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Process Parameter Optimization of Laser Beam Machining for SS-304

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Abstract - *This paper presents an investigation and optimization of process parameters of laser beam machining process on SS-304. LBM uses the light energy from a laser device for the material removal by vaporization and ablation. In the present study, attempt is made to find the optimal machining conditions with Taper (T) and surface roughness (Ra) as objective. It was observed that with increase in laser power, taper and surface roughness increases. Response surface methodologies D optimality test was used to determine the optimal machining parameters, among which the laser power and the cutting speed were found to be the most significant. It was observed that lower laser power and cutting speed is suitable for better taper and surface roughness.*

***Key Words*: LBM, RSM, SS-304**

1. INTRODUCTION

Laser Beam Machining (LBM) is one of the most extensively used non-conventional material removal processes. Its unique feature, that is, the use of thermal energy to machine parts regardless of hardness has been its distinctive advantage in the manufacture of moulds, dies, automotive, as well as aerospace and surgical components. Over the past two decades, the laser has become the tool of choice for most manufacturers in many industrial applications, such as prototype fabricating, welding and machining etc. The role of laser continues to increase in industrial applications especially with the invention of advanced materials, which are difficult to process. The high power laser beam cutting process has advantages in comparison with conventional cutting processes like plasma arc cutting and mechanical cutting. Laser cutting in general is an effective way to reduce production and manufacturing costs.

Dubey and Yadav (2008) while cutting thin sheet of aluminium alloy using pulsed laser performed multi-objective optimization of kerf quality such as kerf deviation and kerf width. They observed assist gas pressure and pulse frequency make significant affect on the kerf quality in the operating range of process parameters [1]. **Kuar et al. (2006)** performed experiments to investigate into CNC pulsed Nd:YAG laser micro-drilling of zirconium oxide (ZrO2). The optimal setting of process parameters such as pulse frequency and pulse width, lamp current, assist air pressure for achieving minimum HAZ thickness and taper of the micro-hole was determined [2]. **Sharma et al. (2010)** conducted experiments based on the Taguchi quality design concept for parameter optimization of the kerf quality characteristics during pulsed Nd:YAG laser cutting of nickel based superalloy thin sheet. The results indicate that the optimum input parameter levels suggested for curved cut profiles are entirely different from straight cut profiles [3]. **Mukherjee and Ray (2006)** presented a generic framework for parameter optimization in metal cutting processes for selection of an appropriate approach. Response Surface Methodology (RSM) is generally employed to design experiments with a reduced number of experimental runs to achieve optimum responses [4]. **Soveja et al. (2008)** studied the influence of the operating factors on the laser texturing process using two experimental approaches: Taguchi methodology and RSM [5].

LBM is an efficient machining process for the fabrication of a complex profiles with various advantages. Although most LBM machine today have process control, but selecting and maintaining optimal setting is still an extremely difficult job which must be addressed. The goal of the present study is to determine the optimal machining parameters for minimum taper and Surface roughness. The response surface methodology was employed to reveal the effect of the machining parameters on the characteristics of the LBM process. D optimality test was used to find the optimal machining parameters satisfying the multiple characteristics of the LBM process.

2. EXPERIMENTAL SET-UP

All the experiments were performed on LBM of Prime Power made DOMINO CP 4000. The LBM machine is shown in Fig. 1. During this study, series of experiments on the SS-304 were conducted to examine the effect of input machining parameters, such as gas pressure, laser power and cutting speed on taper and surface roughness. In this experimental work, nozzle diameter (0.2 mm) and stand-off distance (0.5 mm) were kept constant throughout the experimentation.

Fig -1: Laser Beam Machining Set-up

Machining parameters and their level chosen for this study are presented in Table 1.

Table 1: Machining parameters and their levels

Parameters	Units	Levels		
		-1	0	1
Gas Pressure	Bar	12	13	14
Laser Power	Watt	2500	3000	3500
Cutting Speed	Mm/min	1500	1700	1900

Experiments were carried out in single block. Surface roughness was measured Taylor Hobson surtronic 3 series surface roughness tester and kerf width was measured using profile projector. Total 24 experiments were conducted out of which 20 are as per DOE and 4 for confirmation purpose. Work piece cut after the machining are shown in Fig 2.

Fig -2: Workpiece cut by LBM

3. RESULT AND DISCUSSION

The analysis was made using the popular software specifically used for design of experiment applications known as MINITAB. In present study, it is desirable to minimize both the response parameters.

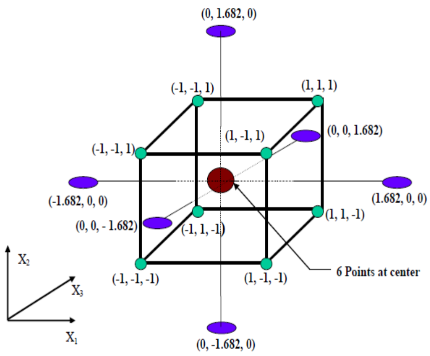

Fig -3: Central Composite Rotatable Design

A. Analysis of Taper

The main effect plot for taper is shown in Fig 4. It shows that the taper is directly proportional to the laser power and cutting speed. Taper decreases with increase in gas pressure initially and then start to increase.

