Defect Analysis on Al 7020 FSW Joints with Mg Interlayering

R. J. Golden Renjith Nimal* and Anselm W. A. Lenin

1Department of Mechanical Engineering, Bharath University, Chennai – 600073, Tamil Nadu, India; goldenrenjith.mech@bharathuniv.ac.in
2School of Mechanical Engineering, Mar Ephraem College of Engineering and Technology, Marthandam – 629171, Tamil Nadu, India

Abstract

The use of light weight materials for industrial application is a driving force for the development of joining techniques. Especially in maintenance of cryogenic tanks, space craft body etc. Friction Stir Welding (FSW) inspired joints of materials because it does not involve bulk melting of the basic components so this can be employed in such of light metal structures manufacturing or maintenance. Here, two Aluminium 7020 plates were welded with Mg as interlayer, using friction stir welding method. The joints were produced using same welding parameters only the variation is done in the traveling speed of the tool. Tensile strength of the joint is determined using a universal testing machine. Hardness of the joint is found out by Rockwell hardness test. To validate the results Scanning Electron Microscope (SEM) and Energy Dispersive X-ray spectroscopy (EDX) testing where done. By analyzing the test result we found that joints with 10mm/min travel speed have comparatively high strength than other joints. Analysis found that even in the 10mm/min travel speed weld contain small defects and it is found that defect plays a vital role in the strength of the material.

Keywords: Defects, Energy Dispersive X-ray spectroscopy (EDX), Friction Stir Welding of Al7020, Light Metal Joining, Mg interlayer, Scanning Electrode Microscope (SEM)

1. Introduction

Friction Stir Welding (FSW) is a solid state welding process where joining takes place below melting temperature of material this characteristics greatly reduces distortion shrinkage, porosity, eliminates solidification defects. FSW has been proven to be an effective process for welding Aluminium alloys, Titanium, Copper, Zinc, Steel, Magnesium, Cast iron. Today FSW is used in research and production in many sectors, including aerospace, automotive, railway, ships building, electronic housings, coolers, heat exchangers, and nuclear waste containers. Main advantages of friction welding are high material saving, low production time and possibility of welding of dissimilar metals or alloys. For example engine pistons, mainly for truck applications can be friction welded. In this process a rotating tool with a pin extending from a larger shoulder is translated along the weld joint. This tool during its path produces frictional heating with temperature below the melting point and the plastic deformation due to the stirring of the material around the pin, produces the weld. The process can be regarded as solid-phase keyhole welding technique since a hole to accommodate the probe is generated, after getting in appropriated position the rotating tool produces heat due to friction between the tool and work pieces then moved along the weld. Hence the joining of the plates is performed.

In this work, friction stir welding is carried out between Al 7020 plates with Mg as the interlayer. The
Defect Analysis on Al 7020 FSW Joints with Mg Interlayering

joints are made between plates with magnesium as interlayer by varying the travel speed of the tool 10, 15, 20, 25, 30mm/min respectively by keeping the tool rotation and feed rate as constant parameters. Tests such as tensile test, Rockwell hardness test where carried out in the FSW joints to find out the mechanical properties of the joints.

A Universal Testing Machine (UTM), materials testing machine is used to test the tensile strength of the joints. The UTM is done by preparing the specimen according to the dimensions and subjected to tensile force which will continued till it breaks and thus we could know the maximum possible strength it posses.

2. Result and Discussion

2.1 Rockwell Hardness Test Result

The Rockwell scale is a hardness scale based on indentation hardness of a material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload. There are different scales, denoted by a single letter, that use different loads or indenters. The result is a dimensionless number noted as HRA, where A is the scale letter.

![Figure 1. Travel speed vs. hardness.](image)

![Figure 2. Travel speed vs. ultimate tensile stress.](image)

From the graph 2a (Figure 1.) we came to know that the specimen with travel speed of 10mm/m shows grater hardness than the other specimen, following 25mm/m and 20mm/m shows second and third most hardness value respectively. The specimen with 15mm/m shows lest hardness value during test.

