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Parametric effect of fiber laser cutting on surface roughness in 5 mm thick mild steel sheet (IS-2062)

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ABSTRACT:

Mild Steel are widely used in the fabrication industry and nowadays have become of importance to other industry as well. This paper investigates experimentally the quality of laser cutting for the mild Steel IS-2062 Grade-A, with the use of a pulsed fibar laser 915,930 and 965 Watt laser cutting system. The quality of the cut has been monitored by measuring the edge roughness (Surface Roughness). This work aims at evaluating processing parameters, such as the laser power, the cutting speed and the gas pressure, for the laser cutting of mild Steel. Result revealed that good quality cuts can be produced in mild steel sheets, at a window of laser cutting speed 1450 mm/min and at a heat input of 915 watts under an assisting O_2 gas pressure of 0.8 bar.

1.0 Introduction:

Laser cutting of metals has become a reliable technology for industrial production. Currently, it is considered as a feasible alternative to mechanical cutting and blanking due to its flexibility and ability to process variable quantities of sheet metal parts in a very short time with very high programmability and minimum amount of waste. Laser cutting does not need special fixtures or jigs for the work piece because it is a non-contact operation. Additionally, it does not need expensive or replaceable tools and does not produce mechanical force that can damage thin or delicate work pieces.[1,2]. Laser cutting have many principles as the same as the conventional fusion cutting methods. But the laser cutting excels in applications requiring high productivity, a high edge quality and minimum waste, due to the fast and precise cutting process. Mild steel is a daily used material and dominantly used in the laser cutting industry. In the last few years, the rapid development of high power fiber lasers provides more efficient, robust new technologies for materials process.[3]

2.0 Experimental Procedures:

The experiments were performed on as received 5 mm thickness sheets of mild steel. Experiments were conducted using a continuous wave YLR – 1000, ytterbium single mode fiber laser with the following specification: 1 kW maximum output power, 1.07 µm wavelength, 14 µm output fiber core diameter. The laser beam was focused using a 125 mm focal length lens, which achieved a beam diameter of nominally 50 µm. Surface roughness was inspected using

Mitutoyo SJ-201 surface roughness measuring instrument.

Fig. 1. YLR-1000 Laser Cutting Machine

3.0 Fiber Laser Cutting:

For a Fiber Laser the gain medium is an Ytterbium doped glass fibre, with the excitation energy being provided by laser diodes, operating around 950nm, coupled by various schemes into the core of the doped fibre. The laser beam wavelength is typically in range 1.07µm to 1.09µm. obviously the physical dimensions of the gain medium for the Fiber Laser are very different from other laser types. A Nd:YAG rod might be 200mm, a CO_2 discharge around 2m, but the gain fibre in a Fiber Laser will be 10's of metres long.

The reflectors used in the Fiber Laser are physically very different from traditional lasers. Typically the mirror will be formed from a dielectric coating on substrate; which will be transmissive at the laser wavelength for the output coupler. For the Fiber Laser, Bragg Gratings written into the core of a fibre are used. These Fibre Bragg Gratings (FBGs) consist of periodic refractive index variations. The longitudinal period of the grating determines the wavelength of the reflected light, and the magnitude of the variation controls the reflected percentage.

Thus is it possible to manufacture the complete Fiber Laser so that the light is contained within fibre components all right up to the beam delivery point at the work piece. **Figure 2** is a schematic of a typical Fiber Laser construction.[4]

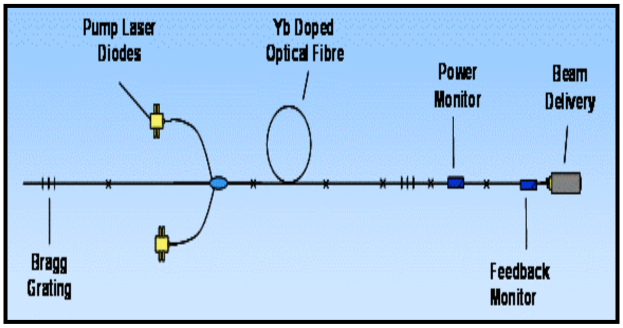

Fig. 2: Fiber Laser Schematic

3.1 Fiber Laser Advantages:

The advantages of the Fiber Laser for Industrial applications can be summarised as follows:

Existing Advantages of Fiber Lasers:

- Good reliability & lifetime
- High stability of laser output leading to consistency of processing
- Small size of overall unit
- Generally longer Warranty than standard lasers.
- Option of Air Cooled or Water Cooled up to a few hundred Watts output power.
- Lower price than equivalent power traditional laser.

Advantages of emerging industrial Fiber Lasers:

- Integrated damage protection against backreflection issues
- Control software offering full functionality and ability to be

integrated into system level controllers.

