PARAMETERS AFFECTING MEHANICAL PROPERTIES OF FRICTION STIR WELDED JOINTS ON AA7075-T6 ALUMINIUM ALLOY

Sivashanmugam M.[1], and Johnrajan A[2]

[1]Research scholar, Department of Mechanical & Production Engineering, Sathyabama University, Chennai, India.
[2]Department of Mechanical & Production Engineering, Sathyabama University, Chennai. India.
E-mail: [1]s_mugam70@yahoo.com

ABSTRACT

Friction stir welding is a solid state joining process and is widely being considered for aluminium alloys. The main advantage of FSW is the material that is being welded undergoes only localized changes. The welding parameter and tool pin profile play a major role in deciding the weld quality. In this work an effort has been made to analyze microstructure of aluminium AA 7075-T6 alloy. Three different tool profiles (Taper Threaded and square) have been used to construct the joints in particular rotational speed. Tensile, Impact, micro hardness of mechanical properties of the joints have been evaluated and the formation of FSP zone has been analyzed microscopically. From the investigation it is found that the threaded cylindrical profile produces highly defined Strength in welds. The welding speed also important criteria for the strength of wed.

Keywords: AA 7075-T6 Aluminium alloy; Friction stir welding; Tool pin profile; FSP zone; Tensile, Impact evaluation.

I. INTRODUCTION

AA7075-T6 is the most widely used material for the construction of leading and trailing edges, Helicopter rotor blades and navy bulk head joiner panels. It has unique combination of properties such as good weld ability, light weight and high strength properties. The normality used welding process properties. The normally used welding process for these materials is TIG, MIG, the electron beam welding process [1]. AA7075-T6 is a heat treatable alloy so for welding the rotational speed is considered for effective welding and the parameters are designed accordingly [2]. So, in considering the need of friction stir welding in vast application, the material is welded using friction application, the material is welded using friction stir welding process. Friction stir Welding (FSW) process is an emerging joining Technology than can eliminate usual defects that occur in the weld area and refine the microstructures, thereby improving strength and ductility, increasing resistance to corrosion and fatigue and enhance the properties of the weld.

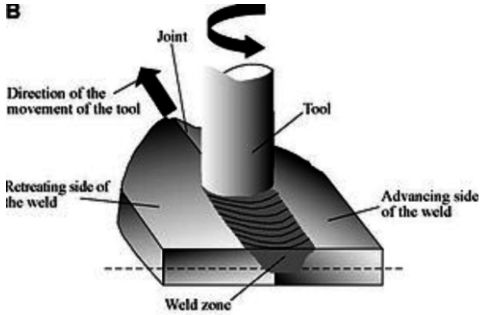

Fig. 1. FSW process of two metal Plates.

Fig. 2. Friction Stir Welding Machine

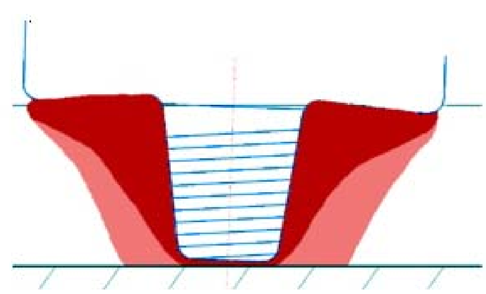

Fig. 3. FSW Pin plunged in the metal plates

Table: 1 Pin profile geometry for Taper tool

Pin dia (d)	6.35 mm
Pin length (L)	6 mm
Shoulder dia (D)	19.05 mm
D/d Ratio of tool	3
Tilt angle	0
Shoulder deepness	0.2 mm
Included angle of taper pin	7.5
Pitch	1 mm
Thread angle	60
Hardness of the tool	50 Rc
Tool material	M2 HSS

