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Comparative Experimental Studies on Effect of Laser Beam Machining Process Parameters on AISI 4130 and AISI 316 Steels

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Abstract

Background / Objectives: Present industrial scenario non-conventional machining one of the revolutions. Among varies machining techniques, Laser Beam Machining is being used to cut linear and applied in hard steel materials.
Methods / Statistical Analysis: An effort is made in current work to machine AISI 4130 and AISI 316 steel materials on Laser Beam Machining. Based on the Machining, the most influenced process parameter is identified and influence of Laser Beam Machining process parameters on Kerf width is analyzed.
Findings / Applications: Machining uses CO2 Laser Beam Machine and Argon Gas is used for shielding gas. Machining consists of linear cut by considering L9 Taguchi Design of Experiments. Input parameters are Laser Power, Speed and Geometrical dimension.
Improvements: Output consists of Kerf width for linear profiles. Experimental results are analyzed with ANOVA Technique for most influenced Process parameters.
Keywords: Laser Beam Machining, ANOVA, Kerf Width, Linear cut.

1. Introduction

In the present trend industries are concentrating on elimination of secondary operations in machining the hard metals. Laser Beam machining process is using to produce the parts without secondary operations and produces the parts accurately with high production rate. Laser beam machining has commercial parts machining of different fields materials like medical, military and scientific research used materials. The Laser Beam Machining are ease of automation for complex cutting patterns, absence of tool wear and breakage, ability to cut at shallow angles, and rapid cutting rates. Metals such as iron, aluminium, etc. are used to make machine parts, because they are hard, strong and do not wear away easily. Using conventional methods leads to these drawbacks Like Less Surface Finish, More Tool Wear, Noisy Operation Causes Sound Pollution, Lower Dimensional Accuracy, They Can't Machine Complex Shapes.

2. Background

The literature pertaining to the LBM process is addressed in the following,
Swapnil Umredkar1 and Vallabh Bhoyar [13] have investigated on sophisticated machining part of undesired substance is vaporised and melted from the parent or domain material using a

focused laser beam. It is clear from the outset that a wide variety of sophisticated devices have evolved to spread the process more effectively over the globe. One of them, which we discussed in this study, is Laser Beam Machining (LBM).

Milo J Madic and Miroslav R Radovanovic [2] have investigations on Analysis of the Heat Affected Zone in CO2 Laser Cutting of Stainless Steel.This research examines how the laser cutting parameters affect the breadth of the heat affected zone (HAZ) while cutting AISI 304 stainless steel with a CO2 laser nitrogen cutting technique

Atish Kumar, Navjot Singh Bandeshah, Nripjit, Arun Nanda, Rajbir Kaur Bandeshah and Chandan Gupta, [1] State of the Art of CO2 Laser Beam Machining on contemporary machining technique used in production engineering is laser cutting. It is superior than the conventional machining method in a number of ways.

Avanish Kumar Dubey and Vinod Yadava [4] has one of the review the most popular advanced machining techniques that uses thermal energy and is non-contact and applicable to a wide variety of materials is laser beam machining (LBM). The undesired substance is melted and evaporated from the parent material using a focused laser beam. It can be used to cut intricate geometric profiles and create tiny holes in sheet metal. CO2 and Nd:YAG lasers are the most well-known types of lasers used in industry for machining.

From the literature, the AISI 4130 and AISI 316 in rectangular profile by using CO2 LBM. Based on the experiment influence of input process parameters on output process parameters kerf are analyzed and the most influenced process parameter identified by using ANOVA.

3. Experimental Process

The Laser beam using to machining the linear rectangular profile on AISI 4130 and AISI 316. The experiments are conducted according to the combination of process parameters Laser Power, Machining Speed and Geometrical Dimension orthogonal Array L9. the experimental process explained in the following.

Material Selection

Based on the literature survey AISI 4130, AISI 316 materials are linear cut by using CO2 Laser Beam Machining.

