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Experiment investigation on mild steel grade E 350 C using CO_2 laser beam machining

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ABSTRACT

Laser beam machining is a predominantly used non-conventional process to cut THE desired shape of sheet metal, plate, section and boxes with greater accuracy at least time. A co₂ laser beam machine to be cut the mild steel grade E 350 C as thickness (TH) of 12 mm, 16 mm and 20mm. In this research work, selected input parameters (IP) were Laser Power (LP), Cutting Speed (CS), Gas Pressure (GP), Nozzle Diameter (ND), Focal Length (FL), and Nozzle Distance (NDS). The experiment investigated the effect of these input parameters on Output Parameters (OP) like to Kerf Width (KW), Perpendicularity (PR), Surface Roughness (SR), Hardness (HRD) and Heat Affected Zone (HAZ). An experiment to be designed by the Taguchi L27 orthogonal array. After the analyzed result, to geted the optimum input parameter for good cutting quality.

Keywords— *Co_2 laser beam, Laser power, Cutting speed, Gas pressure, Nozzle diameter, Focal length, Nozzle distance*

1. INTRODUCTION

The carbon dioxide laser is the most efficient and powerful of all continuous-wave laser devices. Continuous powers have been reported above 30 kilowatts at the far-infrared 10.6 µm wavelength. An electrical discharge is initiated in a plasma tube and its containing carbon dioxide gas. Electron collisions to higher vibrational levels are excited the CO_2 molecules, from which they decay to the metastable vibrational level occurs; which has a lifetime of approximately 2×10^{-3} seconds at low pressure. A population inversion is establishing between certain vibrational levels leads to lasing transition at 10.6 µm, while a population inversion between other vibrational levels can result in lasing transitions at 9.6 µm. A lasing can be obtained in the plasma tube containing CO_2 gas, also other added gases like to He, H_2o, N_2. A efficiency of the CO_2 laser is increased by these additives. The most common gas composition in CO_2 lasers is a mixture of He, N_2 and CO_2. Carbon dioxide lasers are capable of producing tremendous amounts of output power, primarily because of the high efficiency of about 30%, as compared to less than 0.1% for most He-Ne lasers. A main difference between the CO_2laser and gas laser is the optic must be coated, or made of the special material, to be reflective or transmissive at the wavelength of 10.6 µm. The output mirror is made by the germanium when its cooled then occur low loss at 10.6 µm. The CO_2 laser consists of three common laser cavity configurations. The first is the gas discharge tube encountered with the discussion of the He-Ne laser. Secondly is the axial gas flow, where the gas mixture is pumped into one end of the tube and taken out the other. An electrical discharge is used for the replacement of the CO_2 molecules depleted. When nitrogen is added to the co_2 laser then increase the efficiency of the pumping process and transfer energy by the collisions. Associated effects enhance the de-excitation process. A increased the efficiency of pumping sources and stimulated emission by the added helium. The third method is the transverse gas flow. This technique can produce CO_2laser emissions at power levels approaching 25 kW. The CO_2laser has a strong emission wavelength at 10.6 µm. There is another strong line at 9.6 µm and a multitude of lines between 9 and 11 µm. CO_2lasers are highly efficient (10-30%), give high output powers (used for welding and cutting), and applications out-of-doors can take advantage of low transmission loss atmospheric windows at about 10 µm.

1.1 Laser cutting process

An inert gas is used to expel molten material out of the kerf in fusion laser cutting. Nitrogen gas does not exothermically react with the molten material and thus does not contribute to the energy input. Inflame laser cutting, oxygen is used as the assist gas.

In addition to exerting mechanical force on the molten material. This creates an exothermic reaction which increases the energy input to the process. In remote laser cutting, a high-intensity laser beam is evaporating the materials and no assist gas required for the cutting thin sheet metal. The laser cutting process lends itself to automation with offline CAD/CAM systems controlling either three-axis flatbed systems or six-axis robots for three-dimensional laser cutting. Improvements in accuracy, edge squareness and heat input control mean that laser cutting is increasingly replacing other profiling cutting techniques, such as plasma and oxy-fuel. Laser beam machining is classified based on thermal non-conventional processing. Its beam concentrates at one point and melting a material by heating. A co-axial gas jet is used to eject the molten material and create a kerf. A CNC control used for moving the table and tool head and totally material to be cut by the automation process. There are three major varieties of laser cutting: fusion cutting, flame-cutting, and remote cutting.

