A Review of Laser Welding Process for Dissimilar Materials

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Abstract— This paper describes a variety of fundamental research of laser welding of dissimilar material which the authors have recently performed. Laser welding will be a vital joining technique for dissimilar material with their increasing applications in aerospace, aircraft, automotive, electronics and other industries. In this review the research and progress in laser welding of dissimilar material are critically reviewed from different perspectives. Basically two types of industrial lasers, carbon dioxide (CO_2) and neodymium-doped yttrium aluminum garnet (Nd: YAG). Some important laser processing parameters and their effects on weld quality are discussed. This paper deals with the review of papers by authors.

Key words: Laser beam welding, Mechanical properties, Optimization

I. Introduction

Laser Beam welding (LBW) process, is a fusion joining process that produces coalescence of materials with the heat, obtained from a concentrated beam of coherent, monochromatic light called LASER, impinging on the joint to be welded. In the LBW process, the laser beam is directed by mirrors, and then focused to a small spot (for high power density) at the work piece using, lenses then materials being melted and joint with each other. LBW is a non-contact process, and thus requires that no pressure be applied. Inert gas is generally employed, as shielding, to prevent oxidation of the molten metal and filler metal may occasionally be used. Laser beam welding does not generate any micro particles. In addition, the laser can be readily mechanized for automated, high-speed welding, including numerical and computer control.

II. Literature review

Rattana Borrisutthekul, Yukio Miyashita and Yoshiharu Mutoh [1] (2005) have worked on, dissimilar material laser welding between magnesium alloy AZ31B and aluminum alloy A5052-O. Nd–YAG laser with continuous wave was used for welding. In that study, the normal center-line welding of lap joint was carried out by laser welding. It was found that the intermetallic layer formed near interface between two metals significantly degraded the joining strength. FEM heat transfer analysis was carried out to find out an available method to control penetration depth and width of molten metal, which contributes to control thickness of intermetallic compound layer. They have concluded that the shallow penetration depth into lower plate, thin intermetallic layer and then higher joining strength could be obtained in the edge-line welding lap joint.

Jose´ Roberto Berrettaa, Wagner de Rossib, Maurı´cio David Martins das Nevesc, Ivan Alves de Almeidab and Nilson Dias Vieira Junior [2] (2007) have investigated the Pulsed Nd: YAG laser welding of AISI 304 to AISI 420 stainless steels. They have studied the influence of the laser beam position, with respect to the joint, on weld characteristics. Specimens were welded with the laser beam incident on the joint and moved 0.1 and 0.2 mm on either side of the joint. The joints were examined in an optical microscope for cracks, pores and to determine the weld geometry. The microstructure of the weld and the heat affected zones were observed in a scanning electron microscope. Vickers micro hardness testing and tensile testing were carried out to determine the mechanical properties of the weld. The laser beam position, from the AISI 420 steel to AISI 304 steel, a gradual reduction in hardness along the cross-section of the weld zone was observed. The specimen LJ (beam along the joint) attained the maximum welding efficiency. In the tensile test, fracture occurred outside the weld region.

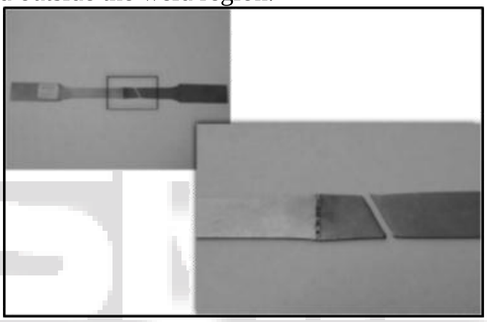

Fig. 1: Tensile test specimen LJ

E.M. Anawa, A.G. Olabi [3] (2008) have worked on, Using Taguchi method to optimize welding pool of dissimilar laser-welded components. In this study, CO_2 continuous laser welding process for joining a dissimilar AISI 316 stainless-steel and AISI 1009 low carbon steel plates. Laser power (1.05-1.43) KW, welding speed (500-1000) mm/min and defocusing distance (-1 to 0) mm combinations were carefully selected with the objective of producing welded joint with complete penetration, minimum fusion zone size and acceptable welding profile. The Taguchi method was applied to the experimental data using statistical software Design-expert 7. Mathematical models were developed to describe the influence of the selected parameters on the fusion zone area and shape, to predict its value within the limits of the variables. Laser power and welding speed has strong effect on fusion area. The focusing position parameter has insignificant effect on the total weld pool size. The model developed can be adequately in predicting the responses within the factors domain.

