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EVALUATION OF THE PROPERTIES OF LASER BEAM WELDING PROCESS

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ABSTRACT--*This article is all about evaluating the laser beam welding process using the stainless steel samples using the recent mechanical testing methods. Here firstly the stainless steel workpieces (SS304 & SS410) are cut to the required dimension of (8cm width * 15cm length * 4mm thickness). Then the cut workpieces are welded using the laser beam welding machine on both the top and bottom layer respectively. After being welded the samples are tested with the mechanical testing methods like bending test, tensile test, etc. Then finally the results are taken from the test and they are to find the properties of laser beam welding process.*

Keywords--*Laser beam, Stainless steel, Mechanical testing, Pulse Frequency*.

I. INTRODUCTION

Welding processes imply the following three-steps: melting the metal to form a weld pool on the site of the future joint, permitting the weld pool to grow to the desired size, and maintaining of weld pool stability until solidification. Welding processes may be achieved using different energy sources: from gas flame and electronic arc to electron or laser beam and ultrasound. Of the energy sources used, the laser beam is notable for having the highest power density currently available to industry (up to 109 W/cm2) that is focusable on a small spot (down to 0.1 mm). The absorption of such energy leads not only to material melting but also to evaporation of the material at the point of contact, forming a cylindrical hole in the material which may extend through the entire plate thickness. Over time, the cavity becomes deeper and forms a canal filled with evaporated material along the direction of the incoming laser beam. The laser beam welding represents a very powerful, productive and efficient technology of joining of various materials, which is used in many industries, from the automotive, aviation, space industries through electronics, medicine to energetic or military industries [1-10]. Modelling and numerical simulation of laser welding processes has been exploited with many advantages for the investigation of physical principles and complex phenomena connected with this joining technology [11-16]. It is generally considered as an effective tool for definition of appropriate welding parameters and optimization of laser welding processes

Process parameters

Laser Prosperities	**Material Prosperities**	**Process Parameters**
Power Density	Composition	Welding Speed
Wavelength	Temperature	Focal Point Position
Polarization	Roughness	Focal Point Size

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Angle of incidence	Surface Quality	Shielding Gas

The laser beam welding process mainly depend on the process parameters of laser beam to have precisive welding bonds throughout the sample. The main process parameters of the laser beam welding technique are 1. laser pulse energy, which is the unit of maximum output energy

2. laser pulse frequency, which shows the amount of pulse energy produced by the laser, 3. Laser beam flare diameter , which helps in evaluating the power density and processing scope of the laser, 4. Choice of power waveform, which is used to produce larger welding spots, 5. Laser pulse waveform, this is the parameter used to control the reflection of the laser.

Experimental Work

The parameters of the laser radiation, adjusted upon the characteristics of the welding materials and the disposal of the welded parts must ensure the raise of the T(ms) temperature from the joint area to a value which is superior to the melting temperature – T(melting), the vaporization temperature T(vaporization), as following: T(melting) < T(ms) < T(vaporization)

The weld joints sectioned by manual sawing are to fit in to size and shape of mounting tool. The presences of burs in the edges removed using a machine run-emery sheet. Mixture of methyl methacrylate and polyvinyl formaldehyde used as resin and hardener to mount the samples and allowed to cure up to 15-30 min. Prior to electro polishing, each specimen are grinded with 120, 240, 600 and 800 emery grits using polishing machine. 9-μm, 6-μm and 3-μm diamond slurry used to achieve fine polishing. Liquid state Mecaprex diamond compounds LD 33E for 9- μm and LDP for 6-μm are used for fine polishing respectively. Reflex 24270 used as coolant during using machine polishing. Electrolytic etching for AISI 316L Stainless Steel joints etched in a solution containing 20 ml hydrochloric acid, 1.0 g of sodium meta bi sulphate and 100 ml distilled water. Each sample are micro graphed at the range of magnification 100 μm to investigate the evolved weld pool and the keyhole regions at the cross sections of butt joint using analysis software with PC controlled optical microscope.

The laser action time frame or the displacement speed of the parts/beam is chosen, so that the penetration of the melting frontline in the materials takes place before the evaporation of their superficial layer, basically the maximum melting depth being reached when the temperature of the material from the surface reaches the boiling point.

