Experimental and Analysis of Butt Weld on Weld Pool Geometry of Aluminium Alloy Plate using Finite Element Method: A Review

Sushil Kumar Maurya[1] Prof. A. K. Jain[2]
[1]Research Scholar [2]Associate Professor
[1,2]Department of Mechanical Engineering
[1,2]Jabalpur Engineering College, Jabalpur (MP), India

Abstract— Gas Tungsten Arc Welding Process is leading in the development in arc welding process which uses a non-consumable Tungsten electrode to produce the weld that increasing higher productivity and good quality [1]. The present investigation highlights Experimental and Analysis of Butt Weld on Weld Pool Geometry of Aluminium Alloy Plate Using Finite Element Method. The welding parameters like welding current, shielding gas flow rate and welding speed play a major role in deciding the joint properties. Welding parameters influence in the mechanical properties. The mechanical properties of welded materials are measured in terms of tensile strength and Brinell hardness using Design of experiment concept; experiments were carried out to predict tensile strength and Brinell hardness of the welded joint. After that temperature distribution and distribution of the stresses in the welded aluminium alloy plate during the welding operation are investigate by finite element method using ANSYS software. In fact, welding of aluminium is one of the biggest challenges to the practicing engineers. At present trend in fabrication industry, it is necessary to have welding because of high reliability, easiness in operation and good surface finishing. This concept can be effectively utilized in the manufacturing of ship building, Pressure vessels, aerospace and transportation equipment such as building of railroad cars, vehicle bodies and missile components.

Key words: GTAW, Aluminium Alloy Plate, Welding Parameter, Welding Joint, Mechanical Properties, FEA, ANSYS

I. INTRODUCTION

Aluminium alloys are light weight structural materials that have been widely used in aviation, aerospace, transportation and other areas for their excellent specific strength and good weldability [4]. In recent years, the applications of aluminium alloy sheets and their welded structures have drawn more and more attention because of their light weight and ease of processing. However, due to rapid heating, the distribution of internal temperature in the weldment with their larger thermal conductivity and lower high-temperature strength often lead to greater stress and deformation of the welded components, which can result in a series of issues such as low intensity, instability of the joint in size and small ductile deformation, thus their further development and applications. With the development of numerical simulation technology, understanding of stresses and deformation has not been dependent solely on the physical measurements. It can be also predicted using finite element simulation methods quickly and accurately[8].At present, the vast majorities of research on the welding numerical simulations are reported to be aiming at MIG welding, but less at the TIG, Particularly at gas tungsten arc welding.

Fig. 1: Aluminium 5083 alloy as base material

Tungsten Inert Gas (TIG) welding is a welding process used for high quality welding of a variety of materials with the coalescence of heat generated by an electric arc established between a non- consumable tungsten electrode and the metal. The process of melting the work piece and filler rod to form a weld results in the formation of fumes and gases. Argon used as shielding gases for better welding because they do not chemically react [2].The inert gas

- Shield the welding area from air, preventing oxidation
- Transfer the heat from electrode to metal
- Helps to start and maintain a stable arc due to low ionization potential

During welding vaporization of alloying elements like magnesium can occur and this vaporization loss of any alloying elements can influence the mechanical properties of the welded joints by affecting the chemistry of the weld pool. Welding parameters such as welding current, gas flow rate and welding speed are taken into account which influences the tensile strength of aluminium alloy joint. Filler wires are continuously feed into weld pool for proper filling the welding seams for good joint. Welding parameters are controlled with electronic control unit.