Fig. 4. (a) Taper Pin (b) Cylinder Pin (c) Square Pin

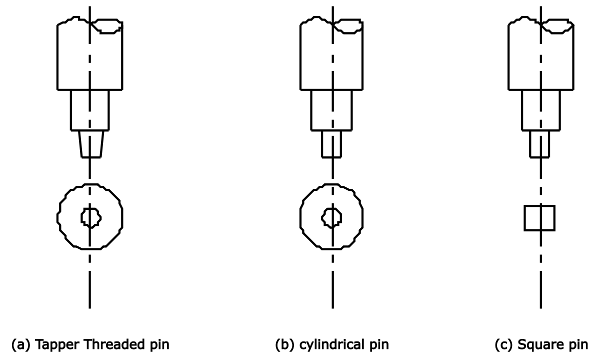

Fig. 5. (a) Untouched base material
(b) Heat affected zone (HAZ)
(c) Thermo mechanically heat affected zone (TMAZ)
(d) Friction stir processing zone (FSP)

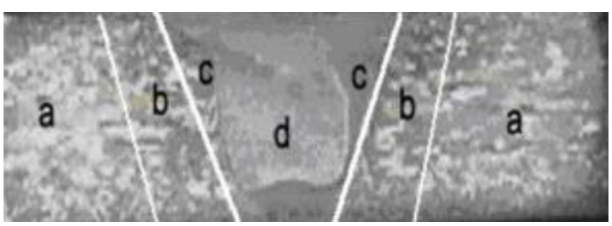

Table 2. Pin profile geometry for square tool

Pin dia	6.35 mm
Pin length (L)	6 mm
Shoulder dia (D)	19.05 mm
D/d Ratio of tool	3
Tilt angle	0
Shoulder deepness	0.2 mm
Hardness of the tool	50 Rc
Tool material	M2 HSS

Fig. 6. FSW Fabricated joint on AA7075

The FSW is usually carried out in solid an is a continuous hot shear autogenous weld involving a non consumable rotating probe of harder material than the material that abutting faces of the joint. The relative motion between the tool and base metals creates frictional heat by forming a plasticized zone near and around the tool. The tool shoulder also helps in containing the plasticized material in the weld region. As the tool traverses forward the plasticized material follows to form solid phase joint. The major advantage of FSW is that it follows local thermo mechanical metal working process without influencing properties of surrounding areas as observed in other welding process [3]. FSW joints consist of four different rejoins, they are (a) untouched base material (b) heat affected zone (HAZ) (c) Thermo mechanically heat affected zone (TMAZ) (d) Friction stir processing zone (FSP). These zones are normally affected by the rotating probe of the tool when it traverses the joint area. So probe should find relationship between tool profile and welding material.[5]

II. EXPERIMENTAL PROCEDURE

The base metal used for the Al-Zn alloy in which the manganese increases the corrosion resistance, ductility and toughness. The aluminum plates are cut into required size of (200 mm × 75 mm) by power saw cutting and grinding. A single pass weld was made in the butt joint area. Butt joints have been made. The tool that was used is a non-consumable tool of made of high speed steel. Three different tools as shown in fig 4. (a) & 4. (b) are made. Using each tool a single joint is made. The machine used for welding was specially made. The welding speed of 800 rpm with table feed of 65 mm/min was taken in consideration [4]. The load applied was 1 ton to achieve better weld without defects. The tool hardness was set between 50 to 70 HRC.

III. TEST METHOD

The welded joints are sliced through power hacksaw and machined to the required dimension to prepare tensile test specimens. American society for testing of materials (ASTME8M-04) guidelines is followed for preparing the test specimens. Tensile test are carried out in the universal testing machine with reference to ASME - sec (ix). Initially there was loaded 100 KN, and then it is loaded gradually at the rate of 1.5 KN/mm as per specification. The specimen fails after necking and load versus displacement has been recorded. The 0.2% offset yield strength; ultimate tensile strength and percentage of elongation have been evaluated. Micro hardness test has been employed (Vickers hardness) for measuring micro hardness across the joint with 0.2 kg load. Similarly the welded joints are sliced through power hacksaw and machined to required dimension to prepare specimen for

Tensile and impact test as shown in fig. 7. American society for testing of materials guidelines is followed for preparing the test specimens. Tensile and impact tests are conducted in the respective machines. The values are recorded.

