International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 10| October 2018 www.irjet.net p-ISSN: 2395-0072

Experimental Investigation of Effect of Laser Beam Machining on Performance Characteristics in Machining OHNS E0300

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Abstract - *Laser Beam Machining is a non-conventional subtractive machining process, in which a laser beam is concentrated on the work piece for machining. In this process, thermal energy is used to remove material from metallic as well as non-metallic surfaces. The laser is focused onto the surface to be machined and hence thermal energy from the laser is transferred to the surface, which results in heating and melting or vaporizing the material and hence further cutting. In LBM quality of machined surface is dependent on many process parameters such as the laser power, cutting speed, assist gas pressure, nozzle distance, focal length, pulse frequency and pulse width, etc. and are most important. Whereas the important performance characteristics measured in LBM are surface roughness (SR), Material removal rate (MRR), kerf width and Heat Affected Zone (HAZ). In this study experiments are carried out using L9 orthogonal array by varying laser power, cutting speed and assist gas pressure for Oil Hardened Non-Shrinking steel (E0300). The results indicated that the cutting speed and cutting power are the most significant parameters affecting the surface roughness and kerf width respectively, whereas the influence of the assist gas pressure is much smaller.*

***Key Words*: *ANOVA, Laser Beam Machining, Signal to Noise Ratio, Surface Roughness, Taguchi Optimization*.**

1. INTRODUCTION

Laser cutting is one of the nonconventional cutting processes most widely used for generating complex shapes and different geometries with zero tool wear, narrow kerf width ,greater accuracy ,ability to be numerically controlled, laser cutting time and reduced heat affected zone [1]. The process are based on thermal interaction when the beam impact on the material ,part of laser radiation is absorbed causing melting, vaporization or chemical state change of material which can be easily removed pressurized assist gas jet [2]. Laser is directed to the required surface and move around to cut the materials in the desired shape. It is basically a specialized light source that has properties that allow it to be focused into small spot [3].

The aim of this paper is to be shed light on the parameters of laser cutting with respect to the eventual quality of the OHNS E0300 [4]. The cutting ability of laser mainly depend upon the thermal and optical properties of material. Rather than mechanical properties [5]. Taguchi's robust design is important tool for design of experimentation which offers a simple and systematic approach to optimize the design for performance, quality and cost [6]. LBM consist of no. of parameters which makes it difficult to obtain optimal parametric combination for machining these materials it required proper design of experiments [DOE] should to be conducted to perform more accurate, less costly and more efficiency experiments. LBM has certain advantageous characteristics, which turns to achieve significant penetration into manufacturing industries.

- High precision
- Small heat –affected zone
- Low level of noise
- No need of special fixtures for the work piece
- No need of expensive or replaceable tools
- Low waste

The laser beams are widely used for cutting, drilling, marking, welding, sintering and heat treatment [7, 8, 9]. The main advantage of laser cutting is that it is a noncontact operative method from which a good precise cutting of complicated shape can be achieved. Also laser can be used to cut variety of materials like wood, ceramic, rubber, plastic and certain metals [10].

OHNS comes under tool steel is widely used in manufacturing tools such as machine screw taps threading, dies, intricate press tool, milling cutters [11]. OHNS steel refers to variety of carbon and alloy steels that are particularly well suited to be made into tools, their suitability comes from there, distinctive hardness, resistance to abrasion their ability to oil cutting edge ,and /or their resistance to deformation at elevated temperature It is highly resistance to corrosion due to its high ratio of elements such as vanadium with a carbon between 0.7-0.15%tools steels are manufactured under carefully controlled conditions to produces the required quality [12]. Oil Hardened non shrinking steel [E0300] there is various uses like blanking ,stamping ,punching ,rotary shear blades, thread cutting tools, milling cutter, reamers ,measuring tools, gauging tools ,wood working tools ,broaches, All press cutting tools and punching tools for reforming ,bending and drawing small plastic and rubber.

The results indicated that the cutting speed and cutting power are the most significant parameters affecting the surface roughness and kerf width respectively, whereas the influence of the assist gas pressure is much smaller.

