International Journal of Advanced Information Science and Technology (IJAIST) ISSN: 2319:2682
Vol.3, No.9, September 2014 DOI:10.15693/ijaist/2014.v3i9.104-108

A Review on Friction Stir Weldment of AA6061 and AA1100 Aluminium Alloys

P. Raj Kumar
ME scholar/Department of MECH
SNS College of Engineering, Coimbatore, India

R.Govind Raj
Assistant Professors/Department MECH
SNS College of Engineering, Coimbatore, India

***Abstract*— Friction stir welding (FSW) is a relatively new solid-state joining process. This joining technique is energy efficient, environment friendly, and versatile. FSW of aluminium alloys have the potential to hold good mechanical and metallurgical properties. The FSW process and tool parameters play a major role in deciding the joint strength. This review reveals with important friction stir welding process parameters involved in weldment of AA6061 and AA1100 aluminium alloy and the optimality of the friction stir welding parameters that is achieved by Taguchi techniques have been discussed. In addition, ANOVA analysis on the L9 orthogonal array with three factors is performed to find the optimality of welding parameters on rotational speed, axial force and transverse speed are being discussed.**

Index terms -Aluminium alloys, Friction stir welding (FSW), orthogonal array, ANOVA, Optimization, Process parameters

I. INTRODUCTION

A. Introduction to Friction stir welding

Friction Stir Welding (FSW), a solid state joining method developed and patented by TWI Ltd., Cambridge, UK in 1991 [12], FSW involves the joining of metals without fusion or filler materials and is derived from conventional friction welding.

The basic concept behind FSW is simple: A non-consumable rotating tool with a specially designed Pin and shoulder is inserted into the abutting edges of the two parts to be joined and traversed along the line of joint. FSW offers an efficient solution to this challenging task since the joining takes place much below the melting temperatures and results in less distortion, lower residual stresses and fewer defects. Joining of dissimilar aluminum alloys is gaining research importance by FSW. The effect of some important process parameters such as rotational speed, Transverse speed and axial force on weld properties is major topics for researchers [7]. In order to study the effect of FSW process parameters, most workers follow the traditional experimental techniques, i.e. varying one parameter at a time while keeping other parameters as constant. Taguchi statistical design is a power full tool to identify significant factor from many by conducting relatively less number experiments. Taguchi's L9 method is adopted to analyze the effect of each processing parameters.

FSW of two dissimilar AA6061 and AA1100 aluminum alloy have been studied and their important process parameters that are influenced on FSW of Aluminium alloy have been discussed. And optimization method by using Taguchi's method of optimization integrated has been discussed. In this study rotational speed, welding speed, axial force is only considered as important process parameters in welding above dissimilar aluminium alloy. In welding the above AA6061 and AA1100 aluminum alloy the important parameters considered for forming design matrix of L9 orthogonal array is rotational speed, welding speed and axial force.

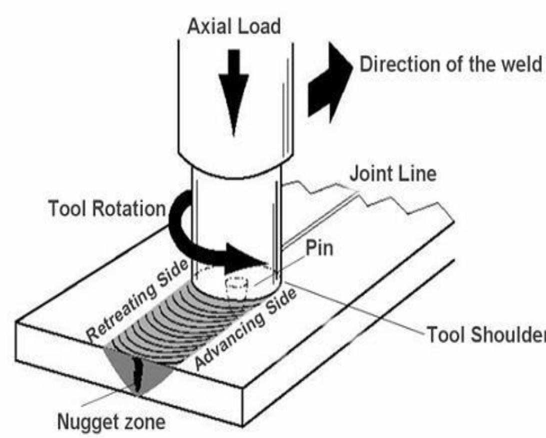

Figure 1.Schematic view of Friction Stir Welding.

B. Important process parameters in FSW:

The FSW tool primarily serves two functions: a) heating the work piece, b) flowing the material to produce the joints. A detailed list of parameters controlling this joining process is given in [3] as follows:

1) Rotational speed (rpm)
2) Welding speed (mm/s)
3) Axial force (KN)
4) Tool geometry
   i) Pin length (mm)
   ii) Tool shoulder diameter, D (mm)
   iii) Pin diameter, d (mm)
   iv) Tool tilt angle (◦)
   v) D/d ratio of the tool

Among the above parameters the important process parameters contributed in friction stir welding process is rotational speed, welding speed and axial force.The percentage

International Journal of Advanced Information Science and Technology (IJAIST) ISSN: 2319:2682
Vol.3, No.9, September 2014 DOI:10.15693/ijaist/2014.v3i9.104-108

of contribution of the rotational speed, welding speed and axial force is shown in the Fig 2.