Table 3. Base metal AA7075 Chemical Composition

Al	Zn	Mg	Mn	Cr	Cu	Fe	Si	Ti	Ni
87.1 to 91.4	5.1 to 6.1	2.1 to 2.8	0.2 to 0.3	0.18 to 0.28	1.4 to 2.0	0.18	0.4	≤ 0.029	≤ 0.029

Fig. 7. Tensile Test Specimen

4. Results and Discussion

A. Tensile strength value

Table 4 Ultimate tensile value & % Elongation

Sl.No	SAMPLE ID	UTS VALUE (N-m)	% ELONGATION
1	$W_S\, T_{11}$	196.8	8.5
2	$W_S\, T_{12}$	191.35	7.0
3	$W_S\, T_{13}$	331.36	8.5
4	$W_S\, T_{21}$	341.79	7.0
5	$W_S\, T_{22}$	228.5	7.0
6	$W_S\, T_{23}$	261.8	7.0

WST11.welding speed Taper thread tool

WST21.welding speed Square tool

B. Impact value

Table 5. Impact value

SL.NO	SAMPLE ID	AMBIENT TEMP (30°*C*)	IMPACT VALUE (J)
1	$W_S\, T_{11}$	30°C	4
2	$W_S\, T_{12}$	30°C	4
3	$W_S\, T_{13}$	30°C	5
4	$W_S\, T_{21}$	30°	4
5	$W_S\, T_{22}$	30°C	4
6	$W_S\, T_{23}$	30°C	6

C. Micro Hardness

The micro hardness values for three different zones namely FSP, HAZ, Base mental is found

