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Analysis of Microstructural Characterization of Solid State Welded Dissimilar Aluminum Alloy Joints (Al2024 & Al7075)

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Abstract:
Friction Stir Welding (FSW) is a solid state welding process. Specifically, it can be utilized to join high strength aviation aluminum and other metallic compounds that are difficult to weld by traditional combination welding. It was performed on 6mm thickness AA2024 and AA7075 unique Aluminum composites. Present study is to observe the Effect of welding speed on microstructures and hardness distribution of the welded joints. The microstructure at AA2024 shows elongated particles of Al_2Cu and MgSi in a matrix of aluminum solid solution and voids were also observed in a matrix. Increment of rotation speed more to than 1120 rpm achieved a blended structure looking like onion rings with intermittent difference in equiaxed grain measure and heterogeneous circulation of alloying components. Finally, the experimental results will be contrasted and microstructures which are analyzed by optical magnifying instrument. From microstructural analysis it is evident that the material placed on the advancing side dominates the nugget region it is observed that the grain size is decreased in friction stir welding with circle with threaded pin profile. Hardness testing has conducted by Vickers hardness at various zones of the welded joints. Hardness values increased with increasing rotation speed and fluctuated in the dissimilar joints due to formation of onion rings and intermetallic compounds, the hardness in the HAZ of joint was found to be minimum.

Keywords: Friction Stir Welding of Al 2024 and Al 7075 Alloys, Microstructure, Micro hardness.

INTRODUCTION:

The heat treatable aluminum alloy AA2024 is utilized broadly in the flying machine industry as a result of its high quality to weight proportion and great flexibility. AA7075 aluminum compound has assembled wide acknowledgment in the creation of light weight structures requiring high quality to weight proportion and good corrosion resistance. Considerable effort has been expended to develop various joining processes and assess their suitability for use in lightweight structures [1–3]. Friction stir welding (FSW) is a relatively new and attractive joining technique which has already generated considerable interest in the aerospace sector as a potential replacement technique for riveting. In general the process is well established particularly for aluminum alloys [4-7]. FSW is often a preferred joining technique not only for aluminum alloys [8-9] but also for other difficult-to-weld metals such as magnesium alloys [10-11] and metal-matrix composites [12-13], etc. The technique is now widely used in many industrial sectors such as marine, aerospace, railway, land transportation, etc. FSW was carried out at various parameters such as transverse speed 60mm/min rotational speed 1400rpm by three different types of high carbon tools and the samples were inspected by optical microscope to obtain the microstructure images. The present research work is gone for comprehension the microstructural changes achieved by friction stir welding process parameters on AA2024-AA7075 unique joints and their effect on hardness.

EXPERIMENTAL SETUP:

Base Materials

The material used for dissimilar Friction stir Welding (FSW) were AA2024 and AA 7075 aluminum alloys. In this welding when two metals are joined with the help of heat generated by rubbing metals against each other. The friction stir welding is mostly used for joining aluminum alloys. The aluminum alloys AA2024-T3 and 7075-T6 are selected for the dissimilar Friction Stir welding process; T3 denotes solution heat-treated and then cold worked, T6 denotes solution heat-treated and artificially aged. The chemical composition and mechanical properties of base metals are presented in Tables 1 and 2, respectively.

Table – 1: Chemical composition of the base materials Al 2024 and Al7075 alloys.

CHEMICAL ELEMENT	Manganese (Mn)	Iron (Fe)	Copper (Cu)	Magnesium (Mg)	Silicon (Si)	Zinc (Zn)	Chromium (Cr)	Titanium (Ti)	Aluminium (Al)
Al 2024 wt%	0.3-0.9	0.50Max	3.8–4.9	1.2-1.8	Max 0.5	0.25 Max	Max 0.1	0.15 Max	90.7-94.7
Al7075 wt%	Max 0.3	0.50Max	1.2-2.0	2.1-2.9	Max 0.4	5.1-6.1	0.18– 0.28	0.2 Max	87.1-91.4

Table - 2: Mechanical properties of the Base material.

Materials	Mechanical properties at room temperature		
	Yield stress (MPa)	Tensile stress (MPa)	Elongation (%)
2024-T3 Al alloy	327	461	29.5
7075-T6 Al alloy	498	593	17.7

FSW is perpendicular to the rolling direction of both the aluminum alloy plates. The side when the direction of the tool rotation and translation motion of the tool is contacts with each other, it is referred as the retreating side. All the welds were butt welds and were carried out using tools made of High speed steel. The shoulder diameter of the tool was 24 mm; the probe had a diameter of 8 mm and a height of 4.7 mm. The tool travelled along the centerline of the weld with constant 5KN load. By varying the process parameters, defect free and high efficiency welded joints were produced.

Microstructural Observation:

The micro structure images were taken from each specimen from its NG which was sectioned to the required size from the FSW joints transverse to the welding direction. The specimen's NG was super finished by using various emery papers and finally taken it into mirror image. Then after we go for etching we use killer's reagent (2mlHF, 3mlHCL, 20mlHNO3 and 175mlH2O) by optimal microscope as per ASTM E-812 standards. The grain arrangement within the nugget is well and equiaxed and the grain size are significantly lesser than that in the base materials (2024) due to the advanced temperature and extensive plastic deformation by the stirring action of the tool probe. Metallurgical investigations on a cross section of the joint were done for the Friction Stir Welded material.

