RESEARCH PAPER | Engineering | Volume - 5 | Issue - 1 | Jan Special Issue - 2015 | ISSN - 2249-555X

# A Review of experimental investigation of post weld heat treatment on the properties of AA 6061-T06 Friction stir welded joint

KEYWORDS: AA 6061, Friction stir welding, Post weld heating, Tensile properties, Microstructure.

Yogesh.K.shukla | Prof.S.P.Patel

**ABSTRACT** This paper reports on studies of the effect of post-weld heating to the AA6061 alluminium alloy and its effect on the properties of friction stir-welded AA6061 aluminum alloy joints.Tensile properties such as yield strength, tensile strength, elongation, hardness were evaluated. Microstructures of the welded joints were analyzed

## I. INTRODUCTION

Welding is a fabrication process that joins materials, usually metals or thermoplastics, by causing coalescence. This is often done by melting the work pieces and adding a filler material to form a pool of molten material that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld.

Friction Stir Welding (FSW) patented by the Welding Institute (Thomas et al,1991).Friction stir welding two or more parts are joined while in the solid states much as in other methods of friction welding that have been in existence. Friction stir welding has enjoyed worldwide interest since its inception because of its advantages over traditional joining techniques.

The process of Friction Stir Welding has been widely used in the aerospace, shipbuilding, automobile industries and in many applications of commercial importance.

### Methodology of fsw process

In FSW, a cylindrical-shouldered tool, with different profiled probe (nib or pin) is rotated at a constant speed and fed at a constant traverse rate into the joint line between two pieces of sheet or plate material, which are butted together. The parts have to be clamped rigidly onto a backing plate in a manner that prevents the butting joint faces from being forced apart. The length of the nib is slightly less than the weld depth required and the tool shoulder should be in Intimate contact with the work surface. The nib is then moved against the work, or vice versa.

Frictional heat is generated between the wear resistant welding tool shoulder and pin, and the material of the work-pieces. This heat, along with the heat generated by the mechanical mixing process and the adiabatic heat within the material, cause the stirred materials to soften without reaching the melting point (hence cited a solid-state process). As the pin is moved in the direction of welding the face of the pin,assisted by a special pin profile, forces plasticized material to the back of the pin whilst applying a substantial forging force to consolidate the weld metal. The welding of the material is facilitated by severe plastic deformation in the solid state involving dynamic recrystallization of the base material.

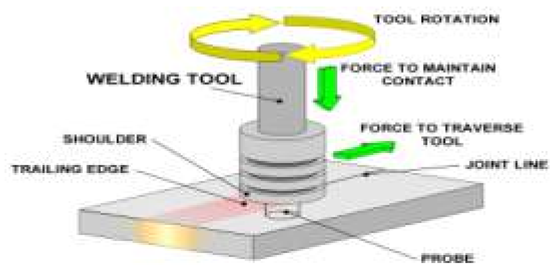


**Fig. 1: Schematic of Friction Stir Welding**

### Aluminium alloys

Aluminium 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 principal alloying constituent. The second digit corresponds to variations of the initial alloy. The third and forth digits correspond to individual alloy variations. Finally the temper designation code corresponds to different strengthening techniques. The chemical composition is given in Table-1. Mechanical and physical properties are given in Tables 2 and 3, respectively.

| Mg | Si | Fe | Cu | Cr | Mn | Zn | Ti | Al |
|---|---|---|---|---|---|---|---|---|
| 0.9 | 0.62 | 0.33 | 0.28 | 0.17 | 0.06 | 0.02 | 0.02 | Bal |

**Table 1. Chemical composition of AA 6061**

| Yield Strength (Mpa) | Ultimate Strangth (Mpa) | Elongation (%) | Reduction in cross sectional area (%) | Hardnes (BHN) |
|---|---|---|---|---|
| 302 | 334 | 18 | 12.50 | 105 |

**Table 2. Mechanical properties of AA 6061**

| Density (g/cm3) | Melting point (oC) | Modulus of Elasticity (Gpa) | Poison ratio |
|---|---|---|---|
| 2.7 | 580 | 70-80 | 0.33 |

**Table 3. Physical properties of AA 6061**

### PROCESS PARAMETERS

The friction stir welding process is dominated by the effect associated with material flow and large mechanical deformation, which is affected by process parameters such

Volume - 5 | Issue - 1 | Jan Special Issue - 2015 | ISSN - 2249-555X

as rotational speed, welding speed and axial force, Heat treatment

**Thomas (1997) [1]** focuses on this study the relatively new joining technology, friction stir welding (FSW). Friction stir welding can be used to join most aluminum alloys and surface oxide presents no difficulty to the process.On the basis of the study it was recommend that numbers of light weight materials suitable for the automotive, railway, marine and aerospace transportation industries can be fabricated by FSW.

