Optimization of the Weldment Shape in Laser Beam Welding on 1018 Steel

Rishabh Nigam[1], Rashi Goyal[1], Kapil Gupta[2]

[1]UG Student, Department of Mechanical Engineering, Hindustan College of Science and Technology, Mathura.
[2]Associate Professor, Department of Mechanical Engineering, Hindustan College of Science and Technology, Mathura

---

Abstract-Laser Beam Welding is a high speed welding process, able to automate production of consistent quality welds. With proper optimization of welding procedures, full advantage can be taken of the low heat input nature of laser welding for a wide variety of materials, Laser welding input parameters play a significant role in determining the quality of a weld joint. In this study, penetration depth and surface width are chosen as variable parameters, required to be optimized with the help of Smart Weld software for maximum melting efficiency and energy transfer efficiency.

Keywords: Laser beam Welding, Welding Parameters, Penetration, Weld Width, Melting Efficiency, Energy Transfer Efficiency, Output power, Travelling Speed.

1. INTRODUCTION

Laser beam welding is a technique used to weld pieces of metal through the use of a laser. The beam acts as a concentrated source of heat, which allows narrow and deep welds with high welding rates. The process is commonly used in high volume applications using automation, as in the automotive industry.

A Laser can be a source of high power having energy density of order of 10^5 KW. When this high power source is focused on the work piece, it melts the metal pieces and fuses them together. The fundamental parts of this process are- LASER, Flashing lamp, Lens and Capacitor.

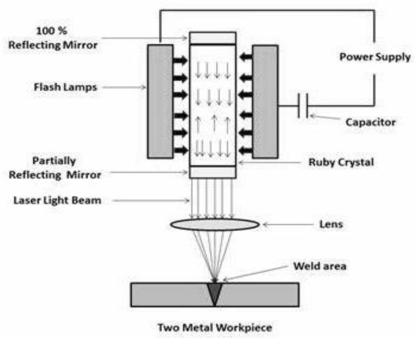


Fig.1 Laser Beam Welding Setup

Laser is generally found in solid, liquid or gaseous state, but for welding only solid Laser are used. The most commonly used Laser is Ruby Laser which is found in rod form doped with a layer of Chromium oxide. The Laser is pumped by flash of very high intensity light generated by a flash lamp. This intense radiation excites the atoms of Laser of Ruby crystal to higher state. As soon as the atom descends to lower energy level it transmits a highly coherent light. This light when is focused with the help of lens on a work-piece, a large amount of heat is produced, which results in subsequent welding of the pieces of metal. In this process heat affected zone is very minimal since the heat is highly concentered precisely on the zone. The spot size of the laser may vary between 0.2 mm and 13 mm, though only smaller sizes are used for welding.

To determine a weld procedure in an analytical manner, one must consider many factors such as thermal input, defect formation along with the quality of weld obtained after completion of process. The tradeoffs of these factors result in good quality of weld.

Some of the defects are -Undercut, Humping, Excess metal, thermal damage and Sagging Cracking (Laser welding can be more susceptible to this due to high cooling rates). The problem gets complicated by the fact that there are many sets of parameters that must be fulfilled to get accurate weld size requirements.

On can speed-up the process of choosing among various welding procedures by choosing amongst various available computer software that give us the opportunity to choose between different models for our weld requirements. There are majorly two advantages of using fusion welding process; namely Energy Transfer efficiency and Melting efficiency.

Computer software gives us the liberty to quantify maximum advantages of performing the experiment with utmost accurate parameters and hence providing us with correct results.

1.1 MATERIAL PROPERTIES

1018 steel is a medium low-carbon steel which has a high formability and strength. It excels in weld ability and has a slightly better machinability than other lower carbon steels. Even though its mechanical properties are not very unique, it still can be easily formed, machined, welded and fabricated.

Table No.1 - Mechanical Properties of Steel 1018

Elongation A50 A_{50}	13 % at 20 °C
Hardness, Rockwell B HRB	73 - 100 [-] at 20 °C
Tensile strength R_m	469 - 689 MPa at 20 °C
Yield strength YS	427 MPa at 20 °C

Table No. 2 Chemical properties of Steel 1018

Element	**Weight %**
Fe	98.16 - 99.26 %
Mn	0.6 - 0.9 %
Ni	0.23 %
Cu	0.2 - 0.23 %
Cr	0.19 %

1.2 ABOUT SOFTWARE

SmartWeld is a Free Open Source Software developed by Sandia Corporation. Smart Weld provides analysis tools to investigate the impact of changes in weld procedures.

Smart Weld is a set of science based software applications which enable engineers, designers, and technologists to determine optimal automatic welding procedures for seam welding, spot welding, laser welding, and many robotic welding applications.

