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Microstructure and Mechanical Properties of Friction Stir Welded Dissimilar Aluminum Joints of AA2024-T3 and AA7075-T6

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Abstract

In this work, the microstructure and mechanical properties of friction stir welded dissimilar butt joints of 2024-to-7075 aluminum alloys were evaluated. Dissimilar aluminum alloys such as 2024-T3 and 7075-T6 plates 3mm thickness were friction stir butt welded. The welding was carried out at a constant welding speed of 100 mm/min and rotation speeds of 400, 800, 1200, 1600 and 2000 min^{-1}.Aluminum compounds Due to their great strength to mass ratio, decent machinability, and great resistance to deterioration, are eye-catching frivolous metals used for mechanical applications in the atmosphere, locomotive, and naval diligence. Nevertheless, the assembling of Al alloys by conservative fusion fusing techniques is challenging. Some of these concerns include the development of subordinate brittle stages, cracking throughout solidification, extraordinary distortion, and lingering stresses.

Keywords: aluminum alloys; fusion technique; brittle material; friction stir welding; dissimilar joint.

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1. Introduction

The joining of high enactment aluminum compounds for the space industry is a predominantly challenging field due to the tremendously low limitations of error and to the robust need for dependable, safe and consistent measures. Friction stir welding is a compact state soldering process tested by TWI for joining very difficult aluminum compounds. The operational principle of Friction stir welding is founded on the accomplishment of a spinning tool that is implanted into the combined line crossing along it, stimulates the substantial and produces the dual [13].

The efficiency of Friction stir welding is linked to the absenteeism of bulk sentiments of the work-piece. This eradicates the solidification glitches during fusing, reduces misrepresentation and residual pressure. Furthermore, the absenteeism of melting permits the joining of unlike metals and compounds. Friction stir welding is a suitable method for welding space aluminum compounds such as 2XXX series, one of the most auspicious areas of solicitation of Friction stir welding [11].

The frictional temperature generated by the fusing tool brands the surrounding factual softer and permits the tool to change along the combined line. Heat during fusing does not surpass the sentimental point of improper metals. Friction stir welding joint is known to usually possess 4regions such as intensively distorted zone known as stir zone, TMAZ, HAZ and BM [5]. After success in fusing of similar metals, efforts have been introduced to join unlike compounds like aluminum compounds to other different aluminum amalgams, copper blends, steels and magnesium composites for enhancing mechanical chattels and chemical chattels such as deterioration resistance.

2. Method

A cylindrical negotiated tool, having a pin and shoulder diameter of 10 mm and 18 mm respectively, was used for this study. The butt friction stir welding was performed parallel to the rolling direction of the plates, and by placing the AA7075-T6 on the advancing side. After the welding was completed, the top and bottom surfaces of the welded plates were machined down to a 4 mm of thickness. This was done to eliminate the stress raisers produced due to the flash material at the top of the weld [5,14].

Flash material is produced on top of the welded plates due to the direct interaction of the tool shoulder and the underneath material that is been extruded and stirred around the pin. Afterwards, specimens for microstructural and mechanical characterization were cut perpendicular to the welding direction by using a water jet cutting, [13].

Chemical and mechanical properties of the base materials are shown in Table (1) and Table (2) respectively. Table (3) shown Welding Conditions. A steel tool with a treated pin has been used with the length of the threaded pin as 2.7 mm, including the curvy tip.

The largest diameter of the pin under the shoulder is equal to 4.6 mm, while the external diameter of the shoulder is 11 mm. the shape of the shoulder is slightly convex [14,15].

Table 1: Chemical composition of base metals.

Materials	Chemical composition (mass %)								
	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
AA2024-T3	0.01	0.08	5.35	0.67	2.07	0.09	0.04	0.05	Bal.
AA7075-T6	0.01	0.08	2.4	0.09	2.52	0.21	7.99	0.06	Bal.

Table 2: Mechanical properties of base metals.

Materials	Mechanical properties at room temperature		
	Yield stress (MPa)	Tensile stress (MPa)	Elongation (%)
AA2024-T3	327	461	29.5
AA7075-T6	498	593	17.7

Table 3: Welding Conditions.