The Rockwell hardness test is performed on each specimen in three zones namely stirs zone (middle zone of the weld), retreating side and advancing side of weld. The hardness is test done in stir zone or nugget zone which is of 49HRB. The hardness of the retreating side is 48HRB and the on advancing side is 48.5HRB.

The hardness test result shows that the test specimen of 10mm/min traverse speed has maximum hardness as compared to the other specimens. Here is the conflict i.e., for the same specimen tensile strength also high so we could go for scanning electron microscopy analysis.

2.2 Tensile Test Result

The tensile sample was prepared as per (ASTM E8M-04) standards. There after test is carried on the weld specimen with Mg interlayer of 5µ.8,9 The results of the tensile test are shown in the Table 2 below. The specimen with 10 mm/min of traverse speed has high tensile strength with ultimate tensile stress of 237N/mm².

| Sl No | Travel Speed of Tool mm/min | Observed Rock well hardness values (HRB) |
|------|-----------------------------|----------------------------------------|
| 1    | 10                          | 48.7                                   |
| 2    | 15                          | 40.7                                   |
| 3    | 20                          | 46.7                                   |
| 4    | 25                          | 48.3                                   |

| Sl No | Travel Speed of Tool mm/min | Ultimate Tensile Stress N/mm² |
|------|-----------------------------|-------------------------------|
| 1    | 10                          | 237.1                         |
| 2    | 15                          | 39.9                          |
| 3    | 20                          | 74.7                          |
| 4    | 25                          | 98.8                          |
Thereafter test is carried on the weld specimen with Mg interlayer of 5µ. The results of the tensile test are shown in the Table 2. The specimen with 10 mm/min of traverse speed has high tensile strength with ultimate tensile stress of 237N/mm². From the plots of travel speed vs. ultimate tensile stress (Figure 2.) it is very clear that when the travel speed of tool is decreased to 10mm/min the strength gets increased. While it is 15, 20, 25, 30 mm/min the strength is lesser than 10mm/min travel speed sample. For further analysis and studies about this character we can go in depth with Scanning Electron Microscope (SEM) and Energy Dispersive X-ray spectroscopy (EDX).

3. Defect Analysis

The type of defect found in this specimen is intergranular stress corrosion fracture; it is defined as grain boundary separation. It can occur by separation of microvoid coalescence on the interface of grains. It is due to severe reduction in grain boundary energy by Gibson adsorption mechanism.

![Defects found in 10mm/min travel speed.](image1)

With an interlayer (Mg) thickness 5µ we could see improper or uneven dispersion of raw material in forward and retreating zones in 15mm/min travel speed. This may lead to the defects/fracture like cleavage and Void and thermal stress accumulation also possible on the edges of these defects. This causes a reduction in tensile strength.

When doing welding with 10 mm/min travel speed (Figure 3.) all the above said defects were removed and only identified fracture morphology is deformed transition zone. It caused by the compressive fatigue cycles. This can be avoiding by slightly improving the weld speed, hence it helps to avoid over drive of shoulder in a same spot again.

Examination by Scanning Electrode Microscopy (SEM) of the origin of fracture at the weld joint reveals dimples formations characteristics of ductile tensile failure. High magnification image of the fracture surface opposite the weld failure clearly displays two distinct fracture surfaces. Figure 4 depicts the weld nugget, which displays transgranular cleavage enveloped by regions of ductile, tensile, dimples.

![Defects found in 15mm/min travel speed.](image2)

In case of 20 mm/min travel speed all the above said defects are present, and especially Intergarnular fracture; this is expected to be the cause of over deposition of impurities than parent material. The SEM Image analysis indicates that there is a mechanical bond zone in the interface between Forward and Stir Zone as well as Retreating and Stir Zone. The interface of substrate does not disappear completely in these zones. Hence the bonding intensity is weaker than metallic self-diffusion. So always the Joint strength of welding with interlayer is slightly varies from self diffused joints.

