.Inoue , A.G.Olabi- Effect ofCO2 lasercuttingprocessparametersonedgequalityandoperating costofAISI316L