International Journal of Research in Science and Technology
Volume 6, Issue 3: July - September, 2019
ISSN 2394 - 9554

PARAMETER OPTIMIZATION OF CO_2 LASER CUTTING MACHINE FOR IMPROVED SURFACE QUALITIES IN IS2062 (E450) STEEL SHEETS

Sayan Ghosh
Mechanical Engineering Department, JIS Insititute of Engineering & Management, Kolkata

ABSTRACT

Now a day's lot of research in the use of various different materials consisting specific properties is being conducted in sector building machines where strength is of prime importance. One such material is steel of grade IS2062 (E450) which has specific properties not present in regular steel. E450 has high yield point and fatigue point on stress strain curve with high weldability and malleability properties. The material thus is used in various applications such as submarines, boilers, chemical vessels, ships, aircraft, light motor vehicle and heavy motor vehicle, infrastructure and material handling equipments. The present paper discusses the effect of CO2 Laser cutting machine parameters such as laser power, cutting speed, gas pressure, standoff distance and focal length on output parameters such as kerf angle and surface roughness. RSM methodology was used to design and conduct experiments using Minitab software. It was concluded from experimentation that a combination of low laser power with high gas pressure and low cutting speed gives the most desirable results.

Keywords— IS2062, laser cutting, optimization, RSM, Kerf angle and Surface roughness.

I. INTRODUCTION

Laser cutting (L.C.) is one of the most generally utilized heat based non-contact type latest machining process which can be utilized to machine wide scope of material. Adalarasan R et al. in 2015 stated that in laser machining, the strong laser beam liquefies the material from that point followed by vaporization of material, this material is then removed by pressurized stream of gas along these lines getting an edge with high cut quality [2,3]. Dubey AK, Yadava V in 2008 found that it is especially reasonable for cutting geometrically complex profile and for making small scale gaps in sheet metal [12]. Presently a-days, for keeping away from delays in cost and time, industries are severe as for the nature of cut/machined surface. Laser cutting is generally utilized machining process for cutting different evaluations of steel principally in light of its cutting rate and machining cost while cutting sheet metals. There are two modes in laser cutting continuous wave mode and pulsed mode out of which continuous wave mode laser cutting is a famous procedure in businesses for cutting maximum share of materials, for example, metals, wood, attractive silicon sheets, paper, elastic, and different composites. Late progressions additionally propose utilization of laser for smaller scale machining of segments [4]. Lasers are comprehensively arranged by the sort of lasing material they utilize, for example, strong state crystals, semiconductor, , ionized gas, atomic gas, fiber laser. Out of these CO2 lasers are generally utilized in companies as they produce high force with ease. Because of these qualities CO2 laser is broadly used to cut thin steel sheets, and the present work is pulled in by the motivation to find ideal information process parameters for Marathwada Auto Cluster, Aurangabad to cut E450 steel sheet.

A. Riveiro et al. in 2011 examined laser cutting on aluminum compounds and found for acquiring great surface completion argon gas is best for aluminum copper combinations, nitrogen for tempered steel and oxygen for carbon steel [1]. Ahmet Hasc-alık and Mustafa Ay in 2013 checked laser slice nature of hard to cut Inconel 718 nickel based super alloy and found that cutting rate impact on surface unpleasantness and kerf tapper proportion higher than laser power [6]. Anders Ivarsona in 2015 expressed that silicon content doesn't influence cut edge quality, expanded manganese content diminishes cut edge quality and expanded carbon content improves cut edge quality in spite of the fact that manganese content is high, in the wake of considering impact of alloying components on laser cutting procedure [8]. Aghdeab SH et al. in 2015 tested laser cutting on aluminum alloys utilizing regression analysis[5]. Yang CB et al. in 2012 was fruitful in making a neural system which was compelling in foreseeing process outputs. [33]. Santhanakumar M et al. in 2016 expressed that RSM is best to foresee process outputs accuretly [25]. As per Sivarao S et al. in 2014 normally, before utilizing RSM structure of examination is created utilizing CCD [29]. Further, Al-Sulaiman et al. in 2009 suggested that gas pressure hugely affect procedure parameter that influences nature of laser cut. [7]. Yan et al. in 2013 utilized CO2 laser cutting on alumina acquiring striation and crack free cut surfaces [32].

