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A review on Effect of Friction Stir Welding Parameters on Mechanical and Metallurgical Properties.

KEYWORDS: Friction Stir Welding, Microstructure, Mechanical Properties, Metallurgical Properties, Rotation and Welding Speed, Tool Pin and Shoulder profile

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ABSTRACT Manufacturing organizations are currently encountering a necessity to respond to rapidly changing customer needs, desires and fluctuating market demand. Markets are affected by diverse customer needs, which demand higher quality, shorter delivery time, higher customer service level and lower prices. Many organizations have realized the need to improve the quality of products & services to compete successfully. To compete in this dynamic environment, these organizations must have to develop new methodologies allowing them to remain competitive and flexible simultaneously so that they can respond to the new demands. Process improvement becomes obligatory to gauge as well as improvise the current manufacturing scenario and hence advent of kaizen automation plays a chief role. This study is focusing on development of low cost automation system by using a lean tool, Kaizen: Continuous Improvement. In Japanese kaizen is for continuous automated improvement designed to eliminate waste on resources of manufacturing system i.e. machinery, material, worker and production methods. Here we will see that how a low cost automation in manufacturing industry can be useful for productivity improvement, fatigue reduction and reduce the chances of injury.

I. INTRODUCTION

Friction Stir Welding a solid state welding process invented at The Welding Institute (TWI) in 1991 by Cambridge, UK. By Wayne Thomas et al.[3] Friction stir welding join two or more parts in solid state[1] as it is join by different friction welding techniques which have been in existence since 1950. Friction stir welding is focused worldwide since its inception because of its numerous advantages over conventional joining process.

Different welding parameters like tool rotation speed, tool traverse speed, tool pin profile, tool shoulder diameter, tool tilt angle, tool offset, welding environment etc. plays major role in mechanical and metallurgical properties of FSWed joints.

II Principle of Friction Stir Welding

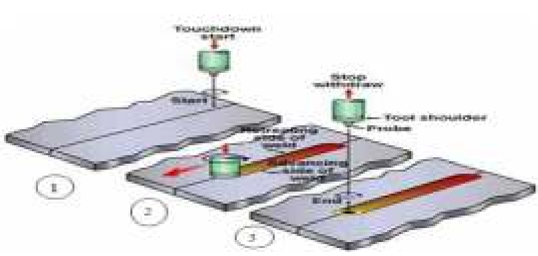

Figure: 1 Friction Stir Welding Process [26]

III Flow of Material & Microstructure study of FSW [27]

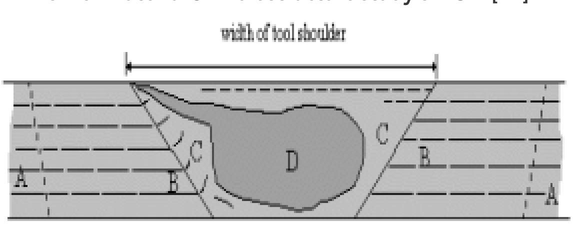

Figure: 2 Microstructural study of Plate [27]

- Unaffected Material or Parent Metal – This is a zone which is a remote place from weld, which has not been deformed, and which is not affected by heat in terms of microstructure or mechanical properties.
- Heat affected zone(HAZ)- This region lie closer to the weld centre which experiences a thermal cycle that modifies the microstructure and/or mechanical properties. However, there is no plastic deformation occurring in this area. In the previous system, this was referred to as the "thermally affected zone". The term heat affected zone is now preferred, as this is a direct parallel with the heat affected zone in other thermal processes, and there is little justification for a separate name.
- Thermo-Mechanically Affected Zone (TMAZ)- In this region, the material has been plastically deformed by the friction stir welding tool, and the heat from the process will also have exerted some influence on the material.
- Weld Nugget- The recrystallised area in the TMAZ in aluminum alloys has traditionally been called the nugget.

IV FSW PARAMETERS

➢ **Welding Forces during the process**

Forces like a download force, traverse force and a lateral force may act on the tool required in order to achieve the best welding cycle.

➢ **Design of The tool**

It is necessary that the tool is strong enough throughout the weld temperature. Hence various tool designs have been proposed in the past years for better weld quality and tool life.

➢ **Angle of Tool Tilt and Plunge Depth**

The angle of tilt around 2-4 degrees is usually adopted in various FSW processes.

➢ **Tool Traverse and Rotational speeds**

From various studies it has been concluded that by increasing the rotation speed of the tool and decreasing the traverse speed of the tool the temperature in the weld region increases.

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- **Tool pin offset**

It is offset between tool rotation axis and joint line of welded piece.

