International Journal of Engineering, Science and Mathematics
Vol. 7Issue4, April 2018(special issue NCIME)
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

PREDICTION OF KERF WIDTH AND ROUGHNESS USING ARTIFICIAL INTELLIGENCE DURING CO_2 LASER CUTTING OF DUPLEX STEEL

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ABSTRACT

Laser cutting process is one of the modern manufacturing process used to machine various materials of different complex shapes. The objective of this project work was to investigate and evaluate the effect of various parameters like laser power, cutting speed and gas pressure during CO2 laser cutting of duplex steel on roughness and kerf width. Response surface methodology (RSM) has been utilized to plan the experiments, for which box behenken design which involves three parameter at three levels were considered. The results were analysed using Analysis of variance [ANOVA] method, which shows that the spindle speed influences roughness and kerf width. The fuzzy logic model was developed in MATLAB using mamdani techniques for which a set of 17 data with input parameters of laser power, cutting speed and gas pressure and responses are kerf width and surface roughness was utilized. Based on the results the proposed fuzzy model can be used to predict the kerf width and roughness during CO_2 of duplex steel.

1. Introduction

Laser stands for Light Amplification by Stimulated Emission of Radiation, was discovered in 1960. Laser light beam is different from normal light beam because of its high temporal and narrow spectral bandwidth. Here amplification of light is achieved by a laser active medium (gain medium). This medium is obtained by stimulated emission of photons from a lower energy state to a higher energy state previously populated by a pump source. In order to start the lasing active in the medium it must be in nonthermal energy distribution known as population inversion. Wavelength of photon is changed according to the need of active medium. The wavelength represents the color and the amount of energy stored. It is important to feed back the generated photon into the active medium using a resonator, so that a large amount of identical photons builds up for further stimulated emission. Pumping action is required which ensures continuous feeding of energy into the laser active medium. This helps in sufficient emission is generated on a continuous basis. Lasers are classified into different ways i.e. according to their mode of operation or type of laser-active medium.

2. Literature review

A. Stournaras et.al.,[2009], used taguchi approach to solve the low coupling of the laser radiation with high reflectivity material as aluminium alloys (AA5083 with 2 mm thickness sheet), is processed in pulsed mode (8,9 and 10 Hz).

Response Surface method(RSM) is a group of mathematical and statistical techniques, often employed in engineering studies with regard to model problems, whose underlying structure is unknown and also optimize the desired output of these problems. They determine

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the contribution of each individual parameter to cutting quality and use regression analysis to develop an empirical model. More accurate estimation of the model parameters is achieved only if the corresponding experiment was conducted using a suitable DOE method. For most RSM studies, a special case of factorial design, the Box–Behnken method, is employed.

3. Methodology

According to box-behnken three parameters with three levels shown in table 1 are considered. The parameters to be examined and the levels of each parameter are sorted out. The box-behnken design with the response used is shown in table 2.

Table 1 Input parameter levels

Levels and parameters	Level 1	Level 2	Level 3
Power (kW)	0.8	0.9	1.0
Speed (m/min)	4.3	4.4	4.5
Pressure (bar)	0.05	0.15	0.25

Table 2 RSM Box-Behnken method

Expt no.	Power (kW)	Speed (m/min)	Pressure (bar)	Kerf Width (mm)	Roughness (µm)
1	1	4.3	0.15	0.46	2.602
2	0.9	4.3	0.25	0.463	2.623
3	0.9	4.3	0.05	0.465	2.641
4	0.8	4.3	0.15	0.466	2.647
5	0.8	4.5	0.15	0.475	2.51
6	0.9	4.5	0.05	0.473	2.492
7	0.9	4.5	0.25	0.471	2.477
8	1	4.5	0.15	0.474	2.5
9	1	4.4	0.25	0.442	2.551
10	1	4.4	0.05	0.444	2.565
11	0.8	4.4	0.05	0.458	2.587
12	0.8	4.4	0.25	0.455	2.575
13	0.9	4.4	0.15	0.46	2.58
14	0.9	4.4	0.15	0.457	2.585
15	0.9	4.4	0.15	0.455	2.573
16	0.9	4.4	0.15	0.454	2.587
17	0.9	4.4	0.15	0.457	2.583

Machining Operations

A CO2 laser cutting system was used for the performance of the experiments. The cuts were performed on 3 mm thickness duplex steel plate, with the use of O2, as assist gas. The profile of the cut shown in figure 1 is first drawn in the work pieces. This profile is then created in the AutoCAD and then saved in to the directory of the laser machine which can be used in for machining. The specification of the CO_2 laser cutting machine was shown in table 3 and the workpiece after machining was shown in figure 2.