The welded tubes were clamped into a rotary chuck. The welding speed was limited by the maximal speed of applied dog rotary chuck which was 17 mm.s−1. To investigate the influence of welding speed on the quality of produced weld joints, the welding speeds of 10 mm.s−1, 14 mm.s−1 and 17 mm.s−1 were used. The laser power was varied from 400 W to 1000 W. During experimental laser beam welding, the temperatures were measured by two thermocouples of the K type. The thermocouples were welded by hand on the both sides of weld joints. In this reason, the location of thermocouples was not the same for all samples. The distance of thermocouples from the weld centerline were a (thermocouple TC1) and b (thermocouple TC2) according to Figure 3a. The welding parameters exploited for the preparation of experimental weld joints are given in Table 3. Experimentally measured temperatures in the dependence on time for the laser power of 600 W, 800 W and 1000 W are plotted in Figures 3b-d. As it follows from these figures, the maximum measured temperatures are influenced not only by the laser power and welding speed but also very significantly by the distance of thermocouples from the welding centerline. The maximum temperatures on the level of 602 °C and 735 °C were recorded for the laser power of 600 W and the welding speed of 10 mm.s−1 and the laser power of 1000 W and the welding speed of 14 mm.s−1 , respectively, with the thermocouples located the closest to the center of the weld joint. Due to the more distant location of thermocouples during the laser welding with higher welding speeds and the same laser power of 800 W, the temperatures measured during the welding with the welding speed of 10 mm.s−1 are lower than that measured by the welding with the welding speed of 17 mm.s−1 and also 14 mm.s−1

II. MODELING

Modeling the laser welding process has been another major research focus. is challenging due to the multi physics nature of the problem that is, it involves laser-material interaction, large temperature variation, plasma formation, vapor-liquid-solid coexistence, and possible solid-state phase transformation [4, 23–25]. As analytical solution of the laser welding process is not possible (except in the case of a simplified physics and geometry model), numerical/computational approaches have been taken. In 2005, Mackwood and Crafer reviewed the literature on thermal modeling up to 2002.

Study of laser induced downward expanded vapour region Laser-induced plasma plays two-fold roles during keyhole formation that the "inverse bremsstrahlung" effect absorption increases the energy coupling leading to plasma re-radiation and the absorption of reflected laser pulses from inner surfaces, called Fresnel absorption that facilitates the keyhole formation at the initial stage. In plasma, density of free electron increases and hence the current induced magnetic force increases, hence, plasma cloud start to flow that formed a vortex at the upper part of keyhole [16] as shown in figure 5. This vortex exhibit drastic change in melting point by Kerr effect and Pockel‟s effect; leads to a strong convectional movements in the melt pool, which has significant influence on heat transfer as discussed earlier about "Marangoni flow "[16, 17].On further increase in laser power as 2150 W ,the interaction of plasma and vapour plume of keyhole generates the side flows of the melt generated beneath the focal spot by the local „piston effect‟ [18]. The tilting of the keyhole front wall and the corresponding dynamic pressure of the ejected vapor plume control the degree of coupling between the vapour plume and the melt pool. When the downward-flowing vapor on the front

III. METHODS TO IMPROVE EFFICIENCY

- Surface Modifications

The tendency of increased absorption with increased surface roughness in case of using CO2 laser for low-alloyed steel processing was noted by Arata and Myamoto . However, this factor has an impact on the absorption level only at the beginning of the welding process; after the stabilization, absorption no longer depends on the optical properties of the surface.

- Preheating Techniques

Preheating of the workpiece improves the LBW process efficiency by modification of the heat conduction characteristics inside the metal. As the temperature of the metal rises, there will be an increase in the photon population, causing more photon-electron energy exchange, as the electrons are more likely to interact with the material rather than oscillate and re-radiate. This phenomenon causes a fall in reflectivity and an increase in the absorptivity with the rise in temperature in the metal and therefore an increase in weld width and depth.