ISSN 2394 - 9554

Thus from this overview it was seen that review on quality attributes for E450 material was not directed and thus it was expected to locate the ideal qualities to cut E450 sheet material. The inspiration of the examination is that a continuous wave mode CO_2 laser cutting machine is utilized in Marathwada Auto Cluster, Aurangabad and E450 steel sheet was recently acquainted with the machine. The underlying setting of parameters made huge kerf angle and poor surface roughness. A low kerf angle and high surface quality is basic if the work piece is to be fitted in a machine. In this manner, the present research work investigates the quality attributes of hot rolled steel (E450) by using RSM model in continuous mode CO_2 Laser cutting.

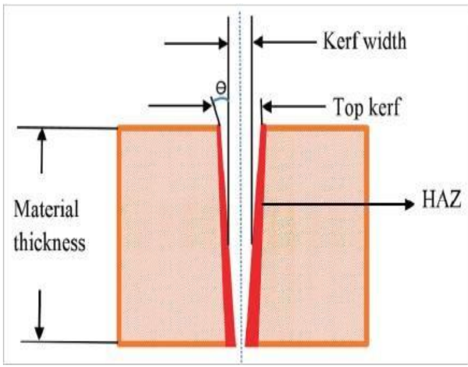

Fig 1. Laser cutting mechanics

II. MATERIALS AND METHODS

Material considered for the study is a steel of grade IS2062 (E450) which has some specific properties that are not present in regular steel. E450 has high yield point and fatigue point on stress strain curve with high weldability and malleability properties. The material thus is used in various applications such as submarines, boilers, chemical vessels, ships, aircraft, light motor vehicle and heavy motor vehicle, infrastructure and material handling equipments. Because of these properties the material is by and large generally utilized as a substitute for typical gentle steel. The table 1 below shows chemical properties of the material.

Table: 1. Chemical composition of E450 steel

C	Mn	Si	S	P	Al	Nb	V	Ti
0.22	1.6	0.45	0.045	0.045	0.02	0.25	0.25	0.25

III. EXPERIMENTATION

The machine utilized to complete experimentation was DOMINO CP 4000. This is exceptionally adaptable laser machine: can be used to cut 2D and 3D objects. It is one of a kind 5-axis machine that cuts three dimensional pieces with any head direction. It can operate at extreme laser power of 4000 W. The beam for current experimentation was engaged to a spot utilizing laser gun of diameter 1.5 mm. A hole and a cut of 10 mm length was made in every sample to measure the kerf width on either side for kerf angle. Dimensions of cut were taken as 20 mm x 20 mm x 2.5 Fig 2 shows the profile pieces cut during experimentation.

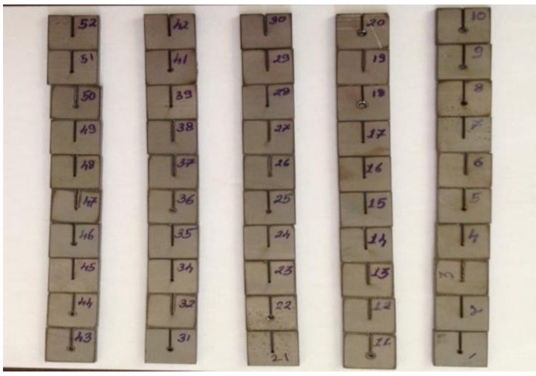

Fig.2. Profile cut for Experiments

The procedure parameters considered for the present investigation were laser power, cutting speed, gas pressure, focal length and stand-off distance. Screening experiments were carried to recognize the scope of chose parameters for least kerf width and dross development. The chosen parameters were fluctuated between two levels (Table 2) and a two level full factorial Centre Composite Design was utilized to lead the cutting

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experiments, which offers vast range to analyse effects between parameters. Value of α was considered at 2.37841.