Sample Number	Welding Speed (mm/min)	Rotation Speed (min^{-1})	Probe diameter (mm)	Shoulder Diameter (mm)	Advancing Side	Retreating Side
1	100	400	4	12	AA2024-T3	AA7075-T6
2		800				
3		1200				
4		1600				
5		2000				
6		400			AA7075-T6	AA2024-T3
7		800				
8		1200				
9		1600				
10		2000				

3. Results

As stated earlier, the AA7075 was positioned on the advancing side (right hand side), while the AA2024was placed on the opposite or rather the retreating side. Due to the differences in fetching response, AA2024 has bright colored regions, whereas the AA7075 has dark colored regions. No void defects are noticeable from the traverse sections in any of the tested parameters. Three main regions can be distinguished on the transverse sections, corresponding to the stir zone (SZ), the thermo-mechanical affected zone (TMAZ), and the heat affected zone (HAZ) [14,17]. The relationship between rotation speed and average grain size in stir zone is shown in figure 1.

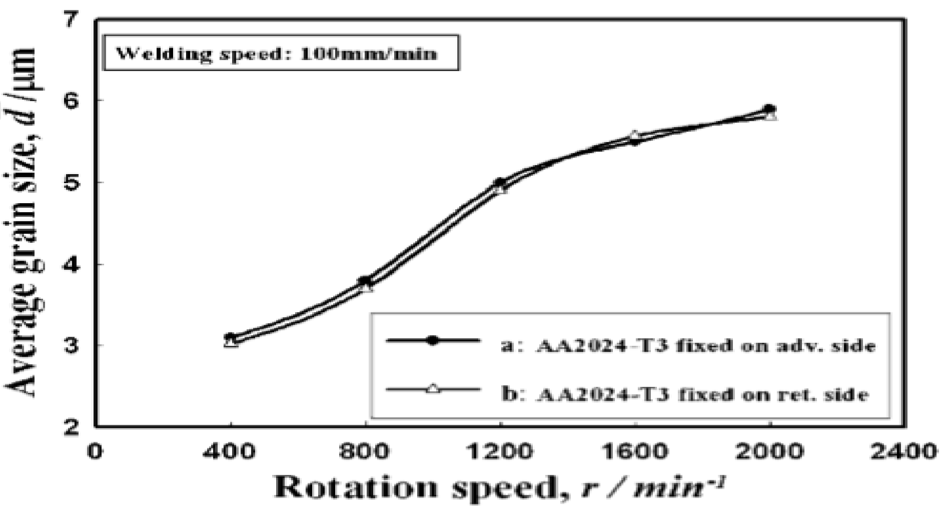

Figure 1: Relationship between rotation speed and average grain size in stir zone.

4. Discussion

The SZ features vortex structures that consists of alternate lamella of material corresponding to the base alloys and a mixture of both. Further examination using EDS confirmed the presence of three distinct layers. Locations A and B consist of the nominal composition for the AA2024 and AA7075 respectively, while location C consisted of a combination of both materials. Similar results have been demonstrated on dissimilar AA2024-AA7075 FSW. The formation of the bands corresponding to the composition of Location C, have been attributed to the plasticized material constrained in the features associated with the tool geometry [11]. In addition to the difference in compositions at these positions, grain size was also different in each region. The grain size in the regions 1, 3, 5, 7 and 9 where the composition is close to that of 2024-T3 Al alloy was lower than that at the regions 2, 4, 6 and 8 corresponding to 7075-T6 Al alloy region. The 2024-T3 Al alloy was fixed on the advancing side. SZ shows a great change of the hardness distribution with increasing rotation speed. For example, hardness beyond 9mm from the welding center line of the joint welded at 400min^{-1} is the same as that of the BM of 2024-T3 Al alloy naturally aged. At about 9mm from center, hardness starts to decrease and reaches a minimum value of 112Hv at about 4mm. beyond that position when going closer to the welding center position, hardness value turns to increase but the values are still lower by 23Hv than that of the BM of 2024-T3 Al alloy. This may be attributed to lower temperature during FSW than the solution temperature of precipitates which brings about an insufficient driving force for larger precipitates to be dissolved during joining, and in consequence to precipitate during natural aging [1,3,4,7]. Stiffness at the middle sharply increases to about 148Hv in SZ and reaches to a maximum value of 152HV at 3mm in TMAZ of 7075-T6 Al alloy side. Beyond 4.0mm from the center, the hardness value begins to decrease and a minimum value about 120Hv was obtained at about 7.5mm. The hardness turn increase again beyond this point and eventually reached to 163Hv which is a mean value of the BM of 7075-T6 Al alloy. The minimum hardness value in the HAZ of 2024-T3 Al alloy located at about 4:0mm from the center while the HAZ of 7075-T6 Al alloy had a minimum hardness value at about 7.5mm from the center. This may be attributed to the deference of precipitation behaviors between two alloys under a given thermal history of the joining. Kissing bond area as function of the weld pitch is shown in figure 2.