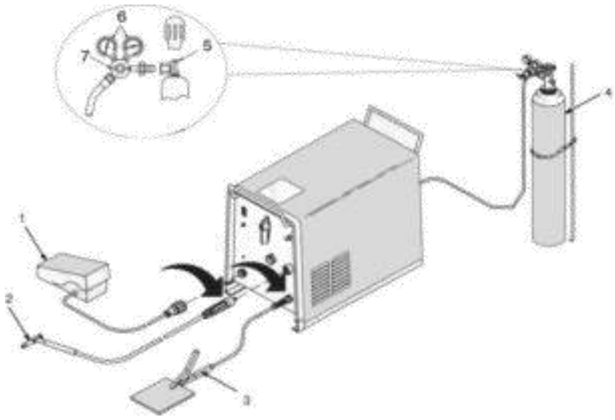


Fig. 2: Schematic Diagram of TIG Welding System.

- Remote control
- Torch
- Work clamp
- Cylinder
- Cylinder valve
- Regulator/Flow gauge
- Flow adjust

AC power supply is preferred for aluminium alloy as compare to DC power supply because aluminium alloy melt at low temperature. The principle of DC power source is to deliver 70% of energy in the form of heat always on positive side but in case of AC power supply, the average of energy output on both terminals will be the same. This is because for one half of wave cycle, positive terminal will have 50% of energy will be on negative terminal. In electrode positive polarity, electrons are moved from base metal to electrode due to strong voltage gradient build up by increased voltage at cathode.

The mechanical properties of Aluminium alloy 5083 is shown in the Table I.

Property	value
Hardness , Brinell	75 HB
Ultimate Tensile Strength	315 Mpa
Proof Stress	125 Mpa
Fatigue Strength	159 Mpa
Elongation at Break	16%

Table 1: Mechanical Properties of Aluminium Alloy 5083

The physical properties of Aluminium alloy 5083 is shown in the Table II.

Property	value
Density	2.65 g/cm^3
Melting Point	570^0C
Thermal Expansion	$25x10^{-6}/K$
Modulus of Elasticity	72GPa
Thermal Conductivity	121 W/m.K
Electrical Resistivity	$0.058x10^{-6}$ Ω .m

Table 2: Physical Properties of Aluminium Alloy 5083

Materials	Al5083	Al5183
Mg	4.45	4.55
Mn	0.7	0.58
Si	0.4	0.1
Fe	0.4	0.27
Zn	0.25	0.06
Cr	0.15	0.11
Ti	0.14	0.11
Cu	0.1	0.01

Table 3: Composition of Base Material and Filler material

II. WELDING PARAMETERS

The parameters that affected the quality and outcomes of the welding process are given below-

A. *Welding Current:*

Higher current in TIG welding can lead to splatter and work piece become damage. Again lower current setting in TIG welding lead to sticking of the filler wire. Sometimes larger heat affected area can be found for lower welding current, as high temperatures need to applied for longer periods of time to deposit the same amount of filling materials. Fixed current mode will vary the voltage in order to maintain a constant arc current.

B. *Shielding Gas Flow Rate:*

The choice of shielding gas is depend on the working metals and effects on the finished weld penetration depth and surface profile, porosity, corrosion resistance, strength, hardness, and brittleness of the weld material. Argon or Helium may be used successfully for TIG welding applications. For welding of extremely thin material pure argon is used.

C. *Welding Speed and Heat Input:*

Welding speed is an important parameter for TIG welding. If the welding speed is increased, power or heat input per unit length of weld is decreases, therefore less weld reinforcement results and penetration of welding decreases. Welding speed is the linear rate at which the arc moves with respect to plate along the weld joint. Welding speed generally conforms to a given combination of welding current and arc voltage. If welding speed is more than required

- Heat input to the joint decreases.
- Less filler metal is deposited than requires, less weld reinforcement.

