ISSN (ONLINE): 2454-9762
ISSN (PRINT): 2454-9762
Available online at www.ijarmate.com

International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE) Vol. 3, Special Issue 9, March 2017

# LASER WELDING AND ITS PROCESS PARAMETERS ANALYSIS

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**ABSTRACT**
**LASER welding is one of the best welding processes and it has a wide range of advantages and applications. But it is not being in use like other unconventional welding processes. LASER welding possesses some advantages High focusing point, Low heat affected zone, High penetration rate, Less welded bead etc., The LASER used here was Nd: YAG pulsed LASER mode of 1.064 µm. The material used was mild steel plate of 1mm thickness. The microscopic structural image of welded sample of the first stage of welding process with constant welding speed and various LASER power proves that "higher the LASER power greater will be the penetration rate". The second stage of welding process with average LASER power and various welding speed, proves that higher the welding speed, lesser will be the Heat Affected Zone. So, for higher thickness of material like rods, high power LASERS should be used. If high power LASER is used in low thickness material then the LASER will be penetrated out from material. At the same time for medium thickness, and high power LASER welding, the welding speed should be high. Otherwise, LASER will be penetrated out from the material. With the microscopic structural studies, we can conclude that in higher welding speed, the lesser will be the strength of welding samples. And by the hardness test, we came to know that the hardness of a material will not increase by performing the LASER welding and weld can withstand cyclic loading or vibration forces.**
**KEYWORDS: LASER, Nd-YAG, Welding Speed, Heat Affected Zone (HAZ).**

## 1. INTRODUCTION TO LASER

### 1.1 LASER

The term laser is the abbreviation for "Light Amplification by Stimulated Emission of Radiation". The laser is the further development of the maser (m=microwave). Although the principle of the stimulated emission and the quantum-mechanical fundamentals have already been postulated by Einstein in the beginning of the 20th century, the first laser - a ruby laser - was not implemented until 1960 in the Hughes Research Laboratories.

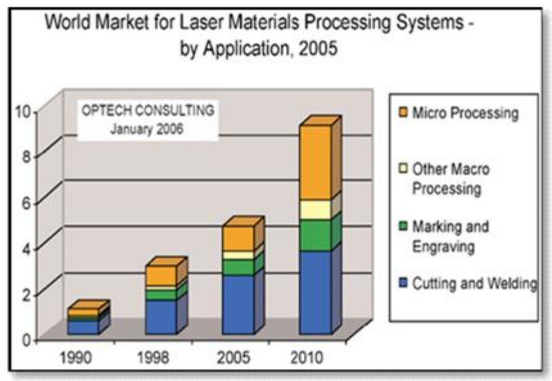


**Fig.1 World market by application of all type of LASER**

### 1.2 Characteristics of Laser

The figure 2 shows the characteristic properties of the laser beam.

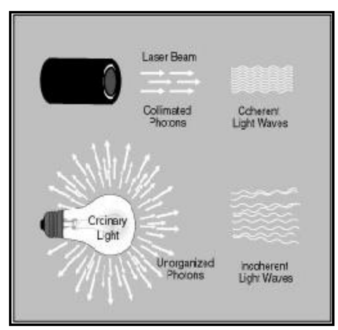


**Fig.2 Characteristics of laser beams**

The Laser beam is

- Monochromatic
- Coherence
- Directionality

### 1.3 Principle of LASER:

Inside the resonator, Figure 1.3, the laser-active medium (gas molecules, ions) is excited to a higher energy level ("pumping") by energy input (electrical gas discharge,

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flash lamps). During retreat to a lower level, the energy is released in the form of a light quantum (photon). The wave length depends on the energy difference between both excited states and is thus a characteristic for the respective laser-active medium.

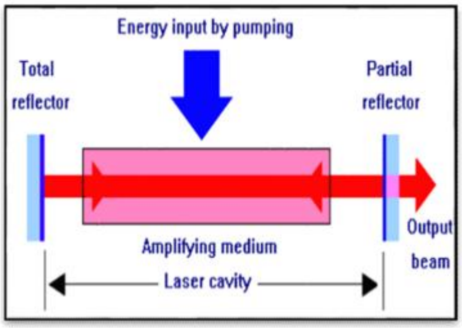



**Fig.3 Principles of laser**

A distinction is made between spontaneous and induced transition. As result, a stationary light wave is formed between the mirrors of the resonator (one of which is semi-reflecting) causing parts of the excited laser-active medium to emit light.

