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Assessment of Kerf Width while working on Laser Beam Machine

Prashant Trivedi[1], Syed Asghar Husain Rizvi[2]
[1,2] Khwaja Moinuddin Chishti Language University, Lucknow
Corresponding author's mail id: sahr.me@gmail.com

***Abstract* - The present work illustrates the working gap that is maintained while working on Laser Beam Machine (LBM). The working gap that develops as a result of laser beam erosion is called kerf width. The gap's size changes as the degree of LBM settings changes. The material being cut affects the Kerf width as well. Scanning Electron Microscopy (SEM) was deployed to estimate the value of kerf width. Due to the beam hitting the wall of the work material, it is larger than the diameter of the beam. Kerf width is always higher than focused beam diameter.**

***Keywords* – Kerf Width, SEM, LBM;**

1. Introduction

The working space created by erosion between the work material and the laser beam is known as the Kerf width. The gap's size changes as the parameter's level changes. The material being cut affects the Kerf width as well.

Using micrographic photographs of the machined specimen, the Kerf width was calculated. The working gap is defined as the kerf width indicated before. Due to the additional laser impacting the wall of the work material, it is wider than the laser's diameter. The Kerf width is always higher than the laser beam diameter.

In their study, Shrivastava et al. [1] discovered that KD increases when standoff distance and gas pressure are raised during the course of the operation. Gas pressure and laser power were determined to be the two most important controlling variables for kerf width, whereas gas pressure and standoff distance were found to be the two most important controlling variables for kerf taper. Similar to this, Rao et al. [2] discovered that process parameter optimisation was carried out to identify the ideal combination of input parameters for enhancing surface integrity.

In their experiment, Gadallah et al. [3] discovered that the Power and Assist gas pressure has a considerable impact on the kerf quality in the operational range of process parameters. Power, oxygen pressure, pulse frequency, cutting speed, and the interplay between oxygen pressure and cutting speed are all found to have a substantial impact on Ra. In another research conducted by Jose Mathew et al [4] RR and pulse energy were found to be the most influencing factors affecting the kerf widths. Increase in pulse energy leads to more material removal.

Due to the fact that the absolute values of the corresponding coefficients for these terms are quite high in comparison to other terms, Dubey et al. [5] came to the conclusion that the pulse width, cutting speed, square effect of pulse width, and interaction effect of pulse frequency and cutting speed are the significant factors for KW. Similar to cutting speed, pulse width, pulse frequency, and square effect of cutting speed all have a substantial impact on MRR.

Joshi et al. [6] came to the conclusion that changes in lamp current had the greatest impact on kerf characteristics (kerf widths and deviation). The study discovered that lower values input parameters are preferred operating cutting parameter values to optimise the dimensional accuracy of laser-cut component. At low lamp current, heat generation is much lower, resulting in a slow rate of material removal.

Thus, from the literature survey it is clear that Kerf Width is an important parameter while studying LBM.

2. Materials and Methodology

Inconel 718 was chosen as the work material. It was cut using Laser Beam Machine. Kerf Width was measured by CARL ZIESS EVO 50 SEM machine available at Department of Material Science and Engineering, IIT Kanpur.

