EFFECT OF POST-WELD HEAT TREATMENT ON THE MECHANICAL AND MICRO STRUCTURAL PROPERTIES OF FRICTION STIR WELDED ALUMINUM ALLOY 7075-T6

L. Srinivas Naik[1], S. Jush Kumar[2], Dr. B. Hadya[3], Dr. Kolli Murahari[4]
[1,2]Associate Professor, Department of Mechanical Engineering,
Anurag Group of Institutions, TS, INDIA
[3]Mechanical Engineering Department, Osmania University, Telangana, India
[4]Mechanical Engineering Department, KL University, Guntur, Andhra Pradesh, India

Abstract

This paper is to examine the consequence of post-weld artificial heat treatment on the friction stir welding of Aluminum Alloy 7075 (AA 7075) for a welding condition of 900 rpm and 31.25 mm/min using right and left screwed pins for two different shoulder diameters. The method followed is that first artificial aging has been carried out as 24 hours at 127°C. Afterwards, in order to study the effect of post-weld aging on tool geometry, micro structural examination, hardness measurements and room temperature tensile tests have been carried out. The results show that left thread screw yields higher mechanical properties and hardness values compared to right thread screw when tested at the same shoulder diameter. It has been observed that post weld aging process compensates the hardness decrease observed in as-welded joints; no significant decrease in hardness is obtained throughout the weld region. For future work it can be suggested to vary the post weld aging situation, such as 12 hours at 127°C. Welding and rotation speeds are other parameters affecting the morphology and mechanical properties; therefore the effect of varying these parameters should be considered. This study has practical implications and direct applicability. It indicates that helix angle rather than shoulder diameter directly affects the quality of the joint. At certain post weld aging conditions, for obtaining a sound welded joint the right tool selection will be of critical importance. The authors have examined the effect of post weld aging for different angles and shoulder diameters. It is believed that examination of the effect of the variation of these parameters on the joint quality provides originality to this work.

Keywords: recrystallization; Morphology; thermo mechanically affected zone; Microstructure; Friction stir welding

I INTRODUCTION

Now a days, researches have been focusing on developing fast and Eco friendly process in manufacturing and this includes Friction stir welding and Processing. Fsw is a solid state welding technique invented and patented by The welding institute (TWI) in 1991 for butt and lap joint of ferrous and non ferrous metals and plastics, FSW is a continuous process that involves plunging a process of a specially shaped rotating tool between the butting faces of the joint. The relative motion between the tool and the substrate generates frictional heat that creates a plasticized region around the immersed portion of the tool Friction stir welding (FSW) is a solid – state joining process that takes place below the melting point of the materials to be coupled. FSW offers ease of handling, precise external process control and high levels of repeatability, thus creating very homogeneous welds. No special preparation of the sample is required during the welding process. FSW of aluminum alloys offers the advantages of low heat input, reduced distortion, therefore, low residual stresses and higher mechanical properties compared to conventional fusion welding methods. Owing to these advantages, FS welded aluminum alloys are widely used in commercial transportation systems and in aerospace industry, where reduced fuel consumption is of vital importance [1]. In this welding process, a rotating welding tool is driven into the material at the interface of, for example, two adjoining plates, and then translated along the interface. Friction heats the material which is then essentially extruded around the tool before being forged by the large down pressure [2]. The FSW tool is fixed to the rotating axis of a CNC machine in the clockwise direction in this study. The basic principle of the FSW process is illustrated in Fig. 1 [3].