If welding speed is slow

- Heat input rate increases.
- Weld width increases and reinforcement height also increases more convexity

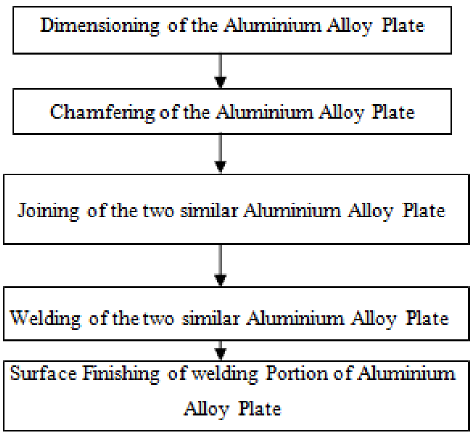
$$\text{Heat Input Rate} = \frac{VxIx60}{v} \quad J/mm$$

V- Arc voltage in volts
I-Welding current in ampere
v-Speed of welding in mm/min.

Welding Parameters	Range
Welding Current	(110-125)A
Arc Voltage	25 V
Welding Speed	(4.65-5.04)mm/min.
Distance of Electrode from work piece	3mm
Shielding Gas Flow Rate	(8-10)L/min.
Current Type	AC
Dimension	200mm*50mm*5mm

Table 4: Welding Parameter of Experiment

III. STEP OF MAKING WORK PIECE



IV. FINITE ELEMENT ANALYSIS

A. *Modeling*

In this work, an aluminium alloy 5083 plate has been modelled as a work piece. The basic thermal analysis performed using ANSYS to determine the temperature distribution and distribution of stresses in the plate, which has a dimension of 200mmX50mmX5mm.

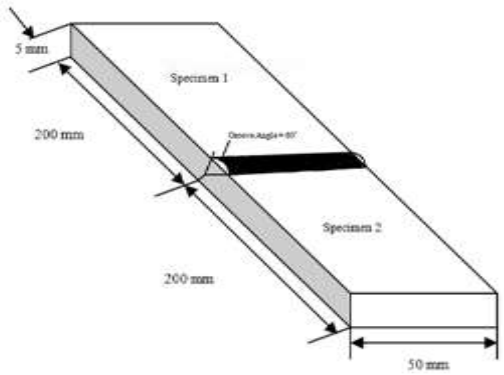


Fig. 3: Geometry of the model

V. LITERATURE REVIEW

The Following literature review describes important research results regarding the welding-

Ji-Kun DING et. al [3] Aluminium alloy joints were fabricated by variable polarity tungsten inert gas welding process and the effects of post weld heat treatment on the tensile properties, microstructure and fatigue behaviour of the welded joints were investigated. TIG welding process was adopted because it could meet the need of cathode cleaning and meanwhile it could reduce the deterioration of tungsten electrode .The welded samples were divided into as welded sample on PWHT sample. The PWHT method used on the samples was solution treatment (535 0C, 30 min), water quenching and artificial aging (175 0C, 12h). The experimental results show that, compared with the AW samples, the microstructure characteristics and mechanical properties of the aluminium alloy joint after PWHT were significantly improved. The improvement of yield strength, Ultimate tensile strength, and fatigue strength are 42.6%, 43.1% and18.4% respectively.

Izzatul Aini Ibrahim et. al [4] Gas metal arc welding (GMAW) process is leading in the development in arc welding process which is higher productivity and good in quality. In this study, the effects of different and good in quality. In this study, the effects of different parameters on welding penetration, micro structural and hardness measurement in mild steel that having the 6mm thickness of base metal by using the robotic gas metal arc welding are investigated. The variables choose in this study is arc voltage, welding current and welding speed. The arc voltage and welding current were chosen as 22, 26 and 30V and 90,150 and 210 A respectively. The welding speed was chosen as 20, 40 and 60 cm/min. The Penetration, microstructure and hardness were measured for each specimen after the welding process and the effect of it was studied as a result, it obvious that increasing the parameters value of welding current increased the value of depth of penetration other than that arc voltage and welding speed is another factor that influenced the value of depth of penetration. The microstructure showed the different grain boundaries of each parameter that affected of the welding parameter.

