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Investigation on effect of tool pin profile on Microstructure and Mechanical Properties of Friction Stir Similar Metals

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Abstract: Recently many reports on Friction Stir Welding (FSW) of various dissimilar systems such as Aluminium alloyAA7075, has been reported. FSW of Aluminium alloys has captured important attention from manufacturing industries, such as Shipbuilding, Automotive, Railway and Aircraft production. Similar welds which include welds between the different series of aluminium alloys has been successfully produced by many researchers. In FSW process, a so-called welding-head pin rotating at speeds usually in excess of a few hundred rpm, travels down the length of contacting metal plates, creating a highly plastically deformed zone through the associated force and frictional heating. Aluminium and its alloys are widely used in industrial applications due to their excellent electrical & thermal conductivities, good strength, corrosion & fatigue resistance. The aim of present study was analogy of the microstructures and mechanical properties of friction stir welded joint of Aluminium alloys AA7075, plates in 6mm thickness.

Index Terms: Aluminium alloy, Similar Materials, Microstructure, Micro hardness and Mechanical Properties, FSW.

1. 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 7075 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.

2. EXPERIMENTAL DETAILS

7075 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 AA7075

Si 0.45 Mg 2.9
Cr 0.19 Fe 0.57
Zn 5.1-6.1 Ti 0.18
Al balance Cu 2.0
Mn 0.3

Table 1: Mechanical Properties of AA7075

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 AA7075

Density (g/cm^3)	Melting Point(^Oc)	Modulus ofElasticity (GPa)	Poison ratio
2.7	580	70-80	0.33

Table 3:Welding parameters elding

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

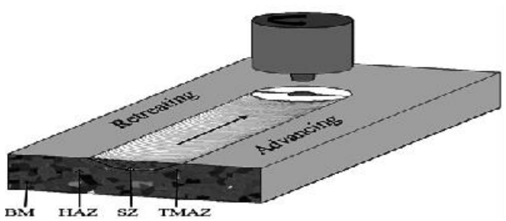

Fig 1 Schematic Drawing of Friction stir Welding

Fig 2 FSW Tool

Conical 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 AA7075, 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

Fig 3: Schematic drawing of FSW   Fig 4: Macrograph of the welded part under 700rpm

3. RESULTS AND DISCUSSIONS

3.1 Tensile test

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.

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

Tensile tests were conducted on FIE/UTN-40 machine.

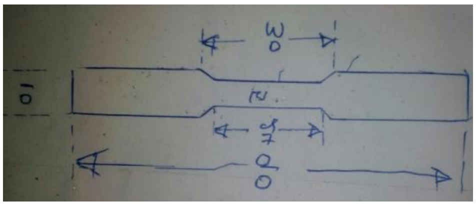

Fig 5: Dimension of the tensile specimen

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 At HAZ Grain size Intercepts MeanInt.length(um)	S700	25.42	180.92	2.90	Weld nugget

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

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.

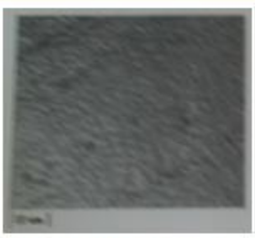

Fig 6 Optical Metallography of Aluminium-Aluminium at Nugget zone

Fig 7 Optical Metallography of Aluminium- Aluminium at HAZ

Grain Size analysis: Results summary

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

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.

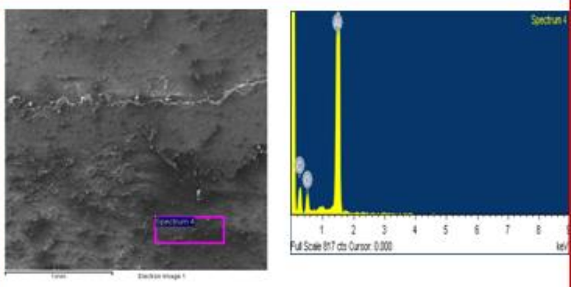

Fig 8 SEM and EDAX analysis

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.

4. 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 7075 alloy using TEM microscopy (Transmission Electron Microscopy).

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