CO_2 Process Parameter Optimization for Machining SS-304

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Abstract

Optimization of process parameters of CO2 laser cutting process on SS-304 has been described in this paper. Laser Cutting Process 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 kerf width (KW) and surface roughness (Ra) as objective. It was observed that with increase in laser power, kerf width 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 kerf width and surface roughness.

Keywords—Laser Cutting, Kerf width, surface roughness, RSM

1. Introduction

Laser Cutting Process 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].
Laser cutting is an efficient machining process for the fabrication of any kind of shape with various advantages. Although most laser cutting 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 with minimum kerf width and surface roughness. The response surface methodology was employed to reveal the effect of the machining parameters on the characteristics of the laser cutting process. D optimality test was used to find the optimal machining parameters satisfying the multiple characteristics of the laser cutting process.

I. EXPERIMENTAL SET-UP

All the experiments were performed on CO2 Laser Cutting Machine of Prime Power made DOMINO CP 4000. The Laser Cutting 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 kerf width 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

2.1. Experimental procedure

The experiments were designed using response Surface Methodology. The experiments has been conducted with three controllable factors namely gas pressure, laser power and cutting speed. On the basis of preliminary experiments conducted by using one variable at a time approach the range of input parameters was selected. Machining parameters and their level chosen for this study are shown in Table 1.

Table 1. Machining Parameters and their levels

Parameters	Units	Levels		
		-1	0	1
Gas pressure	Bar	6	7	8
Laser power	Watt	400	700	1000
Cutting speed	mm/min	2000	2500	3000

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.

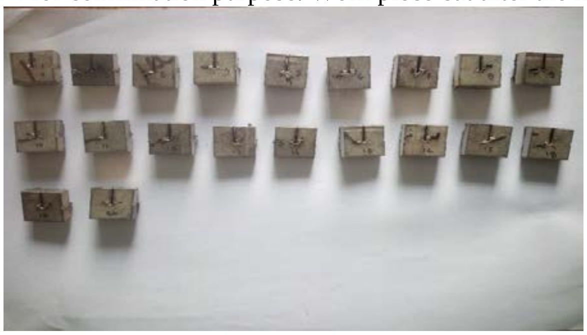

Fig 2: The Specimens Shown Lying Horizontally

III. RESULT AND DISSCUSSION

The analysis was made using the popular software specifically used for design of experiment applications known as MINITAB 16. In present study, it is desirable to minimize both the response parameters.

3.1. Analysis of kerf width

The main effect plot for kerf width is shown in Fig 3. It shows that the kerf width is directly proportional to the laser power and cutting speed. Kerf width decreases with increase in gas pressure initially and then start to increase.

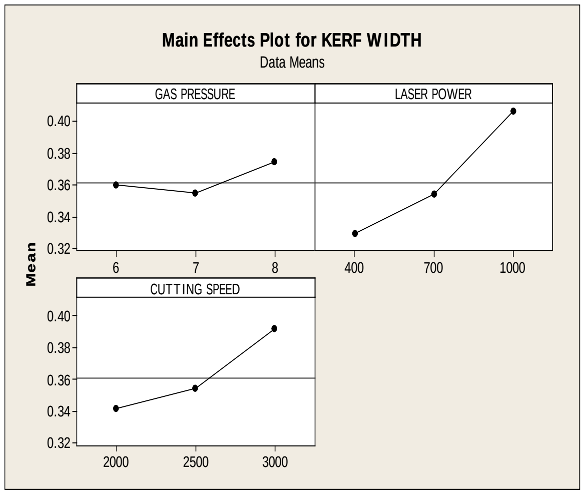

Fig 3. Main Effect Plot for kerf width

3.2. Analysis of surface roughness

The main effect plot for surface roughness is shown in Fig 4. 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.

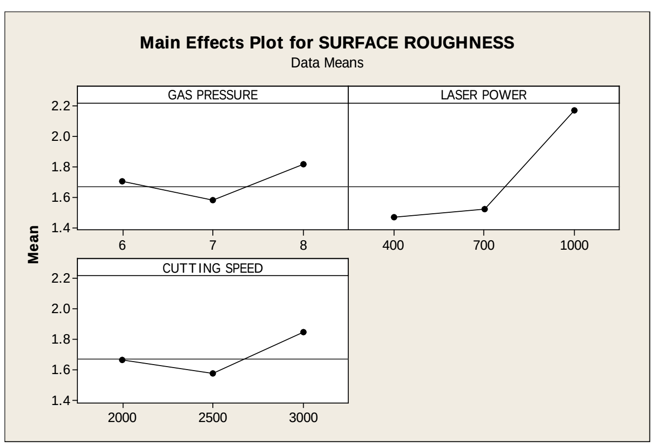

Fig 4. Main Effect Plot for Surface Roughness

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IV. RSM's D-optimal Method

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. Response optimization is often useful in product development when you need to determine operating conditions that will result in a product with desirable properties. In this work to find the optimum parameter setting RSMs response optimizer is used.

Table 2. Response Optimization for kerf width and surface roughness

Parameters	Goal	Lower	Target	Upper	Weight	Import
Kerf Width	Min	0.316	0.316	0.728	1	1
Surface Roughness	Min	0.000 5	0.000 5	0.438 5	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 = 8 Bar
Laser power = 400 Watt
Cutting speed = 2000 mm/min

- Predicted Responses

Kerf Width = 0.25993 mm, desirability = 1.0000
Surface Roughness = 1.38177 µm, desirability = 1.0000

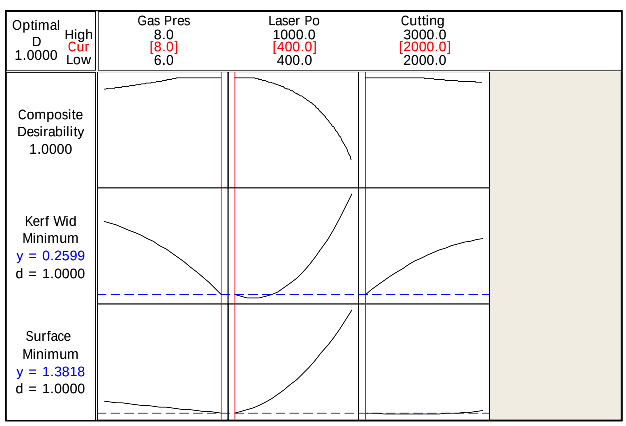

Figure 5. Optimization Plot for kerf width and surface roughness

V. CONCLUSION

The laser cutting of SS-304 was successfully performed. The kerf width 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 kerf width and surface roughness is high. The optimal parameters for performance are gas pressure = 8 bar, laser power = 400 watt and cutting speed = 2000 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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