- Fault diagnostics for improved Warning or Alarm identification
- End of life warning for tracking diode lifetimes
- Reliable, stable and linear Power Monitor integrated to laser.
- Single sourcing for laser and Process Tools (cutting head, welding head or galvanometer based scanners)
- Ability to increase processing performance of reflective materials through periodic enhancements to laser peak power.[4]

4.0 Material Composition of M. S. (IS-2062 GRADE-A)

Elements	% Compositions
Carbon	0.140
Sulphur	0.010
Phosphorous	0.025
Silicon	0.110
Manganese	0.850
Chromium	0.010
Nickle	0.004
Copper	0.004
Aluminium	0.020

Table 1 : Composition of Material

5.0 Major Laser Machine Specifications (YLR-1000 Laser Cutting Machine):

Parameter	Range
Laser Type	Ytterbium Fiber
Mode of Operation	CW
Polarization	Random
Normal Output Power	1000 Watt
Emission Wave Length	1070-1080 µm
Switching ON/OFF	80 µsec
Output fiber core dia	150 µm
Fiber Length	10 m
Frequency	50-60 Hz
Laser source weight	330 kg
Laser cooling water flow rate	6 Lit/min
Laser cooling water temperature	18-26 C^0
Operation voltage three phase	400-460 volt
Operating current	8 A
Starting current	18 A
Work Table	3000 × 1500 mm
Nozzle	1.5 mm

Table 2 : Parameter of YLR-1000 Laser Cutting Machine

6.0 Parameter Considered for Experiment:

6.1 Input Parameters:

Here,
CS = Cutting Speed (mm/min),
LP = Laser Power (watt),
GP = Gas Pressure (bar),

No.	Factors	Levels	Factor Levels Values
1	CS	**3**	1350, 1450, 1470
2	LP	**3**	915, 930, 965
3	GP	**3**	0.8, 0.9, 1.0

Table 3 : Input Parameter of Experiment.

Remaning all machine parameters are considering constant.

6.2 Output Parameters:

Here we are mesuring only one output parameter which is **Surface Roughness** = SR (Ra in µ).

6.3 Experimental Table:

NO.	CS	LP	GP	SR
1		915	0.80	7.7700
2			0.90	8.5780
3			1.00	9.9150
4		930	0.80	8.7530
5	1350		0.90	9.4610
6			1.00	12.7350
7		965	0.80	7.9030
8			0.90	8.5360
9			1.00	9.4630

NO.	CS	LP	GP	SR
10		915	0.80	3.1470
11			0.90	4.1150
12			1.00	4.9150
13		930	0.80	5.3940
14	1450		0.90	6.2430
15			1.00	5.5010
16		965	0.80	3.9830
17			0.90	5.3240
18			1.00	6.1770
19		915	0.80	3.3890
20			0.90	3.4750
21			1.00	3.7870
22		930	0.80	3.7730
23	1470		0.90	4.1910
24			1.00	5.1120
25		965	0.80	4.6320
26			0.90	4.5830
27			1.00	5.7840

Table 4 : Experimental Table.

7.0 Analysis of Results and Discussions:

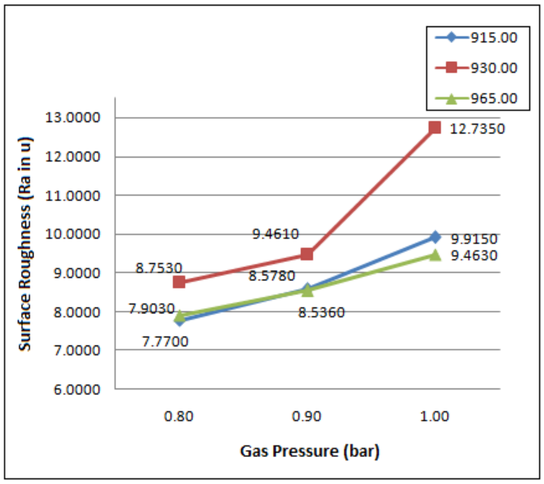

Fig.- 4 Cutting Speed 1350 mm/min, Gas pressure and Laser power versus Surface Roughness.

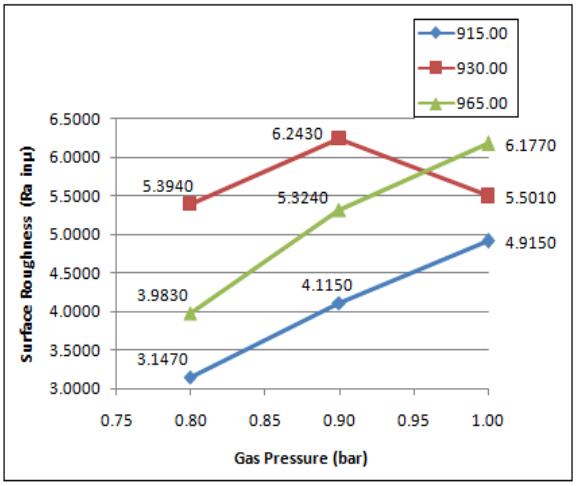

Fig.- 5 Cutting Speed 1450 mm/min, Gas pressure and Laser power versus Surface Roughness.