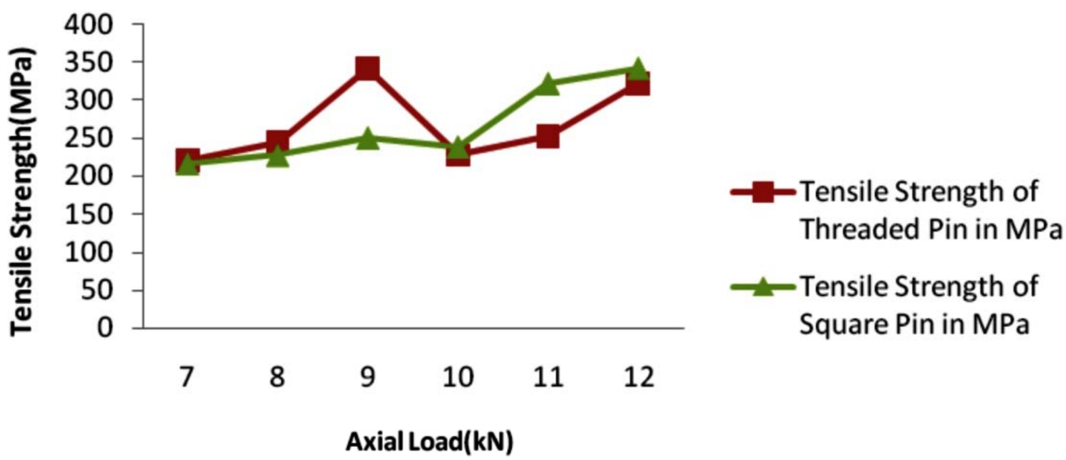

Fig. 8.(a) Effect of Axial Load on Tensile Strength for both Profiles

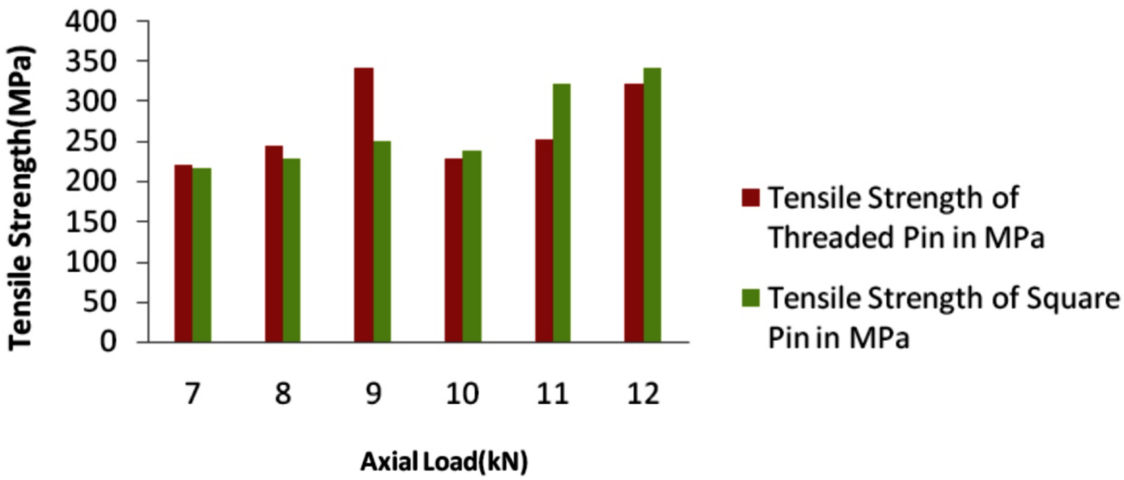

Fig. 8.(b) Effect of Axial Load on Tensile Strength for both Profiles

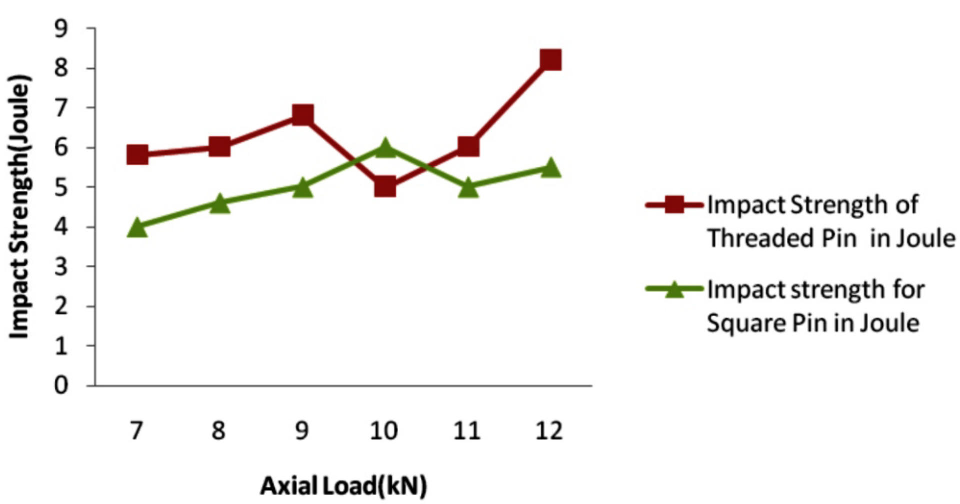

Fig. 8.(c) Effect of Axial Load on Impact Strength for both Profiles

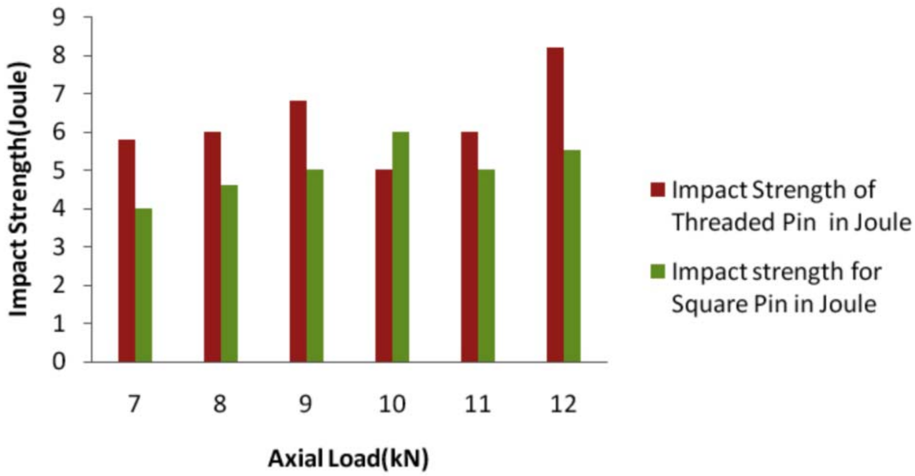

Fig. 8.(d) Effect of Axial Load on Impact Strength for both Profiles

The tensile strength of welding varies according to the axial load fig 8.(a). As in the fig 8.(a) tensile strength for threaded pin profile and square pin profile is varying according to the axial load. the tensile strength for both the profile of pin at 10 N is nearly 225 MPa and at 12 N it obtained 325 MPa, but the tensile strength for threaded pin is maximum at 9 nN which is more than 350 MPa and it reduce as axial load increased. But in case of square pin profile the tensile strength of weld increased continuously.

