Microstructural Modifications of As-Age Hardening 7071 Aluminium Alloy using Friction Stir Welding

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Abstract— Objective: *Friction stir welding (FSW) is a relatively new solid state welding technique for similar and dissimilar materials, especially on current interest with Aluminium 7071 to Aluminim 7071.* ***Method/Analysis:*** *The present paper discusses the process parameters followed by mechanical properties and microstructures which affect the weld strength.* ***Findings:*** *Mechanical properties-Tensile strength attained with different process parameters and Microstructures are obtained by Optical Metallurgical Microscopy (MET SCOPE-1) and a Scanning Electron Microscopy equipped with an X-radiation detector EDS* ***Conclusion/Application:*** *In this study Similar FSW between Al 7071 to Al 7071plates with thickness 6mm were performed. The future research will contain creep tests and microstructural investigations using aluminium 7071 alloy using TEM microscopy (Transmission Electron Microscopy).It is demonstrated that FSW of aluminium to aluminium alloys is becoming an emerging technology with numerous commercial applications.*

Keywords— FSW; Aluminium alloy, Similar, Mechanical properties, Microstructures, SEM.

I. INTRODUCTION

A rotating High Speed Steel pin advances into the workpiece, creating a highly deformed, plastic zone which flows around to its trailing side. No melt occurs, and the weld forms by solid-state plastic flow at elevated temperature. There is no porosity and other fusion weld-type defects associated with the weld zone if the rotational speed (R) and travel speed (T) are optimized.

In this study, we have used light metallography (microscopy) (LM) and Scanning electron microscopy (SEM) to characterize the microstructures in the friction stir weld zone and compare them with the original 6061 aluminium alloy work-piece microstructures. We have also measured the associated micro harness profile extending from the work-piece and through the weld zone. The aim of this paper to present a very brief but comprehensive microstructural overview of this process and illustrate corresponding hardness profiles associated with these microstructures.

II. EXPERIMENTAL DETAILS

7071 aluminium alloy plate (nominally 6mm thick) was used in friction-stir welding experiments to be reported. A series of simulated weld in solid plate sections were conducted, as illustrated schematically in fig 1, at rotational speeds (R) ranging from 500-1000 rpm , and travel speed of 100 mm/min. The high speed steel welding pin fig.2 was used. Welded cross-sections were ground, polished, and etched with Keller's reagent (150ml distilled water, 3ml nitric acid, 6ml hydrochloric acid at room temperature) for optical metallography. Instrumental (digital) Vickers micro hardness measurements were also made throughout the weld zone and into the initial aluminium alloy plate using a 100gf load.

MATERIAL SELECTION & MATERIAL COMPOSITION

Aluminium alloys have steadily increased in aerospace applications because of their excellent strength to weight ratio, Good ductility, Corrosion resistance and cracking resistance in adverse environments.

Chemical Composition of AA7071

Si 0.41	Mg 2.5
Cr 0.17	Fe 0.50
Zn 5.1-6.1	Ti 0.18
Al balance	Cu 2.0
Mn 0.3	

Table.1: Mechanical Properties of AA7071

Yield Strength (MPa)	Ultimate strength (MPa)	Elongation (%)	Reduction in cross-sectional area (%)	Hardness(HN)
302	334	18	12.24	105

Table.2: Physical Properties of AA7071

Density (g/cm^3)	Melting Point(^{O}c)	Modulus of Elasticity (GPa)	Poison ratio
2.7	580	70-80	0.33

Welding Parameters

In this study, downward force and welding speed are kept constant, only the tool rotation speed is varied. The welding parameters are given in Table 1.

Table.3: Welding parameters

Downward force (Tones)	40
Tilt angle (Degrees)	2°
Plunge Depth (mm)	3
Travel speed (mm/min)	100
Tool Rotation speed (rpm)	500, 700, 900, 1000

Tool Parameters:

Straight Cylindrical tool was used as shown in figure. The tool is made up of M2 high speed steel and which was tempered and hardened to 60 HRC. The tool material composition is given in Table 2.

