Optimization of laser cutting parameters for 316L

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Abstract: Optimization of the CO_2 laser cutting parameters for attainment of high cut edge quality in 15 mm stainless steel plate was demonstrated in this study. The tested process parameters included cutting speed, laser power, gas pressure. Optimization of these process parameters enhances the melt removal from the cut kerf so as to prevent the undesired dross adherence on the lower cut edge or even incomplete penetration of the workpiece when the incident intensity is not sufficient to penetrate the workpiece. Dross-free cut edges with lower surface roughness and lower deviation of cut edge squareness could be achieved by reducing the cutting speed from the maximum achievable value. These conditions enhance a high melt removal rate resulting in a high cut edge quality.

***Keyword*-CO_2 laser cutting, Gas pressure, cutting speed, laser power, kerf width, surface roughness.**

INTRODUCTION

Nowadays, laser cutting is a popular cutting process, which finds wide range of application in various manufacturing industries due to its advantages of high cut quality and cost efficiency through mass production. Also, Laser cutting is a non contact type machining process which does not involve any mechanical cutting forces hence no tool wear. In this process of machining, the workpiece material is locally melted by the focused laser light [1]. The melt is then blown away with the aid of assist gas, which flow coaxially with the laser beam, forming a kerf [2]. In metal cutting procedures, different types of assist gases are used such as oxygen, nitrogen etc. In any manufacturing process, it is required to investigate the effect of input parameters on responses in order to achieve the better product quality at minimum cost. Laser cutting requires high investment and offers poor efficiency. Therefore, It is required to select the optimum combination of process parameters for obtain the high production rate at low cost with an acceptable level of quality of cut parts. These parameters affect the special microscopic and macroscopic characteristics of the cut parts, as signified by the kerf width, the width of the heat affected zone and the surface roughness after processing. [5] Extensive research studies have been carried out to investigate the effect of parameters and optimize the parameters to improve the performance of laser cutting process. CO_2 Laser cutting is one of the advanced processes to achieve high precision and accurate assembly with minimum consumption of sheet metal. Austenitic stainless steel is playing vital role in modern industries. Now a day's AISI 316L stainless steel sheet has significant role in automobile industries. However AISI 316L is one of the important materials due to its inherent properties such as high strength, good corrosion resistance. Still machining of AISI 316L with laser cutting is a difficult task due to different profile cutting. Consequently kerf dimensions play the most significant role in determining the productivity and the quality of a product produced with AISI 316L. So this work takes AISI 316L stainless steel as a work piece material for CO_2 laser cutting. With regard, to the laser power, cutting speed and gas pressure are considered as a predominant principal parameter in laser cutting. Lot of researcher and investigations has been done in analyzing the cost and quality of laser cutting. However with regard to the reduction of wastage that is caused in kerf dimension has not been taken up for serious study. Hence this study considers the principal parameters on kerf width for straight and curved profile.

LITERATURE SURVEY

Thawari, G. et al. [1] observed that surface roughness value reduces with increase in cutting speed and frequency and decrease in laser power and gas pressure. N. Rajaram et al. [2] in their work concluded that high powers and lower feed rates gave good surface roughness. Milos Madic et al. [3] observed that the cutting speed should be kept at the highest level assist gas pressure at the lowest level while laser power should be kept at an intermediate level for obtaining minimal surface roughness. Sundar et al. [4] concluded the following: decrease in assist gas pressure shows a good decrease in surface roughness; higher cutting speed produces low surface roughness; there is a direct relation between the laser power and the surface roughness and the effect of laser power was more significant at low levels of laser power; and the effect on stand-off distance on surface roughness was very less significant.

Dhaval P. Patel and Mrugesh B. Khatri [5] identified that kerf width generally increases with increase in assist gas pressure and laser power and decrease in cutting speed. Ghany and Newishy [6] observed that increase in the frequency reduces the kerf width. Yilbas examined the effects of laser output power and cutting speed at the workpiece surface on the resulting kerf size. Kerf width Increases with increase in laser power and decreases with increase in cutting speed. According to Krzyszt et al. lower the cutting speed dross formed is ,more.As cutting speed goes on increasing formation of dross is less.

EXPERIMENAL PROCEDURE

For experimental tests, seventeen samples of 30 mm length and 15 and 20 mm thickness made of AISI316Lstainless steel were prepared. The chosen material has an elevated corrosion resistance against acids and chlorides. Its hardness is around 79 HRB with tensile strength of 558 MPa and yield strength of 290 MPa. 316L grade stainless steel is used in automotive, aerospace, chemical and medical applications. Chemicalcomposition of AISI316L steel in accordance to manufacturer'sspecifications is shown in Table 1.

Table 1. Composition ranges for 316L stainless steels.