- Ambient Conditions Modifications

Katayama et al. 2001 [31] highlighted the potential for reduced pressure laser welding with a high-power. In later experiments with stainless steel, Katayama et al. 2011 [56] with a laser power up to 26 kW achieved an acceptable quality weld of 75 mm penetration depth with a 1 m/min speed single pass LBW at 1 kPa pressure. To achieve the desired pressure level, a vacuum chamber was sealed up, and the pressure was lowered by three rotary pumps. This method has certain limitations by size of the workpiece and use of the method in industry, as the welding process time have to be increased significantly.

IV. RESULTS AND DISCUSSION

The developed and verified simulation model was applied for the design of welding parameters for the laser welding of the thin-walled tubes from the AISI 304 steel. A set of numerical simulations in the program code ANSYS was carried out with the welding speed varied from the required interval from 30 $mm.s^{-1}$ to 60 $mm.s^{-1}$ and the supposed values of laser power from 500 W to 1200 W. For illustration, the temperature fields computed applying chosen welding parameters are depicted in Figure 5. The increase in the laser power at the constant welding speed results in the enlargement of a fusion zone and as well as in the enhancement of the maximum temperature of the weld metal (Figure 5a-c). On the other hand, with the increase in welding speed, the size of a fusion zone decreases (Figure 5d-f). The highest temperatures in fusion zone were reached when the combination of high laser power and low welding speed was applied. In Figure 6, the temperatures of a weld pool and a weld root are shown for considered welding speeds and chosen values of laser power. Based on presented time-temperature dependences, the maximum temperatures attained at the top of the weld pool can be estimated and the possibility of the weld root re-melting can be assessed. For the welding speed of 30 $mm.s^{-1}$ and the laser power of 500 W, the maximum temperature of the weld root is deeply below the liquidus and also the solidus temperature of the AISI 304 steel. This laser power is insufficient for the production of a sound weld joint. By the laser power of 700 W, the weld root can be re-melted as the maximum weld root temperature reaches the liquidus temperature TL. In case of welding with the higher laser power (800 W and more), the weld root temperatures are too high.

V. CONCLUSIONS

A method of welding stainless steel is used which takes care of the corrosive property of the steel. The joints made using this technique are strong, sound, repeatable and with minimum porosity (less than 2 %) as against of more than 1 0 % in the no-gap welds. The proposed technique is independent of the non-uniform gap between the plates that mostly exists in real-time manufacturing. Thus, the method takes care of an important practical constraint. Comprehensive microscopic study proves the process phenomena.

the radiographic test results of 316L stainless steel (SMW01), possibility of 0.5 mm diameter porosity reported for the entire segment of A-B and weld spatters observed on the top surface. The slight root concavity throughout the length of the segment A-B has reported for 316L stainless steel that can be eliminate by providing suitable shroud gas or backup material at the bottom of the weld joint. Otherwise, root concavity can be eliminating by optimizing/reducing input power of the laser pulse. There is no such problem arises in 316 stainless steel weld joints made with 2100 watts laser pulse as heat input power. However, no other defects reported from the joint, hence, this result categorized as No Significant Defect (NSD) welds. Similarly, no signs of thermal induced stress reported from both the weld joints

Future Scope

There are a lot of applications covering a wide range of technical fields, due to the advantages of laser welding – the possibility of welding materials with various properties, with complex shapes and dimensions, achieving a high welding speed, a great quality of laser beam, the entire automatization of the process. For instance, accepting the known industrial application such as energetic equipment, chemistry, planes, there are some recent applications in medicine, electronics and appliances industry. A special application of laser welding is the laser Nd: YAG where some bearings made of Safire and ruby are grounded on iron base and they are used in some measuring devices. The advantages of these bearings are a high accuracy level, low dimensions and weight, frictionless, so they could run without lubrification and a good level of thermic stability. These precious stones have low friction coefficient about 0.1 – 0.15. The Safire has a hard level of its mechanical crack characteristic, it is 9 on the Mohs scale and it is very stable during some work period. Until now the laser welding is the only process which could influence very low its thermal properties.