Process Parameters

The Process parameters Laser power, cutting speed or Machining Speed, Geometrical Dimension are selected for machining. The process parameters combination is considered L9. The selected Process parameters and levels are shown in the Table 1. Similarly, the experimental process parameters combination is shown in Table 2.

Table 1. The Parameters and their Levels

	Laser Power (LP)(W)	Cutting Speed (CS) (m/min)	Geometrical Dimension (GD) (mm)
Level -1	5000	8	0.5
Level -2	5500	9	1.0
Level -3	6000	10	1.5

Table 2. L9 Orthogonal Array

S. No	LP	MS	GD
1	5000.0	08.0	0.5
2	5000.0	09.0	1.0
3	5000.0	10.0	1.5
4	5500.0	08.0	1.0
5	5500.0	09.0	1.5
6	5500.0	10.0	0.5
7	6000.0	08.0	1.5
8	6000.0	09.0	0.5
9	5000.0	08.0	1.0

Experimentation

Experimentation is performed on AISI 4130 and AISI 316 steel material with process parameters combination of Laser Power (LP), Cutting speed (CS), Geometrical Dimension (GD). The experimentation process used machine is shown Figure 1. The AISI 4130 and AISI 316 steel work pieces after LBM operation is shown in figure 2.

Figure 1. Experimentation used CO2 LBM

Figure 2. AISI 4130 and AISI 316 Work Pieces after Laser Cutting

Output Responses

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LBM operation is performed on AISI 4130 and AISI 316 according to the design of experiments L9 orthogonal array design using in table 2. The cutting profile work pieces after Laser Beam Machining is shown in figure 2. The cutting profile dimensions are measured by using optical microscope.

Kerf Width

It is amount of wobble created during cutting and amount of material pulled out of the sides of the cut. The required width of the work-piece which feed in the program for cutting. After machining, obtained width is measured by optical microscope. Kerf width is calculated as difference between programmed width and obtained width and it is expressed in mm. the measured Kerf width by using optical microscope is shown in Figure 3 and the optical microscope captured image is shown in Figure 4.

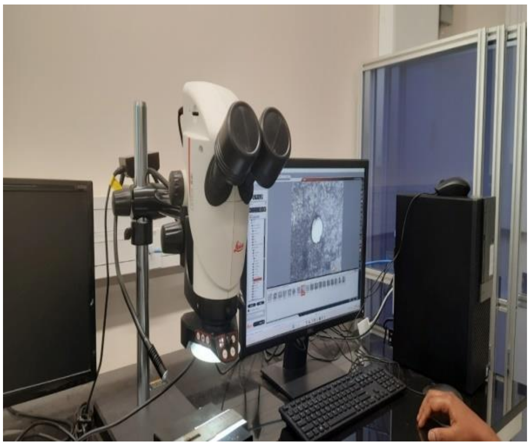

Figure 3. Measurement of Kerf width by Optical Microscope

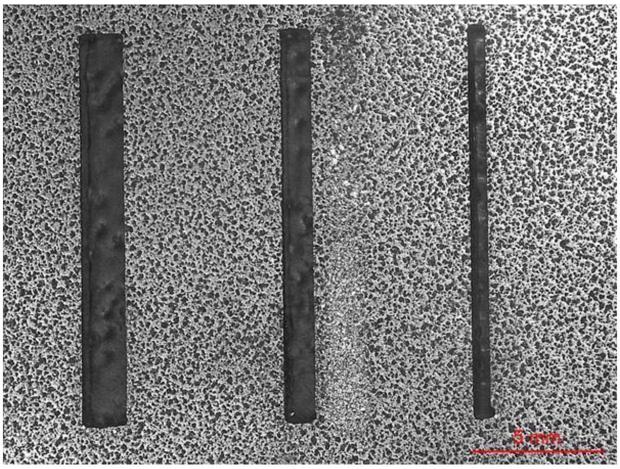

Figure 4. Microscope Captured Images

Table 3. Experimental Measured Values for Laser Cutting on AISI 4130 and AISI 316