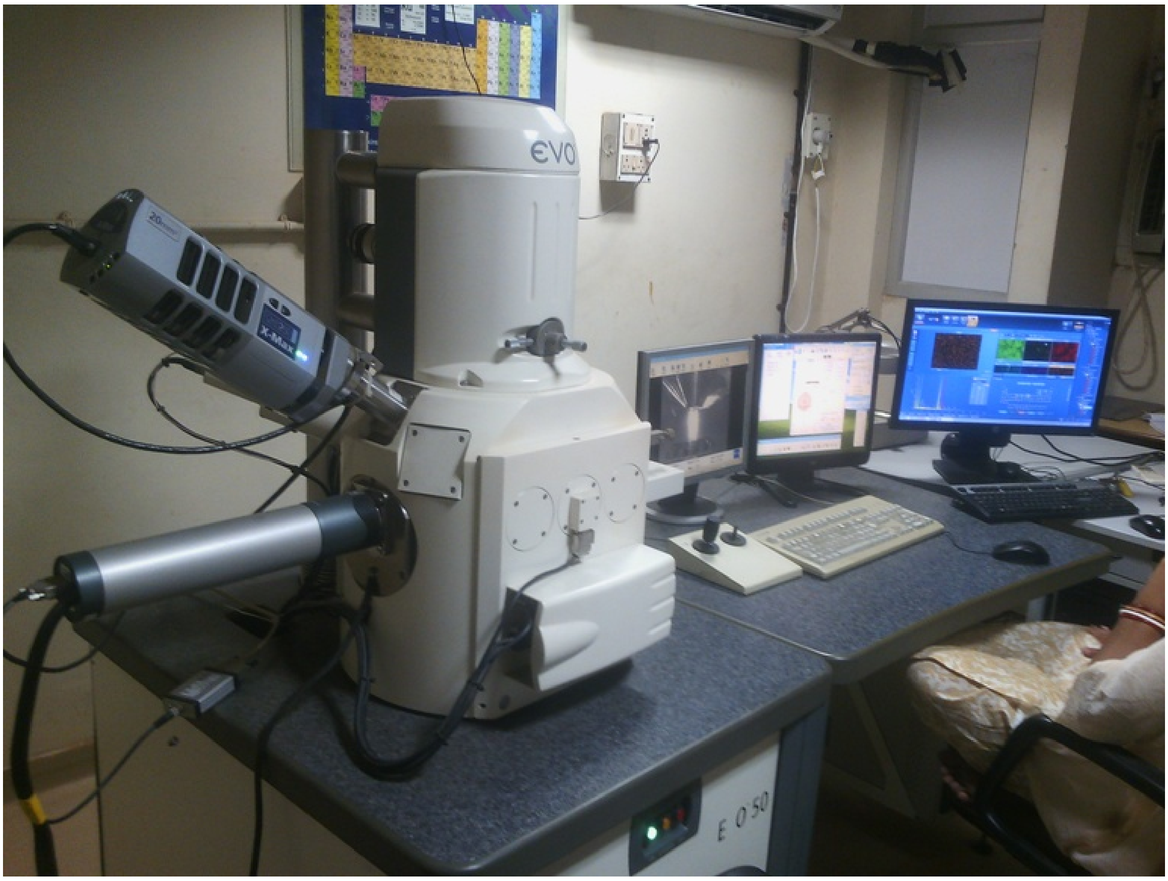

Figure 1. CARL ZEISS EVO 50 SEM MACHINE

The experiments were planned on the basis of Response Surface Methodology. Table 1 on the next page shows the levels of chosen factors of LBM.

Table 1. Level of LBM parameters

Parameters	Levels	Level 1	Level 2	Level 3
	Units	**-1**	**0**	**1**
Cutting Speed	mm/min	2500	3000	3500
Laser Power	Watt	2400	2600	2800
Frequency	Hz	6000	7000	8000

3. Calculations and Discussion

Following Table 2 depicts the results of Kerf width.

Table 2. Calculation of Kerf Width

Exp. No.	Cutting Speed (mm/min)	Laser Power (Watt)	Frequency (Hz)	Kerf Width (mm)
1	2500	2400	6000	0.29
2	3500	2400	6000	0.31
3	2500	2800	6000	0.33
4	3500	2800	6000	0.37
5	2500	2400	8000	0.32
6	3500	2400	8000	0.36
7	2500	2800	8000	0.37
8	3500	2800	8000	0.41
9	2500	2600	7000	0.33
10	3500	2600	7000	0.36
11	3000	2400	7000	0.35
12	3000	2800	7000	0.39
13	3000	2600	6000	0.37
14	3000	2600	8000	0.39
15	3000	2600	7000	0.37
16	3000	2600	7000	0.36
17	3000	2600	7000	0.37
18	3000	2600	7000	0.37
19	3000	2600	7000	0.36
20	3000	2600	7000	0.37