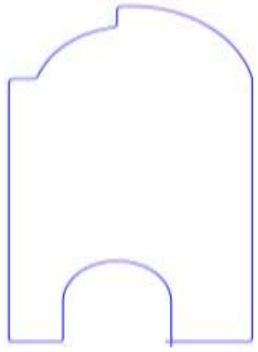

Figure 1 Profile for cutting

Table 3 Specification of LASER Cutting Machine

Specifications		
Model		**Quattro**
Axial travel		Optic transfer
NC Unit		FANUC-16i-LA
Max processing size		1,250mm x 1,250mm
Axis movement		1,260mm (X and Y axis) and 100mm (Z axis)
Max. feed speed		30m/min (X and Y axis) and 15m/min (Z axis)
Positioning accuracy		± 0.01 mm
Max. cutting sheet		6mm
Laser beam	Rated Output	1000W/2000W
	Gas	10L/hour
Output Power		1000W / 2000W

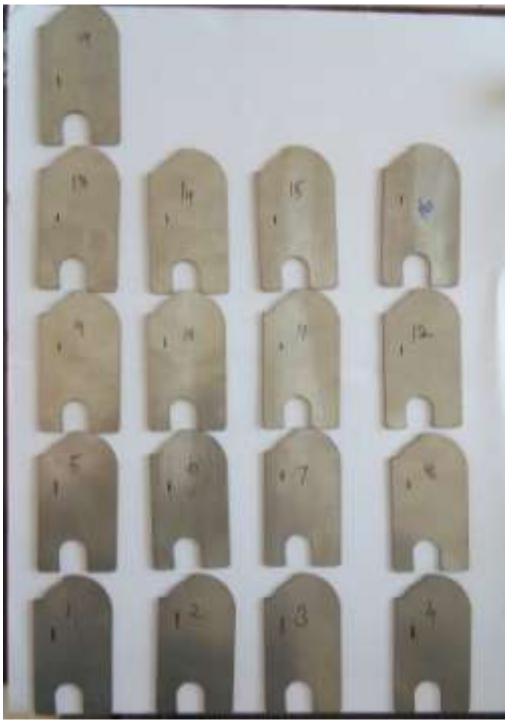

Figure 2 Work Piece after Cutting

4. Fuzzy Optimization Technique

This study aims at developing fuzzy logic model for the prediction of roughness and kerf width in CO_2 laser oxygen cutting of duplex steel. The main goal was set to determine such model that yields best fit of experimental data. The purpose of this fuzzy logic model is to assist in laser cutting process planning. In situations when one need to increase productivity, product quality or other process characteristics, the laser cutting conditions need to be changed and this fuzzy logic model could be used in order to verify whether dross occurs.

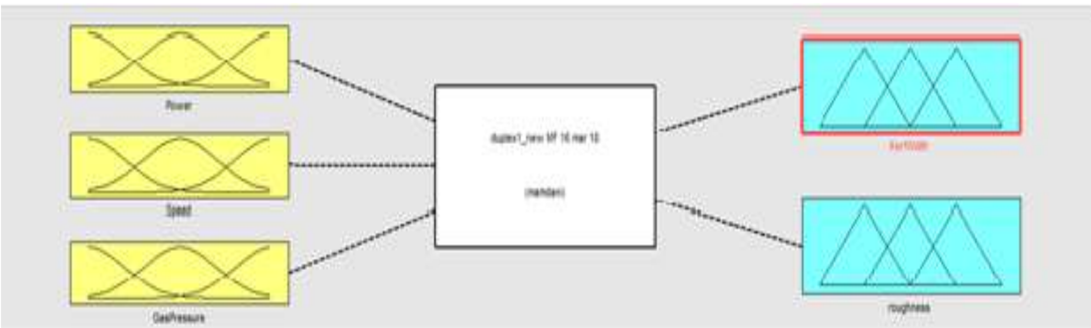

Figure 3 Input and output variables of the fuzzy logic model

In this study, three fuzzy sets are chosen for inputs ("Low", "Medium", and"High") and three fuzzy sets are used for output "LOW" and "HIGH". The input and output variables of

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fuzzy model was shown in figure 3. The minimum and maximum valuesof inputs and outputs, corresponding to experimental hyper space covered, and fuzzy linguistic variables for inputs and output are given to the model. In order to design a proper fuzzy model, triangular membership function shown in figure 4 is commonly used in this work. The Gaussian membership functions are applied for both input and output variables. The membership functions of the fuzzy sets and contained in the data base. The rule base unit contains a series fuzzy rules are describe the relationships between the input and output variables. These rules are basically represented in the form of IF–THEN conditional statements. The present work made by to set 17 IF–THEN rules in rule editor. The fuzzy predicted values are shown in table 4.