.

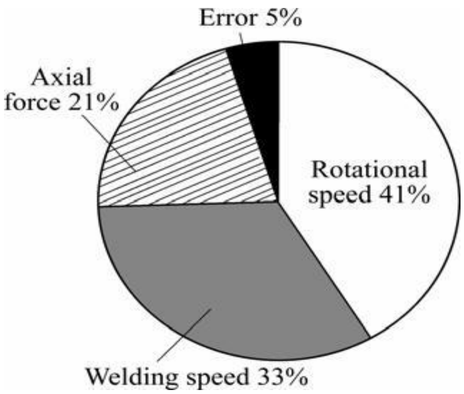

Figure 2. Percentage of parameter contribution factors in FSW

II. RELATED WORK ON FRICTION STIR WELDING OF ALUMINIUM ALLOYS

Rajakumar et.al [10] investigated the sensitivity analysis of friction stir welding process and tool parameters for joining AA1100 aluminium alloy. Lakshminarayanan et.al [7] has discussed various influencing parameters on friction stir welding of RDE-40 Aluminium alloy using Taguchi method.

Saurab Kumar Guptha et.al [9] proposed a methodology to improve the tensile strength of AA6061-T4 aluminium alloy. The author has used Taguchi method to optimize the process parameters. The important process parameters taken in account are rotational speed, welding speed, axial load, for developing design matrix.

ShanmugaSundaram et.al [8] made a systematic study on friction stir welding of AA2024 & AA5083 aluminium alloy and they have optimized process parameters using Taguchi method. L31 orthogonal array was choosen for this study by considering the control factor and their interactions. Through ANOVA the tool rotational speed, Welding speed and axial force are most influencing parameters in deciding the tensile strength of the joint.

Rajamanickam et al. [15] investigated the statistical significance of process parameters such as tool rotation andweld speed on thermal history and Mechanical properties of aluminum alloy AA2014. From analysis of tensile property data of joints, it was concluded that the weld speed was the main input parameter that had the highest statistical influence on tensile properties.

Cavaliere et al. [17] investigated the effect of processing parameters on the mechanical and metallurgical properties of dissimilar AA6082-AA2024 joints produced by friction stirwelding. The joints were produced with different alloypositioned on the advancing side of the tool. The joints were realized with a rotation speed of 1600rpm and by changing the advancing speed from 80 to 115mm/min. It was reported thatthe highest value of micro hardness were reached in the case of dissimilar AA2024-AA6082 when the 2024 alloy was on theadvancing side of the tool and the welding speed was 115mm/min. When 6082 alloy was employed on the advancing side of the tool, the micro hardness profile in the weld nugget appeared more uniform, indicating a better mixing of the material.

Eazhil KM et al. [20] have discussed about Tungsten inert gas welding of AA6063 aluminum alloy using Taguchi method by conducting L27 orthogonal array they have optimized the parameters of TIG welding and improved the Mechanical properties weldments. Koilraj *et al* [14] optimized FSW process with respect tensile strength of the welds and the optimum settings. Furthermore, the optimum values of the rotational speed, transverse speed, and D/d ratio are 700 rpm, 15 mm/min and 3respectively. In addition, they concluded that the cylindrical threaded pin tool profile was the best among the other tool profiles considered.

Hatamleh and DeWald [24] joined AA 2195 and AA 7075 and investigated the peening effect on the residual stresses of the produced welds. Results showed that the surface residual stresses resulting from shot peening on both
The dissimilar combination of aluminum alloy is used in man
AA 2195 and AA 7075 were higher compared to the laser peening due to the high amount of cold work exhibited on the surface from shot peening. Furthermore, high values of tensile stresses were noticed in the mid-thickness on the laser peened samples.

Syed Azam Pasha Quadri (2010) [11] attempt is made to determine and evaluate the influence of the process parameters of FSW on the weldments. The Vickers hardness, tensile strength and radiography are considered for investigation by varying tool speed, tool feed and maintaining constant depth of penetration of weld. Experiments were conducted on AA6351 Aluminium alloy in a CNC Vertical Machining Centre. The output factors are measured in UTM,Vickers hardness tester and Radiography equipment. Results show strong relation and robust comparison between the weldment strength and process parameters and selection of optimum process parameters for efficient weld.