In caseof impact strength figure. 8.(c) maximum impact strength obtained at axial load of 12 N which is more than 8 J when welded by threaded pin profile. But in case of square pin profile maximum impact strength obtained at 10 N which is 5.5 J. The impact strength at 10 N for both the tools comes around 4.5-5.5 J

D. Micro structure

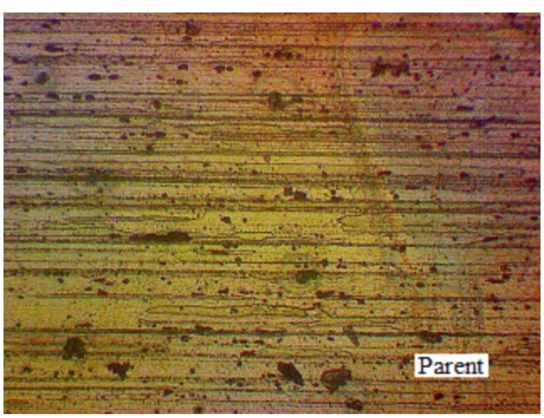

Fig. 9. 20X microstructure

The above figure 9. Shows that the complete cross-section of the FSW zone with the parent metal on both the sides of the plate. (T1-taper thread, 8 kn, 75 mm/min).

The FSW zone [11] shows the presence of some black particles. The tunnel defect has not been formed. Shows the parent metal microstructures which seem to be wrought aluminum alloy. The phases present are the Mg_2Si and fine particles of Cu–Al_2. The matrix also shows the undissolved Al6 (Fe, Mn) inter metallics.

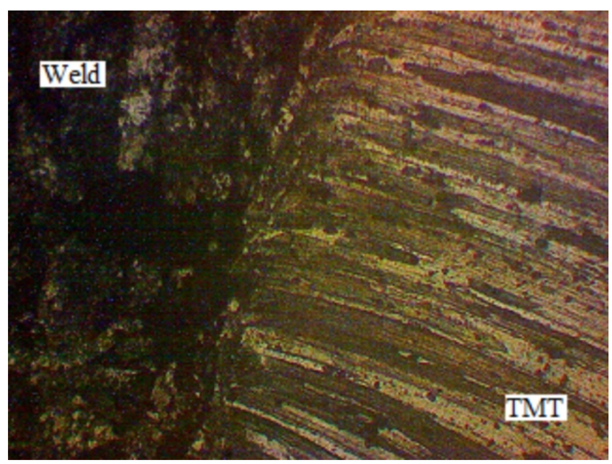

Fig. 10. TMT zone

The above figure 10. Shows that the TMT zone where the direction of the base metal has changed due to the friction stir force and heat. The heat made the dissolved phase re-appear as bigger particles. Shows the interface location of the TMT and weld zones. The particles in the weld zone are finer due to the fragmentation and growth.

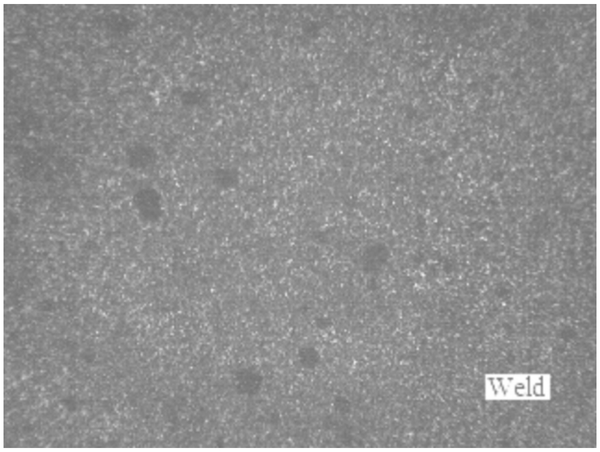

Fig. 11. Magnification: 100XEtchant: Keller's reagent

The above figure 11. Shows the weld zone where the grains are finer and some non-metallic particles are present.