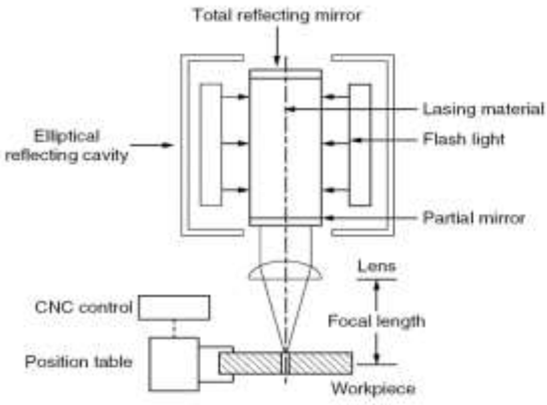

Fig-1: Schematic of Laser Beam Machining

2. EXPERIMENTATION

2.1Experimentation Set-up and material

Laser beam machining (LBM) on OHNS material is performed by using F0M23015NT laser machine having maximum output power of 2.5 KW. Gas used for cutting the material named as oxygen and it was used as an assist gas for cutting with 100% duty cycle. The size of work piece is 100mm*65mm. we cut the square of 25mm*25mm dimensions and central linear cut of 12.5mm on it for measurements of surface roughness and kerf width respectively.

Fig-2 : Experimental setup of Laser beam machine (LBM)

2.2 Selection of process parameters and levels

LBM process is one of the complex process, as it includes various process parameters such as cutting speed, laser power, assist gas pressure, standoff distance and focal length [10,13]. To obtain dimensional accuracy by selection of appropriate parameter sets is not easy duty. Hence it is need to use methodological steps which help to find out and reach near the optimum parametric combination [14, 15]. In industry, production engineer's experience matter while selection of machining parameters [16].So researchers give more importance to their study which helps to find out relation between performance characteristics and process parameters. Here, process parameters are selected by literature survey, self-initial experiment and experience of production engineer [4, 17, 18, 19]. From the study of literature survey, we noted that during laser beam machining laser power, cutting speed, assist gas pressure perform the significant role on performance characteristics. So we choose laser power, cutting speed and assist gas pressure as process parameters [9].

2.2Selection of orthogonal array

Selection of an appropriate orthogonal array for the experiments done on the basis of number of process parameters and its levels. As number of parameters is 3 and number of levels are 3, L9 orthogonal array is selected [20, 21].

Table 1. Process Parameters with levels

Parameters	Unit	Level 1	Level 2	Level 3
Laser power	W	2200	2300	2400
Cutting speed	mm/min	600	700	800
Assist gas press.	MPa	1.18	1.19	1.20

Table 2. Taguchi L9 orthogonal Array Parametric Combinations

Ex. No	Laser power (W)	Cuttings Speed (mm/min)	Assist gas pressure(MPa)
1	2200	600	1.18
2	2200	600	1.19
3	2200	600	1.20
4	2200	700	1.18

5	2200	700	1.19
6	2200	700	1.20
7	2200	800	1.18
8	2200	800	1.19
9	2200	800	1.20

Fig-3: OHNS [E0300] specimen after cut.

Table 3. Experimental Results for SR and kerf width

Ex. No.	Laser Power(W)	Cutting speed (mm/min)	Assist gas pressure (MPa)	SR (μ)	Kerf Width (mm)
1	2200	600	1.18	4.015	0.387
2	2200	700	1.19	4.771	0.382
3	2200	800	1.20	4.417	0.390
4	2300	600	1.19	4.242	0.450
5	2300	700	1.20	3.850	0.364
6	2300	800	1.18	4.594	0.482
7	2400	600	1.20	4.262	0.398
8	2400	700	1.18	4.496	0.380
9	2400	800	1.19	4.541	0.325

3. RESULTS AND DISCUSSION

3.1Analysis of Variance (ANOVA)

ANOVA experimentation satisfies the purpose for the reduction variation of process and hence decisions can be taken considering which parameters affect the performance of the process. It is the statistical technique used to analyze experimental data to take needed decisions [22,23,24]. By using ANOVA, the process parameters are classified as significant and insignificant machining parameters and the p-value determines the importance of the factors or their combinations [2]. Here, 95% of confidence level is used in this analysis. ANOVA analysis carried out in Minitab software and results are shown here [9].