Syarul Asraf Mohamat et. al [5] Flux core arc welding (FCAW) is an arc welding process that using continuous flux cored filler wire. The flux is used is used as a welding protection from the atmosphere environment. This project is study about the effect of FCAW process an different parameters by using welding robotic welding with the variables in welding current, speed and arc voltage with 6mm thickness is used in this study as a base metal. For all experiment, the welding currents were chosen as 90 A, 150A and 210A and the arc voltage is 22V, 26 V and 30V respectively 20, 40 and 60 cm/min. were chosen for the welding speed. The effect will studied process From the study, the result shown increasing welding current will influenced the value of depth of penetration increased .other than that, the factors that can influence the value of depth of penetration are arc voltage and welding speed.

Her-Yueh Huang et. al [6] The Effect of each welding parameter on the weld bead geometry, and then sets out to determine the optimal process parameters using the Taguchi method to determine the parameters. Three kinds of oxides, Fe2O3, SiO2, and MgCO3, were used to investigate the effect of activating flux aided gas metal arc welding (GMAW) on weld bead geometry, angular distortion and mechanical properties in AISI 1020 carbon steel. During welding, a charge coupled device (CCD) camera system was used to observe and record images of the welding arc and analyze the relationship between penetration increase and arc profile. The experimental results showed that activating flux aided GMAW increased the weld area and penetration and tended to reduce the angular distortion of the weldment. The MgCO3 flux produced the most noticeable effect. Furthermore, the welded joint presented better tensile strength and hardness.

V. Balasubramanian et. al [7] In this investigation , an attempt has been made to refine the fusion zone grains by applying pulsed current welding technique. Rolled plates of 6mm thickness have been used as the base material for preparing single pass welded joints. Single V butt joint configuration has been prepared for joining the plates. The filler metal used has been prepared for joining the plates. The filler metal used for joining the plates is AA5356Al-5Mg (wt %) grade Aluminium Alloy.

Shu Xu et. al [8] The dissimilar welding joints of 45, 0Cr18Ni9 and 1Cr9Mo steel using the different welding metal A302 or Inconel182. The thermal stress numerical simulation is carried out to the dissimilar welding joints. The thermal stresses of dissimilar welding joints generated in the heating to 450 ºC from the ambient temperature for 45/1Cr9Mo and 45/0Cr18Ni9 and 500 ºC for 1Cr9Mo/0Cr18Ni9 are calculated by finite element method. It is shown that large tensile stress is generated in the weld metal, fusion line and heat affected zone (HAZ) when the welding metal is A302, while the compressive or low tensile stress is shown in the HAZ and fusion line of 1Cr9Mo or 45 steel. The maximum circumferential stress is presented in 1Cr9Mo or 45 steel, while the large compressive or low tensile stress is shown in 0Cr18Ni9. The stress is decreased when the A302 is changed to Inconel182. It is concluded that the replacement of A302 by Inconel182 can decrease the thermal stress and increase the life of the welding joint.

M Jeyakumar et. al [9] Thermo-mechanical finite element analysis has been performed to assess the residual stress in the butt-weld joints of 2.25Cr1Mo low-alloy-ferrite steel plates and ASTM36 steel plates utilizing the commercial software package ANSYS, employing 2D plane stress models. Temperature dependant properties of the materials are specified. The radial heat flux distribution is considered on the top surface of the weldment. Convective and radiative heat losses are taken into account through boundary conditions for the outward flux. The present 2D plane stress analysis results are found to be in good agreement with existing 3D finite element analysis and experimental results. 2D welding simulations are not only reducing the complexity of the problem, but also providing the nature of residual stress in weldment with reasonable accuracy.