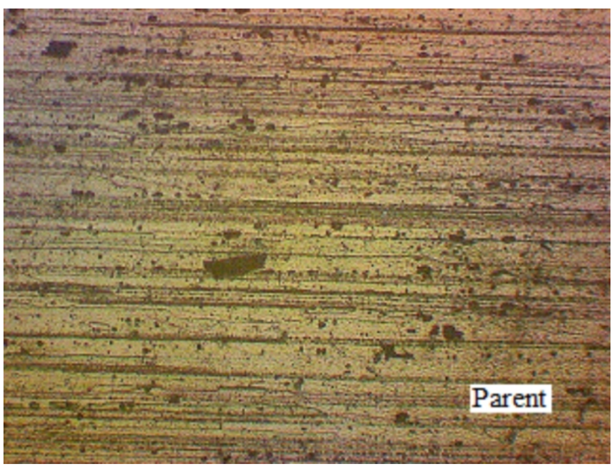

Fig. 12. 20X microstructure

The above figure 12. Shows that the complete cross-section of the FSW zone with the parent metal on both the sides of the plate. The FSW zone shows the presence of unfilled tunnel cavity with the presence of some black particles. The parent metal microstructures which seem to be wrought aluminum alloy. The phases present a

There are the Mg_2Si and fine particles of $Cu{-}al_2$. The matrix also shows the undisolved Al_6 (Fe, Mn) inter metallic. The rolling bands are along the rolling direction of the plate.

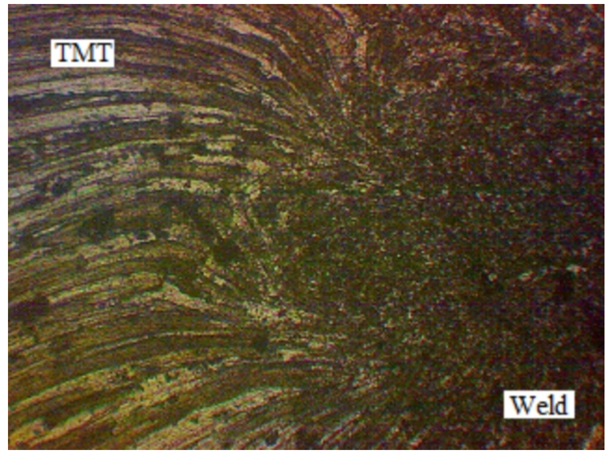

Fig 13. TMT zone
(T2-squre pin profile, 8 kn, 100 mm/min, 9 kn)

The above figure. 13. Shows that TMT zone where the direction of the base metal has changed due to the friction stir force and heat. The heat made the dissolved phase re-appear as bigger particles.

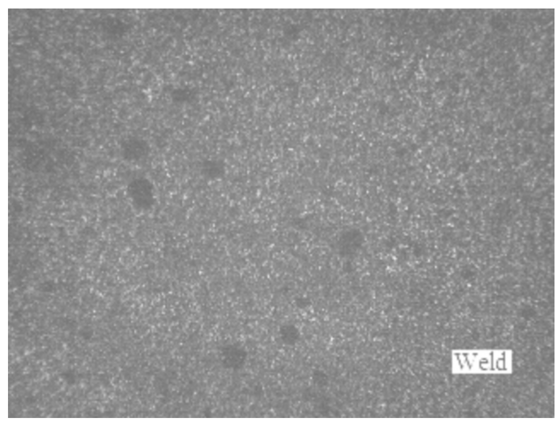

Fig. 14. Magnification: 100X

The above figure 14. Shows that the interface location of the TMT and weld zone. The particles in the weld zone are finer due to the fragmentation and growth