It has 14 Aps namely: - Oslw, Isospot-2d, Iso-2d, Spot-3d, Isoedge, Iso-3d, Iso-2.5d, Weld-3d, Yag, Haztemp, Isospot-3d, Iso3d.Gauss, Weld-2.5d, Weld-2d.

1.3 The OSLW Application

The OSLW application is a specialized application for analyzing continuous wave laser welding in the conduction and keyhole mode. OSLW is useful in developing weld procedures with optimized energy transfer and reduced heat input. It is based on an empirically developed dimensionless parameter model that is applicable to all metals and alloys.

OSLW calculates weld dimensions, parameter values, and several quality parameters including melting efficiency, energy transfer efficiency, and power sensitivity.

1.4 Melting Efficiency- Dimensionless ratio of the amount of heat required to just melt the fusion zone to the work piece net heat input. Welds with low melting efficiency result in excessive heating of the base metal and increased chance for thermal damage and distortion.

$$Melting\ Efficiency = \frac{Energy\ for\ melting}{Net\ heat\ input}$$

$$= \frac{V}{q_i}\left[\Delta h_f + \int_{T_r}^{T_l} C_p(T)\,dT\right]$$

The melting efficiency is affected by laser output power and travel speed. The energy for melting consists of two components: heat of fusion and heat due to the temperature rise.

1.5 Energy Transfer Efficiency- Dimensionless ratio of work piece net heat input to the incident energy output from the power source. A high laser energy transfers efficiency reveals that little laser power is reflected.

$$Energy\ transfer\ efficiency = \frac{net\ heat\ input}{laser\ output\ energy}:$$

$$\eta = \frac{q_i}{q_o}$$

The energy transfer efficiency is known to correlate to the laser beam power density (focus and power).

2. PROCEDURE

To find out the optimum depth and width of the weld to get the maximum melting efficiency and energy transfer efficiency, we conduct the procedure in two steps:

1. Vary the penetration depth and observe the other parameters like weld width, power output, welding speed, melting efficiency and energy transfer efficiency. As our aim is to optimize the depth and width of the weld so we choose the penetration depth where melting efficiency is maximum.

2. Now we fix the penetration depth where melting efficiency is maximum and then vary the width of the weld Again note down the other parameters like weld width, power output, welding speed, melting efficiency and energy transfer efficiency. Finally choose the width where energy transfer efficiency is maximum.

Laser beam welding was carried out with the following Weld schedule parameters:

Focus lens : 5,
Focus spot diameter : 225.00000um,
Spot diameter : 0.0225 cm and
Shielding gas : Argon

2.1 Vary Penetration Depth.

The effect of the process parameter, viz., penetration depth on the weld joint. The procedure was conducted on smart weld software in OSLW application.

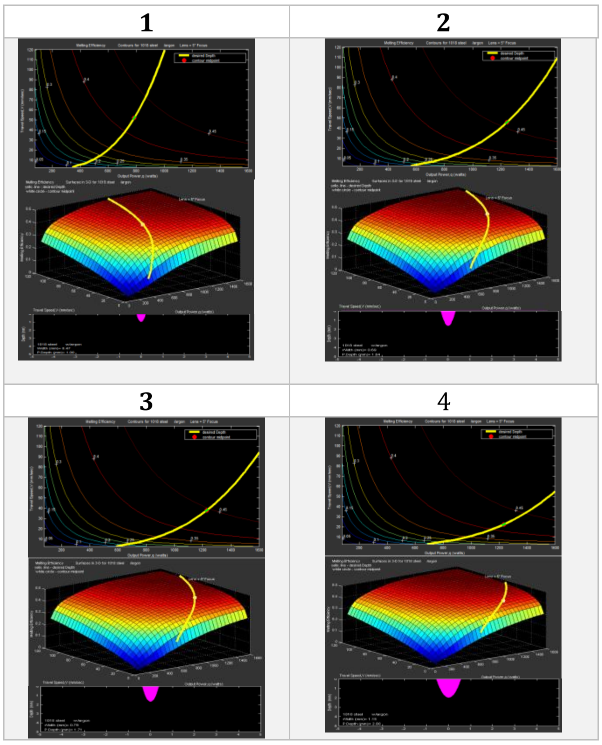


Fig.1 Graphical Representation of Variable output when vary the penetration depth.

The factors and the level values are cited in table 3.