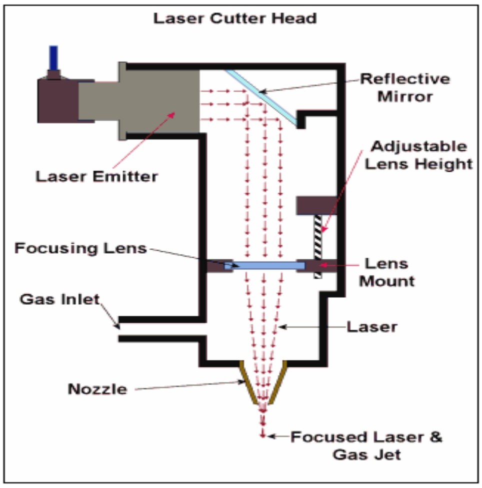

Fig. 1: Laser cutting process

1.2 Literature Survey

N. Rajaram, J. Sheikh – Ahmad and s. Hossein cheraghi[1] study of the effect of the feed rate and laser power on cut quality of steel 4130, power and feed rate had a major effect on the kerf width. kerf width is increased due to the defocusing laser beam. Generally, an increase in feed speed resulted in a decrease in the width of HAZ for the power range between 700 to 1100 watts. The slight increase in striation frequency with an increase in feed speed. Very fine striations were observed at lower feed rates when compared to higher feed rates.

Sachinsrinivasan, Rajeshwar, Skadadevaramath, Vijaykumar, Sureshkumar P [2] have been done optimization of the metal removal rate and surface roughness of cutting stainless steel 3 mm sheet by the co_2 laser cutting machine. The optimal solution obtained for Ra and Rz based on the combination of laser cutting parameters and their levels is cutting speed 7000 mm/min, laser power 2500W and assist gas pressure 14 bar and cutting speed 7000mm/min, laser power 2500W and assist gas pressure 10 bar respectively. ANOVA results indicate that cutting speed plays a prominent role in determining the surface roughness. The contribution of cutting speed, laser power and assist gas pressure to the quality characteristics surface roughness Ra is 2.78, 2.96 and 3.24 µm. Cutting speed and assist gas pressure are the most significant parameters majorly affecting the surface roughness whereas the laser power is much smaller.

Imed Miraoui, Mohamed Boujelbene, Mouna Zaied [3] have been studied the effect of HAZ on cutting of S 235 steel plate by high power co_2 laser cutting machine. Input laser cutting parameters are more affectable on the melted zone, HAZ and microhardness beneath the cut surface. When laser power increases then the dimension of the HAZ is increases. When cutting speed increase then the dimension of the HAZ is decreased. The melted zone depth decreases with cutting speed and increases with laser power. Results show that melted zone depth increase with the laser beam diameter, contrary to HAZ depth in which the diameter has a negligible effect.

S. Stelzer, A. Mahrlea, A. Wetziga, E. Beyera [4] have presenting experiment investigation on fusion cutting of stainless steel by fiber laser and co_2 laser cutting machine. It was found out that a sudden increase in surface roughness is present at a particular sheet thickness. A -observed qualitative differences in cut kerf shapes but with comparable kerf cross-section on areas.

1.3 Mild steel grade E350 C

Mild steel grade E350 C is sustained high tensile strength and high shear strength. Thickness is available for this material up to 1.5 to 300 mm in the market. A width is 1500-4020 mm and length are 3000-27000 mm. A used also for rivet, bolted and welding structure. In mechanical properties, a yield strength 330Mpa and tensile strength 450Mpa, elongation 22% and impact energy 25 J.

Table 1: Chemical composition of mild steel grade E350 C

C (%)	Si (%)	P (%)	S (%)	Cr (%)	Ni (%)	Mo (%)	Ti (%)
0.15	0.33	0.010	0.0017	0.018	0.007	0.001	0.011

1.4 Methodology of experiment

I have to complete the sample experiment on mild steel grade E350 C by Co_2 laser beam machine of Trum-PF Trulaser 3060. Then, I have to conclude 3 level parameters for the design of the experiment (Taguchi approach). Generating the plan of an experiment as an L_{27} orthogonal array by the Taguchi approach in Minitab software.