**K. N. Krishnan 2002) [2]** presented The effect of post weld heat treatment on the properties of 6061 friction stir welded joints. The welding and spindle speeds were 288 mm/minute and 1440 rpm respectively. The PWHT consisted of solution heat treatment and precipitation or ageing treatment. Since the grain growth occurs at higher temperatures, three different temperatures of 520, 540 and 560°C were chosen for the solution heat treatment. The solution treatment was carried out for 1 hour at all the above temperatures. Two precipitation hardening treatments given to the solution heat treated samples were 175°C for 8 hours and 200°C for 1 hour. The hardness tests were conducted on a micro Vickers hardness testing machine is used.. The test was performed in the mid thickness of the specimens. It is clear that the material was brittle and the non standard bend test was more sensitive to material properties. He observed that the solution and ageing treatments to produce high Hardness resulted in failures in the bend test. The PWHT, in general, produced massive grain sizes and equiaxed grains

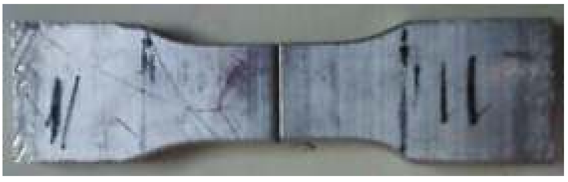

**Fig. 2: Tensile Tested Specimen**

**J.R. Cho et al (2004) [3]** described the numerical results, the surface residual stresses of multi-pass butt weld were measured by the hole-drilling technique and they compared favourably with the finite element analysis predictions by ANSYS software. A post weld heat treatment was applied to the welds. The temperature was increased linearly to 600 C during the initial 1000 s and then cooled to room temperature during the last 2600 s. The maximum residual stresses for K- and V-type weld joints of thick plates were 316 and 265 MPa, respectivel before the post weld heat treatment.After the post weld heat treatments, they were reduced to 39.3 and 30.7 MPa, which is a stress relaxation to less than 15% of the values before the heat treatment.

**C.T. Hsieh et al (2007) [4]** described that the effect of post-weld heat treatment on the notched tensile fracture of Ti–6Al–4V to Ti–6Al–6V–2Sn dissimilar laser welds. A 5 kW CO2 laser was utilized for autogenously bead-on-plate welding in full penetration The main welding parameters included a laser power of 2800W and a travel speed of 1000 mm/min, and the focal point was located at 0.5 mm under the top surface of the plate it found that The constituent in Ti-6-62 (25%) was greater than that in Ti-6-4 (10%), shows the variation in micro hardness from the fusion Zone (FZ) to the base metal (BM) in distinct welds with the PWHT over the temperature range of 426–704 C.

V**. Balasubramanian et al (2007) [5]** presented on Influences of post-weld heat treatment on tensile properties of friction stir-welded AA6061 aluminium alloy joints. A specially designed and developed machine (15 hp; 3000 rpm; 25 kN) was used to fabricate the joints. , the welded joints were grouped into four different categories, namely, (i) Aswelded (AW) joints, (ii) solution treated (ST) joints, (iii) solution treated and aged (STA) joints and (iv) artificially aged (AG) joints. Tensile properties of each of these joints were evaluated immediately after fabrication, without post-weld heat treatment, to obtain the As-welded (AW) joint properties. Solution treatment (ST) was carried out at 530 °C for a soaking period of 60 min. For the ST, joints were placed in an induction furnace and heated from room temperature to the 530 °C solution temperature at a rate of 100 °C per hour. After completion of the soaking period, the joints were removed and quenched in a cold water bath. Artificial aging (AA) treatment was carried out at 160 °C for a soaking period of 18 h. Tensile tests were carried out with a 100 kN, electro-mechanical controlled Universal Testing Machine (FIE, India, Model:UNITECH 94001). Microstructure analysed by TEM micrographs.They observed that a simple artificial aging treatment was found to be more beneficial than other treatment methods to enhance the tensile properties of the friction stir-welded AA6061 aluminium alloy joints

**N. T. Kumbhar et al (2008) [6]** described on Friction Stir welding of Al 6061 Alloy The 6061 Al plates were welded using three different tool rotation speeds and tool traverse speeds The tool rotation speeds used in this study were 710, 1120 and 1400 rpm and the tool traverse speeds of 63, 80 and 100 mm/min were used The tool tilt in all the trials was kept constant at 2°. Some of these samples were given a post weld heat treatment schedule consisting of solution zing at 530°C for 30 min and then aged at 160°C for different periods of 4, 8, 12 and 18 hrs. These samples were then grinded successively on SiC papers of grit 220 to 600. hese were then used for optical microscopy, EPMA and SEM analysis for microstructure analysis.

**Hakan Aydin et (2009) [7]** they investigated on The effect of post-weld heat treatment on the mechanical properties of 2024-T4 friction stir-welded joints.The experiments were conducted on 2024 aluminum alloy.The welding tool was used truncated cone pin The tool rotated at 2140 rpm, and the tool advancerate was 40 mm/s. The original metal used in this study is 2024 aluminum alloy in the T4 temper state, which results from water quench at approximately 0 C after a solution treatment of the alloy at 510 C for 2.5 h. It is observed that the drop in micro-hardness at the weld zone compared to the base material of the joints This is a result of abnormal grain growth throughout the friction stir-welded zone.

