# A Literature Review on Effect of Laser Welding Parameters on Mechanical Properties and Microstructure

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*Abstract*— Laser welding is a high speed welding process, capable of automated production of consistent quality welds. Compared with many other arc welding processes, fewer passes or higher welding speeds can be used, with lower usage of welding consumables. 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, producing welds with acceptable hardness and toughness properties. This paper reviews the various notable works in field of laser welding and magnifies on the effect of various laser welding parameters on the mechanical properties and the microstructure.

*Key words:* Tensile strength, Hardness, EDS (Energy Dispersion Spectography), DOE.

## I. INTRODUCTION

Laser Beam welding is a method of fusing two pieces of metal together by using a high-heat laser. This technique uses one of two types of welding equipment: a solid state welder or a gas laser welder. These machines both create a precise bond by emitting a dense photon beam that can work with both thin and thick pieces of metal. This type of welder is popular in producing airplanes, cars and spacecraft, but has a few disadvantages that prohibit it from working in all industries.

Welding with laser beams works because of a dense beam of photons that each type of machine produces. This light ray heats metals up quickly so that the two pieces fuse together into one unit. The light beam is very small and focused, so the metal weld also cools very quickly. Laser beam welding machines can give off a continuous beam to work with thicker metals, or short pulsing bursts to bind thinner materials.

Laser beam welding works well with metals like steel, aluminium, and titanium. Consequently, industries that use these metals typically embrace laser welders. Automotive, aeronautic and aerospace production facilities are well known as the main users of laser welding technique. The laser beam welding industry has utilized lasers for speed, accuracy and power, but there are also a few reasons some do not use this technology. There is a concern with retinal damage when using laser welders, especially solid state machines. To counteract this, operators are encouraged to wear protective eyewear. Another concern is cracking. Metals, like high carbon steels, often crack due to rapid cooling rate of a weld made by laser.

## II. WORKING PRINCIPLE OF LASER WELDING

Laser welding operates in two fundamentally different modes: conduction limited welding and keyhole welding. The mode in which the laser beam will interact with the material it is welding will depend on the power density of the focused laser spot on the work piece.

Conduction limited welding occurs when the power density is typically less than $10^5$W/cm$^2$. The laser radiation is absorbed only at the surface of the material and does not penetrate into the material. Therefore, conduction limited welds exhibit a high width to depth ratio.

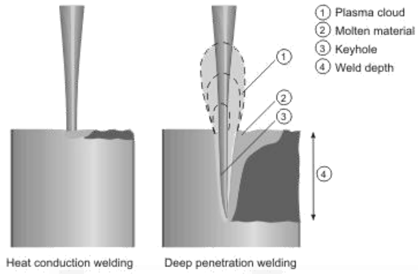


Fig. 1: Types of Welds

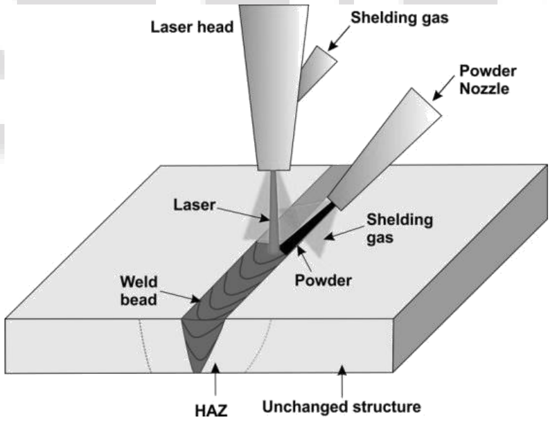


Fig. 2: Schematic of Laser Welding

Laser welding is more usually accomplished using higher power densities, by a keyhole mechanism. When the laser beam is focused to a small enough spot to produce a power density typically > $10^6$-$10^7$ W/cm$^2$, the work piece surface vaporizes before significant quantities of heat can be removed by conduction. The focused laser beam penetrates the work piece and forms a cavity called a 'keyhole', which is filled with metal vapor or ionized metal vapor (plasma). This expanding vapor or plasma contributes to the prevention of the collapse of the molten walls of the keyhole in to this cavity. Furthermore, the coupling of the laser beam to the work piece is improved dramatically by the formation of the keyhole. Deep penetration welding is then achieved by traversing the keyhole along the joint to be made (or moving the joint with respect to the laser beam) and results in welds with a high depth to width. Under the action of vapor pressure and surface tension, the molten material at the leading edge of the keyhole flows around the cavity created by the beam to the back, and solidifies to form the weld. This action leaves a top bead with a chevron pattern, which points towards the start of the weld.

