EXPERIMENTAL INVESTIGATION OF SS321 AND SS316L USING CO_2 LASER CUTTING MACHINE

1. Miss Riya Patel –M.E student at Merchant Engineering Collage Basna,Gujarat
2. Mr.J.D.Patel - Assistant Professor MIT, Piludara, Gujarat

ABSTRACT

Industries demand always for efficient process for cutting advance materials like tool steel, super alloys, ceramics and composites with high precision and better surface finish. These materials are having tremendous hardness. Conventional machining do not serve the purpose. To meet these challenges non-conventional machining process are useful. Non-conventional processes achieve dimensional accuracy and better surface finish. Laser cutting is one of the useful processes to cut complex shapes with high accuracy. Laser cutting is a two-dimensional machining process in which material removal is obtained by focusing a highly intense laser beam on the work piece. The laser beam heat subsequently melts/vaporizes the work piece throughout the thickness or depth of the material thus creating a cutting front. The molten material is expelled from the cutting front by a pressurized assist gas jet. CO_2 laser cutting becomes a competitive and economical option which fulfils the demand of present industrial need. CO_2 laser cutting is a complex machining process controlled by a large number of process parameters such as Laser Power, Pulse frequency, cutting speed, gas pressure etc. For optimum machining performance selection of process parameter and setting of various input parameters play a crucial role on response like MRR, Surface finish and kerf width. Little change in one parameter plays significant effect towards response. Process parameter it's effect and optimization of process parameter towards response need to be analysed. In present study an attempt is made to investigate the effect of Laser power, Cutting speed and gas pressure on SS321 and SS316L materials. The output response are Material Removal Rate (MRR), Kerf width and Surface roughness. A Response surface Method (RSM) with L20 array has been used for analysis purpose. Experimental work carried out in controlled environment. Analysis has been done with Minitab17 statistical analysis software. ANOVA analysis used to calculate percentage contribution of each parameter towards response. Multi objective analysis carried out by Grey relational grade (GRG) method and AHP/MOORA method. The experimental data and its analysis state that Laser power, Cutting speed and Gas pressure affects differently for single objective and for multi objective.

Keyword: - *Laser Cutting, RSM,ANOVA,Optimization, AHP, MOORA, GRA so on..*

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1. INTRODUCTION

Laser (light amplification by stimulated emission of radiation) is called a coherent and amplified beam of electromagnetic rays. The key element in making a practical laser is the light amplification achieved by stimulated emission due to the incident photons of high energy. A laser comprises three principal components, namely, the lasing medium, means of exciting the lasing medium into its amplifying state (lasing energy source), and optical delivery/feedback system. Additional provisions of cooling the mirrors, guiding the beam and manipulating the target are also important. The laser medium may be a solid (e.g. Nd:YAG or neodymium doped yttrium–aluminium–garnet), liquid (dye) or gas (e.g. CO_2, He, Ne) .

1.1 Process Principal of Laser Cutting Process

Laser cutting is a two-dimensional machining process in which material removal is obtained by focusing a highly intense laser beam on the work piece. The laser beam heat subsequently melts/vaporizes the work piece throughout the thickness or depth of the material thus creating a cutting front. The molten material is expelled from the cutting front by a pressurized assist gas jet. The assist gas, in addition to facilitating the material removal by melt expulsion, may also help in enhanced material removal through chemical reactions such as oxidation of the material. The cutting of the material then proceeds by the movement of the cutting front across the surface of the material. This is carried out by the motion of either focused beam and/or the work piece relative to each other in figure 1