Pawel Kolodziejczak and Wojciech Kalita [4] (2008) have worked on, Properties of CO_2 laser-welded butt joints of dissimilar magnesium alloys. CO_2 Laser with maximum power of 2.5 kW and scanning velocity from 2.5 to 5 m/min. The work pieces of die-cast alloys AZ91 and AM50 with thicknesses of 4.5 mm have been butt-welded with helium used as a shielding gas. In this study, the analysis of microstructures of the joints and measurements of hardness distribution. The static tensile strength tests and the three point bending tests have allowed determining the mechanical properties of the joints. The corrosion resistance tests performed by the electrochemical method. They concluded that under chosen conditions of welding (laser power: 2 kW, welding rate: 0.067 m/s, helium shielding, the focal position of the beam on the material surface) the joints have very narrow fusion zones with nearly parallel boundaries and they are practically free of pores and cracks. Hardness is achieved 100 HV. Tensile strengths for AM50 joint at fracture is lower and for AZ91 is higher than those for base metal samples. For both alloys the corrosion resistance is relatively low.

M.M.A. Khan, L.Romoli , M.Fiaschi , G.Dini and F.Sarri [5] (2010) have investigated the, Experimental design approach to the process parameter optimization for laser welding of martensitic stainless steels in a constrained overlap configuration. The laser welding of martensitic AISI 416 and AISI 440FSe stainless steels in which outer shell was 0.55 mm thick. A set of mathematical models were developed relating welding parameters to each of the weld characteristics. The quality criteria set for the weld to determine optimal parameters were the minimization of weld width and the maximization of weld Penetration depth, resistance length and shearing force. Laser power and welding speed in the range 855–930 W and 4.50–4.65 m/min, respectively, with a fiber diameter of 300 µm. They concluded that full factorial design can be used to optimize the laser welding process in order to obtain the most desirable weld quality in terms of weld bead geometry and mechanical strength respectively, to obtain stronger and better welds. The optimum setting of welding parameters is laser power of 800–840W and welding speed of 4.75–5.37m/min.

M.J. Torkamany, S. Tahamtan and J. Sabbaghzadeh [6] (2010) have worked on, Dissimilar welding of carbon steel to 5754 aluminum alloy by Nd: YAG pulsed laser. They have investigated the decrease formation of intermetallic components during laser welding, effect of laser power, pulse duration and overlapping factor. Tensile test was performed to identify the effect of each parameter on the weld. The phase composition was characterized by energy dispersive spectrometry and Vickers micro hardness test and microstructure by optical and scanning electronic microscopes. Results obtained show that increasing peak power (in constant pulse energy), pulse duration (in constant peak power) and overlapping factor (in constant pulse energy and peak power) will increase percentage of intermetallic components (PIC). Improvement in the tensile strength was attributed to low values of intermetallic components in weld metal. They have concluded an optimized peak power, pulse duration and overlapping factor (PP = 1.43 kW, D = 5 ms and O_f = 80%) which can produce a joint with low PIC, high quality surface and high tensile strength without any macroscopic defects.

M. Weigl and M. Schmidt [7] (2010) have worked on, Influence of the feed rate and the lateral beam displacement on the joining quality of laser-welded copper-stainless steel connections. In this study the influence of a lateral displacement of the laser beam and the feed rate on the metallurgical properties of the dissimilar materials connection is investigated. The effects of these parameters are selected on the base of metallographic specimen, micro-hardness measurements and element analysis. Experimental researches feed rates between 0 m/min and 30 m/min are used in combination with a fixed laser power of 3.000 W. By applying no lateral beam displacement (centered irradiation) and accordingly 100 µm towards the copper base material, the weld zone becomes more and more symmetrical. In order to reach a maximum of joint surface and thereby also a maximum of tensile strength and conducting cross-section at a fixed energy input per unit length of 12 J/mm, joining geometry and laser system, a laser beam displacement of 100 µm in the direction of the copper base material can be recommended.

Y. Farazila, Y. Miyashita, Wang Hua, Y. Mutoh, Y. Otsuka [8] (2011) have investigated that, YAG laser spot welding of PET and Metallic Materials. In this study, direct joining for dissimilar materials joint between plastic and metallic materials. Experimental result showed polyethylene terephthalate (PET) (0.5 mm t) could be successfully joined to aluminum alloy (A5052) (1 mm t), stainless steel (SUS 304) (2 mm t) and copper (Cu) (1 mm t). Shear tensile test was carried out to evaluate the joining strength. They concluded that Welding conditions were obtained in lower heat input for PET/SUS304 joint compared with the PET/A5052 and PET/Cu joints. In PET/Cu joint, the joining strength was almost constant and joining strength increased in the case of PET/A5052 and PET/SUS304 with increasing heat input. According to the cross-sectional observation of the joint, no molten pool was observed in the case of PET/Cu joint and molten pools could be seen for the PET/A5052 and PET/SUS304 joints. From the result of thermal conductive analysis, heat was rapidly distributed throughout the material for the case of PET/Cu and PET/A5052 joints.