Table No.3 – Problem and Diagnostic Table

Sample No	**1.**	**2.**	**3.**	**4.**
Problem statement				
Penetration depth (mm)	0.80	1.20	1.60	2.00
Weld width (mm)	0.40	0.53	0.65	1.15
Weld schedule parameters				
Output power (watts)	634	939	1243	1233
Traveling speed (mm/sec)	53.44	51.16	49.80	22.50
Diagnosis parameter				
Melting efficiency	0.41	0.44	0.46	0.42
Energy Transfer Efficiency	0.46	0.55	0.63	0.69

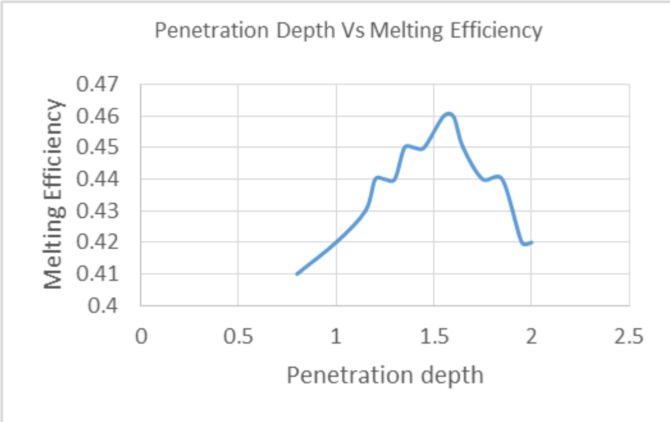


Fig 2. Penetration depth vs Melting Efficiency

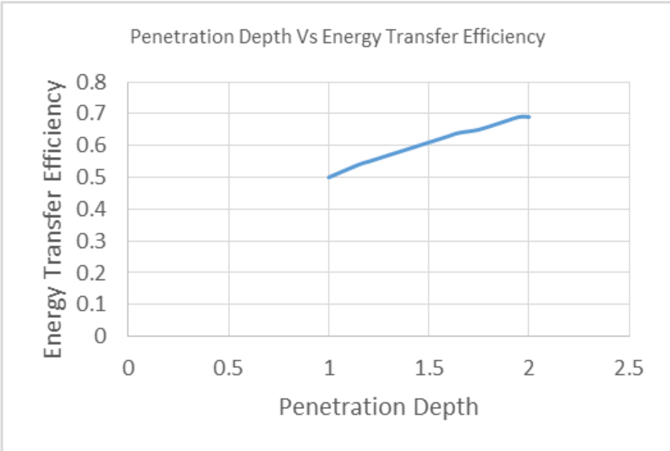
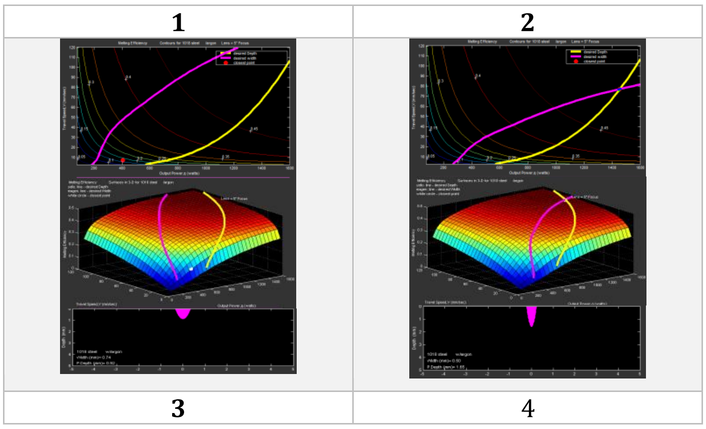


Fig 3. Penetration depth vs Energy Transfer Efficiency

2.2 Vary Surface Width

The penetration depth is kept constant at 1.60 mm as here we get the maximum melting efficiency. Now we vary the surface width to find out the width where energy transfer efficiency will be maximum.



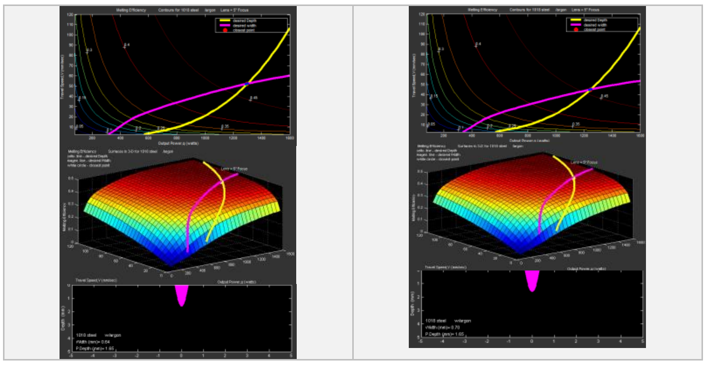


Fig.4 Graphical Representation of Variable output when vary the penetration width.

The factors and the level values are cited in table 4.

Table No.4 – Problem and Diagnostic Table

Fix Penetration depth and vary surface width	**1.**	**2.**	**3.**	**4.**
Problem statement				
Penetration depth (mm)	1.60	1.60	1.60	1.60
Weld width (mm)	2.30	3.30	4.30	5.30
Weld schedule parameters				
Output power (watts)	761	1013	1338	1243
Traveling speed (mm/sec)	5.90	10.84	16.71	49.80
Diagnosis parameter				
Melting efficiency	0.26	0.36	0.41	0.46
Energy Transfer Efficiency	0.67	0.70	0.74	0.63

.