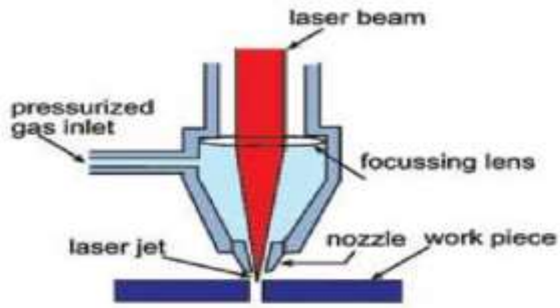

Fig -1 Laser Beam Machining

Laser cutting is a high-speed, repeatable, and reliable method for a wide variety of material types and thicknesses producing very narrow and clean-cut width. The process is particularly suited as a fully or semi automated cutting process for the high production volumes. One of the first industrial applications of laser cutting using 200 W laser is cutting of slots in die boards. The lasers are now capable of cutting a wide range of metallic materials such as steels, super alloy, copper, aluminum, and brass, and nonmetallic materials such as ceramic, quartz, plastic, rubber, wood. For CO_2 laser cutting Jarosza et. al. (2016) analyses the effect of cutting speed on heat-affected zone (HAZ) and surface roughness in laser cutting of AISI316L stainless steel. Test samples were cut with varying cutting speed, while other process parameters remained constant. Surface roughness of each test sample was measured in several places along cut depth. Photos of cut surfaces were taken with the use of stereoscopic microscope equipped with a camera. Results were analyzed. Cutting speed has a visible effect on surface roughness, width of the heat-affected zone and presence of macro-irregularities, such as presence of dross, molten and burnt material. With the decrease in cutting speed, HAZ width also increases, and below a certain threshold (less than 50% of maximum recommended value of cutting speed) lower part of the cut surface becomes visibly damaged. Kotadiya et.al. (2016) investigated effect of process parameter for SS-304 material using CO_2 laser cutting. Stainless steel is an important engineering material that is difficult to be cut by oxy-fuel methods because of the high melting point and low viscosity of the formed oxides. However, it is suitable to be cut by laser. The objective of this work is to do parametric analysis of process parameters of CO_2 laser cutting system on surface characteristics of the cut section in the cutting of 5mm Stainless Steel (SS) sheet (ASTM 304). In this study, the laser cutting parameters such as laser power, cutting speed and gas pressure are analyzed and optimized with consideration of work piece surface roughness. Design of experiments (DOE), ANOVA and Response Surface Methodology (RSM) approaches are used to analyze the laser cutting variables and find out the optimum value for surface roughness. By analyzing, it is observed that the laser power has more effect on responses rather than cutting speed and gas pressure.

2. EXPERIMENTAL PROCEDURE

The experimental part regarding Laser machining centre of this research work was carried out at Metizfab Solutions, Ahmedabad (Model: Trumatic L2530-Trumpf) Metizfab Solutions is Ahmedabad based Sheetmetal fabricators situated at Vatva G.I.D.C which is near to most of G.I.D.C.'s and industrial areas and also convenient for transportation or material movement. Metizfab Solutions are Involved in doing jobwork of Elevators, Machine covers, Electric panels, Automobile parts, Pharmaceutical machineries, Parts of agriculture equipments etc.

In this experimental work, the sample is laser cutting at five different levels of cutting parameter i.e. laser power, cutting speed and gas pressure as shown in table 1.

Table-1: Parameter and their levels

Machining process parameter		Level				
		1	2	3	4	5
1	Laser Power(watt)	964	1100	1300	1500	1636
2	Cutting Speed(m/min)	0.96	1.1	1.3	1.5	1.64
3	Gas Pressure(bar)	5.61	8	11.5	15	17.34

Table-2: Chemical Composition of SS321 and SS316L

Element	SS321		SS316L	
	Found in Test	Required	Found in Test	Required
Carbon	0.030	0.080 max.	0.026	0.030 max
Silicon.	0.610	0750max	0.430	0.75 max
Sulfur	0.001	0.030 max	0.001	0.03 max
Phosphorus	0.024	0.045 max	0.027	0.045 max
Manganese	1.420	2.000 max	1.180	2.00 max
Nickel	9.020	9.000 to 12.000	10.100	10.0 min. – 14.0 max.
Chromium	17.090	17.000 to 19.000	16.630	16.0 min. – 18.0 max.
Moly	0.063	0.07 max	2.010	2.00 min. – 3.00 max.
Titanium	0.300	0.700 max	0.300	0.4 max
Nitrogen	0.015	0.100 max	0.09	0.10 max.