Table.4: Tool Parameters

Material	C	Cr	W	Mo	V	Fe
M2	0.85	4.0	6.0	5.0	2.0	Remaining

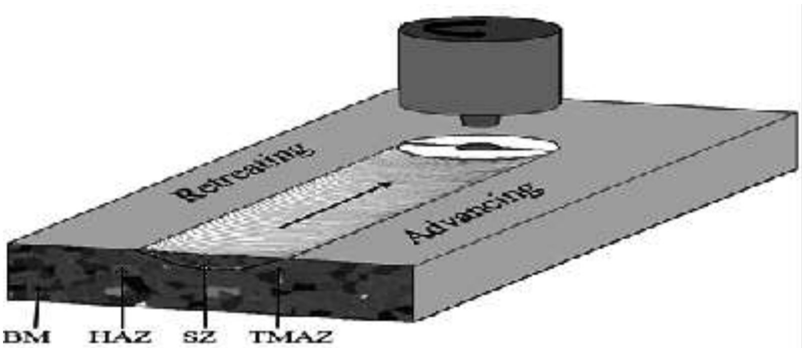

Fig.1: Schematic Drawing of Friction stir Welding

Fig.2: a FSW Tool

Tapered tool made up of HSS, its
Tool probe or pin length = 4.8mm
Pin diameter = 4mm
Shoulder diameter = 25mm
Shoulder length = 26mm

Weld trails

Four sets of welding trails were made at the base material AA7071, only by varying the tool rotation speed and keeping downward force, travel speed, plunge depth and tilt angle as constant, the values of the parameters are given in Table 3.

Table.5: Weld trails

Specimen Code No.	S500	S700	S900	S1000
Downward force (Tones)	40	40	40	40
Tilt angle (Degrees)	2°	2°	2°	2°
Plunge Depth (mm)	3	3	3	3
Welding Speed (mm/min)	100	100	100	100
Tool Rotation speed (rpm)	500	700	900	1000

Fig.3: Schematic drawing of FSW

Fig.4: Macrograph of the welded part under 700rpm

Tensile tests were performed to determine the tensile properties of the weld material such as tensile strength and percentage of elongation. One specimen of each was tested at S500 and S700 condition were measured and reported. The tensile tests specimens were cut as per the ASTM 8 standard size on the 6mm thick plate. Tensile tests were conducted on FIE/UTN-40 machine.

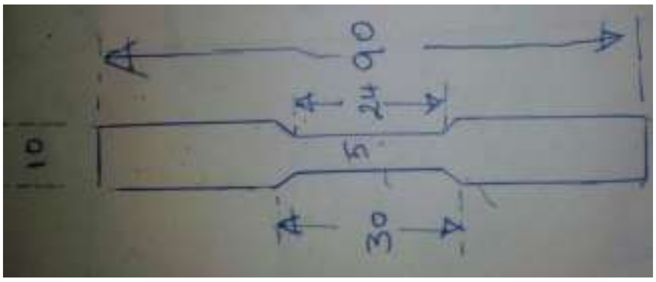

Fig.5: Dimension of the tensile specimen

III. RESULTS AND DISCUSSIONS

3.1 Tensile test

Table.6: Tested specimen results

S.N0	Specimen Code	Breaking load KN	Tensile Strength MPa	Elongation %	Fracture position
1	S500	16.200	136.778	2.740	Weld nugget
2	S700	25.42	180.92	2.90	Weld nugget
3	Base Metal (ASTM Hand book,Vol.9)	----	330	18	-------

3.2 Microstructure:

The microstructure of the different regions of the welded similar material is shown in fig 6&7. Though the weld undergoes considerable amount of the thermal cycle, there is no significant changes in the microstructure of the base metals. The conclusion of the given sample had grain size number as per ASTME 112 has 5.5 at nugget zone and 5.5 at heat affected zone.

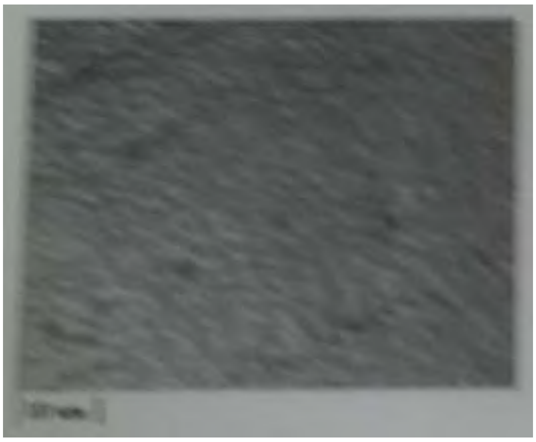

Fig.6: Optical Metallography of Aluminium-Aluminium at Nugget zone Grain Size analysis: Results summary