Table 2: Control factor and it is level

Factors	Unit	Level 1	Level 2	Level 3
Thickness	mm	12	16	20
Laser power	watt	2200	3000	4130
Cutting speed	mm/min	2100	3000	3860
Gas pressure	bar	0.6	0.8	1.0
Nozzle diameter	mm	1.0	1.4	1.7
Focal length	mm	1.1	1.4	2.0
Nozzle distance	mm	0.8	0.9	1.0

1.5 Result and its discussion

Table 3: Result of experiment

Trial	Thickness (mm)	LP (w)	CS (mm/min)	GP (bar)	ND (mm)	FL (mm)	NDS (mm)	KW (mm)	PR (mm)	SR (µm)	Hardness (RHN)	HAZ (µ)
1	12	2200	2100	0.6	1.0	1.1	0.8	2.2	2.0	23.34	36	1330
2	12	2200	2100	0.6	1.4	1.4	0.9	2.9	1.8	16.38	30	1420
3	12	2200	2100	0.6	1.7	2.0	1.0	3.1	2.1	26.3	34	1200
4	12	3000	3000	0.8	1.0	1.1	0.8	1.6	1.9	10.2	29	810
5	12	3000	3000	0.8	1.4	1.4	0.9	1.9	1.3	7.10	26	590
6	12	3000	3000	0.8	1.7	2.0	1.0	2.4	2.0	14.9	33	920
7	12	4130	3860	1.0	1.0	1.1	0.8	1.4	1.2	11.56	30	630
8	12	4130	3860	1.0	1.4	1.4	0.9	1.2	1.1	6.21	28	570
9	12	4130	3860	1.0	1.7	2.0	1.0	1.3	1.0	5.20	25	550
10	16	2200	3000	1.0	1.0	1.4	1.0	2.6	3.0	20.9	36	1100
11	16	2200	3000	1.0	1.4	2.0	0.8	1.8	1.6	16.37	32	780
12	16	2200	3000	1.0	1.7	1.1	0.9	2.4	2.9	22	33	910
13	16	3000	3860	0.6	1.0	1.4	1.0	2.0	1.9	13.28	34	360
14	16	3000	3860	0.6	1.4	2.0	0.8	1.6	2.0	10.49	31	210
15	16	3000	3860	0.6	1.7	1.1	0.9	2.2	2.3	18	32	690
16	16	4130	2100	0.8	1.0	1.4	1.0	1.4	1.3	6.98	29	470
17	16	4130	2100	0.8	1.4	2.0	0.8	1.0	1.0	7.47	26	540
18	16	4130	2100	0.8	1.7	1.1	0.9	1.0	1.2	4.56	29	880
19	20	2200	3860	0.8	1.0	2.0	0.9	3.1	2.6	30.22	37	530
20	20	2200	3860	0.8	1.4	1.1	1.0	2.6	1.8	23.14	35	140
21	20	2200	3860	0.8	1.7	1.4	0.8	2.4	2.0	21.67	29	560
22	20	3000	2100	1.0	1.0	2.0	0.9	1.9	1.7	10.8	31	650
23	20	3000	2100	1.0	1.4	1.1	1.0	1.4	1.2	6.92	34	190
24	20	3000	2100	1.0	1.7	1.4	0.8	1.8	1.5	7.66	25	380
25	20	4130	3000	0.6	1.0	2.0	0.9	1.2	1.4	10.2	28	710
26	20	4130	3000	0.6	1.4	1.1	1.0	1.3	1.9	13.96	32	850
27	20	4130	3000	0.6	1.7	1.4	0.8	2.0	2.2	12.46	30	620