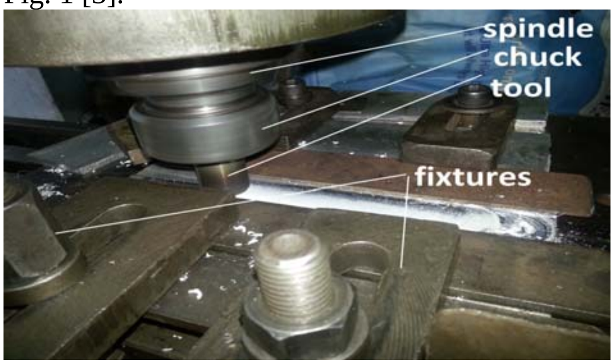

Figure1. FSW technology schematic view

The microstructure of the welded joint is formally divided into four zones: base material, heat affected zone (HAZ), thermo mechanically affected zone (TMAZ) and the nugget zone (NZ). The nugget zone is composed of fine-equaled grains which are formed under high temperature and large deformation in the weld center due to the stirring process [4]. The TMAZ is the region surrounding the nugget on either side where there is less heat deformation compared to the weld center [5]. The simultaneous rotational and translational motion of the welding tool during the welding process creates a characteristic asymmetry between the adjoining sides. The side where the tool rotation coincides with the direction of the translation of the welding tool is called the advancing side (AS), while the other side, where the two motions, rotation and translation counteract is called the retreating side (RS) [6, 7]. Fig. 2 shows the weld region macrostructure of an aluminum alloy joined by friction stir welding [3].

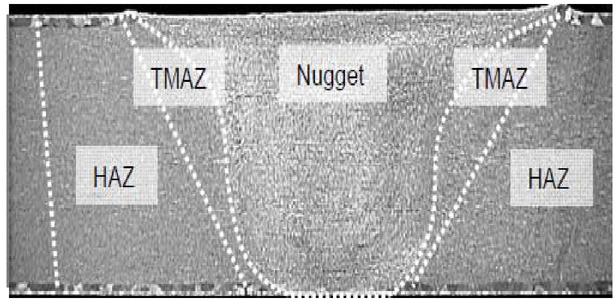

Figure2. Cross section of FSW joint; (BM) Base Material, (HAZ) Heat Affected Zone, (TMAZ) Thermo Mechanically Affected Zone, Nugget Zone (NZ), Advancing Side (AS), Retreating Side (RS) Tool geometry, which consists of a threaded pin and a houlder, is one of the most influential aspects of the friction stir process (FSP) development. The tool geometry plays a critical role in material flow and in turn, governs the traverse rate at which FSW can be conducted [3]. In this study, right and left thread pin screwed welds have been utilized in order to study the effect of pin structure on the mechanical and microstructural properties of the post-weld heat treatment welded joints. For the right thread screwed pin, two different shoulder diameters have been employed to observe the effect of temperature input into the work piece. Optimum rotation and welding speeds have been determined as 900 rpm and 31.5 mm/min as the result of studies investigating the effect welding parameters on the FSW of AA7075 [8]. While there has been several studies focused on the variation of rotation and welding speeds to optimize the welding parameters and study their microstructures for aluminum alloys, limited research has been carried out on the effects of tool structure. Moreover, further research needs to be carried out on the effect of post-weld aging on the tool structure. Therefore, in this study, AA 7075-T6 plates have been post-weld heat treatment after being joined by FSW. The effect of post weld aging on tool geometry, namely the helix angle and shoulder diameter, has been investigated in terms of microstructure, hardness variation and tensile properties

II METHODOLOGY

FLOW CHART OF METHODOLOGY:

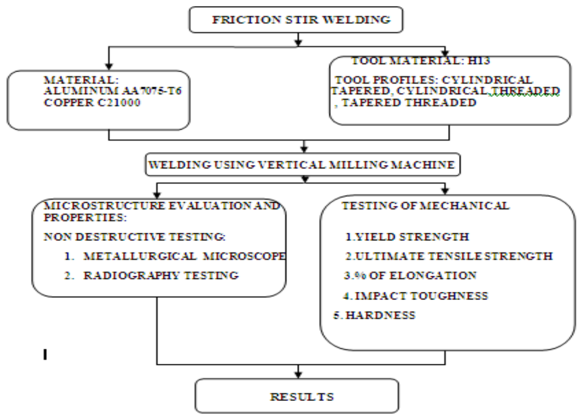

Table1 AA7075-T6 Chemical Composition

MATERIAL	Zn	Mg	Cu	Si, Fe, Ti, Cr
AA 7075-T6	5.6-6.1%	2.1-2.5%	1.2-1.6%	<0.5%

Table2 Mechanical Properties of AA7075-T6

Yield Strength	Ultimate Tensile Strength	% Of Elongation At Break	Fracture Toughness	Brinell Hardness	Young's Modulus	Poisson Ratio
503 MPa	572 MPa	11.0	25MPa $m^{1/2}$	150	71.7 GPa	0.33

Table3 Chemical of Composition H13 Tool Material.