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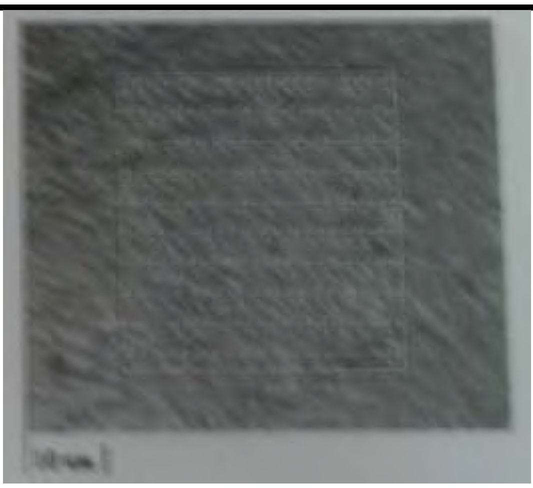

Fig.7: Optical Metallography of Aluminium- Aluminium at HAZ

Fields measured : 1
Analyzed Area : 5005 sq. mm
Standard used : ASTM E 112

At NZ	Grain size#
Grain size	5.5
Intercepts	139
MeanInt.length (um)	50.9
Std dev.	.
95% CI	.

At HAZ	Grain size #
Grain size	5.5
Intercepts	157
Mean Int.length (um)	45.1
Std dev.	.
95% CI	

3.3 SEM and EDX analysis:

Elemental analysis of the macro regions in weld zone was performed using a scanning electron microscope (SEM) equipped with an EDX system. This analysis was conducted to gauge the distribution of alloying elements in the FSW zone. SEM image was analyzed at a magnification of 50X. EDAX was taken at the center of the weld zone as shown in the fig.8 Presence of Al (57.58%), C (33.76%) and O (8.66%) were prominent in that region.

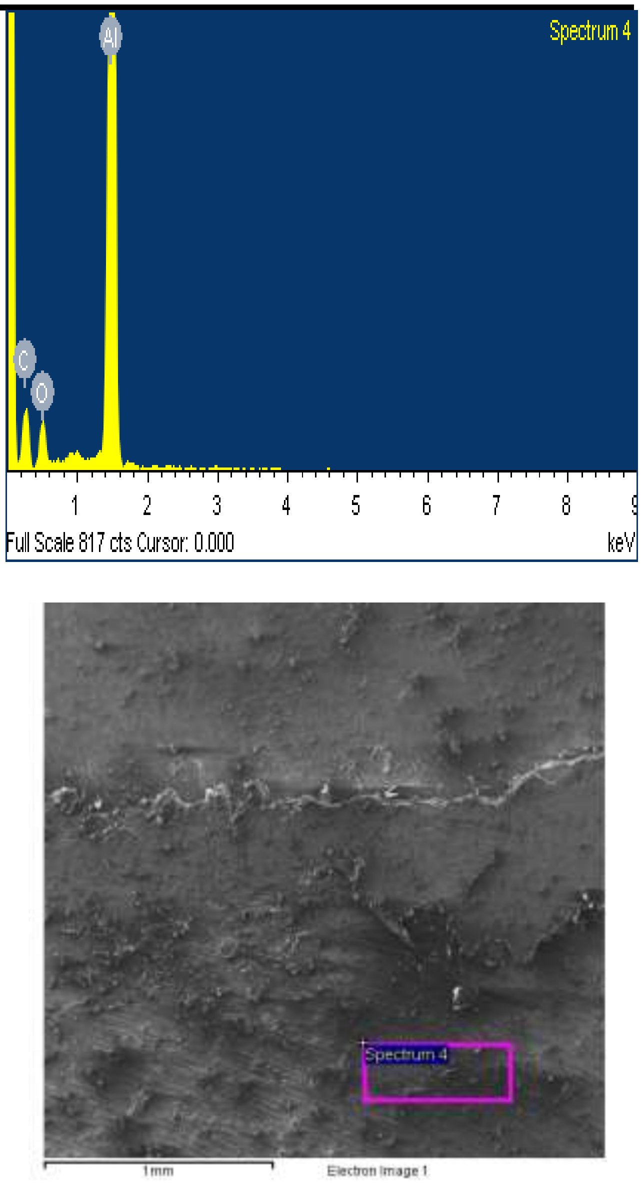

Fig.8: SEM and EDAX analysis

3.4 Hardness:

Vickers hardness tests were conducted across the regions of the weld spacing of (0.25mm) Average hardness value of 420 HV was obtained across the weldment for tapered pin.

IV. CONCLUSION

The FSW process parameters were optimized with respect to mechanical and metallurgical properties of the weldments. Tensile strength for S700 has more value than S500 also at nugget zone and HAZ the grain size is 5.5 the future research will contain creep tests and microstructural investigations using aluminium 6061 alloy using TEM microscopy (Transmission Electron Microscopy).

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