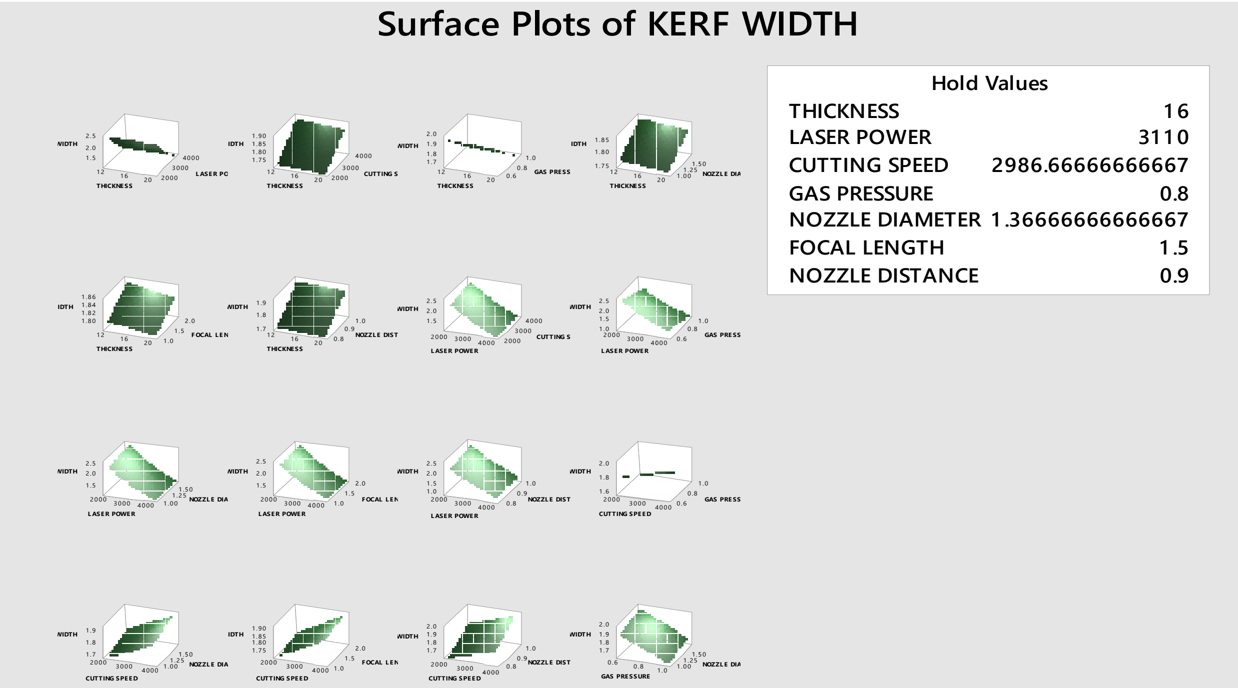

Fig. 1: Surface plot of kerf width

After the performed experiment, when thickness 16 mm, laser power 4130 W, cutting speed 2100 mm/min, gas pressure 0.8 bar, nozzle diameter 1.7 mm, focal length 1.1 mm, nozzle distance 0.9 mm then got kerf width 1.0 mm. When thickness 20 mm, laser power 2200 W, cutting speed 3860 mm/min, gas pressure 0.8 bar, nozzle diameter 1.0 mm, focal length 2.0 mm, nozzle distance 0.9 mm then got kerf width 3.1mm.