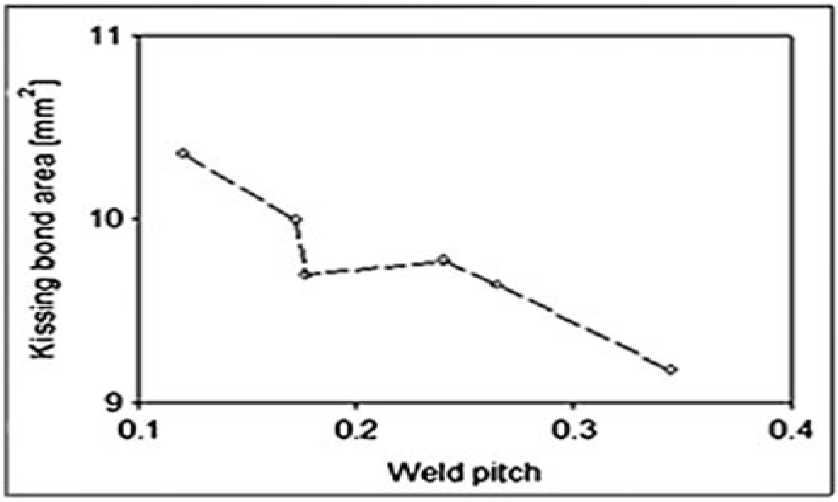

Figure 2: Kissing bond area as function of the weld pitch.

As such, a fraction of the material is trapped in the features of the tool and subjected to extended deformation periods, allowing the material to be intermixed before being deposited in the SZ [18]. The formation of vortex structures or ‘‘onion rings’’ is typical of FSW, but is exaggerated in the welding of dissimilar metals. These lamellar structures are attributed to the stirring action of the threaded tool, the in-situ extrusion, and to the transverse motion in the welding direction. In fact, the thickness of the bands of unmixed material was also modified as the tool rotational speed was increased in the dissimilar welding ofAA6061-to-AA7050. Microstructural examination of the longitudinal sections revealed that the spacing between the material bands decreased with the increasing tool rotational speed [18].

Average values for the material bands interspacing of 460, 350 and 300 lm were obtained for a tool speed of 270, 340 and 410 rpm respectively. This implies that a more uniform mechanical mixing was achieved at higher tool rotational speeds [13,14].

5. Conclusion

On the basis of the experimental campaign, the following conclusions can be drawn:

- The defect morphology strictly depends on the process parameters, such as the welding pitch. In particular, the KB-A decreases increasing the welding pitch; i.e. the defect area increases with the heat input. This occurs because at high values of the weld pitch, the heat generation is too low, and, as a consequence, the material remixing and flow is low, resulting in a minor extension of the defect zone. On the contrary, no trends are appreciable for the KB-L.
- The results of the hoop stress test allow to affirm that the skin keeps the good mechanical properties of the base material. All the joints preserve more than the 80% of the base material tensile strength, while the best joints are over than the 90% [11].
- The T-pull test does not show any trend in dependence of the process parameters; this due to the particular shape of the specimen. Two critical areas are identified in the joints: the kissing bond defect that constitutes a preferential path for the crack initiation and propagation and the knee of the stringer that is the most solicited section during the test. Hence, the first crack starts in correspondence of the defect, but the catastrophic failure occurs in the second of the two abovementioned zones.

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