In the field of production metal working, and particularly in welding, especially $CO_2$ and Nd-YAG lasers are applied for their high power outputs. The simple and systematic layout of the basic laser system is shown in above figure. This system is fully based on the principle of producing laser, which has the reflectors at both the ends of the active medium. Among them one is fully reflected surface and another is of partially reflecting surface, through which the laser beam will get ejected with its corresponding wave length. A pumping device is placed above the active medium that is act to pump the photos from the ground state level to the excited state. The resulting photon has the same properties as the exciting photon. In order to maintain the ratio of the desired induced emission *I* spontaneous emission as high as possible, the upper energy level must be constantly overcrowded, in comparison with the lower one, the so-called "laser-inversion". And possess types like,

- $Co_2$ Laser
- Solid State Lasers

2. LASER WELDING AND SELECTION OF LASER

**2.1 Introduction To Laser Welding:**

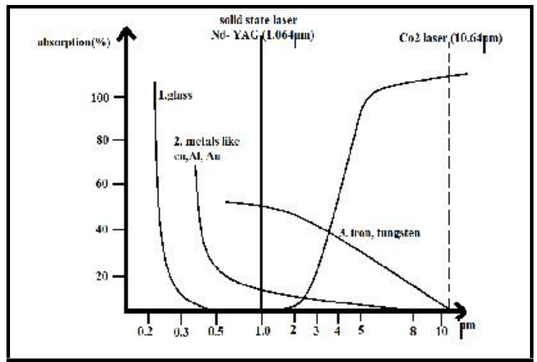
Laser welding is a non-contact process that requires access to the weld zone from one side of the parts being welded. The weld is formed as the intense laser light rapidly heats the material-typically calculated in milli-seconds. The beam provides a concentrated heat source, allowing for narrow, deep welds and high welding rates. The process is frequently used in high like Electron Beam Welding (EBW), laser beam welding has high power density (on the order of 1 $MW/cm^2$) resulting in small HAZ and high heating and cooling rates.

**2.2 Selection of Laser For Welding**

The welding material should absorb the wavelength of the laser used. The wave length of Nd- YAG and CO2 lasers are as follows

- Nd- YAG laser - 1.064 micrometer
- CO2 laser - 10.64 micrometer

The selection of laser for performing welding is clearly understood by the following graph. Materials like glass, having good absorption capacity only at the wavelength above 10 micrometer. So, $CO_2$ laser, whose wavelength is 10.64 micrometer, is highly suitable for welding glasses.




**Graph.1 Selection of laser for various materials**

Materials like copper, aluminum, gold will have high reflectional capability. They have about 20% of absorption capacity at 1 micrometer and 0% of absorption capacity at about 8 micrometer wavelengths.

3. CONCEPTIUAL DIAGRAM

The layout of solid state laser welding process is shown below,

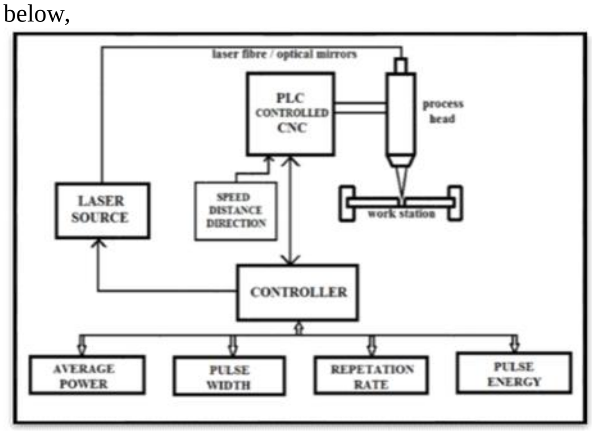



**Fig.4 Conceptual diagram**

**3.1 Process Description**

As per the conceptual diagram, the laser beam will be produced from the process head. The laser will be generated by laser source. And this laser source is controlled by the

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controller in terms of the following terms indicated i.e., Average power, Pulse width, Repetition rate, Pulse energy. All these four terms were inter- linked with each other, so that one will change with respect to another.