## III. LITERATURE REVIEW

*P. Sathiya, K. Panneerselvam, R. Soundararajan [1]* showed that Laser welding input parameters play a very significant role in determining the quality of a weld joint. The joint quality can be defined in terms of properties such as weld bead geometry, mechanical properties and distortion. Therefore, mechanical properties should be controlled to obtain good welded joints. In this study, the weld bead geometry such as depth of penetration (DP), bead width (BW) and tensile strength (TS) of the laser welded butt joints made of AISI 904L super austenitic stainless steel were investigated. Full factorial design was used to carry out the experimental design. Artificial Neural networks (ANN) program was developed in MatLab software to establish the relationships between the laser welding input parameters like beam power, travel speed and focal position and the three responses DP, BW and TS in three different shielding gases (Argon, Helium and Nitrogen). The established models were used for optimizing the process parameters using Genetic Algorithm (GA). The developed ANN model is suitably integrated with optimizing algorithms like GA to optimize the welding parameters. For the optimized welding parameters of GA, the laser welding joints were processed. Joints exhibit better quality. The good agreement between the theoretically predicted (GA) and experimentally obtained tensile strength, depth of penetration and bead width confirms the applicability of these evolutionary computational techniques for optimization of process parameters in the welding process.

*G.R. Mirshekari, A.Saatchi, A.Kermanpur, S.K.Sadrnezhaad [2]* have shown in their work a comparative study on laser welding of NiTi wire to itself and to AISI304 austenitic stainless steel wire . Microstructures, mechanical properties and fracture morphologies of the laser joints were investigated using optical microscopy, scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), X-ray diffraction analysis (XRD), Vickers micro hardness (HV0.2) and tensile testing techniques. The results showed that the NiTi–NiTi laser joint reached about 63% of the ultimate tensile strength of the as-received NiTi wire (i.e.835MPa) with rupture strain of about 16%.This joint also enabled the possibility to benefit from the pseudo-elastic properties of the NiTi component. However, tensile strength and ductility decreased significantly after dissimilar laser welding of NiTi to stainless steel due to the formation of brittle intermetallic compounds in the weld zone during laser welding. The micro hardness values from the weld zone toward the base metal increased in NiTi–NiTi joint, while it decreased in NiTi–SS joint. In addition, NiTi – NiTi joint was fractured in ductile manner at the weld zone near the fusion line, while brittle failure occurred at the center of the NiTi–SS weld zone.

*Lifang Mei, Genyu Chen, Xiang zhong Jin, Yi Zhang, Qiang Wu [3]* presented some useful results on deep-penetration laser welding of high-strength galvanized steel sheets, which had been carried out by a self-made CO2 laser unit with maximum power output of 1.5kW.The work pieces of high-strength galvanized automobile steels with thickness of 1.5mm were butt-welded with argon as the shielding gas. The effects of such factors as laser power, welding speed, focal position, shielding gas and zinc vaporization on the quality of welds are investigated. With the processing parameters optimized and the proper shielding gas used in both co axial and side-blow direction, most of the defects, such as pores, cracks and softening in HAZ, can be avoided in laser welding joints. The microstructure, the hardness distribution and the elemental distribution in the welding joints can be changed due to laser heating and recrystallization. In order to determine the mechanical properties of the welding joints, the static tensile strength was tested. Experimental results indicated that both the strength and micro hardness of welding joints were higher than those of the base metal. The deep punching performance acquired by adopting Ar as shielding gas is better than that acquired by adopting N2 as shielding gas .Meanwhile; the effect of zinc vaporization on welding joints can be effectively controlled by means of blowing side shielding gas. The experimental results indicate that the promising welding quality can be obtained under the chosen condition of taking Ar as shielding gas, laser power P as 1300W, defocusing amount Df as 0.4mm, welding speed v as 1.0 m/min, coaxial-blown shielding gas-flow rate q as 2.5 $m^3$/h, side-blown shielding gas-flow rate q as 1.8 $m^3$/h, and side-blown angle α as 301.

*A.G. Olabi, F.O. Alsinani, A.A. Alabdulkarim, A. Ruggiero, L. Tricarico , K.Y. Benyounis [4]* investigated dissimilar full-depth laser-butt welding of low carbon steel and austenitic steel AISI316 was investigated using CW 1.5kW CO2 laser. The effect of laser power, welding speed and focal point position on mechanical properties (i.e., ultimate tensile strength, UTS and impact strength, IS) and on the operating cost C was investigated using response surface methodology (RSM). The experimental plan was based on Box–Behnken design; linear and quadratic polynomial equations for predicting the mechanical properties were developed. The results indicate that the proposed models predict the responses adequately within the limits of welding parameters being used a laser power value of 1.1 kW is suggested as an optimum input process value to obtain excellent welded joints produced from austenitic stainless steel AISI316 and low carbon steel. The welding speed is the most effective parameter affecting the main weld bead dimensions as the area and the middle width, and it has to be set right on certain values to make all the responses optimized. Being focal point position fixed around -0.41 mm and laser power on 1.17 kW, setting welding speed on 72.66 cm/min, all the weld bead dimensions come out very reduced as area can be minimized by more 9% and middle width by 14%, spending 20% less money than the first criteria solution cost. Anyway, depending on the desired impact strength value for the specific application, if any, and on how much important and critical are mechanical properties on that, fixing welding speed on 57.93 cm/min, focal point position on -0.35 mm and laser power on 1.30kW, can be more efficient and smart, as it ensures a pretty higher value of ultimate tensile strength (360MPa) and impact strength (70.44J).