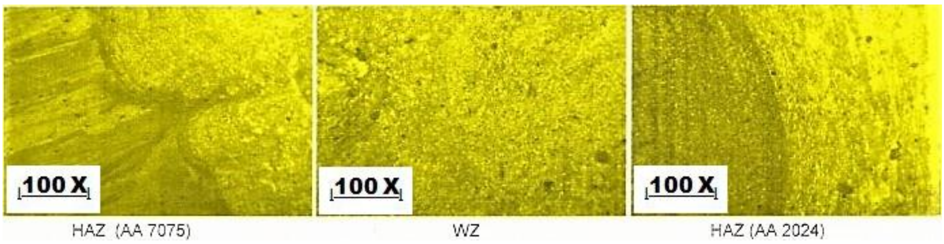
Hardness Test:

Hardness is the resistance of a material to localized deformation. The hardness tests were carried out according to test procedure IS 1501:2002 ASTM standards using Vickers hardness testing machine. The principle in this test is that a defined shaped indenter is pressed into the material. Vickers microhardness testing (Wilson Rockwell, R5000) was performed out along a mid-thick line across the cross section of the welds at a distance of 2 mm from the top surface using a 0.5kg load. The indenting force is applied for a certain decided amount of time. Microhardness tests were carried out at the cross section normal to the FSP direction. The test was conducted at room temperature (28 ° C) and the measurement of hardness was taken at three different places on each sample to obtain an average value of hardness.

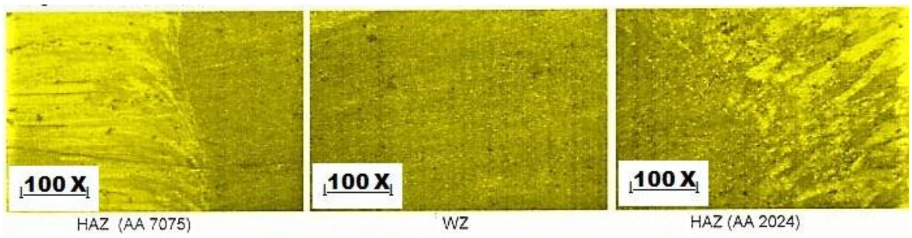
RESULTS AND DISCUSSION

Microstructure

In this work, FSW dissimilar welds of AA 2024-AA7075 joints were successfully obtained and the microstructures of the material were observed under optical metallurgical microscope (met scope-1). The Microstructure of the friction stir welded AA 2024 and AA7075 joint consists of different zones such as stir zone, thermo mechanically affected zone, heat affected zone and base metal. The microstructure images show typical grain structures of different regions in FSW Al2024-Al7075. The Nugget Zone consists of fine equiaxed grains due to dynamic recrystallisation and the grains in NZ are much smaller than those in other regions. The experimental results also reveal that the microstructure consist fine grains and intermetallic particles. It is observed that the fusion zone contains coarse grains with more concentration intermetallic compounds which are homogeneously distributed in the aluminium matrix. This is mainly due to cooling rate, as it decreases with increasing the heat input. Typical microstructure images of the friction stir welded material are shown in Fig.



(a). friction stir welded joint with Taper threaded tool



(b). friction stir welded joint with square tool

(c). friction stir welded joint with Taper conical tool

Figure 1: microstructure images of FSW joints by different tools.

Microhardness

The microhardness profile along the centre line on a cross-section of the welds at a tool rotation speeds of 900, 1120, 1400 rpm. The hardness values within the stir zone by using the three different pin profile tools such as taper threaded, taper conical and square. The stir zone by using the taper conic tool pin profile has higher hardness 158.10 HV compared to other tool pin profiles such as taper threaded and square. This is due to the generation of extremely fine grains in the stir zone. There is a steadily decreasing hardness from the stir zone, minimum hardness near the HAZ/TMAZ interface and an increase in hardness across the HAZ and weld nugget. The lowest hardness of FSW joint is observed in the TMAZ region. Elongated and deformed grains causes softening in this region may be the reason for reduction in hardness. Softening is caused by coarsening and disintegration of reinforcing accelerates during the thermal cycle of the FSW. Hardness was observed to be higher in the weld region contrasted with the HAZ and TMAZ areas, regardless of joining by utilizing different tool profiles. The hardness value of the FS welded specimen are shown in the below Table.

Table – 3: Micro hardness values for the Al 2024 and Al 7075 Friction stir welded joints.

Specimen No	Hardness value (Hv)
1	135.10
2	145.16
3	137.70
4	132.63
5	142.70
6	147.76
7	158.10
8	150.73
9	149.70

CONCLUSION

In summary, AA 2024 and AA 7075 aluminum alloys were friction stir welded at various welding parameters, and the microstructures of various specimens at different regions are observed and the following conclusions are reached.

- The micro structure shows fusion between weld and base metals. The microstructure at Al 2024 - Al 7075 welded joint shows elongated particles.

- Welded material consists of dendrites of Al solid solution with fine grain and intermetallic particles are observed.
- No cracks and blow holes are observed at Welded portion and HAZ.
- An increase of equiaxed grain size in the Stirred Zone with increasing rotation speed.
- Higher hardness 158.10 HV observed at the stir zone which was friction stir welded by the taper conic tool pin profile.
- Therefore, it is concluded that the generation of refined grains in the stir zone is a main factor that caused increased the hardness at the stir zone.

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