Grade		C	Mn	Si	P	S	Cr	Mo	Ni	N
316L	Min	-	-	-	-	-	16.0	2.00	10.0	-
	Max	0.03	2.0	0.75	0.045	0.03	18.0	3.00	14.0	0.10

AISI 316L stainless steel material cuts with Amada machine. Assist gas used during cutting process is nitrogen. Parameters used to the cuttings are cutting speed, laser power and gas pressure. Parameters are varied for every cut. Range for 15mm thickness was varied. It is as follows,

For 15 mm thickness

Cutting speed 210-230 mm/min, Laser power 5000- 5500 watt, Gas pressure 8-12 Bar

Table 2. Experimental input and output parameters.

	Factor 1	Factor 2	Factor 3	Response 1
Run	A:power	B:cutting speed	C:gas pressure	surface roughness
	watt	mm/min	bar	micron
1	5000	220	12	6.875
2	5500	220	12	5.4
3	5250	220	10	5.241
4	5250	220	10	5.78
5	5250	210	12	6.908
6	5500	210	10	6.27
7	5500	230	10	4.664
8	5250	220	10	5.888
9	5000	210	10	6.88
10	5250	230	8	4.524
11	5250	220	10	5.849
12	5250	210	8	6.997
13	5250	220	10	5.287
14	5000	220	8	4.38
15	5000	230	10	4.009
16	5500	220	8	4.875
17	5250	230	12	4.027

Values of surface roughness were measured. It was measured with surface roughness tester. Software used for the analysis is design of expert (DOE) in which Box Behnken method is used because of its accuracy. Above table 2 shows input and output parameters. Power, cutting speed and gas pressure are the input parameters while surface roughness is the output parameter. Afters the analysis some graphs are obtained. Table 3 shows analysis of variance for surface roughness.

Table 3. Analysis of variance

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	14.51	9	1.61	5.00	0.0227	significant
A-power	0.1093	1	0.1093	0.3390	0.5787	
B-cutting speed	12.08	1	12.08	37.47	0.0005	
C-gas pressure	0.7405	1	0.7405	2.30	0.1734	
AB	0.4001	1	0.4001	1.24	0.3021	
AC	0.9702	1	0.9702	3.01	0.1264	
BC	0.0416	1	0.0416	0.1291	0.7300	
A^2	0.1558	1	0.1558	0.4834	0.5093	
B^2	0.0064	1	0.0064	0.0200	0.8915	
C^2	0.0049	1	0.0049	0.0152	0.9053	
Residual	2.26	7	0.3224			
Lack of Fit	1.85	3	0.6176	6.12	0.0563	not significant

The Model F-value of 5.00 implies the model is significant. There is only a 2.27% chance that an F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant. In this case B is a significant model term. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve the model. The Lack of Fit F-value of 6.12 implies there is a 5.63%

chance that a Lack of Fit F-value this large could occur due to noise. Lack of fit is bad for the model to fit. This relatively low probability (<10%) is troubling.

Actual Equation = 49.9984 + 0.0138715 * power + -0.908162 * cutting speed + 6.616 * gas pressure + 0.0001265 * power * cutting speed + -0.000985 * power * gas pressure + -0.0051 * cutting speed * gas pressure + -3.078e-06 * power^2 + 0.00039125 * cutting speed ^2 + -0.00853125 * gas pressure^2

The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor. The levels should be specified in the original units for each factor. This equation should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor and the intercept is not at the center of the design space.

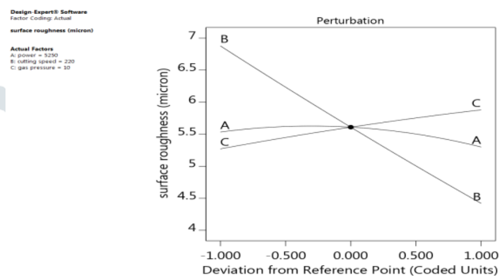

Fig. 1 Perturbation graph

Fig. 1 shows perturbation graph. It shows that as laser power decreases there is decrease in surface roughness. Major effect is shown by cutting speed. As cutting speed increases there is increase in surface roughness and very small effect is observed by gas pressure.

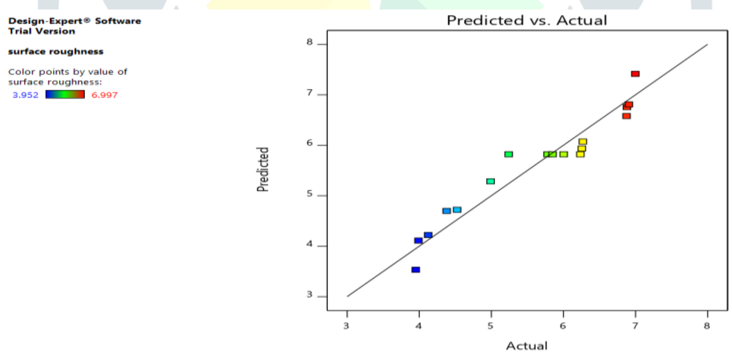

Fig. 2 Actual vs predicted surface roughness

Above Fig. 2 shows that all the calculated values are correct. Predicted and actual values are in good agreement with each other.