The recent literature dissimilar welding of aluminium alloy have been studied, this study mainly focus towards Taguchi’s integrated ANOVA analysis of AA6061 and AA1100 dissimilar aluminium alloy.

III. OVERVIEW OF THE TAGUCHI METHODOLOGY

A. Taguchi method:

Taguchi method is efficient problem solving tool, which can upgrade/improve the performance of the product, process, design and system with a significant slash in experimental time and cost [6].This method that combines the experimental design theory and quality loss function concept has been applied for carrying out robust design of processes and products and solving several complex problems in manufacturing industries. Further, this technique determines the most influential parameters in the overall performance. The optimum process parameters obtained from the Taguchi

International Journal of Advanced Information Science and Technology (IJAIST) ISSN: 2319:2682
Vol.3, No.9, September 2014 DOI:10.15693/ijaist/2014.v3i9.104-108

method are insensitive to the variation in environmental condition and other noise factors. The number of experiments increases with the increase of process parameters. To solve this complexity, the Taguchi method uses a special design of orthogonal array to study the entire process parameters space with a small number of experiments only. Taguchi defines three categories of quality characteristics in analysis of (Signal/ Noise) ratio, i.e. the lower the better, the larger the better and nominal the better. The S/N ratio for each process parameters is computed based on S/N ratio analysis. Regardless of the category of the quality characteristics, a larger S/N ratio corresponds to better quality characteristics. Therefore, the optimal level of process parameter is the level of highest S/N ratio. Furthermore, a statistical analysis of variance (ANOVA) can be performed to see which process parameter is statistically significant for each quality characteristics.

The following are the steps to be followed for process parameter optimization [11].

- Step 1: Determine the quality characteristic to be optimized.
- Step 2: Identify the noise factors and test conditions.
- Step 3: Identify the control factors and their alternative levels.
- Step 4: Design the matrix experiment and define the data analysis procedure.
- Step 5: Conduct the matrix experiment.
- Step 6: Analyze the data and determine optimum levels for control factors.
- Step 7: Predict the performance at these levels.

B. Selection of Orthogonal Array (OA)

Before selecting a particular OA to be used as a matrix for conducting the experiments, the following two points must be considered: 1) The number of parameters and interactions of interest; 2) The number of levels for the parameters of interest.

The non-linear behavior, if exists among the process parameters, can only be studied if more than two levels of the parameters are used. Therefore, each parameter was analyzed at three levels. To limit the study, it was decided not to study the second order interaction among the parameters. Each three level parameter has 2 degrees of freedom (DOF=numberoflevels−1), the total DOF required for 3 parameters each at three levels is 6(=3× (3−1)).As per Taguchi’s method, the total DOF of selected OA must be greater than or equal to the total DOF required for the experiment. So an L9 OA having 8(=9−1) degrees of freedom were used for this methodology.

IV. PHYSICAL AND CHEMICAL PROPERTIES OF AA6061 AND AA1100 ALUMINIUM ALLOYS:

Aluminum alloys are designated based on international standards. These alloys are distinguished by a four digit number which is followed by a temper designation code. The first digit corresponds to the principle alloying constituent. The second digit corresponds to variations of the initial alloy. The third and fourth digits correspond to individual alloy variations. Code corresponds to different the chemical composition and Mechanical propertiesaregiveninTable-1.andphysical propertiesaregivenin Tables2.

Chemical compositionand Mechanical properties of AA6061 Aluminium alloy are summarized intable 1.

Chemical composition (wt. %)	
Mg	0.9
Si	0.62
Fe	0.33
Cu	0.28
Cr	0.17
Mn	0.06
Zn	0.02
Ti	0.02
Al	Balance
Mechanical properties	
Yield strength (MPa)	302
Ultimate strength (MPa)	334
Elongation (%)	18

Physical properties of AA6061 Aluminium alloy are summarized intable 2.

Density (g/cm^3)	2.7
Melting point(ºC)	580
Modulusof Elasticity(GPa)	70-80
Poisonratio	0.33

AA1100 alloy is commercially pure aluminum with excellent forming characteristics. This alloy has very good machinability. Best results are obtained when machining is done with the alloy in hard temper. Systematic studies have been performed on the dissimilar friction stir welding, and the relationship between the various welding parameters and the resulting weld properties have not been identified.

Dissimilar welding of aluminium alloy are core demand of the aircraft industries to substitute the traditional joining technologies with low costs and high efficiency ones such as friction stir welding in the future advanced design[2].Thechemical composition and Mechanical properties of AA1100 aluminium alloy is given inTable-3.and physical properties are given in Tables4

Chemical compositionand Mechanical properties of AA1100Aluminium alloy are summarized table 3.