P. Naghinazhad Ahmadi et. al [10] In this study finite element analysis of residual stresses in two dissimilar plates was performed with the commercial software ANSYS, which includes moving heat source, material deposit, temperature dependent material properties, metal plasticity and elasticity, transient heat transfer and mechanical analysis. In first stage of study, after determining suitable filler wire for safely joining of austenitic stainless steel to carbon steel by Shaeffler's diagram , a macro in ANSYS Parametric Design Language (APDL) was generated and the developed procedure applied in butt-welding of similar plates, and the results were compared with experimental result of researchers and then, the method implemented in welding simulation of dissimilar plates and residual stresses magnitude and distribution in longitudinal and transverse directions were obtained. A sequentially coupled thermo-mechanical analysis, element birth and death technique and Von Mises yield criterion and Bilinear Isotropic Hardening (BISO) rule were implemented in this analysis.

Salawadagi Sushant S. et. al [11] In this paper the effect of welding parameters like welding current, welding voltage, welding speed and weld plate angle of residual stresses generated in mild steel plates during welding. In this paper experimental verification of temperature distribution by FEM is carried out, the verified methodology is used for parametric optimization for minimum residual stress.

Binnur Goren Kiralet. al [12] This study aims to model friction stir welding of the aluminium alloys using the finite element method. For this purpose, transient thermal finite element analyses are performed in order to obtain the temperature distribution in the welded aluminium plate during the welding operation. Heat input from the tool shoulder and the tool pin are considered in the finite element model. A moving heat source with a heat distribution simulating the heat generated from the friction between the tool shoulder and the work piece is used in the heat transfer analysis. Three dimensional models are carried out by using ANSYS and Hyperxtrude commercial software. APDL (ANSYS Parametric Design Language) code is developed to model moving heat source and change boundary conditions.

VI. CONCLUSION

From the above literature survey we find that there are many researches done on experimental and numerical investigation of Butt welding. But it is found that welding of aluminium is a big challenge by conventional arc welding process. There are very few researches done on Aluminium alloy so we want to do research on this material. Welding depend on its control on welding current and other parameters. Welding of the Aluminium alloy plate by changing the welding current and welding speed to get a high strength joint. Effect of welding speed and applied current on the tensile strength of weld joint and hardness of the weld pool. After that finite element analysis for temperature distribution and distribution of the stresses in the welded Aluminium alloy plate.

REFERENCES

[1] en.wikipedia.org/wiki/GTAW
[2] OP Kanna, A text book of welding technology, Dhanpat Rai Publications Ltd, 2006, P3.
[3] Ji-Kun DING, dong POWANG, Ying wang, Hui DU. Effect of post weld heat treatment on properties of variable polarity TIG welded AA2219 aluminium alloy joints. Science Direct 24 (2014) 1307-1306.
[4] Izzatul Aini Ibrahim, Amalina Amir, Abdul Ghalib. The effect of Gas metal arc welding (GMAW) Processes on different welding parameters. Sciverse Science Direct 41(2012)1502-1506.
[5] Syarul Asraf Mohamat, Izatul Aini Ibrahim, Amalina Amir. The effect of Flux Core Arc Welding (FCAW) processes on different parameters. Sciverse Science Direct 41(2012) 1497-1501.
[6] Her-Yueh Huang. Effects of activating flux on the welded joint characteristics in gas metal arc welding. Materials and Design 31 (2010) 2488–2495.
[7] V. Balasubramanian, V. Ravisankar, G. Madhusudhan Reddy. Effect of pulsed current welding on fatigue behaviour of high strength aluminium alloy joints. Science Direct 29 (2008) 492–500.
[8] Shu Xu. Thermal Stress Analysis of dissimilar welding joints by Finite Element Method. Sciverse Science Direct 15 (2011) 3860 – 3864.
[9] M Jeyakumar, T Christopher, R Narayanan & B Nageswara Rao. Residual stress evaluation in butt-welded steel plates. Indian journal of Engineering & material sciences. Vol.18, December 2011, PP. 425-438.
[10] A. Mostafapour Asl, S. Nadimi B. Oliaei and P. Naghinazhad Ahmadi. Investigation and analysis of weld induced residual stresses in two dissimilar plates by finite element modelling.IJAEA, Volume 2, Issue 3, PP. 1-9(2009).
[11] Salawadagi Sushant S. & Kumbhar S. B. Parametric Optimization of Butt Weld for Minimum Residual Stress. International Journal on Mechanical Engineering and Robotics (IJMER) ISSN (Print): 2321-5747, Volume-1, Issue-2, 2013.
[12] Binnur Goren Kıral1, Mustafa Tabanoglu, H. Tarik Serindag.Finite Element Modeling of Friction Stir Welding in Aluminium Alloys Joint. Mathematical and Computational Applications, Vol. 18, No. 2, pp.122-131, 2013.
[13] Aniruddha Ghosh, Somnath Chattopadhyaya, R.K.Das. Effect of Heat input on Submerged Arc Welded Plates Science Direct 10 (2011) 2791–2796.
[14] Mukesh, Sanjeev Sharma. Effect of Parameters on Weld Pool Geometry in 202 Stainless Steel Welded Joint Using Tungsten Inert Gas (TIG) Process. International Journal of Science and Modern Engineering (IJISME) ISSN: Volume-1, Issue-12, November 2013.
[15] S. Senthil Kumar*, S. Denis Ashok, S. Narayanan. Investigation of Friction Stir Butt Welded Aluminium