REFERENCES

1. Paul Williams, Jeffrey Sowards, Brian Simonds, Measuring laser beam welding power using the force of light, 2016
2. D T Swift hook, A E F Gick, Penetration welding with lasers, 1973.
3. Mansori Miyagi, Hongze Wang, Ryohei Yoshida, Effect of alloy element on weld pool dynamics in laser welding of aluminum alloys, 2018.
4. Wojciech Suder, Supriyo Ganguly, Stewart Williams, Bagus Yudodibroto, Root stability in hybrid Laser welding, 2017.
5. D C Saha, E Biro, AP Gerlich, YN Zhou, Fiber laser welding of Al Si coated press hardened steel,2016.
6. Vlastimir Nikoolic, Milos Milovancevic, Dalibor Petkovic, Dejan Jocic ,Milan Savic,2018.
7. Bekir Sami Yilbas, Mian Mobeen Shaukat, Abdul Aziz Afzal, Fahran Ashraf, Optics and laser technology, 2019
8. Davide Rossin , Method and apparatus for laser beam welding,2017.
9. J.Xie ,Dual beam laser welding,2002.
10. Phillip W. Fuerschbach, Jerome T. Norris, Xuili He and Tarasankar DebRoy, Understanding metal vaporization from laser welding,2003.
11. Mikhail Sokolov1*, Antti Salminen1,2, Improving Laser Beam Welding Efficiency 2014.
12. D. W. MOON AND E. A. METZBOWER ,Laser Beam Welding of Aluminum Alloy 5456,1983.
13. J.-H. CHO AND S.-J. NA, Three-Dimensional Analysis of Molten pool in GMA-Laser Hybrid Welding,2009.

14. Abdel-Monem El-Batahgy1 Abdel-Fattah Khourshid2Thoria Sharef Effect of Laser Beam Welding Parameters on Microstructure and Properties of Duplex Stainless Steel ,2011.
15. A. Dasgupta and J. Mazumder, Alloying Based Laser Welding of Galvanized Steel,2000. J Xie and AKar, Laser Welding of Thin Sheet Steel with Surface Oxidation,1999.
16. David Foyt, MD, Jeffry P. Johnson, MD, Andrew J. Kirsch, MD, Jeffrey N. Bruce, MD, and Jack J. Wazen, MD,Dural Closure With Laser Tissue Welding,1996.
17. C Betrand, Y Le Petitcorps, L.Albringre, V Dupuis, The laser welding technique applied to the non precious dental alloys procedure and results, 2001.
18. Charles E. Albright, Shichan Chiang, High speed laser weding discontinuities,1988.
19. Akira matsunawa ,Seiji katayama, Solidification of laser welded stainless steels,1984
20. Jon J. Yagla, 1 Richard S. Haag,' and Matthew E. Scott 1,Laser Welding Analysis and Experiments,1995.
21. J Xie and AKar, Laser Welding of Thin Sheet Steel with Surface
22. Oxidation,1999.
23. John Stavridis & Alexios Papacharalampopoulos & Panagiotis Stavropoulos ,Quality assessment in laser welding: a critical review,2018.
24. Behzad Fotovvati , Steven F. Wayne, Gladius Lewis, and Ebrahim Asadi, A Review on Melt-Pool Characteristics in Laser Welding of Metals,2017.
25. Josefine Svenungsson, Isabelle Choquet, Alexander F. H. Kaplanb,Laser welding process – a review of keyhole welding modelling,2015.
26. S.T. Auwal1,2 & S. Ramesh1 & F. Yusof1 & S. M. Manladan1,3A review on laser beam welding of copper alloys,2018.
27. Mohammad Muhshin Aziz Khan, Laser Beam Welding of Stainless Steels,2012
28. MoriakiOno*, Yukio Shinbo**, Akihide Yoshitake*** and Masanori Ohmura, Development of Laser-arc Hybrid Welding.
29. Cristian CORBA, Peti FERENCZ, Ioan MIHĂILĂ, Laser welding, 2009.
30. Jon J. Yagla, 1 Richard S. Haag,' and Matthew E. Scott 1,Laser Welding Analysis and Experiments,1995.
31. Ingemar Eriksson, Per Gren, John Powell, and Alexander F. H. Kaplan, New high-speed photography technique for observation of fluid flow in laser welding,2010