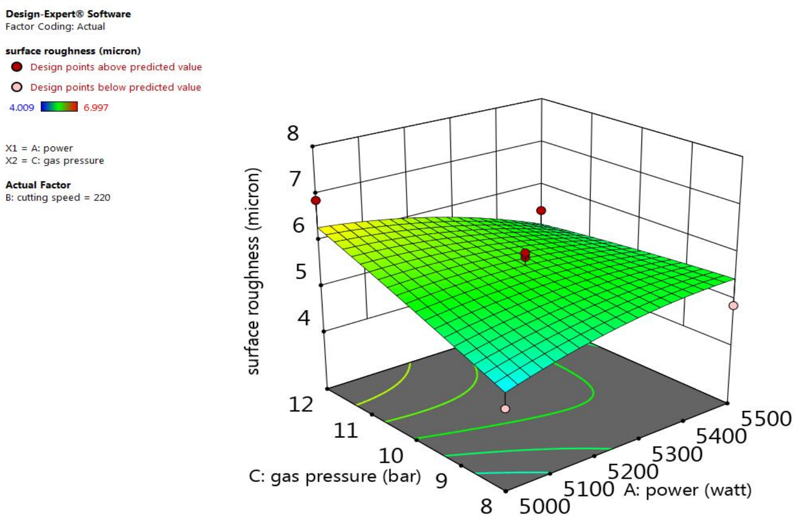

Fig. 3 3D graph between surface roughness Vs power and gas pressure

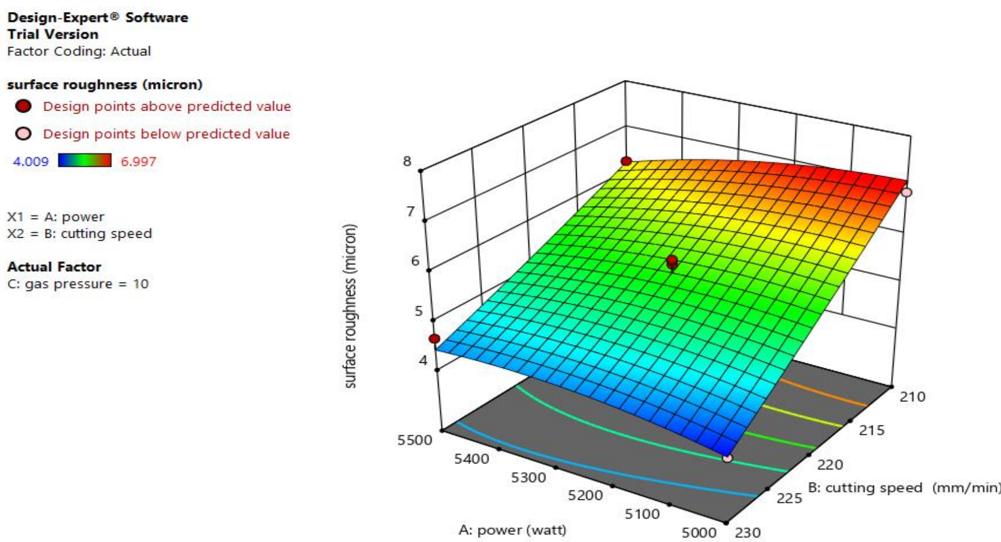

Fig. 4 3D graph between surface roughness Vs power and cutting speed.

Fig. 3 and 4 shows the effect of cutting speed, laser power and gas pressure on surface roughness. Effect of gas pressure is generally negligible. As cutting speed goes on decreasing roughness goes on increasing. To keep roughness minimum cutting speed should be high.

CONCLUSION

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 lower part of the cut surface becomes visibly damaged. The use of highest researched cutting speedproduces cut surfaces with good roughness and negligible heat-affected zone. The lower of usedcutting speeds produces a surface with lower roughness, but at the expense of visible heat-affected zone, taking up approximately 20% of the cut surface. Biggest differences in surface roughness are visible in the lower part of cut surfaces. Lowest researched cutting speed has no practical use. It results in a damaged surface which wouldrequire further machining to produce satisfactory results. Moreover, it requires the longest time to cut the material. Therefore, it is not viable in any case to use it. Similarly roughness decrease with increase in cutting speed and increase with increase in power and gas pressure. As the cutting speed increase formed dross are less.so to minimize dross cutting speed should be high.

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