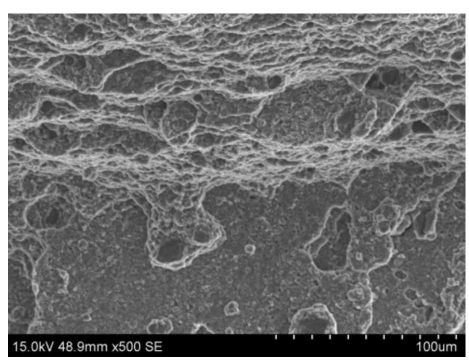

Fig. 15. Frctrographs of FSW at 500x

Table 6: Hardness value for different weld parameters

SAMPLE	PARAMETERS	BASEMETAL	HAZ	WELD
SAM PLE 1 Taper Threaded Pin	RST11- 1600 RPM, 8KN, (RS13)	182	152	141
SAMPLE 2, Taper Threaded Pin	RST21- 8KN, 75mm/min, 1500RPM	182	154	147
SAMPLE 3 Square Pin	RST21, 7 KN, 75mm/min, 1500RPM	182	156	150
SAMPLE 4 Square Pin	RST22, 9KN, 75mm/min, 1500RPM	182	178	162

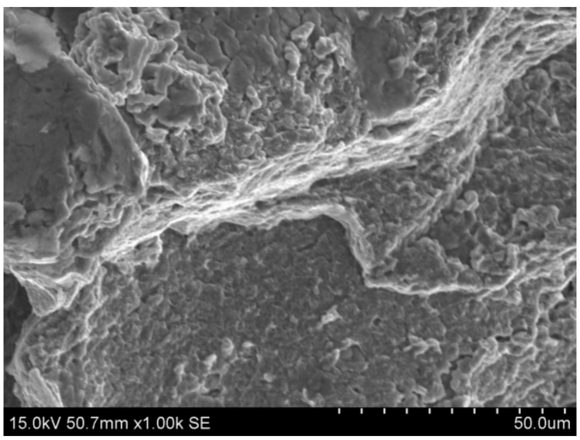

Fig. 16. Frctrographs of FSW at 100x

The SEM Image were studied at 100x and 500x. The precipated solid solutions were appeared in the fractrograph image. Considerable grain refinement has been achieved by FSW at plastic flow condition

V. CONCLUSION

1. Considerable grain refinement has been achieved due to friction stir welding and the plastic flow. Due to retracting and advanced force the grains are formed dynamic recrystallized zone.

2. The threaded cylindrical profile has been best suited at 800 rpm for better weld results and higher quality for this alloy.

3. The results can be applied for replacement of rivets in aircraft, rocket propulsion and automobile sectors where this alloy is used.

4. In (table 4) the effect of the axial load and tensile strength has been concluded in this table the graph between tensile strength (Mpa) on Y-axis and axial load (KN) on X-axis has been drawn. This tensile strength and axial load is concluded based on two tool profile namely thread pin and square pin. As the axial load increases in thread pin profile the tensile strength also increases upto 9 KN and reach to the 350 Mpa and then after further increment of the axial load the tensile strength starts to decreases. But in case of square thread pin the tensile strength gradually increases as the axial load increases. The point where both the profile is having same tensile strength is at 10 KN of axial load at which tensile strength is nearly 225 Mpa.

5. The effect of the axial load and impact strength has been concluded in which the impact strength (Joule) on Y-axis and axial load (KN) on X-axis has been drawn. Here also the impact strength of the material increases during the increment of axial load upto 9 KN and then decreases. So at 10 KN the impact strength of both tool profiles is nearly same.

6. The microstcture and SEM Image were studied at 100x and 500x. The precipated solid solutions were appeared in the fractrograph image. Considerable grain refinement has been achieved by FSW at plastic flow condtion.

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M.Sivashanmugam is currently working as Asst. Professor in the Department of Mechanical and Production Engineering, Sathyabama University, Chennai, India. He has one-year industrial experience, five years workshops superintend, five years Transport Manager, Three years senior Project Officer and eight years teaching experience in Sathyabama University.

He has participated and presented 15 research papers in International/National conference and three of his papers were published in the International/National Journals. He is a Life member of The Indian Welding Society (IWS), He is a Life member The Indian Institute of Welding (IIW) Indian Society of Technical Education (ISTE) and He is a Life member in Society of Manufacturing (SME).