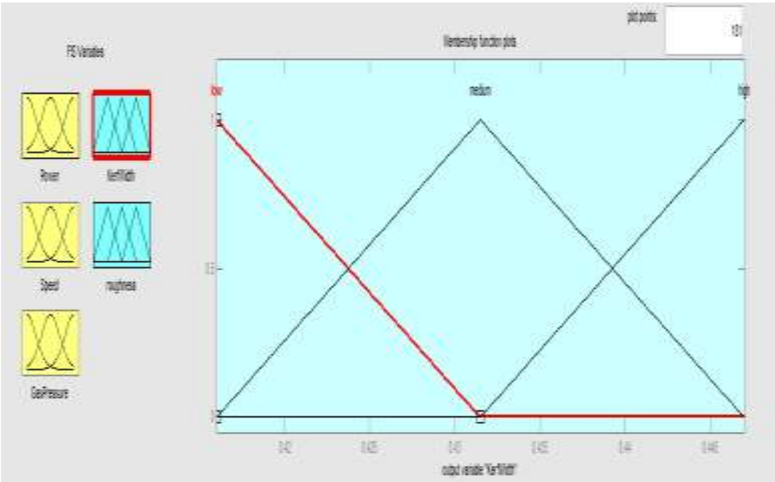

Figure 4 Fuzzy membership function

Table 4 Fuzzy Predicted values

Expt. No.	**Kerf width**	**Roughness**
1	0.421	2.13
2	0.431	2.45
3	0.431	2.13
4	0.431	2.13
5	0.431	2.13
6	0.431	2.13
7	0.431	2.13
8	0.431	2.13
9	0.431	2.13
10	0.431	1.81
11	0.431	2.13
12	0.442	2.13

13	0.431	2.13
14	0.431	2.13
15	0.431	2.13
16	0.431	2.13
17	0.431	2.13

From figure 5 and 6 it was observed that the experimental kerf width and roughness are in agreement with fuzzy predicted kerf width and roughness.

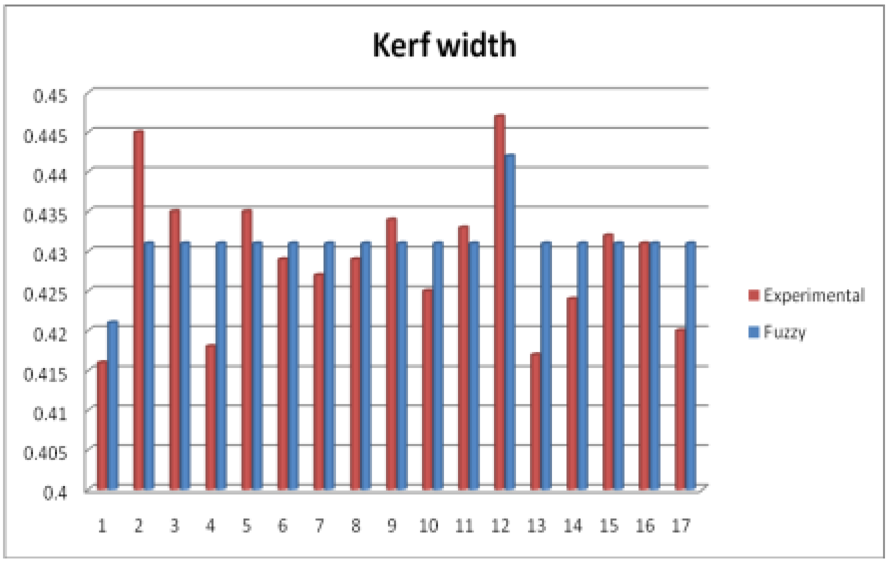

Figure 5 Experimentalvs Fuzzy predicted values for Kerf width

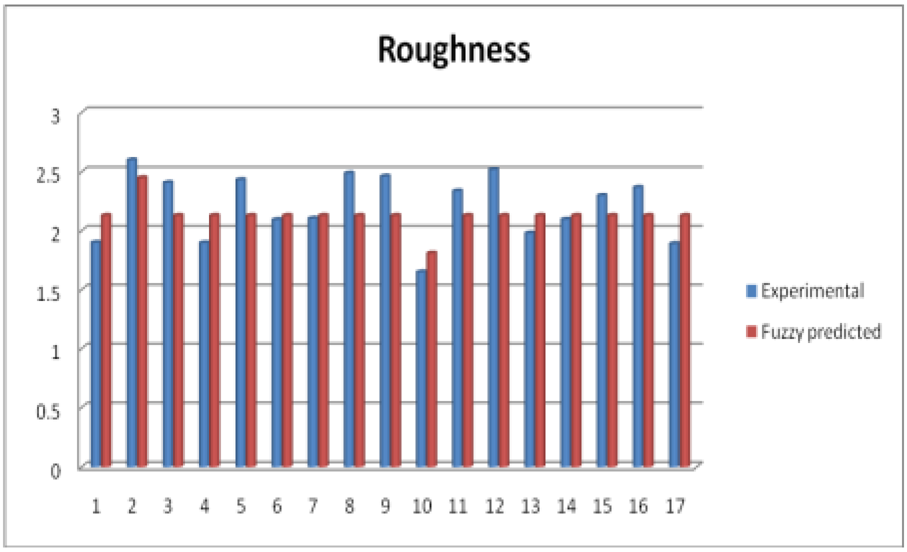

Figure 6 Experimental vs Fuzzy predicted values for Roughness

5. Conclusion

The work presented here is an overview of the prediction of roughness and kerf width using fuzzy logic during CO_2 laser cutting of duplex steel.Mamdani fuzzy model were generated for kerf width and roughness considering the input parameters laser power, cutting speed and assist gas pressure. The absolute mean error percentage of the fuzzy predicted and the experimental values for kerf width is 1.34% and for roughness is 9.30% which indicated that the predicted fuzzy model can be used to predict the kerf width and roughness during CO_2 laser cutting of duplex steel.

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