V Review of Literatures

Muhsin J.J. et al.[1], Ahmed Khalid Hussain [8], A.K. Lakshinarayan [13], Zhaohua Zhang et al. [23], P. Cavaliere et al. [25] have investigated effect of tool rotation and welding speed (traverse speed) on the mechanical and microstructural properties.

Muhsin J.J. et al [1] made friction stir welded samples of 7020-T53 aluminum alloys with 5 mm thickness. They fabricated FSW tool from a tool steel labeled as X12M. The tool had concaved shoulder (2°) and tool pin profile was cylindrical with right hand threads of 1 mm pitch and height of tool pin 4.7 mm slightly less than sample thickness. The shoulder and pin diameters of tool was 18 mm and 6 mm respectively. They had used K-type thermocouple of 1.5 mm diameter to measure temperature of welded samples at various locations. Four tool rotation speeds were taken of value 710 rpm, 900 rpm, 1120 rpm and 1400 rpm. Two tool traverse speed were taken of value 40 mm/min and 16 mm/min. finite element analysis was also carried out to know temperature distribution. They found that axial load decreases with increase in rotational speed because that decreases strength due to temperature increases in penetration. They also conclude by numerical results that temperature at weld zone increases with increase in tool rotation speed but decrease with increase in traverse (welding) speed.

Ahmed Khalid Hussain [8] performed friction stir welding on CNC vertical milling machine for AA6351 aluminum alloys by tool made up of high speed steel (Wc-Co). Four tool rotation speed were taken of values 770, 900, 1150 and 1350 rpm. Four tool travel speed (welding speed) were taken of values 75, 90, 108 and 115 mm/min. Friction Stir Welding was performed in double side welded condition. They observed that tensile strength increases with increase in rotation speed. It was also found by them that tensile strength was higher at lower welding speed. They have performed tensile, hardness and radiography tests.

A.K. Lakshinarayan [13] investigated effect of tool rotation speed, tool travel speed (welding speed) and axial force on RDE 40 aluminum alloy by Taguchi method. Cause and effect diagram which affect weld quality was also take in account.

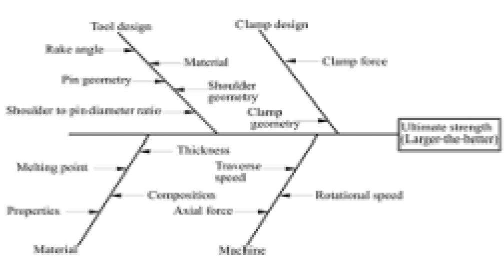

Fig: Causes and Effect Diagram [13]

They found that tool rotation speed has 41% contribution, traverse speed has 33% contribution and axial force has 21% contribution on tensile strength of test specimen. They had also found optimum values after conformation test for the selected test condition. These values of rotation speed, traverse speed and axial force were 1400 rpm, 45 mm/min and 6 KN respectively.

Zhaohua Zhang et al. [23] were studied the effect of tool rotation for 5052-H112 aluminum alloys of 1 mm thickness. They carried out friction stir welding for lap joint. They observed all the four zones by optical microscope. They revealed that microstructure grows coarser with increasing tool rotation speed. They observed two types of fracture mode and defined that fracture mode was associated with type of external loading it is not dependent on rotation speed of tool.

P. Cavaliere et al. [25] investigated effect of tool rotation speed and traverse speed for dissimilar Al AA6082-AA2024 material of 4 mm thichness. Tool was made up of C40 tool steel with conical threaded pin profile with large diameter of 3.8 mm and small diameter of 2.6 mm and shoulder diameter of 9.5 mm. Constant rotation speed of 1600 rpm and two different traverse speed of 80 and 115 mm/min were taken to investigate mechanical and microstructure properties. They found best fatigue strength on advancing side with advancing speed of 115 mm/min.

H.K.Mohanty et al. [2], M.Mehta et al. [6], D.H.Lammlein et al. [12], Dwight A. Burford et al. [17], Yan-hua Zhao [19], H. Khodaverdizadeh [20], S Rajkumar et al. [22] etc worked with different tool shoulder and pin profile.

Three tool pin profiles straight cylindrical, tapered cylindrical and trapezoidal were taken by H.K.Mohanty et al. [2] which is fabricated from SS310 for AA1100 aluminum alloys plat of 6 mm thickness. Three welding and rotational speed were also taken of values 80,160,212 mm/min and 710, 1000, 1400 rpm respectively. After response surface modeling, regression analysis and conformation test they conclude that tensile strength, percentage elongation and nugget hardness increases with increase in welding speed up to certain value and then after decrease. Tool probe geometry is very much responsible for achieving weld quality.