3.1Signal to noise ratio (S/N ratio)

In Taguchi method [25, 26], the S/N ratio that is ratio of signal to noise and in this ratio signal represents the required value (i.e., the mean for output characteristics), and noise represents the undesirable value (i.e., the square deviation for the output characteristics). It means that the S/N ratio is the ratio of mean output value to square deviation. It is denoted by 'η' with a unit dB. The S/N ratios can be classified as smaller-the-better, larger-the-better, and nominal-the-best [27]. Among these we can choose as per our requirement for the optimization of performance characteristics. Having much effect of the category of the performance characteristics, it is seen that the larger algebraic value of S/N ratio yields to the better performance characteristics. Therefore the optimal level is at the parametric level having highest S/N [6].

Table 4. Response Table for S/N Ratios for surface Roughness (smaller the better)

Levels	Laser Power (LP)	Cutting speed (CS)	Assist Gas Pressure (AGP)
1	-4.1437	-3.8487	-4.0964
2	-3.9163	-4.0977	-4.2870
3	-4.181	-4.2879	-3.8509
Delta	0.2647	-0.4392	0.4361
Rank	3	1	2

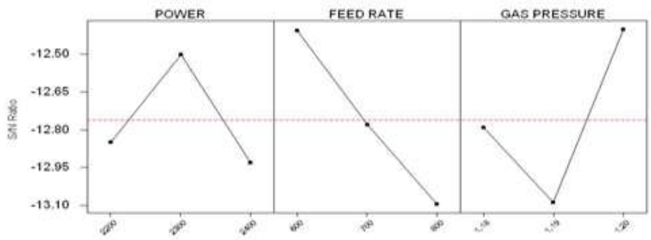

Fig-4 : S/N ratio for SR

The graph indicates that SR is minimum when cutting speed at level 1 (600), laser power at level 2 (2300) and Assist gas pressure SR will be at level 3 (1.20). Analysis of variance

[28,29] is carried out to find out relevant significance of the parameters affecting the surface roughness. And with help of ANOVA table 5, significant process parameters for surface roughness are identified. Cutting speed has maximum effect on SR.

Table 5. Response Table for S/N Ratios for Kerf Width (smaller the better)

Source	DF	SS	MS	F	P
Regression	3	0.002332	0.000777	0.27	0.848
Residual Error	5	0.014615	0.002923		
Total	8	0.016946			

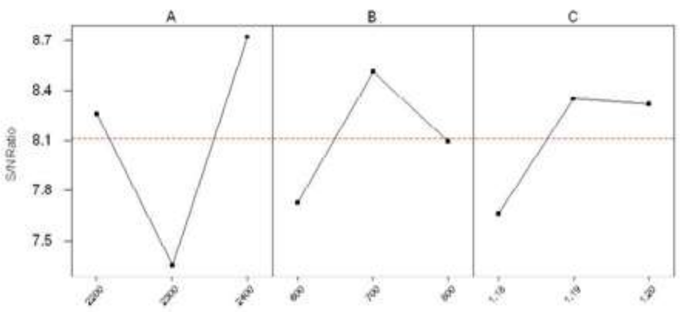

Fig-5 : S/N ratio for Kerf Width

The graph shows that Kerf Width is minimum when Laser Power is at level 2(2300), cutting speed is at level 1 (600) and Assist Gas Pressure is at level 1 (1.18). Analysis of variance is carried out to find relevant significance of the parameters affecting the kerf width. And with help of ANOVA table, significant process parameters for kerf width are identified. Laser Power has maximum effect on kerf width.

4. Conclusion

This paper presents the effect of LBM process parameters on SR and kerf width while machining Oil Hardened Non Shrinking Steel (E0300). The following conclusion can be drawn for effective machining of Oil Hardened Non Shrinking Steel (E0300) by LBM process as follows:

Feed rate is the most significant factor for SR during LBM. Whereas Laser power and Assist gas pressure are sub significant process parameters. The parametric combination for optimum surface roughness is LP1-CS2-AGP1.The optimal parameter setting for the SR found is (2300-900-0.7). Similarly Laser power is the most significant factor for kerf width during LBM. Meanwhile Assist gas pressure and Feed rate are sub significant in influencing. The optimal parametric combination for kerf width is LP2-CS2-AGP1. The optimal parameter setting for the kerf width found is (2400-900-0.7).

It is concluded that the Feed rate plays a significant role in enhancing SR and Cutting Power plays a vital role in governing kerf width. The confirmation experiments were conducted using the optimum combination of the machining parameters obtained from Taguchi analysis. As a result, optimization of the performance characteristics of the LBM such as SR and Kerf width are improved together by using the method proposed by this study.

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