M. Weigla, F. Alberta and M. Schmidta [9] (2011) have worked on, enhancing the ductility of laser-welded copper-aluminum connections by using adapted filler materials. Laser micro welding of direct copper-aluminum connections typically leads to the formation of intermetallic phases and an embrittlement of the metal joints. Adapted filler materials it is possible to reduce the brittle phases and thereby enhance the ductility of these dissimilar connections. As the element silicon features quite a well compatibility with copper and aluminum, filler materials based on Al-Si and Cu-Si alloys are used. Laser power of 2500 W, Pulse duration of 10 ms and Laser wavelength of 1.064 nm. They have concluded that, the Comparing CuSi3 and AlSi12 filler materials, the higher silicon percentage of AlSi12 reduces the viscosity of the fused metal and thereby the element intermixture in the weld spot more than comparable welds with CuSi3.

A. Ruggiero, L.Tricarico, A.G.Olabi and K.Y.Benyounis [10] (2011) have investigated weld-bead profile and costs optimization of the CO_2 dissimilar laser welding process of low carbon steel and austenitic steel AISI316. The effect of laser power (1.1–1.43 kW), welding speed (25– 75 cm/min) and focal point position (- 0.8 to - 0.2 mm) on the weld-bead geometry (i.e. weld-bead area, A; upper width, Wu; lower width, Wl and middle width, Wm) and on the operating cost C was investigated using response surface methodology (RSM). The results indicate that the proposed models predict the responses adequately within the limits of welding parameters being used. They have used regression equations to find optimum welding conditions for the desired geometric criteria. They have concluded that the welding speed is the parameter that most significantly influences the main weld bead dimensions.

A. G. Olabi, F. O. Alsinani, A. A. Alabdulkarim, A. Ruggiero, L. Tricarico, K. Y. Benyounis [11] (2013) have worked on, Optimizing the CO_2 laser welding process for dissimilar materials. A dissimilar full-depth laser-butt welding of low carbon steel and austenitic steel AISI316 was investigated using CW 1.5 kW CO_2 laser. The effect of laser power (1.1-1.43 kW), welding speed (25-75 cm/min) and focal point position (-0.8 to -0.2 mm) 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 a three level Box–Behnken design with 5 centre points; linear and quadratic polynomial equations for predicting the mechanical properties were developed. They have concluded that a laser power value of 1.1 kW is suggested as an optimum input process value to obtain excellent welded joints. Efficient and cheap welds could be achieved using the optimal welding conditions obtained.

Vijay D. Bhujbal and Ashok P. Tadamalle [12] (2013) have worked on, Optimization of laser welding process by fuzzy logic technique. In this work, Laser welding of two dissimilar metals namely Inconel 625 and stainless steel 304L plates has been carried out to attain optimum tensile strength of the weld joint. The process parameters such as laser power P (1200-1400 W), travel speed T (1-2 mm/sec), laser energy E (170-200 Joule/mm^2), and laser current C (155-175 Ampere). They have used Taguchi method based on four factor three levels design. The optimization of the process parameters is carried out by using fuzzy logic technique and the results are compared by regression analysis and ANOVA. They concluded that Regression analysis that current and power are the most significantly affecting parameters. Estimated UTS values are within difference of 6 N/mm^2 and 38 N/mm^2 and Estimated DOP values are within difference of 4 microns for process parameters E, P, T for Inconel 625+SS and SS+SS specimens respectively. It was found that values of parameters namely depth of penetration and ultimate tensile strength obtained from fuzzy logic and regression was in close agreement with each other.

Cosmin Florin GROZA, Dragoş BUZDUGAN and Ion MITELEA [13] (2013) have investigated that, Modelling of Nd-YAG continuously laser welding process of TI-6Al-4V and X5CrNi18-10 using factorial design. In this study, the modelling of the main process parameters of continuously Nd-YAG laser welding using a copper foil with a thickness of 600 µm between the two materials, which solves largely the metallurgical incompatibility. The range of values; the power variation from 3000 to 4000 W, at constant the welding speed, the speed variation within 2 to 3 m/min, at constant power, the focal spot diameter was 200 µm, and the beam was centered at 40 to 60 µm in relation to the copper – stainless steel interface. The protective gas used was argon. They concluded that the optimum value of process parameter that ensure a good quality of welded joints, power 4000 W, welding speed 3 m/min, the position of the laser beam, 40 µm.