M.Mehta et al.[6] made experimental and theoretical investigation to know influence of shoulder diameter on thermal cycle, peak temperature, power requirement and torque for AA7075-T6. They used following energy conservation equation.

$$\rho C_p \frac{\partial (u_i T)}{\partial x_i} = -\rho C_p U_1 \frac{\partial T}{\partial x_1} + \frac{\partial}{\partial x_i}\left(k \frac{\partial T}{\partial x_i}\right) + S_{in} + S_b$$

Where ρ is density of material, Cp and K are temperature dependent specific heat and thermal conductivity of material, ui is the velocity component, T is temperature and U1 is welding velocity Sin and Sb are source terms due to interfacial heat generation per unit volume at the tool workpiece interface and heat generation rate due to plastic deformation in the workpiece away from the interface respectively. They conclude from three dimensional heat transfer and visco plastic model that increase in shoulder diameter increases peak temperature, spindle power and torque requirement for all rotational speeds. They have identified tool shoulder diameters 30, 25 and 20 mm for 355,560 and 710 rpm to tool rotation respectively.

D.H.Lammlein et al. [12] investigated effects of shoulderless conical tools in friction stir welding. They had used to computation fluid dynamics process model also. Conical tools were taken with the angle of 80° and 90°. They had derived that 90° tool was better than 60°, 80° or 120° tools. Dwight A. Burford et al. [17] employed concave, flat and convex shoulder of friction stir welding tool to reduce surface damage on butt and lap joints.

Yan-hua Zhao [19] examined effects of four types of tool pin profile cylindrical, conical, threaded cylindrical and threaded

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conical. They had found that best tensile strength was achieved form conical threaded pin profile.

H. Khodaverdizadeh [20] investigated the effect of two tool pin profile threaded cylindrical and square for pure copper. Microstructure was observed by optical microscopy. They found that square pin profile produce higher degree of plastic deformation due to its higher eccentricity and pulsation effect it also give higher peak temperature.

S Rajkumar et al. [22] investigated effect of different tool rotation, welding speed, tool shoulder diameter, pin diameter and tool hardness. They observed that joint prepared with 1400 rpm tool rotation, 60 mm/min welding speed, 8 KN axial force with 15 mm shoulder diameter, 5 mm pin diameter and 45 HRC hardness had 77% joint efficiency.

CONCLUSION

After review of these literatures, it is observed that lot of research was carried out in the direction of optimizing process parameters like tool rotation speed, tool traverse speed and tool geometry to increase joint efficiency of FSW process.
It is also noted that tensile strength increase with increase with tool rotation speed and decrease with tool traverse speed.
It is also noted that temperature also has the same relationship with tool rotation speed and tool traverse speed like tensile strength.