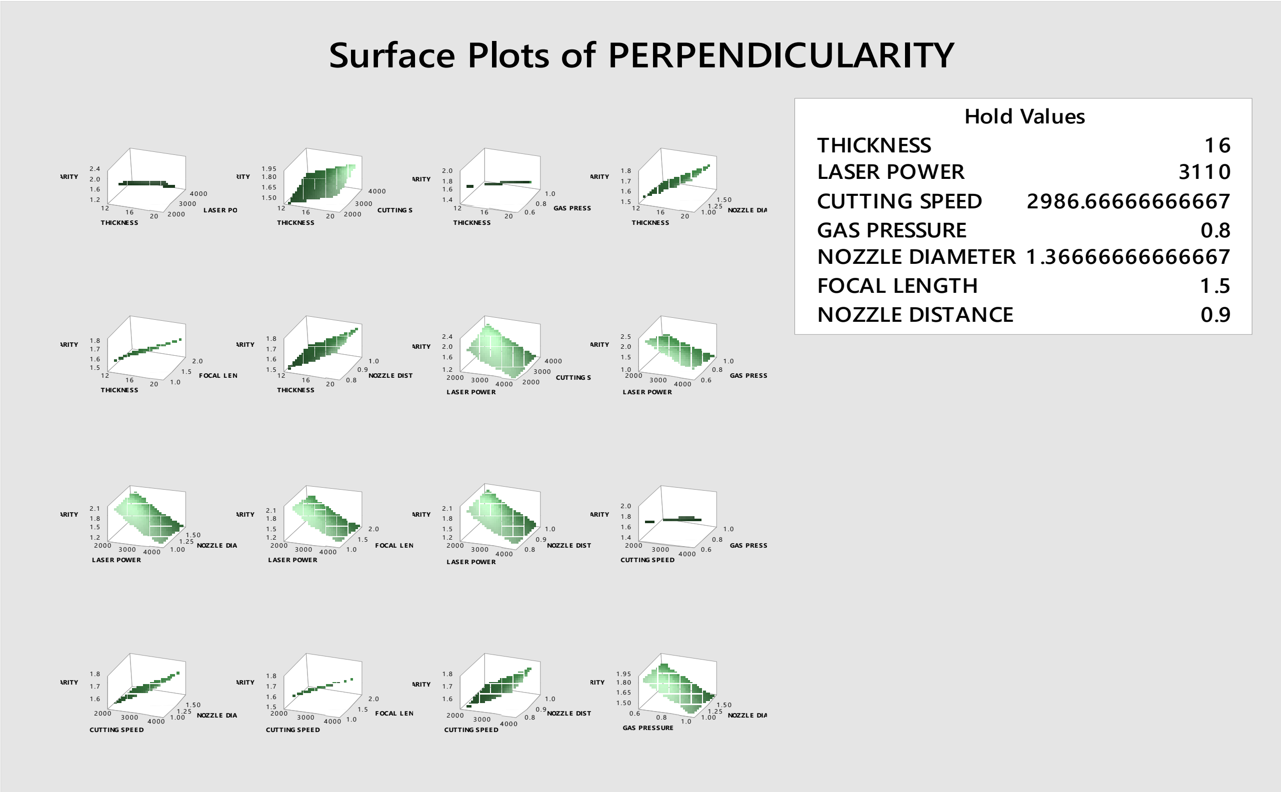

Fig. 2: Surface plot of perpendicularity

After the performed experiment, when thickness 12 mm, laser power 4130 W, cutting speed 3860 mm/min, gas pressure 1.0 bar, nozzle diameter 1.7 mm, focal length 2.0 mm, nozzle distance 1.0 mm then got perpendicularity 1.0 mm. When thickness 16 mm, laser power 2200 W, cutting speed 3000 mm/min, gas pressure 1.0 bar, nozzle diameter 1.0 mm, focal length 1.4 mm, nozzle distance 1.0 mm then got perpendicularity 3.0 mm