MATERIAL	C	Cr	Fe	Mo	Si	V
ANSI H13	0.32-0.4	5.13-5.25	>=90.95	1.33-1.4	1	1

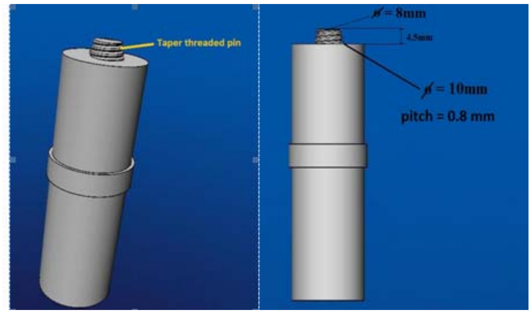

Figure2 Cylindrical Tapered threaded tool

Sheets of Al-alloys, Al 7075, 5 mm thick, 200 mm long and 75 mm wide were selected for but joint welding. Vertical milling machine of power rating 10HP with maximum spindle rotational speed of 2400 rmp manufactured by HMT used for welding Al-alloys, Chemical composition and Mechanical Properties of AA7075 as shown in table 1 and 2 respectively The tool used for this process was made of H13 quenched and tempered steel tool with a shoulder of 20mm diameter with a probe pin, 10 mm probe diameter and 4.9 mm long. Shown in Figure.1 and was tilted by 2^0 to provide compressive force to the stirred weld zone. the shoulder diameter increases, the sticking torque, MT, increases, reaches a maximum and then decreases.H13 Chemical composition as shown in table3 First of all the plates which need to be welded are kept on the backing plate and they are rigidly fixed to the machine table with help of fixtures, because during welding the plates may get separated due to the force arising during welding. Initially a hole of 8mm diameter was drilled so that the plunging forces on the tool are get eliminated which are impact in nature and thereby increasing the life of tool. Then the welding tool is inserted in to the spindle of the machine and spindle is made to rotate at desired welding speed and the pin of welding tool is slowly inserted into the predrilled hole. And the tool is kept rotating in the predrilled hole for some time without giving feed, so that the sufficient amount of heat is generated due to friction between tool and material so that the temperature of joints is such that the plastic flow of the material is possible during forward motion of tool or during welding period. Then the feed is given to the tool and due to the plastic flow the material at the interface of the two plates the weld joint is formed. For all welding conditions the welding speed (feed of tool) is kept constant at 31.25mm/sec, because in this experiment we want to study the effect of tool profile and rotational speed on the properties of the friction stir welded joint we have to keep the welding speed (feed of tool) to be constant so that we can be able to study the effect of tool profile and rotational speed. At the end of welding, before pulling the tool out of the joint the feed is stopped and the tool is pulled out of the joint. Like this by changing the tool and rotational speed the welding was performed on the aluminum alloy plates. The Tool pin is then moved against the work piece, 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 leading 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 as shown above Figure2.

III RESULTS AND DISCUSSION

MORPHOLOGY

Irrespective of the tool design, the material that flows around the tool undergoes extreme levels of plastic deformation, which leads to a recrystallized, fine equaled grain structure on the order of 4-6mm diameter formed under high temperature and plastic deformation in the weld region due to the stirring process. In the base metal, equaled grains are oriented along the rolling direction, as shown in Fig. 4. In the transition region between the weld zone and the base metal (BM), the grain dimension increases compared to the nugget zone and the grain orientation possesses a less equaled character. The region adjacent to the nugget zone, i.e., TMAZ is characterized by a highly deformed structure, Fig. 4. The base metal elongated grains were deformed in an upward flowing pattern around the nugget zone. Although the TMAZ underwent Plastic deformation, complete recrsytallization did not occur in this zone due to insufficient deformation strain [10-12]. In the HAZ, which starts at a distance of around 6-10 mm away from the weld center, a large amount of resident parent material grains start to appear, Fig. 4.