**Rui-dong Fu et al (2012) [8]** investigated the Effect of welding heat input and post-welding natural aging on hardness of stir zone for friction stir-welded 2024-T3. The H13 steel tool consisting of 8 mm diameter shoulder and 3 mm diameter pin was employed. There were two FSW welds for each group of welding heat input condition. The one was used for subsequent analysis of hardness and microstructure at as-weld state. The other one was used for PWNA (Post-welding natural aging) treatment in natural environment for over one year. From the microstructure analysis well known, the PWNA has no effect on the variation of the grain size in the SZ (stir zone).They found the average hardness in the SZ of the joint welded at 1500 rpm and 1000 mm/min achieves the BM level. In comparison PWNA on the improvement of the hardness in the SZ is limited the variation in the strengthening-phase particles plays a more important

Volume - 5 | Issue - 1 | Jan Special Issue - 2015 | ISSN - 2249-555X

role than does grain size in the SZ for the improvement of hardness.

**Momoh I.M et al (2013) [9]** they focused on the mechanical properties of 0.33%C low alloy steel was investigated in the post weld heat treated (PWHT) condition. The samples, after machining, were proceed for annealing process .It heated to 950 °C temperature in the region of 30 – 50°C above the A1 of the Fe – Fe3C phase diagram for 1 hour. Then allowed to cool in air at a controlled rate. After proceed to Normalizing process. It heated to 950 °C temperature in the region of 30 – 50°C above the A1 of the Fe – Fe3C phase diagram for 1 hour then allowed to cool in air at a controlled rate. After proceed to Quenching process. Hardness and tensile properties of the selected steel when subjected to heat treatment after welding following a universally accepted.

**Ehab.A.El-Danaf (2013) [10]** it investigated on Microstructure and mechanical properties of friction stir welded 6082 AA in as welded and post weld heat treated conditions. Microstructure and mechanical properties of friction stir welded 6082 AA in as welded and post weld heat treated conditions The tool was manufactured from Mo–W tool steel with a flat shoulder of of 6 mm, and 5 mm long The microstructure on the transverse section (TD-ND) for most samples was studied by optical microscopy (OM). It is observed that the hardness and strength were partially recovered. The grain size barely exhibited a change whereas the texture displayed a significant diminish in the Goss orientation after PWHT.

**Conclusion**

From the study of review paper concludes that the tensile strength of the FSW joints the aluminum alloys were increased by the PWHT process.The hardness values are improved by the PWHT process because of coarsening of grains size. The maximum strength in the weld was achieved by post weld solution treatment and ageing which resulted in uniform precipitation throughout the weld of HAZ and base metal.

**REFERENCE**

[1] W M Thomas, E. Nicholas, J. Needham et al. Friction Stir Butt Welding. International patent application, No. PCT/GB92/02203 and GB patent application, No. 9125978.8, 1991. | [2] K. N. Krishnan, "The effect of post weld heat treatment on theproperties of 6061 friction stir welded joints", Journal of materials science, published by ELSEVIER, Volume No-37, Pg- 473-480,2002 | [3] J.R. Cho and B.Y. Lee, "Investigation of residual stress and post weld heat treatment of multi-pass welds by finite element method and experiments", Journal of Materials and Processing Technology, Pg 1690-1695, (2004). | [4] C.T. Hsieh and C.Y. Chu, "The effect of post-weld heat treatment on the notched tensile fractureof Ti–6Al–4V to Ti–6Al–6V–2Sn dissimilar laser welds International Scientific Journal –Archives of Materials & Design, Volume- 59, Pg. 268-275,March, 2014 | [5] K. Elangovan and V. Balasubramanian, "Influences of post-weld heat treatment on tensile properties of friction stir-welded AA6061 aluminium alloy joints", Journal of materials characterization, published by ELSEVIER, Volume No-59, Pg 1168–1177, Sept,2007 | [6] N. T. Kumbhar and K. Bhanumurthy, "Friction Stir welding of Al 6061 Alloy", Asian Journal of Experiment sciences, Volume No-22, Pg- 63-77, Feb, 2008. | [7] Hakan Aydin and Ali Bayram, "The effect of post-weld heat treatment on the mechanical properties of 2024-T4 friction stir-welded joints International Journal of Materials & Design , A published by ELSEVIER, Volume No-37, Pg- 2568–2577, Nov,2009. | [8] Rui-dong Fu and Jian-feng Zhang, "Effect of welding heat input and post-welding natural aging on hardness of stir zone for friction stir-welded 2024-T3 aluminium alloy thin-sheet" International Journal of Materials Science & Engineering, published by ELSEVIER, Volume No-553 , Pg 319–324, August,2012. | [9] Momoh I.M and Oshodin T, L. Lityñska-Dobrzyñska, A. Pietras , "Investigating the Mechanical Properties of Post Weld Heat Treated 0.33%C Low Alloy Steel", International Journal of Science and Technology,Volume -2 ,( ISSN 2049-7318), Pg 433-437,June- 2013 | [10] Ehab A. El-Danaf , "Microstructure and mechanical properties of friction stir welded 6082 AA in as welded and post weld heat treated conditions",International Scientific Journal –Archives of Materials & Design, Volume-47,Jan,2013.