The process head is then connected with the PLC (Programmable Logic Controller) controlled CNC machine, which is also controlled by the common controller described above. Here we can control the following terms by using this PLC controlled CNC are its welding speed, distance to be weld, Standoff distance, direction of welding.

### 3.2 Formula Used

The formula used to calculate the pulse energy average power is stated below. We can also calculate pulse power, pulse width with this formula.

**Pulse energy:** The formula used to calculate the pulse energy is given below

| SL. NO | Description | Specifications |
|---|---|---|
| 1. | LASER type | Solid state: Nd-YAG |
| 2. | Wave mode | Pulsed laser mode |
| 3. | Wave length | 1.064 µm |
| 4. | Metal used | Mild Steel plates |
| 5. | Thickness of plates | 1 mm thick |
| 6. | LASER power | 100w, 130w, 150w |
| 7. | Welding speed | 1m/min, 0.75m/min, 0.5m/min |

$$\mathbf{Q = P_H \times {}^{2}{}_{H}}$$

Where,
**Q** in kilo joule, $\mathbf{P_H}$ in kilo watt, ${}^{2}{}_{\mathbf{H}}$ in Nano second.

**Average power:** The formula used to find out average power is given below

$$\mathbf{P_{AV} = P_H \times {}^{2}{}_{H} \times F_P}$$

Where,
$\mathbf{P_H}$ in kilo watt,
${}^{2}{}_{\mathbf{H}}$ in nano second,
$\mathbf{F_P}$ in hertz.

### 3.3 Characterisation of Welding

The Table.1 provides all the details regarding the welding that has been carried out in this project.

**Table.1 LASER welding characterization**

### 3.4 System Parameters

The Table.2 describes the parameters that are associates with the welding system that is used for the welding of these 1mm thickness MS plates.

| S.NO | SYSTEM PARAMETERS | TYP: ECO 4600 |
|---|---|---|
| 1. | Laser type | Nd:YAG |
| 2. | Max. mean power | 160 W |
| 3. | Pulse peak power | 7.5 kW |
| 4. | Max. pulse energy | 80 J |
| 5. | Pulse duration | 0.4 - 20 ms |
| 6. | Pulse frequency | 0.5 - 20 Hz |
| 7. | Focus diameter | 0.2 – 2.0 mm |
| 8. | Line voltage (V/Ph/Hz) | 400/3/50-60 |

**Table.2 LASER welding system parameters**

4. ANALYSIS OF WELDED SAMPLES

Laser welding finds a large range of applications and advantages, which we have seen in previous chapters. Here, we are going to analyze the welded samples with corresponding parameters. Before that it is very much important to learn the advantages of laser welding over various conventional welding processes like arc welding, submerged arc welding, gas welding, metal inert gas welding, tungsten inert gas welding, plasma welding etc. Laser welding also possess some other advantages like smaller welded bead, narrow heat affected zones, full penetration etc. Laser welding process is very simple and quite faster that other welding process.

| AVG. POWER | PEAK POWER | PULSED WIDTH | PULSED FREQUENCY | WELDING SPEED |
|---|---|---|---|---|
| 150 W | 7.5 kW | 10 ms | 2.000 Hz | 0.5 m/min |
| 130 W | 7.5 kW | 10 ms | 1.733 Hz | 0.5 m/min |
| 100 W | 7.5 kW | 10 ms | 1.333 Hz | 0.5 m/min |

### 4.1 Specimen for Metallurgical Testing:

After the welding gets over, the next step is to analyze the welding parameters, which we have discussed in the third chapter. Initially, we have to cut a small sample from the welded work piece, which is done by using a specified abrasive cutter. After the sample is cut from the welded plate with the dimensions

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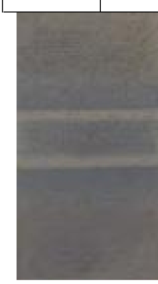
**Table. 3 Welding Stage-1**

which are proposed by the respective testing laborites as per the machine equipment requirements. Because the sample to be tested should have polished surface. The clear microscopic image will obtain only with grinded samples. The next step is to polish the sample, which will be done manually. The following figures are the samples cut from the welded plates for analysis.