 

*Shanmugarajan B., Chary J N. , Padmanabham G., Arivazhagan B. , Shaju K. Albert , Bhaduri A.K. [5]* studied Influence of variables such as laser power, welding speed, shielding gas and laser beam mode on microstructure and mechanical properties. Here autogenously bead-on-plate (BoP) laser welding studies were carried out on 3mm thick 304B4 grade stainless steel using a 3.5kW slab CO2 laser. Dye penetrant testing, microstructural analysis, bead geometry measurements, micro hardness survey, and micro structural analysis in both as-weld and post-weld heat treated conditions were carried out. The microstructural and bead geometry analyses of the welds have shown that the welds were free from cracks in the fusion zone (FZ) and also in the heat affected zone (HAZ) for all the welding parameters studied. The Gaussian mode has given a very narrow weld width compared to donut mode. During welding use of helium and nitrogen has reduced the width of the FZ and HAZ. The as-weld micro hardness was more than double the base metal, and the peak hardness was shifted from the center to the fusion boundaries with the increase in heat input. The PWHT has reduced the hardness of both the FZ and HAZ.

*Mingjun Zhang, Genyu Chen , Yu Zhou, Shenghui Liao [6]* examined the effect of the processing parameters on the weld bead geometry and the microstructure and mechanical properties of the optimal joint were investigated. The results show that the focal position is a key parameter in high-power fiber laser welding of thick plates. There is a critical range of welding speed for achieving good full penetration joint. The type of top shielding gas influences the weld depth. The application of a bottom shielding gas improves the stability of the entire welding process and yields good weld appearances at both the top and bottom surfaces. The maximum tensile stress of the joint is 809 MPa. The joint fails at the base metal far from the weld seam with a typical cup–cone-shaped fracture surface. Welding speed, Focal position and shielding gas are the parameters that are studied. The weld depth increases when a top shielding gas is applied in the following order: argon < nitrogen < helium. The application of a bottom shielding gas improves the stability of the entire welding process, yielding good weld appearances at both the top and bottom surfaces.

*A. Squillace, U. Prisco, S. Ciliberto, A. Astarita [7]* studied the influence of welding speed and laser power on weld quality of 1.6 mm thick Ti − 6Al − 4V sheets autogenously laser beam welded in butt configuration using a Nd-YAG laser. The joint quality was characterized in terms of weld morphology, microstructure and mechanical properties. An under fill defect, controlling the whole weld geometry, was observed both at the weld face and root surface. In dependence of the specific heat input, this defect showed a maximum, which separates two different welding regimes: keyhole welding, at low heat input, and a welding regime where heat conduction around the keyhole is predominant, at high heat input. Influence of the under fill radius on the weld fatigue life was also assessed. Weld morphology is strictly influenced by the welding regime wherein they are produced. The welds under investigation, compared with the base material, reach similar tensile performance with a reduced ductility. Fatigue life of the investigated welds is strongly influenced by the value of the under fill radius. Indeed, the S–N curve tends to move towards region of higher cycles as the value of the under fill radius increases; this means that the fatigue strength of the welded joints can be improved by partially or totally eliminating the under fill. The fatigue fracture initiates and propagates near the lower point of the under fill convexity at the interface between the FZ and the HAZ.

## IV. CONCLUSION

1) Laser welding input parameters play a very significant role in determining the quality of a weld joint. The joint quality can be defined in terms of properties such as weld bead geometry, mechanical properties and distortion.
2) The content of Mn and Cr element in welding joints is favourable for enhancing the tensile strength and the corrosion fatigue resistance of welding joints.
3) The welding speed is the most effective parameter affecting the main weld bead dimensions as the area and the middle width.
4) The depth of penetration and width of the welds were found to increase with heat input.
5) The focal position is a key parameter in high-power fiber laser welding of thick plates.
6) Weld morphology is strictly influenced by the welding regime wherein they are produced.

## V. FUTURE SCOPE

For researchers there is wide scope for analyzing and developing new optimum parameters for different size and different materials. Also different materials that can be laser welded are Steels, Niickel Alloys, Titanium, Aluminium Alloys and Copper.

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