REFERENCE

[1] Muhsin J.J.,Moneer H.Tolephih,Muhammed A.M.,Effect of Friction Stir Welding Parameters(Rotation and Transverse) Speed on the Transient Temperature Distribution In Friction Stir Welding of AA 7020-T53,ARPN J. Engg and Applied Sciences, Vol.7 No.4, April 2012 | [2] H.K.Mohanty,D. Venkateswarly, M.M.Mahapatra,Pradeep Kumar,N.R.Mandal,Modeling the Effect of Tool Probe Geometries and Process Parameters on Friction Stirred Aluminum Welds, J. Mechanical Engg. And Automation 2012, 2(4): 74-79 | [3] R.Palanivel, P.Koshy Mathews, The Tensile Behavior of Friction Stir Welded Dissimilar Aluminum Alloys, MTAEEC9, 45 (6) 623(2011), UDK 669.715:621.791 | [4] Indira Rani M.,Marpu R.N., A.C.S.Kumar, A Study of Process Parameters of Friction Stir Welded AA6061 Aluminum in O and T6 Conditions, ARPN J. Engg and Applied Sciences, Vol.6 No.2, February 2011 | [5] C.Blignault, D.G.Hattingh,M.N.James, Optimizing Friction Stir Welding Via Statistical Design of Tool Geometry and Process Parameters, JMEPEG(2012) 21:927-935, DOI: 10.1007/s 11665-011-9984-2,ASM Internationa | [6] M.Mehta,A.Arora,A.De, T.Debroy, Tool Geometry for Friction Stir Welding-Optimum Shoulder Diameter, The Minerals, Metals & Materials Society 2011, DOI: 10.1007/s11661-011-0672-5,ASM International | [7] P.Ganesh,V.S.Senthil Kumar, Finite Element Simulation in Superplastic Forming of Friction Stir Welded Aluminum Alloy 6061-T6, Int. J. of Integrated Engg Vol. 3 No. 1 (2011) p. 9-16| [8] Ahmed Khalid Hussain, Evaluation of Parameters of Friction Stir Welding For Aluminum AA 6351 Alloy, Int. J of Engg Science and Technology Vol. 2(10),2010,5977-5984 | [9] P.Prasanna, B.Subba Rao,G.Krishna Mohana Rao, Finite Element Modeling For Maximum Temperature in Friction Stir Welding and Its Validation, Int J Adv Manuf Technol(2010) 51:925-933, DOI 10.1007/s00170-010-2693-4 | [10] Mohamed Assidi, Lionel Fourment, Accurate 3D Friction Stir Welding Simulation Tool Based on Friction Model Calibration, Int J Material Forming 2, Supplement 1(2009) 327-330, DOI: 10.1007s 12289-009-0541-6 | [11] G.Buffa, L. Fratini,S.Pasta, Residual Stresses In Friction Stir Welding: Numerical Simulation and Experimental Varification, Int Center for Diffraction Data 2009 | [12] D.H.Lammlein, D.R.Delapp, P.A.Fleming, A.M.Strauss, G.E.Cook, The Application of Shoulderless Conical Tools in Friction Stir Welding: An Experimental and Theoretical Study, Materials and Design 30 (2009) 4012-4022 | [13] A.K.Lakshminarayanan, V. Balasubramaniuam, Process Parameters Optimization for Friction Stir Welding of RDE-40 Aluminum Alloy Using Taguchi Technique, Trans. Nonferrous Met. Soc. China 18 (2008) 548-554 | [14] N.T.Kumbhar and K.Bhanumurthy, Friction Stir Welding of Al 6061 Alloy, Asian J Exp Sci Vol. 22, No 2, 2008: 63-74 | [15] R.W.Fonda, K.E. Knipling, J.F.Bingert, Mircrostructural Evolution Ahead of Tool in Aluminum Friction Stir Welds, Scripta Materialia 58 (2007) 343-348 | [16] G.Buffa, J.Hua, R.Shivpuri, L.Fratini, Design of the Friction Stir Welding Tool using the Continuum Based FEM Model, Materials Science and Engineering A 419(2006) 381-388 | [17] Dwight A. Burford, Bryan M.Tweedy, Christian A.Widener, Influence of Shoulder Configuration and Geometric Features on FSW Track Properties, 6th International Symposium on Friction Stir Welding, Saint-Sauveur, Nr Montréal, Canada, October 10-13, 200 | [18] W.M.Thomas,I.M.Norris,D G Staines, E R Watts, Friction Stir Welding-Process Developments and Various Techniques, The SME Summit 2005, Oconomowoc, Milwankee | [19] Yan-hua Zhao, San bao Lin, Lin Wu, Fu xing Qu, The Influence of Pin Geometry on Bonding and Mechanical Properties in Friction Stir Weld 2014 Al alloy, Materials Letter 59 (2005) 2948-2952 | [20] H. Khodaverdizadeh, A. Heidarzadeh, T Saied, Effect of Tool Pin Profile on Microstructure of Friction Stir Welded Pure Copper Joints, Materials and Design 45(2013) 265-270 | [21] Tran Hung Tra, Masakazu Okazaki, Kenji Suzuki, Fatigue Crack Propagation behavior in Friction Stir Welding of AA6063-T5: Roles of Residual Stress and Microstructure, Int J Fatigue 43 (2012) 23-29 | [22] S Rajkumar, C. Murlidharan, V. Balasubramanian, Influence of Friction Stir Welding Process and Tool Parameters on Strength Properties of AA7075 –T6 Aluminum Alloy Joints, Materials and Design 32(2011) 535-549 | [23] Zhaohua Zhang, Xingi Yang, Jialong Zhang, Guang Zhou, Xiaodong Xu, Binlian Zou, Effect of Welding Parameters on Microstructure and Mechanical Properties of Friction Stir Spot Welded 5052 Aluminum Alloy, Materials and Design 32(2011) 4461-4470 | [24] Rui dong Fu, Zeng qiang Sun, Rui Cheng Sun, Ying Li, Hui jie Liu, Lei Liu, Improvement of Weld Temperature Distribution and Mechanical Properties of 7050 alloy by submerged Friction Stir Welding, Material and Design 32(2011) 4825-4831 | [25] P. Cavaliere, A. De. Santis, F. Panella, A. Squillace, Effect of Welding Parameters on Mechanical and Microstructural Properties of Dissimilar AA6082-AA2024 joints produced by Friction Stir Welding, Materials and Design 30 (2009) 609-616 | [26] http://www.twi.co.uk/technical-knowledge/published-papers/friction-stir-welding-of-aluminium-alloys/, February 2014 | [27] Fu Zhi-hong, He Di-qiu, Wang Hong, Friction Stir Welding of Aluminum Alloys, Journal of Wuhan University of Technology- Mater. Sci. Ed., Volume 19, No.1, (March-2004)