S. No.	LP (W)	MS (M/min)	GP (bar)	Kerf Width (mm)	
				AISI 4130	AISI 316
1	5000.0	08.0	0.5	0.109	0.314
2	5000.0	09.0	1.0	0.132	0.221
3	5000.0	10.0	1.5	0.075	0.215
4	5500.0	08.0	1.0	0.099	0.279
5	5500.0	09.0	1.5	0.075	0.187
6	5500.0	10.0	0.5	0.092	0.314
7	6000.0	08.0	1.5	0.099	0.244
8	6000.0	09.0	0.5	0.151	0.285
9	5000.0	08.0	1.0	0.07	0.25

4. Results and Discussions

ANOVA Results of Linear Cutting Kerf Width for AISI 4130 Steel

ANOVA for the Kerf Width results of the AISI 4130 LBM Cutting is shown in Table-4.

Table 4. ANOVA of Kerf Width of AISI 4130 Linear Cutting

Source	DF	Seq SS	Adj SS	Adj MS	F-value	P-value	% C
LP	2	0.000604	0.000604	0.000302	0.55	0.644	10.19
CS	2	0.002460	0.002460	0.001230	2.26	0.307	41.54
GD	2	0.001768	0.001768	0.000884	1.62	0.381	29.85
Error	2	0.001090	0.001090	0.000545			
Total	8	0.005922					
S = 0.02334 R-Sq = 81.6% R-Sq(adj) = 26.4%							

Experimental F- Value is greater than F table = 19.00 @ (2,2) and P-Values are less than 5%. The process parameters have significant effect on the weld joints at 95% confidence level. From the Table – 4, the percentage of contribution results shows that the Cutting Speed has contribution of 41.54% on Kerf Width, followed by Geometrical Dimension 29.85% and Laser Power 10.19%.. R2 81.6% confirms the reliability of the model. Hence, it is observed that the Cutting Speed has a greater influence on Kerf Width on AISI 4130. The influence of AISI 4130 Linear Cutting by using LBM input process parameters on Machining Speed as shown figure 5.

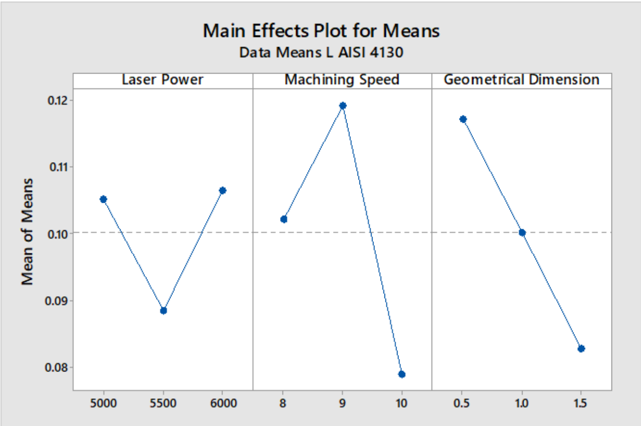

Figure 5. Influence of Mean Effects Plot on Kerf Width of AISI 4130 LBM Cutting

ANOVA Results of AISI 316 LBM for Kerf Width

ANOVA for the Surface Roughness results of the AISI 316 LBM Cutting is shown in Table - 5.

Table 5. ANOVA of KW of AISI 316 LBM

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% C
LP	2	0.000194	0.000194	0.000097	1.11	0.474	1.21
CS	2	0.003500	0.003500	0.001750	20.09	0.047	21.95
GD	2	0.012075	0.012075	0.006037	69.31	0.014	75.74
Error	2	0.000174	0.000174	0.000087			

Total	8	0.015942					
S = 0.009333 R-Sq = 98.9% R-Sq(adj) = 95.6%							

From the Table 5 the contribution percentage of values shows that the Geometrical Dimension has contribution of 75.74 % on Kerf width, followed by Cutting Speed 21.95% and Laser Power 01.21%. R2 98.9% confirms the reliability of the model. Hence, it is observed that the Geometrical Dimension has a more influence on Kerf width of AISI 316. The influence of AISI 316 steel cutting by using Laser Beam Machining input process parameters on Kerf width as shown figure 6.