Table 2. Levels of laser cutting parameters chosen for experimentation

Cutting Parameters	Unit	Low level	High level
Laser power	W	1500	2500
Cutting speed	mm/s	800	1800
Gas Pressure	Bar	1	2
Focal length	Mm	0.5	1.5
Stand-off distance	Mm	0.5	1.5

The cutting preliminaries were executed on E450 sheet according to the structured profile cut. The response reactions were kerf angle and surface roughness. The kerf angle was calculated using following formula

Kerf Angle = $\frac{(Upper\ \text{kerf}\ width - Lower\ \text{kerf}\ width) \times 1}{2\pi t}$ Where t= thickness of sheet

A vision measuring machine MITUTOYO (OSL 2010) having a 2D inbuilt software, was used to measure kerf width on both the sides. Surface Roughness was estimated utilizing MITUTOYO Surftest SJ-411. The values of output parameters are shown in table 3.

Table 3. Response for various combinations of input parameters

Laser power (W)	Cutting speed (mm/min)	Assist gas pressure (bar)	Focal distance (mm)	Stand-off distance (mm)	Kerf angle (deg)	Surface roughness (µm)
2000	1300	1.5	1	1	3.1578	3.6869
2000	1300	1.5	1	1	3.1575	3.6289
2000	1300	1.5	1	1	3.3549	3.4769
2000	1300	1.5	1	1	3.2458	3.4869
1500	800	2	1.5	0.5	2.3755	1.3779
1500	800	2	0.5	1.5	2.3755	1.3779
1500	1800	2	1.5	1.5	7.7414	6.6129
2500	800	1	1.5	0.5	2.9263	1.4879
1500	1800	1	1.5	0.5	2.3755	1.3779
2500	1800	2	1.5	0.5	7.9343	6.5699
2500	800	2	1.5	1.5	1.3755	0.3779
2000	1300	1.5	1	1	2.9989	1.6219
2500	1800	1	1.5	1.5	2.6417	1.5979
2000	1300	1.5	1	1	3.7314	3.6179
2500	800	2	0.5	0.5	1.0776	0.3560
1500	1800	1	0.5	1.5	6.0088	5.4109
2000	1300	1.5	1	1	2.3172	1.4059
2500	800	1	0.5	1.5	8.6417	7.5579
2500	1800	1	0.5	0.5	8.4021	7.5669
2500	1800	2	0.5	1.5	7.4583	6.5839
1500	1800	2	0.5	0.5	1.8116	0.3839
1500	800	1	1.5	1.5	2.2576	1.4979
2000	1300	1.5	1	1	2.3155	1.0279
1500	800	1	0.5	0.5	2.3755	1.3779
2000	1300	1.5	1	1	3.4468	3.6069
2500	1800	1	1.5	0.5	6.2290	5.4659
2500	800	2	0.5	1.5	1.2748	0.4269
2500	800	2	1.5	0.5	2.1911	1.4479

ISSN 2394 - 9554

2500	800	1	1.5	1.5	2.3755	1.3779
2000	1300	1.5	1	1	2.1255	1.0279
2500	1800	2	1.5	1.5	6.9595	5.5119
2500	1800	1	0.5	1.5	7.3516	6.5599
1500	800	1	0.5	1.5	2.3528	1.4999
1500	800	2	1.5	1.5	1.1957	0.5009
1500	1800	2	0.5	1.5	1.3755	0.3779
2500	1800	2	0.5	0.5	6.3792	5.4949
1500	1800	2	1.5	0.5	7.1521	6.4519
2000	1300	1.5	1	1	2.4468	1.5699
2000	1300	1.5	1	1	2.3072	1.5969
1500	800	2	0.5	0.5	2.2688	1.5089
1500	800	1	1.5	0.5	2.3755	1.3779
1500	1800	1	0.5	0.5	2.3755	1.3779
2500	800	1	0.5	0.5	2.2548	1.5649
1500	1800	1	1.5	1.5	7.2155	6.5215