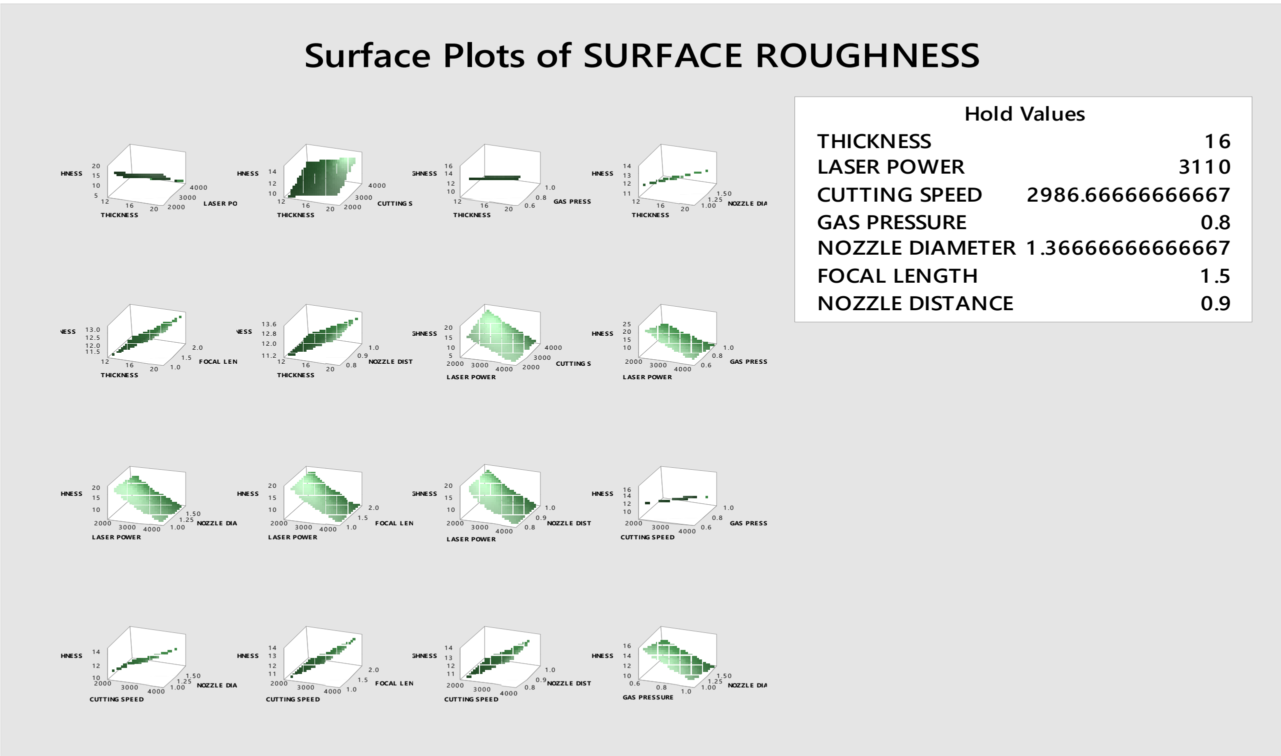

Fig. 3: Surface plot of surface roughness

After the performed experiment, when thickness 16 mm, laser power 4130 W, cutting speed 2100 mm/min, gas pressure 0.8 bar, nozzle diameter 1.7 mm, focal length 1.1 mm, nozzle distance 0.9 mm then got surface roughness 4.56 µm. When thickness 20 mm, laser power 2200 W, cutting speed 3860 mm/min, gas pressure 0.8 bar, nozzle diameter 1.0 mm, focal length 2.0 mm, nozzle distance 0.9 mm then got surface roughness 30.22 µm.