Test pieces are prepared by cutting on shearing machine. And experiment carried on CO_2 laser cutting machine.

Fig -2 Experiments Photos

Table-3 DOE for SS321

RunOrder	PtType	Blocks	Power	Speed	Pressure	KW	MRR	SR
1	0	1	1300	1.3	11.5	0.3705	10.5651	11.9625
2	1	1	1500	1.5	8	0.3935	13.1170	13.1577
3	0	1	1300	1.3	11.5	0.3695	10.5371	11.7015
4	0	1	1300	1.3	11.5	0.3715	10.5941	11.8123
5	1	1	1100	1.5	8	0.3900	16.7159	11.8152
6	1	1	1100	1.1	8	0.4282	12.8458	11.8152
7	0	1	1300	1.3	11.5	0.3785	10.7937	11.8025
8	1	1	1100	1.5	15	0.3969	17.0091	13.9231
9	1	1	1500	1.1	8	0.4730	14.1892	11.9613
10	-1	1	1300	1.64	11.5	0.4297	18.4165	11.8152
11	1	1	1100	1.1	15	0.4983	18.6858	13.8625
12	-1	1	1300	0.96	11.5	0.5336	14.5517	12.6837
13	-1	1	964	1.3	11.5	0.4983	16.6096	12.3400
14	1	1	1500	1.5	15	0.4413	18.9113	14.1020
15	-1	1	1300	1.3	5.61	0.4608	17.2806	12.4728
16	0	1	1300	1.3	11.5	0.3726	10.6255	11.8233
17	-1	1	1636	1.3	11.5	0.4496	16.8605	13.4487
18	0	1	1300	1.3	11.5	0.3737	10.6568	11.8146
19	-1	1	1300	1.3	17.34	0.4457	14.8551	14.8747
20	1	1	1500	1.1	15	0.4820	14.4601	13.9778

Table-4 DOE for SS316L

RunOrder	PtType	Blocks	Power	Speed	Pressure	KW	MRR	SR
1	0	1	1300	1.3	11.5	0.4766	15.8706	9.7196
2	1	1	1500	1.5	8	0.4744	18.7762	10.3509
3	0	1	1300	1.3	11.5	0.4712	15.6896	9.7052
4	0	1	1300	1.3	11.5	0.4699	15.6443	9.7210
5	1	1	1100	1.5	8	0.4372	17.6034	9.7096
6	1	1	1100	1.1	8	0.4321	13.2681	9.7096
7	0	1	1300	1.3	11.5	0.4756	15.8365	9.7246
8	1	1	1100	1.5	15	0.4301	16.9785	10.1703
9	1	1	1500	1.1	8	0.4633	13.7618	9.6885
10	-1	1	1300	1.64	11.5	0.4361	18.1193	9.7096
11	1	1	1100	1.1	15	0.4554	13.5002	10.4901

12	-1	1	1300	0.96	11.5	0.4357	11.5866	10.0793
13	-1	1	964	1.3	11.5	0.4339	15.1365	10.5012
14	1	1	1500	1.5	15	0.4657	17.9129	10.7707
15	-1	1	1300	1.3	5.61	0.4514	16.3929	10.2563
16	0	1	1300	1.3	11.5	0.4746	15.8033	9.7145
17	-1	1	1636	1.3	11.5	0.4773	14.9167	10.3533
18	0	1	1300	1.3	11.5	0.4722	15.7240	9.7096
19	-1	1	1300	1.3	17.34	0.4920	17.3051	11.0320
20	1	1	1500	1.1	15	0.5000	15.1057	10.4763