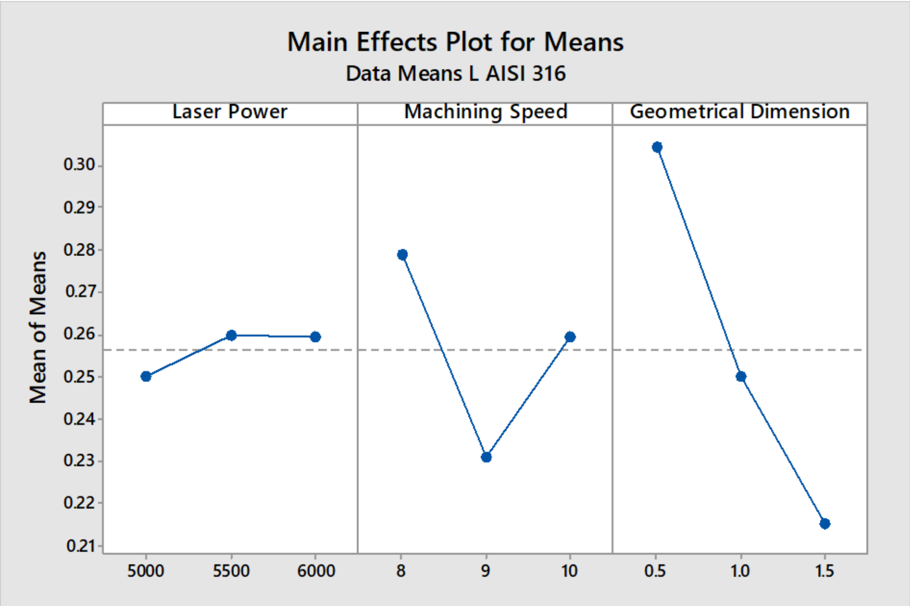

Figure 6. Influence of Mean Effects Plot on Kerf Width of AISI 316 Steel Cutting

Performance Curves

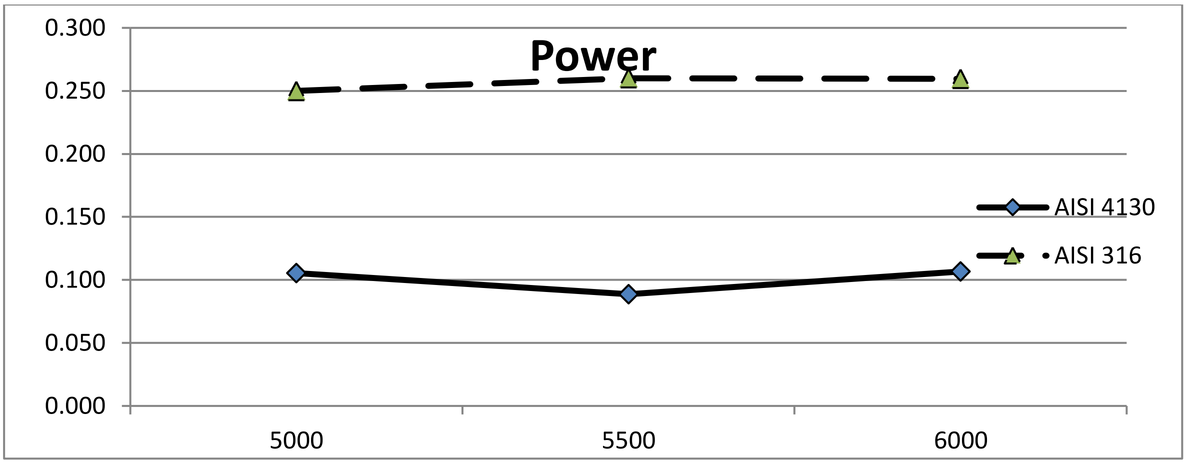

Figure 7. Linear Metal Cutting of Laser Power Vs Kerf Width

Performance characteristic curves are drawn Laser Power based on the experimental results of Kerf Width obtained from laser cutting of AISI 4130 and AISI 316 steels as shown in the

following.
Laser Power is varying 5000 W to 6000 W on laser cutting of AISI 4130 and AISI 316. In the linear cutting processes, the power is increasing based on that Kerf Width is also increasing between 5000W to 6000W.
Performance characteristic curves are drawn Cutting Speed based on the experimental results of Kerf Width obtained from laser cutting of AISI 4130 and AISI 316 steels as shown in the following (Figure 8).