Chemical composition (wt. %)	
Mg	0.015
Si	0.125

Fe	0.508
Cu	0.061
Cr	0.006
Mn	0.004
Zn	0.0016
Al	Balance
Mechanical properties	
Yield strength (MPa)	105
Ultimate strength (MPa)	110
Elongation (%)	27

Physical properties of AA1100Aluminium alloy are summarized in table 4.

Density (g/cm^3)	2.71
Melting point(ºC)	660
Modulusof Elasticity(GPa)	70-79
Poisonratio	0.34

V. PROCESS FLOW CHART FOR SCHEME OF INVESTIGATION

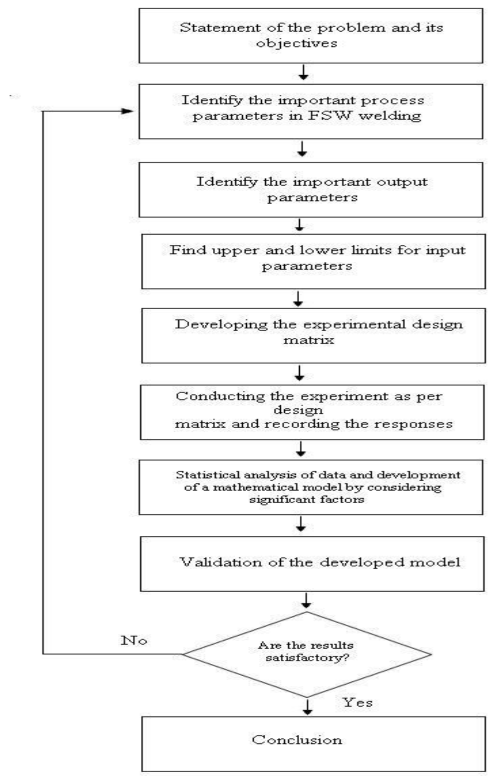

Figure 3.Steps involved in scheme of investigation

VI. CONCLUSION AND FUTURE WORK

Friction stir welding of AA6061 and AA1100 using Taguchi method is mainly done for commercialization of joints between aluminium alloys. This work mainly focuses on the most influencing parameters that are involved in the friction stir welding of Aluminium alloy. Aircraft industries are mostly in the need of optimal function of dissimilar Aluminium alloy.

In summary the review on friction stir welding of dissimilar Aluminium alloy using Taguchi analysis is successfully conducted. This will provide comprehensive insight to the research who are try to find new combination of aluminium alloys. Further new studies and new combination of aluminium alloy and optimization of Friction stir welding parameters for good weldment still need to be developed.

REFERENCES

[1] Elatharasan, V.S.Senthilkumar, An Experimental Analysis and optimization of process parameters of Friction Stir Welding of AA 6061 – T6 Aluminium alloy using RSM.ICONDM 2013, Vol 64, 2013.

[2] Cavaliere P, Cerri E, SquillanceA.Mechanical response of 2024-7075 aluminium alloys joined by friction stir welding.J Mater sci 2005; 40:3669-76.

[3] Leitao C, Chaparro BM, Rodrigues DM. Formability of similar and dissimilar friction stir welded AA5182-H111 and AA6061-T4 tailored blanks. Mater Des 2009; 30:3235-42.

[4] Lakshminarayanan AK, Balasubramanian V, Elangovan K. Effect of welding process on tensile properties of AA6061 aluminium alloy joints. Int J AdvManuf Technology 2007:1-11

[5] MONTGOMERY D C. Design and analysis of experiments [M] .IV Edison NY: John-Wiley & Sons, Inc, 2006

[6] ROSS P J. Taguchi techniques for quality engineering [M]. NY Tata McGraw Hill, 1988

[7] Lakshminarayanan AK, Balasubramanian V. Process parameters optimization for friction stir welding of RDE-40 aluminium alloy using Taguchi technique Trans.Nonferrous Met. Soc. China 18(2008) 548-554.

[8] ShanmugaSundaram N, Murugan N, Tensile behavior of dissimilar friction stir welded joints of aluminium alloys. Materials and Design 31(2010) 4184-4193.

[9] Saurabh Kumar Gupta, Pandey K.N, Appilication of Taguchi Method for Optimization of Friction Stir Welding Process Parameters to Joining of Al alloy Advanced Material Manuf& characterization Vol3 Issue I (2013) .