Central composite design (CCD) is the most popular class of second order designs suggested by Box and Wilson. Central composite rotatable design (CCRD) is capable of predicting independent, quadratic and interaction effects of different parameters on the responses. Total 20 experiments (8 factorial runs, 6 axial runs, 6 central points) have been carried out at five levels. The typical plan of experiments using CCRD. Total twenty experiments were performed based on L20 orthogonal array shown in this research. The effect of different parameters such as Laser Power(watt), Cutting Speed(m/min) and Gas Pressure(bar) of above materials was analyzed and observed the Material removal rate, kerf width and surface roughness of all twenty cutting sample. Then we Calculate ANOVA using Minitab 16.

3. RESULT AND DISCUSSION

3.1 Response Surface Regression: KW for SS321

R-Sq = 81.44% R-Sq(pred) = 0.00% R-Sq(adj) = 64.74%

Table -5 ANOVA Table for KW for SS321

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Percentage
Power	1	0.007002	0.007002	0.007002	10.3	0.005	14.01
Speed	1	0.013818	0.013818	0.013818	14.9	0.003	27.64
Pressure	1	0.000858	0.000858	0.000858	0.92	0.359	1.72
Power*Power	1	0.000928	0.000928	0.000928	2.06	0.006	1.86
Speed*Speed	1	0.011855	0.013475	0.013475	14.53	0.003	23.72
Pressure*Pressure	1	0.006077	0.006077	0.006077	6.55	0.028	12.16
Power*Speed	1	0.000047	0.000047	0.000047	0.05	0.827	0.09
Power*Pressure	1	0.000051	0.000051	0.000051	0.05	0.82	0.10
Speed*Pressure	1	0.000075	0.000075	0.000075	0.08	0.782	0.15
Residual Error	10	0.009277	0.000928				18.56
Total	19	0.049987					100.00

Polynomial model

KW for SS321=3.23097 -0.00185019 * Power -2.17495 * Speed -0.0259183 * Pressure + 0.000000696494 * Power * Power + 0.764467 * Speed * Speed + 0.00167634 * Pressure * Pressure + 0.0000605171 * Power * Speed - 0.00000359898 * Power * Pressure -0.00438068 * Speed * Pressure

3.2 Response Surface Regression: KW for SS316L

R-Sq = 94.43% R-Sq (pred) = 59.80% R-Sq(adj) = 89.42%

Table -6 ANOVA Table for KW for SS316L

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Percentage
Power	1	0.003599	0.003599	0.003599	77.01	0	42.89
Speed	1	0.002134	0.002134	0.002134	47.86	0.0 2	25.43
Pressure	1	0.00093	0.00093	0.00093	19.9	0.001	11.08
Power*Power	1	0.000274	0.000424	0.000424	9.06	0.013	3.27
Speed*Speed	1	0.00025	0.00025	0.00025	2.47	0	2.98
Pressure*Pressure	1	0.000001	0.000001	0.000001	0.02	0.888	0.01
Power*Speed	1	0.000001	0.000001	0.000001	0.02	0.882	0.01
Power*Pressure	1	0.000017	0.000017	0.000017	0.37	0.558	0.20
Speed*Pressure	1	0.000716	0.000716	0.000716	15.32	0.003	8.53
Residual Error	10	0.000467	0.000467	0.000047			5.57
Total	19	0.008391					100.00

Polynomial model

KW for SS316L = -0.575851 + 0.000421441 * Power +0.958257 * Speed + 0.0167174 * Pressure - 0.000000135549 * Power * Power - 0.310197 * Speed * Speed + 0.0000213197 * Pressure * Pressure - 0.00000917698 * Power * Speed + 0.00000209462 * Power * Pressure - 0.0135173 * Speed * Pressure