| AVG. POWER | PEAK POWER | [illegible] | PULSED FREQUENCY | [illegible] |
|---|---|---|---|---|
| 150 W | 7.5 kW | [illegible] | [illegible] | [illegible] |
| 130 W | 7.5 kW | 10 ms | 1.733 Hz | 0.5 m/min |
| 100 W | 7.5 kW | 10 ms | 1.333 Hz | 0.5 m/min |





**Sample-1 Sample-2 Sample-3**

**Fig.5 Images of tested samples**

**Table. 4 Welding Stage-2**

### 4.2 Laser Welding Parameters

The welding is carried out in two sets. The first stage is by keeping the welding speed constant (i.e.), about 0.5 m/min and by varying the average power as 150W, 130W, and 100W respectively. The next stage of welding is done by keeping the average laser power constant about 130w and by varying the welding speed as 0.5 m/min, 0.75 m/min and 1m/min. So we get 3 sets of welded samples at each stage of welding which means the total sum of six sets of welded samples.

**Welding Stage-1:** keeping welding speed constant and varying the average power is listed in table 3.

**Welding Stage-2:** keeping average power constant and varying the welding speed is listed in table 4.

### 4.3 Microscopic Image Studies

The aim of the examination is to determine the metallurgical structure of materials. The fusion zone, the heat affected zones and the distribution of passes are clearly visible and the interpretation is possible. The microscopic structural images of keeping welding speed constant as 0.5 m/min and varying the power as 150W, 130W, 100 W are shown below. The depth of penetration of the first stage of welding is also shown below.

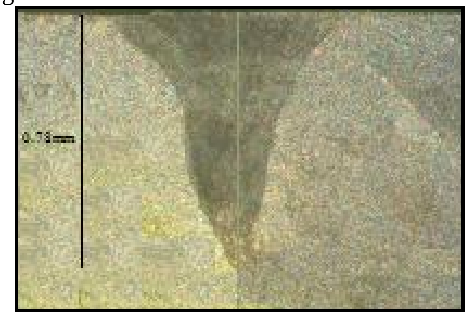



**Fig.6 MI Sample 1 Butt Joint: 150W**

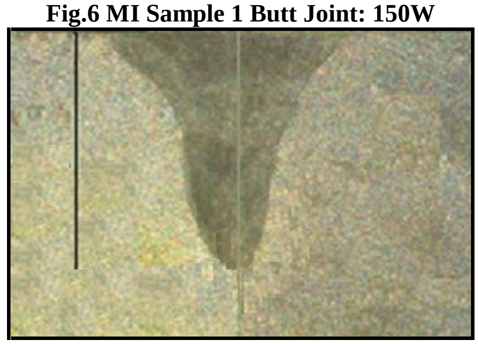


**Fig.7 MI Sample 2 Butt Joint: 130W**

| AVERAGE POWER | PEAK POWER | PULSED WIDTH | PULSED FREQUENCY | WELDING SPEED |
|---|---|---|---|---|
| **130 W** | **7.5 kW** | **10 ms** | **1.733 Hz** | **0.50 m/min** |
| **130 W** | **7.5 kW** | **10 ms** | **1.733 Hz** | **0.75 m/min** |
| **130 W** | **7.5 kW** | **10 ms** | **1.733 Hz** | **1.00 m/min** |

**Fig.8 MI Sample 3 Butt Joint : 100W**

The microscopic structural image of welded sample of the first stage of welding process proves that "higher the laser power then the greater will be the penetration rate".

The microscopic structural images of keeping the average power as 130w and varying the welding speed as 0.5 m/min, 0.75 m/min, 1 m/min is shown below. The weld strength and the HAZ is also shown below.