[10] Rajakumaret.al Optimization and sensitivity analysis of friction stir welding process and tool parameters for joining AA1100 aluminium alloy Int. J. Microstructure and Materials Properties, Vol. 6, Nos. 1/2, 2011.

[11] Datta S, Bandyaopadhyay A, Pal PK. Application of Taguchi philosophy for parametric optimization of bead geometry and HAZ width in submerged arc welding using a mixture of fresh flux and fused flux. Int J AdvManufTechnol 2008; 36:689–98.

[12] Xiancong He et.al, A review of numerical analysis of friction stir welding Progress in Materials Science 65 (2014) 1–66.

[13] Sadeesh P, VenkateshKannan M et.al, Studies on friction stir welding of AA2024 and AA6061 aluminium alloy.Procedia Engineering 75 (2014) 145 – 149.

[14] Koilraj, M., Sundareswaran, V., Vijayan, S., &Rao, S. R. K. Friction stir welding of dissimilar aluminum alloys AA2219 to AA5083 – Optimization of process parameters using Taguchi technique. Materials and Design 2012; 42:1–7.

[15] N. Rajamanickam, V. Balusamy, M. G. Reddy, and K. Natarajan "Effect of process parameters on thermal history and mechanical properties of friction stir welds," *Materials and Design*, vol. 30, pp. 2726-2731, 2009.

[16] S. Malarvizhi, and V. Balasubramaniam, "Effect of welding processes on AA2219 aluminium alloy joint properties," Trans. Nonferrous Met. Soc. China, vol. 21, pp. 962-973, 2011.

[17] P. Cavaliere, D. A. Santis, F. Panella, and A. Squillace, "Effect of welding parameters on mechanical and microstructural properties of dissimilar AA6082-AA2024 joints produced by friction stir welding,"Materials and Design, vol. 30, pp. 609-616, 2009.

[18] Montgomery DC. Design and analysis of experiments. 5th Ed. New York: JohnWiley and Sons; 2001.

[19] ShanmugaSundaram N, Murugan N. Dependence of ultimate tensile strength of friction stir welded AA2024-T6 aluminium alloy on friction stir welding process parameters. IntSci J Mechanika 2009; 78(4):17–24.

[20] Eazhil KM et.al, Optimization of Tungsten inert gas welding on 6063 Aluminium alloy on Taguchi method.Int J of Research and Scientific innovations volume 1 Issue 3, Aug 2014 ISSN 2321 – 2705.

[21] Shigematsu I, Kwon YJ, Suzuki K, Imai T, Satio N. Joining of 5083 and 6061 aluminum alloys by friction stir welding. J Mater SciLett 2003; 22:353–6.

[22] Vijayan S, Raju R, Rao SRK. Multi-objective optimization of friction stir welding process parameters on aluminum alloy AA 5083 using Taguchi based grey relation analysis. Accept Mater ManufProcess 2010; 25(11):1206–12.

[23] J Yoganand et.al, Optimization of GMAW Process Parameters in Austenitic Stainless Steel Cladding Using Genetic Algorithm Based Computational Models Experimental Techniques (2012) © 2012, Society for Experimental Mechanicsdoi:10.1111/j.1747-1567.2011.00803.x.

[24] Omar Hatamleh, Adrian DeWald, "An investigation of the peening effects on the residual stresses in friction stir welded 2195 and 7075aluminum alloy joints", Journal of Materials Processing Technology 209(2009), pp. 4822–4829.

[25] Ahmed Khalid Hussain, Syed Azam Pasha Quadri "Evaluation of parameters of friction stir welding for aluminium AA6351 alloy International Journal of Engineering Science and Technology Vol. 2(10), 2010, 5977-5984.

Authors Profile

P.Raj Kumar received the **B.E.** degree in Mechanical engineering from the Adithya Institute of Technology, Coimbatore, Anna University, Chennai, India, in 2013.Currently doing his **M.E.** in Manufacturing Engineering in SNS College of Engineering, Coimbatore, India. His research interest includes Welding (Friction Stir Welding, Ultrasonic Welding), Lean Manufacturing, Tribology and Surface Engineering.

R.Govind Raj received the **B.E.** degree in Mechanical engineering from the Sri Ramakrishna Institute of Technology, Coimbatore, Anna University, Chennai, India, in 2010.He completed his **M.E.** in Engineering Design, from Maharaja College of Engineering, Coimbatore, India. His research interest includes Welding Technology, Lean Manufacturing, Surface Engineering.