3.3 Response Surface Regression: MRR for SS321

R-Sq = 78.64% R-Sq(pred) = 0.00% R-Sq(adj) = 59.41%

Table -7 ANOVA Table for MRR for SS321

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Percentage
Power	1	38.444	54.219	54.2186	14.42	0.003	21.85
Speed	1	41.165	49.372	49.3722	13.13	0.005	23.39
Pressure	1	41.832	41.832	41.8324	11.13	0.008	23.77
Power*Power	1	1.265	1.265	1.2654	0.34	0.575	0.72
Speed*Speed	1	10.671	10.671	10.6715	2.84	0.123	6.06
Pressure*Pressure	1	4.827	4.827	4.8271	1.28	0.284	2.74
Power*Speed	1	0.176	0.176	0.1757	0.05	0.833	0.10
Power*Pressure	1	0.001	0.001	0.0006	0	0.99	0.00
Speed*Pressure	1	0	0	0.0001	0	0.997	0.00
Residual Error	10	37.588	37.588	3.7588			21.36
Total	19	175.97					100.00

Polynomial model

MRR for SS321= 189.505 - 0.132276 * Power - 120.659 * Speed - 3.00776 * Pressure + 0.0000484912 * Power * Power + 46.2732 * Speed * Speed + 0.139081 * Pressure * Pressure + 0.00370545 * Power * Speed - 0.0000121541 * Power * Pressure - 0.00419062 * Speed * Pressure

3.4 Response Surface Regression: MRR for SS316L

R-Sq = 96.84% R-Sq(pred) = 75.84% R-Sq(adj) = 94.00%

Table -8 ANOVA Table for MRR for SS316L

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Percentage
Power	1	1.0779	1.0779	1.0779	5.57	0.04	1.76
Speed	1	51.8943	51.8943	51.8943	268.21	0	84.71
Pressure	1	0.1926	0.1926	0.1926	1	0.342	0.31
Power*Power	1	0.6716	0.5583	0.5583	2.89	0.12	1.10
Speed*Speed	1	1.3332	0.9609	0.9609	4.97	0.05	2.18
Pressure*Pressure	1	2.886	2.886	2.886	14.92	0.003	4.71
Power*Speed	1	0	0	0	0	0.995	0.00
Power*Pressure	1	0.0954	0.0954	0.0954	0.49	0.499	0.16
Speed*Pressure	1	1.1736	1.1736	1.1736	6.07	0.034	1.92
Residual Error	10	1.9349	1.9349	0.1935			3.16
Total	19	61.2595					100.00

Polynomial model

MRR for SS321= - 19.3364 + 0.0123729 * Power + 32.7911 * Speed -0.297726 * Pressure - 0.00000492077 * Power * Power - 6.45545 * Speed * Speed+ 0.0365309 * Pressure * Pressure + 0.0000247415 * Power * Speed + 0.000155972 * Power * Pressure - 0.547166 * Speed * Pressure

3.5 Response Surface Regression: SR for SS321

R-Sq = 95.09% R-Sq (pred) = 62.53% R-Sq(adj) = 90.68%

Table -9 ANOVA Table for SR for SS321

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Percentage
Power	1	0.9741	0.9741	0.97412	10.09	0.01	4.95
Speed	1	0.0005	0.0005	0.00046	0	0.946	0.00
Pressure	1	9.1123	9.1123	9.11229	94.38	0	46.32
Power*Power	1	1.4947	2.2457	2.24573	23.26	0.001	7.60
Speed*Speed	1	0.1461	0.4007	0.40072	4.15	0.069	0.74
Pressure*Pressure	1	6.4754	6.4754	6.47537	67.07	0	32.91
Power*Speed	1	0.1985	0.1985	0.19847	2.06	0.182	1.01
Power*Pressure	1	0.1783	0.1783	0.17832	1.85	0.204	0.91
Speed*Pressure	1	0.1279	0.1279	0.12794	1.33	0.276	0.65
Residual Error	10	0.9655	0.9655	0.09655			4.91
Total	19	19.6732					100.00