Alloy Flat Plates using Spindle Motor Current Monitoring Method. Science Direct 64 (2013) 915 – 925.

[16] M. Zubairuddin, S. K. Albert, V. Chaudhari, V. K. Suri. Influence of phase transformation on thermo-mechanical analysis of mechanical analysis of modified 9Cr-1Mo Steel. Science Direct 5(2014)832-840.

[17] G. I. Mahiskar, R. B. Chadge, S. P. Ambade, A. P. Patil. Thermo-mechanical analysis of multi-pass bead-on-plate welding. Science Direct 5(2014)2522-2531.

[18] K.C. Ganesh, M. Vasudevan, K.R. Balasubramanian, N. Chandrasekhar. Modeling, Prediction and Validation of Thermal Cycles, Residual Stresses and Distortion in type 316 LN Stainless Steel Weld Joint made by TIG Welding Process. Science Direct 86 (2014) 767 – 774.

[19] Harinadh Vemanaboina, Suresh Akella and Ramesh Kumar Buddu. Welding Process Simulation Model For Temperature and Residual Stress Analysis. Science Direct 6 (2014) 1539 – 1546.

[20] K. Suresh Kumar. Analytical Modeling of Temperature Distribution, Peak Temperature, Cooling Rate and Thermal Cycles in a Solid Work Piece Welded By Laser Welding Process. Science Direct 6 (2014) 821 – 834.

[21] K. Abburi Venkata, S. Kumar, H. C. Dey, D. J. Smith. Study on the Effect of Post Weld Heat Treatment Parameters on the Relaxation of Welding Residual Stresses in Electron Beam Welded P91 Steel Plates. Science Direct 86 (2014) 223 – 233.

[22] Daniel Ramos-Jaime, Ismael Lopez Juarez, Pedro Perez. Effect of process parameters on robotic GMAW bead area estimation. Science Direct 7 (2013) 398 – 405.

[23] Gurinder Singh Brar. Finite Element Simulation of Residual Stresses in Butt Welding of Two AISI 304 Stainless Steel Plates. International Journal on Theoretical and Applied Research in Mechanical Engineering (IJTARME) ISSN: 2319 – 3182, Volume-2, Issue-1, 2013.

[24] Nuraini, Azmah Hanim. The Effect of Welding Process Parameter on Temperature and Residual Stress in Butt-Joint Weld of Robotic Gas Metal Arc Welding. Australian Journal of Basic and Applied Sciences, 7(7): 814-820, 2013 ISSN 1991-8178.

[25] S. Dinesh Kumar. Finite element analysis of butt welded joints under cyclic loading. Discovery, Volume 23, Number 78, September 4, 2014.