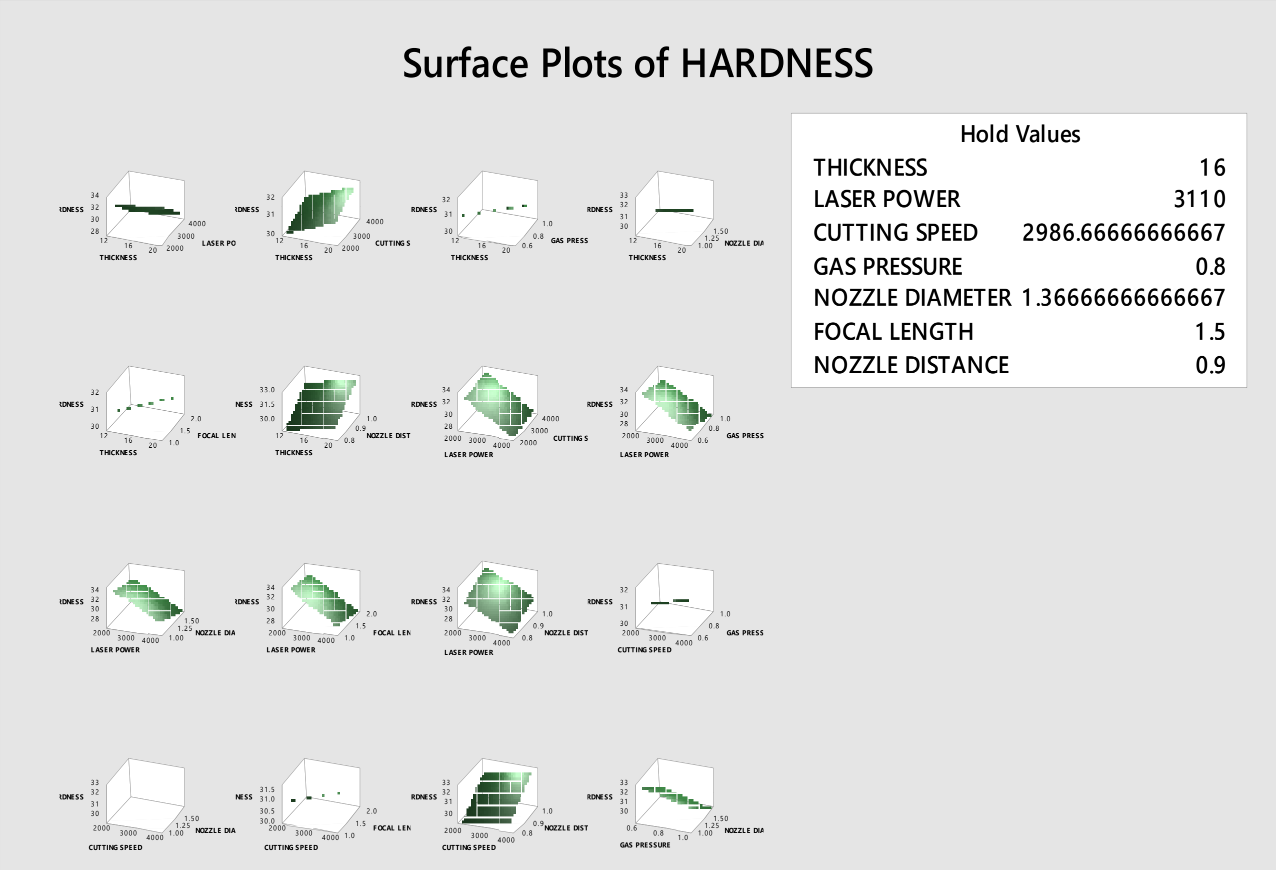

Fig. 4: Surface plot of hardness

After the performed experiment, when thickness 12 mm, laser power 4130 W, cutting speed 3860 mm/min, gas pressure 1.0 bar, nozzle diameter 1.7 mm, focal length 2.0 mm, nozzle distance 1.0 mm then got hardness 25 RHN. When thickness 20 mm, laser power 2200 W, cutting speed 3860 mm/min, gas pressure 0.8 bar, nozzle diameter 1.0 mm, focal length 2.0 mm, nozzle distance 0.9 mm then got hardness 37 RHN.