Polynomial model

MRR for SS321 = 39.1607 - 0.02699 * Power - 13.9093 * Speed - 0.513046 * Pressure + 0.00000986887 * Power * Power + 4.16879 * Speed * Speed + 0.0547198 * Pressure * Pressure + 0.00393768 * Power * Speed - 0.000213281 * Power * Pressure - 0.180662 * Speed * Pressure

3.6 Response Surface Regression: SR for SS316L

R-Sq = 89.02% R-Sq(pred) = 16.80% R-Sq(adj) = 79.14%

Table -10 ANOVA Table for SR for SS316L

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Percentage
Power	1	0.06722	0.06722	0.06722	1.78	0.211	1.96
Speed	1	0.00002	0.00002	0.00002	0	0.984	0.00
Pressure	1	1.0315	1.0315	1.0315	27.36	0	30.03
Power*Power	1	0.49522	0.64704	0.64704	17.16	0.002	14.42
Speed*Speed	1	0.00038	0.00797	0.00797	0.21	0.656	0.01
Pressure*Pressure	1	1.20006	1.20006	1.20006	31.83	0	34.94
Power*Speed	1	0.20371	0.20371	0.20371	5.4	0.042	5.93
Power*Pressure	1	0.00014	0.00014	0.00014	0	0.952	0.00
Speed*Pressure	1	0.05914	0.05914	0.05914	1.57	0.239	1.72
Residual Error	10	0.37703	0.37703	0.0377			10.98
Total	19	3.43443					100.00

Polynomial model

MRR for SS321 = 26.2325 - 0.0185391 * Power - 5.29643 * Speed -0.295778 * Pressure + 0.00000529731 * Power * Power + 0.587804 * Speed * Speed + 0.0235567 * Pressure * Pressure + 0.00398938 * Power * Speed - 0.00000602316 * Power * Pressure - 0.122826 * Speed * Pressure

3.7 Main effects of variable parameter of Kerf width

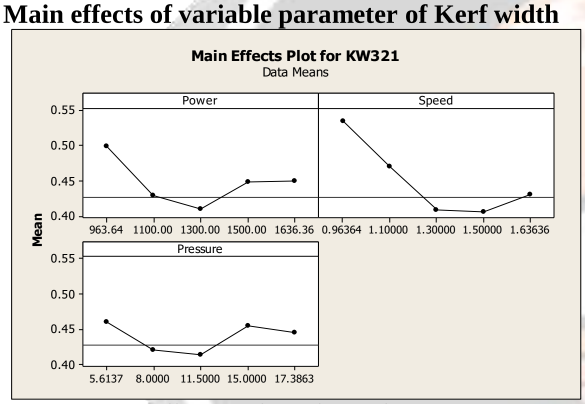

Fig- 3 Main Effects Plot for kerf width for SS321 material

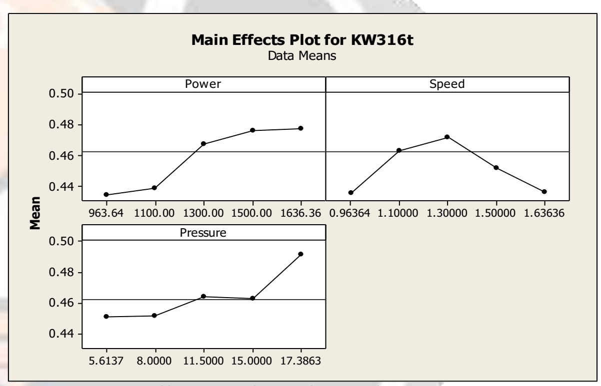

Fig- 4 Main Effects Plot for kerf width for SS316L material

The Graph shows that as Power increases the kerf width increases. Power increases heat energy hence the kerf become wider. As Cutting speed increases the kerf width decreases. Lesser time over surface area observed due to speed. Initially kerf increases but after reaching value nearer to mid-range it starts decreasing kerf. As Pressure increases the kerf width continuously increases. More gas flow lead to drag out with more speed. Kerf become wider with increases the pressure.