B. R. Moharana and S. K. Sahoo [14] (2014) have worked on, An ANN and RSM integrated approach for predict the response in welding of dissimilar metal by pulsed Nd: YAG laser. They have presented work on two dissimilar metals such as copper and AISI 304 stainless steel. Three process parameters such as laser power, welding speed and pulse duration with three levels each. A statistical design of experiment (DOE) technique i.e. Response Surface Methodology (RSM) is adopted for analysis of maximizing the tensile strength. The back propagation artificial neural network (ANN) technique is used to predict the strength of the welded area. The predicted data are compared with the experimental results and is found to be in agreement. They have concluded that Laser power is directly proportional to the strength means increasing in the laser power from 5.8 - 6.2 kW the tensile strength is also increasing. When welding speed increases, the weld strength increases slightly at the optimum level. Again the pulse duration is also directly proportional to strength. Experiments validated that the desired high quality welds can be achieved using the optimal parameters obtained by the RSM design.

III. CONCLUSION

Many researchers have worked on different type of materials with various types of laser. Researchers have used varieties of design of experiment (DOE) technique like as full factorial design, Taguchi method, Box-Behnken design and Response surface methodology and different types of techniques for optimization and prediction model by ANN and neuro fuzzy approach. Some studies conducted on various behaviours like effect of process parameters on different types of material and thickness, weld bead geometry, mechanical properties, heat affected zone (HAZ) of the laser welded joints.

REFERENCES

[1] Rattana Borrisutthekul, Yukio Miyashita and Yoshiharu Mutoh / Dissimilar material laser welding between magnesium alloy AZ31B and aluminum alloy A5052-O / Science and Technology of Advanced Materials 6 (2005) 199–204.

[2] Jose´ Roberto Berrettaa, Wagner de Rossib, Maurı´cio David Martins das Nevesc, Ivan Alves de Almeidab and Nilson Dias Vieira Junior / Pulsed Nd: YAG laser welding of AISI 304 to AISI 420 stainless steels / Optics and Lasers in Engineering 45 (2007) 960–966.

[3] E.M. Anawa, A.G. Olabi / Using Taguchi method to optimize welding pool of dissimilar laser-welded components / Optics & Laser Technology 40 (2008) 379–388.

[4] Pawel Kolodziejczak and Wojciech Kalita (2008) / Properties of CO2 laser-welded butt joints of dissimilar magnesium alloys / journal of materials processing technology 209 (2009) 1122–1128.

[5] M.M.A. Khan, L.Romoli , M.Fiaschi , G.Dini and F.Sarri / Experimental design approach to the process parameter optimization for laser welding of

martensitic stainless steels in a constrained overlap configuration / Optics & Laser Technology 43 (2011) 158–172

[6] M.J.Torkamany, S.Tahamtan and J. Sabbaghzadeh (2010) / Dissimilar welding of carbon steel to 5754 aluminum alloy by Nd: YAG pulsed laser / Materials and Design 31 (2010) 458–465.

[7] M. Weigl and M. Schmidt / Influence of the feed rate and the lateral beam displacement on the joining quality of laser-welded copper-stainless steel connections / Physics Procedia 5 (2010) 53–59.

[8] Y. Farazila, Y. Miyashita, Wang Hua, Y. Mutoh, Y. Otsuka / YAG laser spot welding of PET and Metallic Materials / JLMN-Journal of Laser Micro / Nano engineering Vol. 6, No. 1, 2011.

[9] M. Weigla, F. Alberta and M. Schmidta / Enhancing the ductility of laser-welded copper-aluminum connections by using adapted filler materials / Physics Procedia 12 (2011) 332–338.

[10] A. Ruggiero, L.Tricarico, A.G.Olabi and K.Y.Benyounis / Weld-bead profile and costs optimization of the CO_2 dissimilar laser welding process of low carbon steel and austenitic steel AISI316 / springer publication 2011.

[11] A. G. Olabi, F. O. Alsinani, A. A. Alabdulkarim, A. Ruggiero, L. Tricarico, K. Y. Benyounis / Optimizing the CO2 laser welding process for dissimilar materials / Optics and Lasers in Engineering 51 (2013) 832–839.

[12] Vijay D. Bhujbal and Ashok P. Tadamalle / Optimization of laser welding process by fuzzy logic technique / International Journal of Engineering Science and Innovative Technology (IJESIT) Volume 2, Issue 4, July 2013.

[13] Cosmin Florin GROZA, Dragoş BUZDUGAN and Ion MITELEA / Modelling of Nd-YAG continuously laser welding process of TI-6Al-4V and X5CrNi18-10 using factorial design / 15. - 17. 5. 2013, Brno, Czech Republic, EU.

[14] B. R. Moharana and S. K. Sahoo / An ANN and RSM integrated approach for predict the response in welding of dissimilar metal by pulsed Nd: YAG laser / Universal Journal of Mechanical Engineering 2(5): 169-173, 2014.