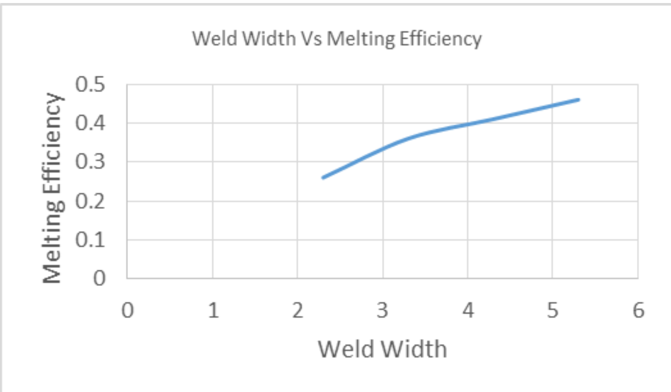


Fig 5. Penetration depth vs Melting Efficiency

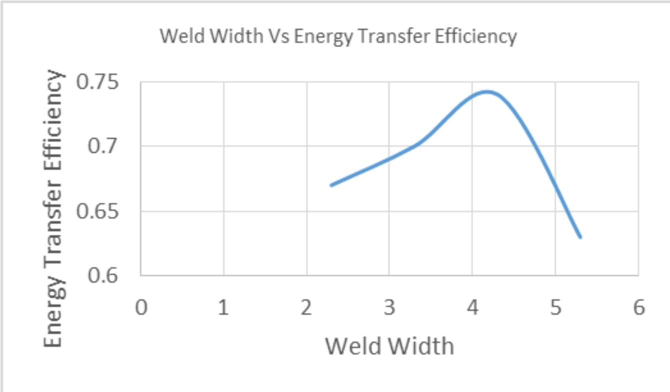


Fig 6. Penetration depth vs Melting Efficiency

3. Conclusions

1. It is observed that initially the weld width is constant but as the penetration depth increases the weld width increases proportionally with increase in cross-sectional area of weld.

2. The output power gradually increases with simultaneous increase in penetration depth from 0.80mm to 1.60mm. Also, at 1.60mm maximum output power is received. But beyond that, output power seems to considerably decrease with increase of penetration power. As it is dependent on various factors like frequency of emission of atoms, material, etc.

3. We also observed, that with increase of penetration depth, travelling speed decreases. As, the travelling speed is depended on the intensity of laser, latent heat, etc. Since when penetration depth is increased, the cross-sectional area also increases which requires more intensity of laser and latent heat to melt the material.

4. As penetration depth increases the melting efficiency increases tangentially with laser's output power and travelling speed. It increases with travel speed at low speeds and decreases at high speeds.

5. With the increase of penetration depth, the Energy transfer efficiency increases. As, the energy transfer efficiency depends on the laser beam power density.

6. It is observed that penetration depth at 1.60mm gives the maximum output power along with maximum melting efficiency and travelling speed.

Above observations suggested that when penetration depth is 1.60mm and weld width is 4.3mm, melting efficiency and energy transfer efficiency are maximum Also higher power output with ample amount of time available to weld the material properly. For efficient and economical welding, we kept penetration depth as 1.60 mm and surface width as 4.3 mm.

4. References

[1]. The SmartWeld software", Sandia Corporation "http://smartweld.sourceforge.net/".

[2]. Fuerschbach ,Phillip W., Eisler G. Richard "Weld Procedure Development with OSLW- Optimization Software for Laser Welding" The Mathworks, Inc

[3].Properties of 1018 steel, "https://matmatch.com /materials/minfc273-astm-grade-10"

[4] OSLW Application,

"http://smartweld.sourceforge.net/Apps/oslw_app.htm

[5] Walsh C.A., "Laser Welding - Literature Review" July 2002. Materials Science and Metallurgy Department, University of Cambridge, England. Corpus ID: 34575375

About the Authors:

	Rishabh Nigam is doing his B.Tech in Mechanical Engineering from Hindustan College of Science & Technology, Farah, Mathura. His Area of Interest are Bimetallic Weld and Finite Element Analysis.
	Rashi Goyal is doing her B. Tech in Mechanical Engineering from Hindustan College of Science & Technology, Farah, Mathura. Her Area of Interest are Bimetallic Weld and Additive Manufacturing
	Kapil Gupta is working as Associate Professor in Department of Mechanical Engineering, Hindustan College of Science & Technology, Farah, Mathura. His Area of Interest are Bimetallic Weld, Additive Manufacturing and Lean Manufacturing.