3.8 Main effects of material removal rate (MRR)

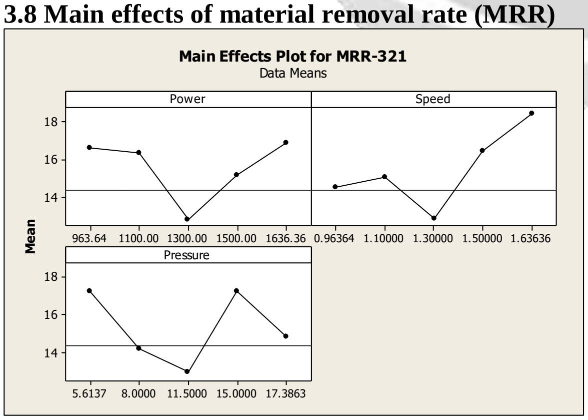

Fig- 5 Main Effects Plot for material removal rate for SS321

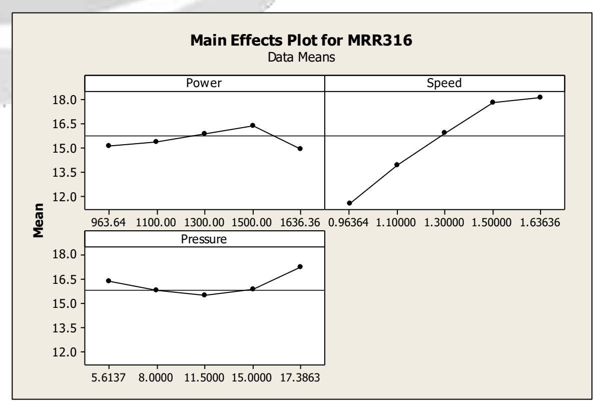

Fig- 6 Main Effects Plot for material removal rate for SS316L

The Graph shows that as Power increases the MRR initially decreases and then after increases constant. Power increases heat energy and hence more material removed over the cut area As Cutting speed increases the MRR increases. Lesser time over surface area observed due to speed. This may affect another response. As Pressure increases the MRR decreases. Increase in Gas pressure leads to more focused cutting zone. The concentrated laser burn small zone, hence MRR decreases.