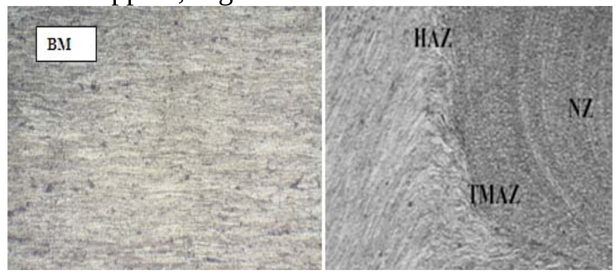

Figure4. Four different zones associated with FSW: equaled grains oriented along the rolling direction in the BM, deformed grains in TMAZ and fine recrystallized grains in the NZ and comparably larger grain sizes than the nugget zone in the HAZ

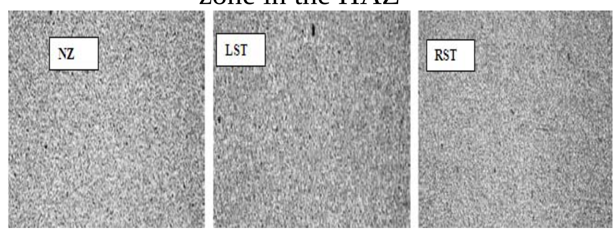

Figure.5. Nugget zone microstructures of post weld heat treatment (a) right thread screw with shoulder diameter of 15 mm, (b) right thread screw with shoulder diameter of 20 mm and (c) left thread screw with shoulder diameter of 20 mm

In Fig. 5, the nugget zone microstructures of the three conditions after post weld aging process are given. It can be seen that all three conditions possess less equaled grains compared to the base metal. Left thread screw, Fig. 5c, has comparably smaller average grain sizes compared to right thread screw, Figs. 5a and b. As can be seen from the Figures, there is no porosity formation in the nugget zone.

IMPACT TESTING

The Charpy impact test was performed to determine the impact energy of similar aluminum alloys AA7075 friction stir weldments at rotational speed of the tool 900 rpm and tool feed speed of 31.25 mm/min. as per ASTM. Impact Strength is 2J. This low strength is due to the joint considered for the Impact test is taken at the beginning of the weld. Impact Strength is 4J at 540rpm is due to the joint considered for the Impact test is taken at the beginning of the weld

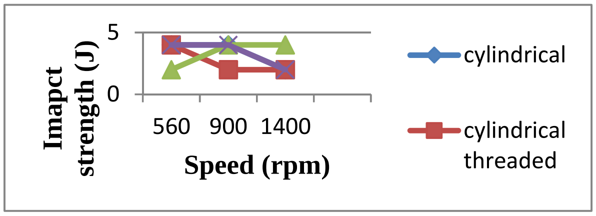

Figure 7 Impact Strength of FSW AA7075-T6 joints.

MICRO HARDNESS

Micro hardness measurements (HV) have been conducted for all joints, in order to determine the hardness properties across the weld region. The middle section (3 mm from the top surface) has been chosen for the hardness measurements. Hardness distribution for the three types of joints is given in Fig. 6. As seen from the Figure, the hardness gradient is the same for both advancing and retreating sides. The hardness distribution reveals that helix angle is more dominant on the hardness compared to shoulder diameter. The average hardness value across the weld region is about 70 HV for the right thread screw joint for 15 and 20 mm shoulder diameters, while for the left thread screw it is around 75 HV. Also, for as welded FSW joints, some decrease in hardness is observed at the HAZ in literature [8], post weld aging seems to compensate this decrease; as the figure depicts there is no significant decrease in hardness throughout the weld region.

TENSILE PROPERTIES

The room temperature tensile properties of the post-weld heat treatment FS welded joints obtained from flat transverse tensile tests are given in Table 3. The given results are the average of minimum three tests. The transverse flat welded specimens all have failed at the transition region between the nugget zone and the HAZ. As seen in Table 3, the mechanical properties of joint C is, which has a shoulder diameter of 15 mm, are higher compared to Joints A and B, with 20 mm shoulder diameters. For the same shoulder diameter, the joint welded by using left thread screw yielded higher mechanical properties. The reason for this could be Joint B possesses smaller average grain diameter in the nugget zone compared to Joint A, and also it has relatively higher hardness values throughout the weld region.