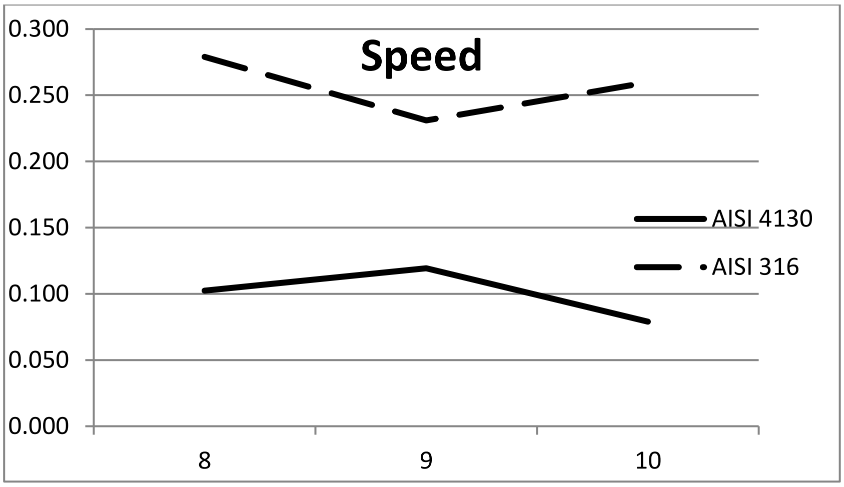

Figure 8. Linear Metal Cutting of Cutting Speed Vs Kerf Width

Performance characteristic curves are drawn Geometrical Dimension based on the experimental results of Kerf Width obtained from laser cutting of AISI 4130 and AISI 316 steels as shown in the following (Figure 9)

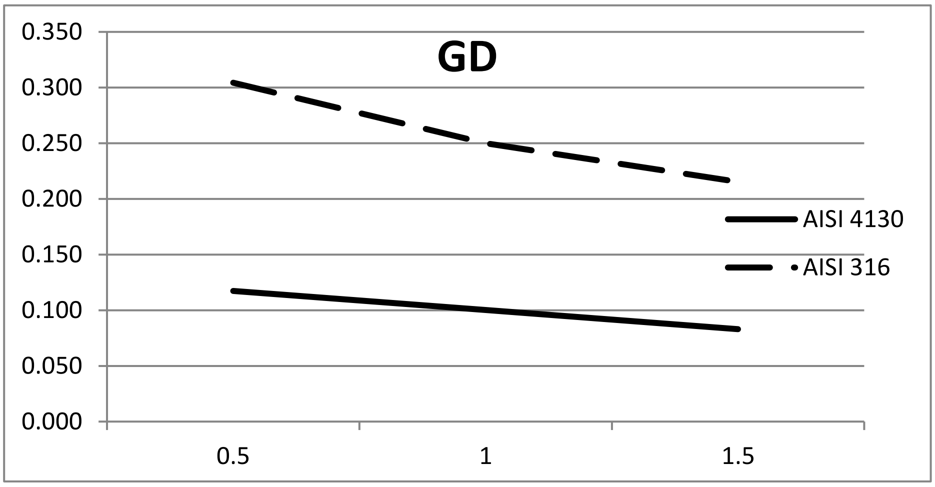

Figure 9. Linear Metal Cutting of Geometrical Dimension Vs Kerf Width

From the Figure 9, it shows the Geometrical Dimensions are increasing the kerf with is decreasing.