3.9 Main effects of surface roughness (SR)

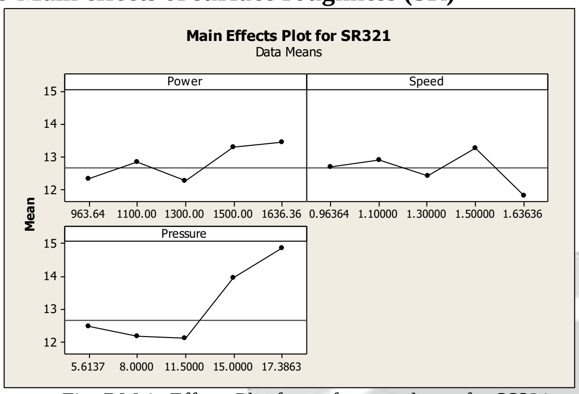

Fig- 7 Main Effects Plot for surface roughness for SS321

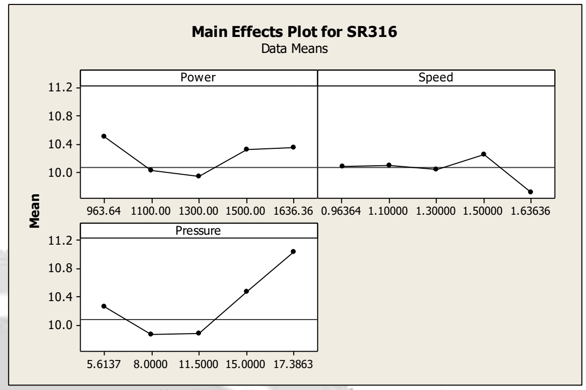

Fig- 8 Main Effects Plot for surface roughness for SS316L

The Graph shows that as Power increases the Surface roughness initially decreases then increases. It means increase power value after certain range give poor surface this is because of increases in terms of heat energy. As Cutting speed increases the surface roughness increases, it means surface finish going to be deteriorate As Pressure increases the surface finish initially decreases and the increases. Hence higher gas presser in laser cutting is always desirable for good finish in cut area.

4. OPTIMIZATION

The results obtained for evaluation and selection of laser cutting process parameter using combine application of AHP/MOORA method is presented in this research. In this ranking of all 20 alternatives is carried out based on the weighted assessment value. According to performed experimental design, it is clearly observed that experiment or alternative number 10 gives the best multi- performance features of the Laser cutting process among the 20 experiments by MOORA technique also 10^{th} rank in GRA technique.

5. Confirmation test

The confirmation test is the final step undertaken during this experiment on the optimize run no 10 for both material. The purpose of the confirmation runs is to validate the conclusion drawn during the analysis phases. In addition, the confirmation tests need to be carried out in order to ensure that the theoretical predicted model for optimum results using the software was accepted or in other word to verify the adequacy of the models that were developed. Three confirmation tests were carried out in order to compare the experimental results from the prediction made by the ANOVA. The parameters values were selected between the high and low range of the process factor that have been studied from previous experiment.

Table -11 True value of confirmation test experiment

Exp. No.	Laser Power (W)	Cutting Speed (m/min)	Gas Pressure (bar)
10	1300	1.64	11.5

Comparison of the test results

Based on the above discussed in chapter the comparison of the test results between the theoretically prediction and confirmation test results was the final consideration that will evaluate whether the optimum parameters predicted were in the allowable range.

Table -12 Comparison test results for SS321

Exp. No.	Experimental (Confirmation test)			Prediction by model		
	KW	MRR	SR	KW	MRR	SR
1	0.4056	17.3778	11.9587	0.4069	17.3854	12.2790
2	0.4156	17.3825	12.0152			
3	0.4045	17.3648	12.1478			

Table -13 Comparison test results for SS316L

Exp. No.	Experimental (Confirmation test)			Prediction by model		
	KW	MRR	SR	KW	MRR	SR
1	0.4356	18.3187	9.7836	0.4329	18.2998	9.7902
2	0.4289	18.3024	9.7758			
3	0.4361	18.3325	9.8962			

Tables 12 & 13 show the comparison of test results between theoretical prediction and confirmation test is very nearest.

6. CONCLUSIONS

- Parametric analysis for MRR, surface roughness and kerf width shows that effect of process parameter is always vary with response. Significant parameter may be different for different response output.
- As Cutting speed increases the kerf width decreases. This is because Less
- Time over surface area observed with increase of speed. As Pressure increases the kerf width continuously increases. Increase in pressure accelerate kerf drag in both SS321 and SS316L.
- As Power increases MRR initially decreases and then after it increases. This is because of increase in heat energy which leads to more material removed over the cut area. Increase in cutting speed increases the MRR. As Pressure increases the MRR decreases. Increase in Gas pressure leads to more focused cutting zone.
- Increase in power and cutting speed reduces surface finish means increases roughness while increase in pressure improves the surface finish.
- Single objective optimization need to set process parameter as per below required response.

1500	1.5	15	Maximum MRR
1100	1.5	15	Minimize Kerf Width
1500	1.1	8	Minimize Surface Roughness

- GRG and AHP/MOORA base multi objective optimization help to select set of process parameter which gives higher MRR and Surface finish. Run order 10 gives higher MRR with higher surface finish.

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