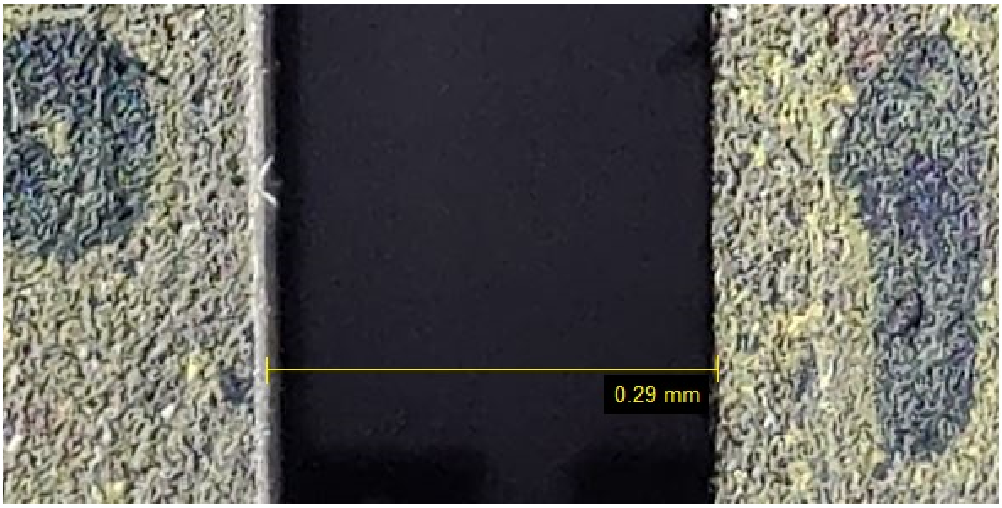

Figure 2. Sample 1

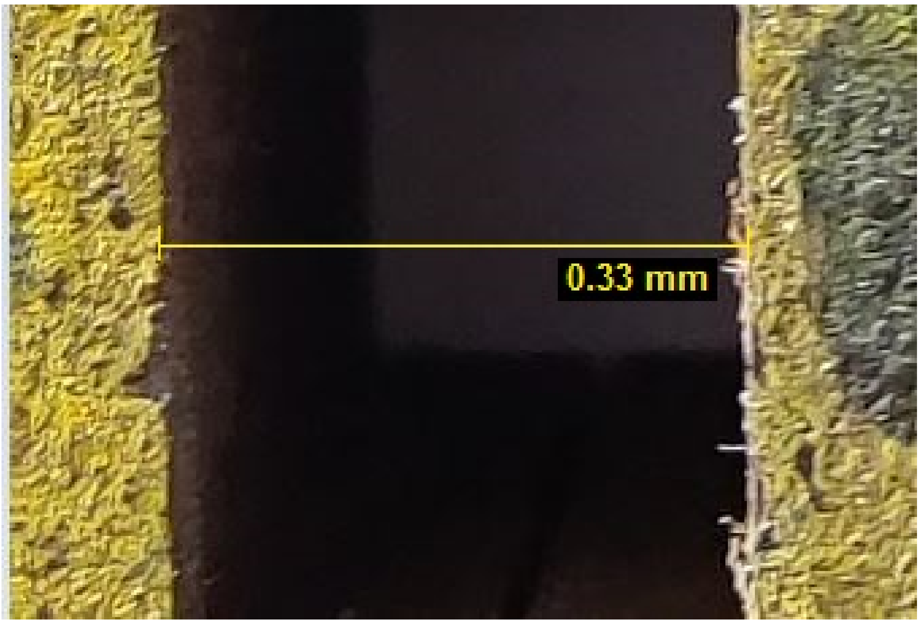

Figure 3. Sample 3

The RSM statistic investigation was performed to determine appropriate polynomial equation so as to represent relation between the LBM process variables and kerf width for present set of experiments. A quadratic model is proposed for Kerf Width based on the lack of fit and sequential model sum of square (SMSS) tests in Tables 3 and 4, respectively.

Table 3. Lack of Fit Test analysis for Kerf Width

Source	Sequential p-value	Lack of Fit p-value	Adjusted R^2	Predicted R^2	
Linear	< 0.0001	0.0057	0.7075	0.5805	
2FI	0.9500	0.0031	0.6493	-0.3281	
Quadratic	**0.0001**	**0.1368**	**0.9380**	**0.7796**	**Suggested**
Cubic	0.3046	0.0862	0.9489	-8.4520	**Aliased**

Table 4. Sequential Model Sum of Square analysis for Kerf Width

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Mean vs Total	2.56	1	2.56			
Linear vs Mean	0.0119	3	0.0040	16.32	< 0.0001	
2FI vs Linear	0.0001	3	0.0000	0.1145	0.9500	
Quadratic vs 2FI	**0.0033**	**3**	**0.0011**	**21.19**	**0.0001**	**Suggested**
Cubic vs Quadratic	0.0003	4	0.0001	1.53	0.3046	Aliased
Residual	0.0003	6	0.0000			
Total	2.57	20	0.1286			

Analysis of Variance for Quadratic model was conducted for kerf width of the Inconel 718 specimens as depicted in Table 5 below. The model F value of 32.95 implies its significancy. Cutting speed, laser power, frequency, quadratic term of cutting speed are influential terms. Values greater than 0.1000 indicate the model terms are not significant. A p-value greater than the 0.10 specifies that the model term is insignificant.

We got to find that all the parameters (p-value < 0.0001) were the influencing factor for kerf width with is in line to the previous literature.

Table 5. ANOVA analysis of quadratic model of Kerf Width

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.0153	9	0.0017	32.95	< 0.0001	significant
A-Cutting Speed	0.0029	1	0.0029	56.17	< 0.0001	
B-Laser Power	0.0058	1	0.0058	111.94	< 0.0001	
C-Frequency	0.0032	1	0.0032	62.97	< 0.0001	
AB	0.0000	1	0.0000	0.9717	0.3475	
AC	0.0000	1	0.0000	0.9717	0.3475	
BC	0.0000	1	0.0000	0.0000	1.0000	
A^2	0.0021	1	0.0021	41.09	< 0.0001	
B^2	0.0000	1	0.0000	0.3975	0.5425	
C^2	0.0001	1	0.0001	2.83	0.1236	
Residual	0.0005	10	0.0001			
Lack of Fit	0.0004	5	0.0001	2.86	0.1368	not significant
Pure Error	0.0001	5	0.0000			
Cor Total	0.0158	19				

4. Conclusion

The present investigation reported for improvement of the LBM outcomes assessed the influence of LBM parameters during machining of Inconel 718. T The investigation reported that by using appropriate set of LBM parameters, optimum results can be achieved. Further, Scanning Electron Microscopy (SEM) test were carried to estimate the KW. From the research, following conclusion were drawn.

- A quadratic model is proposed for Kerf Width based on the lack of fit and sequential model sum of square (SMSS) tests.
- The model F value of 32.95 implies that the model is significant. This implies that the model represents the data within the required 95% confidence interval.
- In this case cutting speed (A), laser power (B), frequency (C), quadratic term of cutting speed (A2) are significant model terms.
- We got to find that all the parameters (p-value < 0.0001) were the influencing factor for kerf width with is in line to the previous literature.

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