5. Conclusion

In the present work, machining of AISI 4130 and AISI 316 in linear profile cutting by LBM according to Taguchi DOE have been done. The input parameters are combination L9 is using Taguchi Technique. Based on the Experimental results and discussions, the following conclusions are made:

i. ANOVA of experiment based on influenced process parameter and significant process parameter are identified.
Most influenced process parameter is Cutting speed of max percentage of contribution in analysis of variance for means of AISI 4130 and Similarly for AISI 316 most influenced process parameter is Geometrical Dimension.

ii. Performance curves drawn based on input process parameters and significant process parameters are identified.
As the laser power is increases the kerf width is increased. Similarly work piece machining speed is increases kerf width is also increases and as Geometrical Dimension is increasing the kerf width is decreased.

The laser Beam using to cutting the linear profiles according to experimental process parameters combination. Based on the optioned micro scope profiles images are analyzed on linear shapes. The liner shape profile micro scope images are better shape profile and there is no under and over cuts.

References

1. Atish Kumar, Navjot Singh Bandeshah, Nripjit, Arun Nanda, Rajbir Kaur Bandeshah and Chandan Gupta, State of the Art of CO2 Laser Beam Machining, International Journal of Emerging Technology and Advanced Engineering, 2014, 4 (4), 993-999.
2. Milo J Madic and Miroslav R Radovanovic, Analysis of the Heat Affected Zone in CO2 Laser Cutting of Stainless Steel, Thermal Science, 2012, 16 (2), S363-S373.
3. F Abedin and Devi K Kalla, Review on Heat Affected Zone (HAZ) in Laser Machining, Proceedings of the 6th Annual GRASP Symposium, Wichita State University, 2010.
4. Avanish Kumar Dubey and Vinod Yadava, Laser Beam Machining-A Review, Elsevier International Journal of Machine Tools & Manufacture, 2008, 48, 609-628.
5. John T Mesia Dhas, “The Functional and Storage Risks Associated to the Size Estimation of Parallel Computing Applications”, Advances in Parallel Computing, 40, 373-379, 2022, doi:10.3233/APC220052.
6. Avanish Kumar Dubey and Vinod Yadava, Experimental Study of Nd:YAG Laser Beam Machining-An Overview, Elsevier Journal of Materials Processing Technology, 2008, 195, 15–26.
7. Kaushal Pratap Singh, Susheel Kumar Upadhyay, Deepak Kumar Gupta, Sahil Panu and Girish Dutt Gautam, An Analysis the Effect of Process Parameters on Heat Affected Zone in Laser Cutting Using Response Surface Methodology, International Journal of Emerging Technology and Advanced Engineering, 2014, 4 (2), 850-855.
8. Adelmann, B & Hellmann, R 2011, ‘Fast laser cutting optimization algorithm’, Physics Procedia, vol.12, no. Part A, pp. 591-598.
9. Ahn, DG & Byun, KW 2009, ‘Influence of cutting parameters on surface characteristics of cut section in cutting of Inconel 718 sheet using CW Nd: YAG laser’, Transactions of Nonferrous Metals Society of China, vol. 19, no.1, pp.32-39.

10. Almeida, IA., Rossi, W De, Lima, MSF., Berretta, JR., Nogueira, GEC., Wetter, NU., & Jr, NDV. 2006a, 'Optimization of titanium cutting by factorial', Journal of Materials Processing Technology, vol. 179, no. 1- 3, pp. 105-110.
11. Amit Sharma & Vinod Yadava 2012, 'Modeling and optimization of cut quality during pulsed Nd: YAG laser cutting of thin Al-alloy sheet for straight profile', Optics & laser Technology, vol. 44, no. 1, pp. 159- 168.
12. Anand K, Birendra Kumar Barik, Tamilmannan K, Sathiya P 2015, 'Artificial neural network modeling studies to predict the friction welding process parameters of Incoloy 800H joints', Engineering Science and Technology, An International Journal, vol. 18, no. 3, pp. 394-407.
13. Mredkar, Swapnil & Bhoyar, Vallabh. (2019). Advance Manufacturing Processes Review Part V: Laser Beam Machining (LBM).