Table.3. Mechanical Properties of the post weld heat treatment Friction Stir welded joints and BM

Joint	Yield strength $R_{p0.2}$ (MPa)	Ultimate tensile strength R_m (MPa)	Total elongation (%)	Joint efficiency in terms of R_m (%)	Mismatch ratio, M $\left(M=\frac{R_{p0.2WM}}{R_{p0.2BM}}\right)$
A	143	206	0.41	43	0.36
B	183	258	0.87	54	0.47
C	223	300	0.79	63	0.57
BM	390	480	13.8	-	-

Mismatch ratio is defined as the ratio of the weld metal yield strength to that of the base metal. It provides a means of comparing the relative strength of the joints. From Table 3, it is seen that compared to the BM yield strength values post weld heat treatment joints possess 36%-57% mismatch ratios.

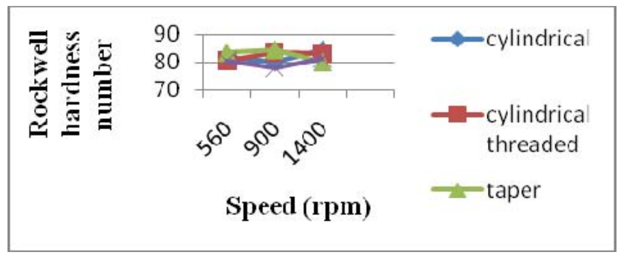

Figure.6.Hardness distribution along the weld region

CONCLUSIONS

Welding was carried out using different thread angles of the threaded pin, namely right and left thread and for right

1. FSW was applied successfully to AA 7075 with no porosity
2. Observed in the nugget zone. The nugget zone exhibited a recrystallized fine grain structure with grain sizes increasing moving from the weld region to the base metal.
3. Post weld aging process compensates the hardness decrease observed in as-welded joints; no significant decrease in hardness is obtained throughout the weld region.
4. It has been seen that left thread screw yields higher mechanical properties when tested at the same shoulder diameter.
5. Observed that low spindle seed give higher mechanical properties.
6. Small shoulder diameter improves more strength.

.

REFERENCES

[1] C.G. Rhodes, M.W. Mahoney, W.H. Bingel, Effects of friction stir welding on microstructure of 7075 Aluminum, Scripta Materialia 36/1 (1997) 69-75.

[2] R.S. Mishra, Z.Y. Ma, S.R. Sharma, M.W. Manohey, Microstructural modification of cast Aluminum alloys via friction stir processing, Materials Science Forum 426-432 (2003) 2891-2896.

[3] L. Srinivas naik, S. Jush kumar, K. Murahari., Int., JMER, (2016), Tool Design and Analysis of Friction Stir Welding Process by using FEA.Vol-6, Issu-9, 7- 16.

[4] C. Zhou, X. Yang, G. Luan, Investigation of microstructures and fatigue properties of friction stir welded Al-Mg alloy, Materials Chemistry and Physics 98 (2006) 285-290.

[5] W. Tang, X. Guo, J.C. McClure, L.E. Murr, Heat input and temperature distribution in friction stir welding, Journal of Materials Processing and Manufacturing Science 7 (1998) 163-172.

[6] C. Zhou, X. Yang, G. Luan, Fatigue properties of friction stir welds in Al 5083 alloy, Scripta Materialia 53 (2005) 1187-1191.

[7] M. Czechowski, Low cycle fatigue of friction stir welded Al-Mg alloys, Journal of Materials Processing Technology 164-165 (2005) 1001-1006.

[8] Ç. Yeni, The effect of welding parameters on the microstructure and mechanical properties of friction stir welded AA 7075, Practical Metallurgy 45/10 (2008) 479-494.

[9] G. Liu,L E Murr, C-S. Niou, J.C. McClure, F.R. Vega, Microstructural aspects of the friction-stir welding of 6061- T6 Aluminum, Scripta Materialia 37/3 (1997) 355-361.

[10] R.S. Mishra, Z.Y. Ma, Friction stir welding and processing, Materials Science and Engineering 50 (2005) 1-78.

[11] Z.Y. Ma, R.S. Mishra, M.W. Mahoney, Superplastic deformation behavior of friction stir processed 7075 Al Alloy, Acta Materialia 50/17 (2002) 4410-4430.

[12] Y.S. Sato, H. Kokawa, M. Enmoto, S. Jogan,Microstructural evaluation of 6063 Aluminum during friction-stir welding, Metallurgical and Materials Transactions A 30/9 (1999) 2429-286.