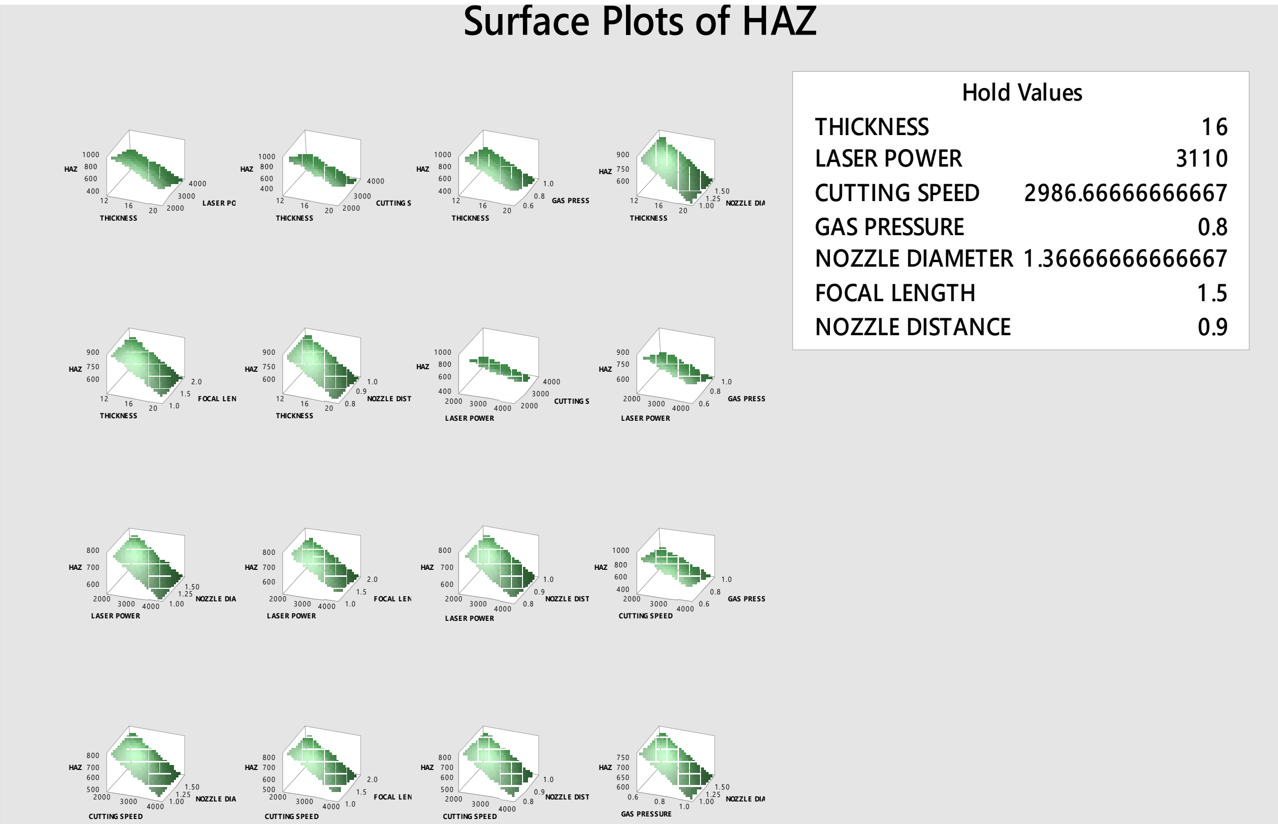

Fig. 5: Surface plot of HAZ

After the performed experiment, when thickness 20 mm, laser power 2200 W, cutting speed 3860 mm/min, gas pressure 0.8 bar, nozzle diameter 1.4 mm, focal length 1.1 mm, nozzle distance 1.0 mm then got HAZ 140 micron. When thickness 12 mm, laser power 2200 W, cutting speed 2100 mm/min, gas pressure 0.6 bar, nozzle diameter 1.4 mm, focal length 1.4 mm, nozzle distance 0.9 mm then got HAZ 1420 micron.

2. CONCLUSION

Kerf width has an important role in achieving the desired cutting quality. When laser cutting of MS plate then various parameter affects kerf width. After the performed experiment, when thickness 16 mm, laser power 4130 W, cutting speed 2100 mm/min, gas pressure 0.8 bar, nozzle diameter 1.7 mm, focal length 1.1 mm, nozzle distance 0.9 mm then got kerf width minimum. When thickness 20 mm, laser power 2200 W, cutting speed 3860 mm/min, gas pressure 0.8 bar, nozzle diameter 1.0 mm, focal length 2.0 mm, nozzle distance 0.9 mm then got kerf width maximum.

Perpendicularity has an important role in achieving the desired cutting quality. When laser cutting of MS plate then various parameter affects perpendicularity. After the performed experiment, when thickness 12 mm, laser power 4130 W, cutting speed 3860 mm/min, gas pressure 1.0 bar, nozzle diameter 1.7 mm, focal length 2.0 mm, nozzle distance 1.0 mm then got perpendicularity minimum. When thickness 16 mm, laser power 2200 W, cutting speed 3000 mm/min, gas pressure 1.0 bar, nozzle diameter 1.0 mm, focal length 1.4 mm, nozzle distance 1.0 mm then got perpendicularity maximum.

Surface roughness has an important role in achieving the desired cutting quality. When laser cutting of MS plate then various parameter affects surface roughness. After the performed experiment, when thickness 16 mm, laser power 4130 W, cutting speed 2100 mm/min, gas pressure 0.8 bar, nozzle diameter 1.7 mm, focal length 1.1 mm, nozzle distance 0.9 mm then got surface roughness minimum. When thickness 20 mm, laser power 2200 W, cutting speed 3860 mm/min, gas pressure 0.8 bar, nozzle diameter 1.0 mm, focal length 2.0 mm, nozzle distance 0.9 mm then got surface roughness maximum.

Hardness has an important role in achieving the desired cutting quality. When laser cutting of MS plate then various parameter affects hardness. After the performed experiment, when thickness 12 mm, laser power 4130 W, cutting speed 3860 mm/min, gas pressure 1.0 bar, nozzle diameter 1.7 mm, focal length 2.0 mm, nozzle distance 1.0 mm then got hardness minimum. When thickness 20 mm, laser power 2200 W, cutting speed 3860 mm/min, gas pressure 0.8 bar, nozzle diameter 1.0 mm, focal length 2.0 mm, nozzle distance 0.9 mm then got hardness maximum.

HAZ has an important role in achieving the desired cutting quality. When laser cutting of MS plate then various parameter affects HAZ. After the performed experiment, when thickness 20 mm, laser power 2200 W, cutting speed 3860 mm/min, gas pressure 0.8 bar, nozzle diameter 1.4 mm, focal length 1.1 mm, nozzle distance 1.0 mm then got HAZ minimum. When thickness 12 mm, laser power 2200 W, cutting speed 2100 mm/min, gas pressure 0.6 bar, nozzle diameter 1.4 mm, focal length 1.4 mm, nozzle distance 0.9 mm then got HAZ maximum.

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