4. Conclusion

The result of this work predicts weld specimen with Mg interlayer of 5micron with 10mm/min tool travel speed shows higher tensile and hardness strength than other specimens with travel speed of 15, 20, 25 mm/min.
In the defect analysis on Al 7020 FSW joints we found intergranular stress corrosion fracture and dimples plus intergranular cracks, as per ASTM standards. The reason of this defect or crack may be occurred due to uneven heat dispersion, presence of impurity, vibrations, or oxide formations, which are common problems arises during FSW. But we can remove these problems by preheating specimen surface. Cleaning specimen by proper techniques: Avoiding unwanted vibrations and movements of machines. To go further the research can be extended with pre and post heat treatments to improve the grain structure and to avoid deformed transition zone. If the transition layer is vanished the strength will becomes similar to parent metal.

5. References

1. Lee W-B, Yeon Y-M, Jung S-B. Mechanical properties related to microstructural variation of 6061 Al alloy joints by friction stir welding. Mater Trans. 2004; 45(5):1700–5.
2. Anbuselvi S, Rebecca J. A comparative study on the biodegradation of coir waste by three different species of Marine cyanobacteria. J Appl Sci Res. 2009; 5(12):2369–74. ISSN: 1815-932x.
3. Ceschini L, Boromei I, Minak G, Morri A, Tarterini F. Effect of friction stir welding on microstructure, tensile and fatigue properties of the AA7005/10 vol.% AlO$_3$ composite. Composites Science and Technology. 2007; 67:605–15.
4. Rekha CV, Aranganna P, Shahed H. Oral health status of children with autistic disorder in Chennai. European Archives of Pediatric Dentistry. 2012; 13(3):126–31. ISSN: 1818-6300.
5. Zhang B-G, Chen G-Q, Zhang C-G, Ni J-Q. Structure and mechanical properties of aluminum alloy/Ag interlayer/steel non-centered electron beam welded joints. Transactions of Nonferrous Metals Society of China. 2011; 21:2592–6.
6. Karthikeyan T, Subramaniam RK, Johnson WMS, Prabhu K. Placental thickness and its correlation to gestational age and fetal growth parameters: A cross sectional ultrasonographic study. J Clin Diagn Res. 2012; 6(10):1732–5. ISSN: 0973-709X.
7. Winiczenko R, Kaczorowski M. Friction-welding of ductile cast iron using interlayers. Materials and Design. 2012; 34:444–51.
8. Shirley Gloria DK, Immanuel B, Rangarajan K. Parallel context-free string-token petri nets. International Journal of Pure and Applied Mathematics. 2010; 59(3):275–89. ISSN: 1311-8080.
9. Elangovan K, Balasubramanian V. Influence of tool pin profile and welding speed on the formation of friction stir processing zone in AA2219 aluminium alloy. J Mater Process Tech. 2008; 200:163–75.
10. Sathish Kumar M, Karrunakaran CM, Vikram M. Process facilitated enhancement of lipase production from germinated maize oil in Bacillus spp. using various feeding strategies. Australian Journal of Basic and Applied Sciences. 2010; 4(10):4958–61. ISSN: 1991-8178.
11. Guo J, Gougeon P, Chen XG. Microstructure evaluation and mechanical properties of dissimilar friction stir welded joints between AA1100-B$_4$C MMC and AA6063 alloy. Mater Sci Eng. 2012; 553:149–56.
12. Coelho RS, Kostka A, dos Santos JF, Kaysser-Pyzalla A. Friction – stir dissimilar welding of aluminium alloy to high strength steels: Mechanical properties and their relation to microstructure. Mater Sci Eng. 2012; 556:175–83.
13. Kimio T, Natarajan G, Hideki A, Taichi K, Nanao K. Higher involvement of sub telomere regions for chromosome rearrangements in leukemia and lymphoma and in irradiated leukemic cell line. Indian Journal of Science and Technology. 2012 April; 5(1):1801–11.
14. Cunningham CH. A laboratory guide in virology. 6th edn. Minnesota: Burgess Publication Company; 1973.
15. Sathishkumar E, Varatharajan M. Microbiology of Indian desert. In: Sen DN, editors. Ecology and vegetation of Indian desert. India: Agro Botanical Publ; 1990. p. 83–105.
16. Varatharajan M, Rao BS, Anjaria KB, Unny VKP, Thyagarajan S. Radiotoxicity of sulfur-35. India: Proceedings of 10th NSRP; 1993. p. 257–8.
17. Available from: http://www.indjst.org/index.php/vision