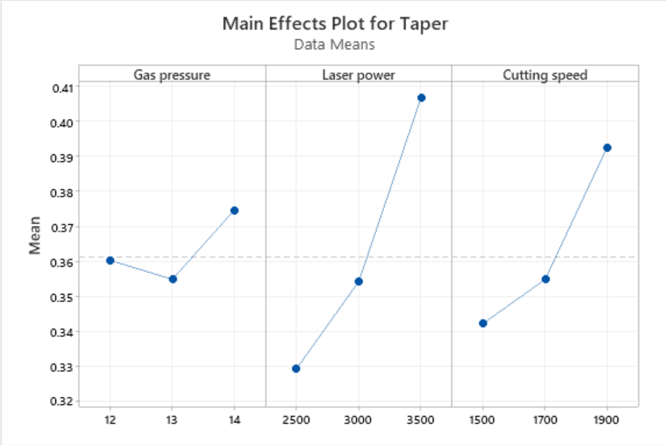

Fig. 4. Main effect plot for Taper

B. Analysis of surface roughness

The main effect plot for surface roughness is shown in Fig 5. It shows that the surface roughness is directly proportional to the laser power. Surface roughness decreases with increase in gas pressure and cutting speed initially and then start to increase.

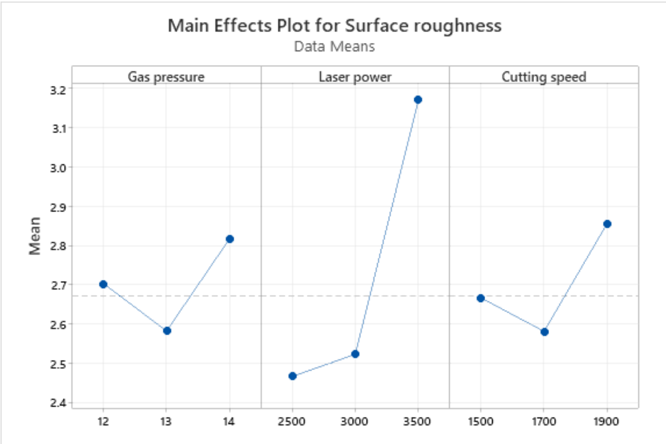

Fig. 5. Main effect plot for Ra

4. OPTIMIZATION

Response Optimizer helps to identify the factor settings that optimize a single response or a set of responses. For multiple responses, the requirements for all the responses in the set must be satisfied. In this work to find the optimum parameter setting RSMs response optimizer is used.

Table 2: response optimizer for Taper and Ra

Parameters	Goal	Lower	Target	Upper	Weight	Import
Taper	Minimum	0.298	0.298	0.494	1	1
Surface Roughness	Minimum	2.430	2.430	3.510	1	1

From the plot it is observed that the composite desirability is obtained as 1.0000 reflecting the setting of input variables marked by red color will provide optimum responses value

- Global Solution

Gas Pressure = 14 Bar
Laser Power = 2500 Watt
Cutting Speed = 1500 mm/min

- Predicted Responses

Taper = 0.29429 ^{0}, desirability = 1.0000
Surface Roughness = 2.4132 µm, desirability = 1.0000

- Composite Desirability = 1.0000

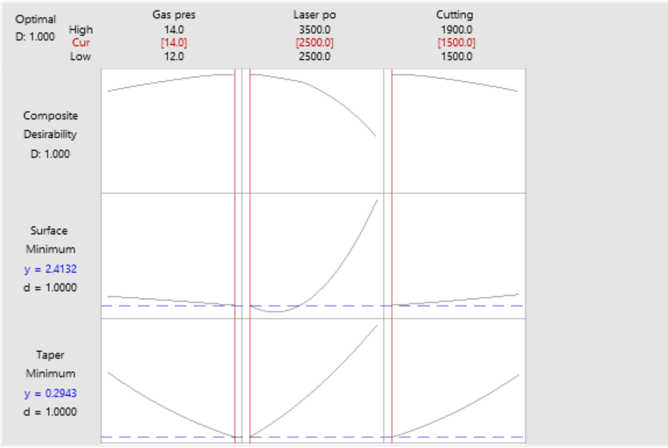

Fig -6: Optimization Plot for Taper and Surface Roughness

4. CONCLUSIONS

The laser beam machining of SS-304 was successfully performed. The Taper and surface roughness were evaluated. It is observed that increase in laser power drastically reduces the machining time to machine the workpiece at the same time taper and surface roughness is high. The optimal parameters for performance are gas pressure = 14 bar, laser power = 2500 watt and cutting speed = 1500 mm/min. It was observed that laser power is most significant among all parameters followed by cutting speed and gas pressure.

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