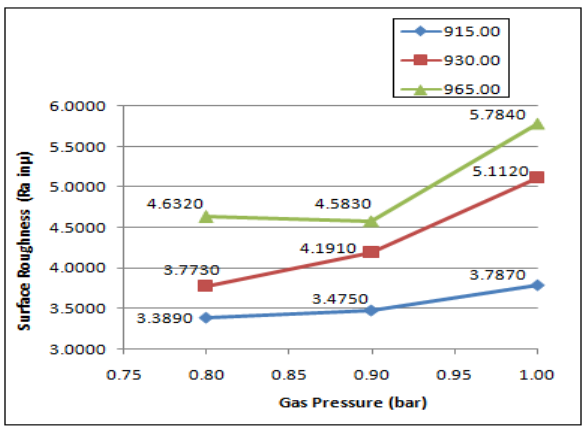

Fig. – 6 Cutting Speed 1470 mm/min, Gas pressure and Laser Power versus Surface Roughness.

The experimental condition used for cutting the 5 mm thick mild steel is above given **Table3**, summarizes (Table 4) the variation of surface roughness as a fuction of Laser Cutting Speed 1350, 1450,1470 mm/min, Laser Power 915, 930, 965 Watt and Gas pressure 0.8, 0.9 and 1.0 bar.

(1) From **Fig. 4** As the Cutting Speed is 1350 mm/min, Laser Power is 915 Watts the Gas Pressure is increases from 0.8 to 1.0 bar then the Surface Roughness is increases from 7.7700 to 9.9150 μm. Similarly for same Cutting Speed the Laser Power is taken 930 Watts the Gas Pressure increases 0.8 to 1.0 bar then Surface Roughness is increases from 8.7530 to 12.7350 μm and same Cutting Speed the Laser Power is taken 965 Watts the Gas Pressure increases 0.8 to 1.0 bar then Surface Roughness is increases from 7.9030 to 9.4630 μm.

(2) From **Fig. 5** As the Cutting Speed is 1450 mm/min, Laser Power is 915 Watts the Gas Pressure is increases from 0.8 to 1.0 bar then the Surface Roughness is increases from 3.1470 it is best result of this experiment to 4.9250 μm. Similarly for same Cutting Speed the Laser Power is taken 930 Watts the Gas Pressure increases 0.8 to 0.9 bar then Surface Roughness is increases from 5.3940 to 6.2430μm and when the Gas Pressure increases 0.9 to 1.0 bar then Surface Roughness is decreases from 6.2430 to 5.5010 μm and same Cutting Speed the Laser Power is taken 965 Watts the Gas Pressure increases 0.8 to 1.0 bar then Surface Roughness is increases from 3.9830 to 6.1770 μm.

(3) From **Fig. 6** As the Cutting Speed is 1470 mm/min, Laser Power is 915 Watts the Gas Pressure is increases from 0.8 to 1.0 bar then the Surface Roughness is increases from 3.3890 to 3.7870 μm. Similarly for same Cutting Speed the Laser Power is taken 930 Watts the Gas Pressure increases 0.8 to 1.0 bar then Surface Roughness is increases from 3.7730 to 5.1120 μm and same Cutting

Speed the Laser Power is taken 965 Watts the Gas Pressure increases 0.8 to 1.0 bar then Surface Roughness is increases from 4.6320 to 5.7840 µm.

As per **ANOVA Analysis** we can find the percentage contribution of input parameters for Srface Roughness as shon in below **Table- 5.**

Sources of Variation	**Percentage Contribution (%)**
Factor – **A** Cutting Speed	80.24
Factor – **B** Laser Power	5.12
Factor – **C** Gas Pressure	7.54
Error	7.10
Total	**100**

Table : 5 Percentage contribution of Process Parameter for Surface Roughness

8.0 Conclusions:

The effects of Cutting Speed, Gas pressure and Laser Power on quality characteristics of laser cut mild Steel specimens have been studied in this work. As per ANOVA Analysis we can found that the Factor A – Cutting Speed is most signeficant factor for Surface Roughness of Mild Steel 5 mm thickness sheet.

Results revealed that good quality cuts can be produced in mild steel sheets, at a window of laser cutting speed 1450 mm/min and at a heat input of 915 Watts under an assisting O_2 gas pressure of 0.8 bar the surface roughness is 3.1470 µm.

9.0 References:

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