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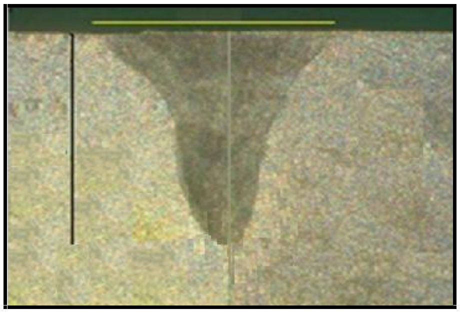


**Fig.9 MI Sample 4 Butt Joint : 0.5 m/min.**

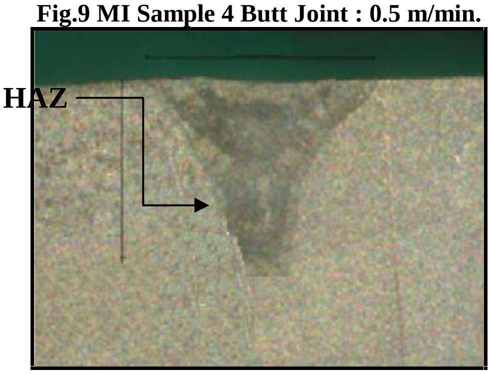



**Fig.10 MI Sample 5 Butt Joint: 0.75 m/min.**

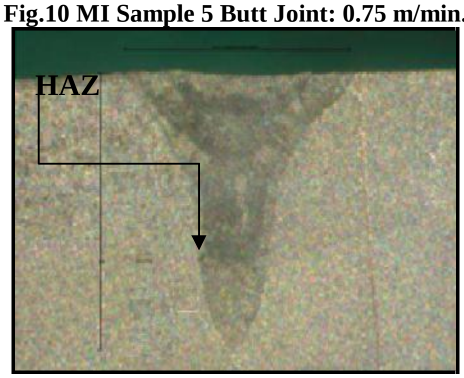



**Fig.11 MI Sample 6 Butt Joint: 1 m/min.**

The microscopic structural image of welded sample of the first stage of welding process proves the higher the welding speed the lesser will be the heat affected zone.

5. CONCLUSION

The main objective of this project is to analysis the process parameter of laser welding. While carrying out the project, we came to know that the laser welding is superior over all conventional welding process like arc welding and one of the best among some unconventional welding process like plasma and electron beam welding process. Laser welding possesses some exclamatory advantages like High focusing point, Low heat affected zone, No extra electrode is needed etc.

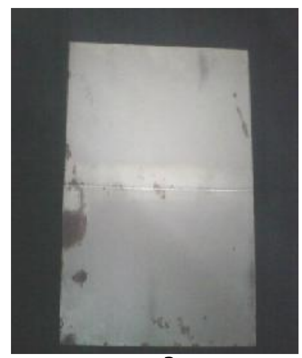
Less welded bead, no direct contact between tool and work piece. The microscopic structural image of welded sample of the first stage of welding process proves that "higher the laser power then the greater will be the penetration rate". Then the second stage of welding process proves that higher the welding speed the lesser will be the heat affected zone. So for higher thickness of material, like rods, the high power lasers should be used. If high power laser is used in low thickness material then the laser will be penetrated from material. At the same time for medium thickness, and high power laser welding the welding speed should be high. Otherwise the laser will be penetrated out from the material. With the microscopic structural studies, we can conclude that in higher welding speed, the lesser will be the strength of welding samples.

By conducting the hardness test, we came to know that the hardness of a material will not increase by performing the laser welding, and plates can withstand cyclic loading or vibration forces. But in some unconventional welding process, the welded sample does not withstand such a vibration or cyclic load. So from this we concluded that laser welding is one of the best welding processes and it has a wide range of advantages and applications, but the only disadvantage is that installation of laser welding equipment is costly.

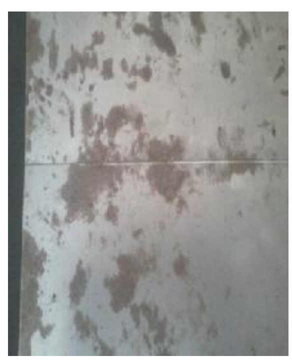
**APPENDICES**

The images of the welding images of the first stage of welding are attached here.

**1**



**2**



**3**

**4**

**5**


**6**

**Sample 1: Welding plate(150w and 0.5 m/min)**
**Sample 2: Welding plate (130W and 0.5 m/min)**
**Sample 3: Welding plate (100W and 0.5 m/min)**
**Sample 4: Welding plate (0.5 m/min and 130W)**
**Sample 5: Welding plate (0.75 m/min and 130W)**
**Sample 6: Welding plate (1 m/min and 130W)**

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