IV. RSM

RSM investigates the connection between different factors. It includes number of different scientific and factual methods which is additionally used to prepare experimental models. The RSM model is utilized to improve response parameters that are constrained by different input parameters. Whenever applied appropriately RSM model can amplify productivity of any process. The upsides of this technique over different strategies incorporate decreased expense for carrying out experimentation. RSM helps to draw various complicated 3D plots which are not possible by different techniques. These advantages have provoked its application in the present research work.

4.1 Regression Equation for kerf angle

Kerf angle = 14.254 - 0.0054 Laser power

+ 0.0004 Cutting speed – 13.24 Assist gas pressure

- 8.12 Focal distance – 4.123 Stand-off distance

+ 7.24 Assist gas pressure*Assist gas pressure

+ 2.148 Focal distance*Focal distance

+ 1.547 Stand-off distance*Stand-off distance

- 0.0025 Laser power*Assist gas pressure

- 0.0005 Laser power*Focal distance

- 0.0024 Cutting speed*Assist gas pressure

+ 0.0001 Cutting speed*Focal distance

- 0.0003 Cutting speed*Stand-off distance

+ 0.15 Assist gas pressure*Focal distance

+ 0.25 Assist gas pressure*Stand-off distance

+ 0.64 Focal distance*Stand-off distance (2)

Table .5 Model Summary for kerf angle

S	R-sq	R-sq (adj)	R-sq (pred)
1.61248	91.18 %	85.24 %	4.35 %

4.2 Regression Equation for surface roughness

Surface roughness = 32.64 - 0.0065 Laser power

+ 0.0054 Cutting speed – 26.85 Assist gas pressure

- 0.89 Focal distance - 0.98 Stand-off distance

+ 4.23 Assist gas pressure*Assist gas pressure

- 0.215 Focal distance*Focal distance

- 0.315 Stand-off distance*Stand-off distance

+ 0.0025 Laser power*Assist gas pressure

+ 0.0001 Laser power*Focal distance

+ 0.0005 Laser power*Stand-off distance

+ 0.0004 Cutting speed*Assist gas pressure

– 0.0004 Cutting speed*Focal distance

- 0.0002 Cutting speed*Stand-off distance

+ 0.315 Assist gas pressure*Focal distance

+ 0.365 Assist gas pressure*Stand-off distance

+ 1.215 Focal distance*Stand-off distance (3)

Table .6 Model Summary for surface roughness

S	R-sq	R-sq(adj)	R-sq(pred)
1.01578	94.25 %	88.25 %	69.45 %

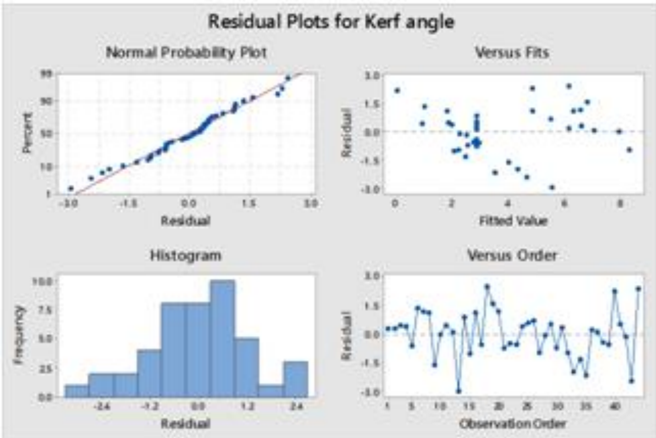

Fig. 3. Residual Plot for kerf angle

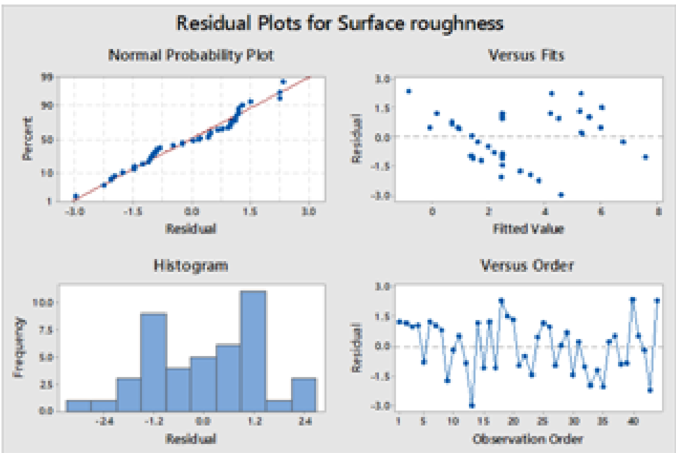

Fig. 4. Residual Plot for surface roughness

V. RESULTS AND DISCUSSION

RSM uses measurable strategy to break down laser cutting procedure parameters and structure polynomial conditions of second order. The numerical model which was made utilizing RSM in Minitab 17 programming checks the individual and merged effects of laser cutting procedure parameters on both kerf point (Eq.2) and Surface roughness (Eq.3). RSM's Center Composite Design was utilized for experimentation. The quadratic models are introduced in the wake of disposing of the unimportant terms (Eq. 2 and 3). The noteworthy terms for kerf point incorporate cutting speed, Focal distance*Focal distance, Stand-off distance*Stand-off distance, Laser power*cutting speed, Laser power*Assist gas pressure and cutting speed*cutting speed, Laser power*Assist gas pressure for surface roughness. The R-squared qualities were seen as % (Table 5) and 94.25 % (Table 6) their closeness to 100% portrays the model wellness. The effect of each input parameters is as stated under:

Laser power:- It was observed that with an increase in laser power there is an increase in kerf width as well as angle and surface roughness so optimized laser power was found to be close to lower range i.e. 1715.6845 W.

Cutting speed:- By speeding up the nozzle onto the workpiece there was increase in both output responses so ideal level was found to be nearer the lower level i.e. 913.8813 mm/s.

Gas pressure:- Higher gas pressure helped to remove all the debris material forcefully which resulted in increased kerf width and angle however surface roughness value decreased. Thus suggested level for gas pressure was 1.8614 bar.

Focal length: With an increase in focal length first kerf angle increased however surface roughness wasn't affected much so focal length was selected as 1.2644 mm.

Stand-off distance: With an increase in standoff distance, kerf angle and surface roughness were found to be equally affected so idea setting was selected to the middle of the range as 0.9321 mm.

VI. CONCLUSION

The present research work is an examination report on cut quality attributes saw in continuous wave CO_2 laser cutting of IS2062 steel (E450). Response Surface Method was utilized to make quadratic models for both kerf angle and surface roughness, and desirability modelling was applied to discover ideal estimations of laser cutting parameters. The quadratic model generated thus could be utilized to anticipate the responses inside the scope of the working parameters, and the assessment disclosures will provide an appropriate guidance for continuous wave CO_2 laser cutting of E450 sheet. The experimentation depended on full factorization by CCD unlike Taguchi's modelling that incorporates diminished number of cutting experiments. Utilization of Center composite plan in RSM was seen to help study the impact of parameters along their whole range, to distinguish the ideal persistent wave CO_2 laser cutting condition for E450 steel sheet as Laser power

=1715.68 W, Cutting speed=918.8813 mm/min, Gas pressure

= 1.8614 bar, Focal length = 1.2644 mm and Stand-off distance = 0.9321 mm These ideal parameters were found to give best quality attributes with kerf angle = 3.2614° and surface unpleasantness = 1.0363µm.

ACKNOWLEDGMENT

The authors would like to extend their sincere thanks to the 'Marathwada Auto Cluster', Aurangabad, Maharashtra, India for extending their facility and guidance to carry out the research work.

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