70(10A): 242-246; 2022. DOI: 10.18311/jmmf/2022/32758

Print ISSN : 0022-2755

Journal of Mines, Metals and Fuels

Contents available at: www.informaticsjournals.com/index.php/jmmf

A Review on Tensile, Microhardness and Microstructural Properties of Aluminum AA2219 Alloy Joints Obtained by Friction Stir Welding Process

Rahul Biradar and Sachinkumar Patil

*School of Mechanical Engineering, REVA University Bengaluru, Karnataka, India. *Email: rahulbiradar100@gmail.com*

Abstract

A high strength of aluminium alloy is entitled AA2219. It has been majorly used in aircraft and the construction of cryogenic fuel tanks in missiles. A novel solid-state joining technique named as friction stir welding (FSW) has been proven to be capable of joining advanced materials like AA2219 alloy with better quality of joints. Various researchers are studied the joint properties of FSW and reported better corrosion resistance, natural heat protection, microstructural and mechanical properties. This review study emphasizes various joint characteristics of AA2219 alloy, such as tensile, microhardness, and microstructural characteristics of joints are obtained by FSW.

Keywords: *AA2219 aluminum alloy: FSW: Tensile properties: Hardness: Microstructure: Joint characterization.*

1 Introduction

In the aircraft industry, utilizing light weight metals like aluminium and its alloys reduces overall weight. The 2000 series aluminium alloys are extensively used in aircraft and automotive applications. AA2219 is recognised for its max strength ratio and resistance to stress corrosion cracking. A set of alloys designated as AA2219-T87 is frequently used in missiles, including NASA's spacecraft [1-2]. Strong metallic alloys are challenging to join by conventional fusion welding techniques. It can be welded using this environmentally friendly and energy-efficient technique [3-6]. When joining metals by using traditional welding methods, flaws are arising such as fractures, porosity, fine micro-structure, and the production of brittle intermetallic compounds may occur [7-9]. Friction stir welding (FSW) can produce a high-quality joints and defect-free welds [10-12]. Wide industrial utilization are considering copper, due to its high thermal and electrical conductivity, great chemical stability, toughness, and plasticity. FSW is becoming a viable alternative to fusion welding for joining metallic materials, Lee at al [13]. The very first researcher conducted research on copper's FSW. When compared to base metal, the nugget region grain size is fine and evenly distributed, Ashwath et al [14]. FSW joints work hardening behaviour was investigated. With increase welding speed, in the stir region and heat affected region the grain size are decreased. Lin et al [15]. When the qualities of pure copper plate friction stir welded with tungsten inert gas (TIG) were evaluated, it was discovered that FSW of copper created a more effective weld than TIG. Further, Noor et al [16] reported AA2219 and AA7475 dissimilar aluminum alloy and observed that in nugget zone there is a lot of grain refinement. Kamalbabu et al [17] reported FSW study on AA2219/PP and evidenced irregular shape area and a minor interfacial irregularity may be observed in the thread hole of the hybrid AA2219/PP interface. Anderson et al. [18] 2219-T87

**Corresponding Author*

a combination of plasticity induced crack and uneven crack propagation rates of the base material were related to roughness-induced cracks. The change in crack development was not due to residual stresses. Srinivasan et al. [19] investigated a study on AA2219-T87 the enhancing structure and provides in the nugget areas are dissolving and coarsening. Moreover, Chen et al. [20] reported FSW study on AA2219-T62 is a thermal-mechanical technique that does not require bulk fusion and can be used to join all common aluminium alloys without causing liquid cracking, solidification cracking, porosity and other problems. The effect of variations in numerous operating conditions, like surface oxide, upon its joint's characteristics can be determined. Fig.1 shows the applications for FSW in various industries.

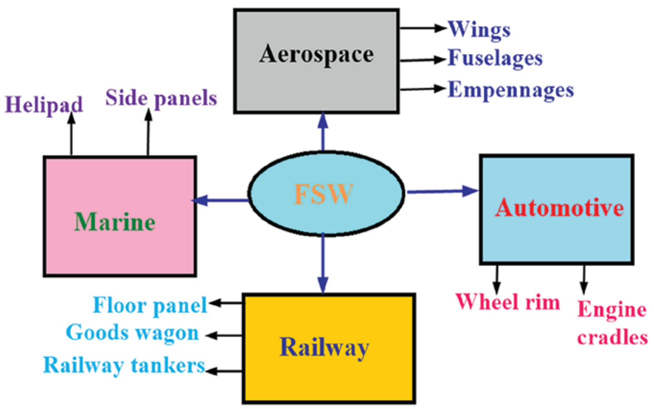

Figure 1: Industrial applications of FSW

2.0 Brief Review of FSW

The Welding Institute (TWI) developed the FSW process in 1991. Like traditional welding, the FSW process does not require melting of base metals, which saves energy [21]. FSW acts on the simple and direct concept, as shown in Fig.2.

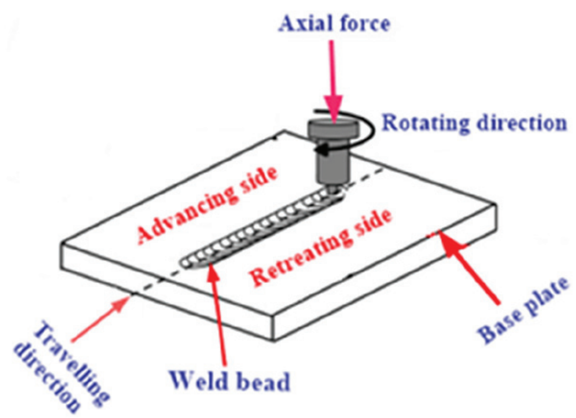

Figure 2: Principle of FSW

Rotating tool with a shoulder and pin is connected into the plates' abutting edges and moving throughout the joint line. It has a number of benefits. Furthermore, the procedure does not necessitate the use of filler wire, gas shielding, or expert technicians. There is no smoke, porosity, spatter, or significant post-weld shrinkage using the FSW method. There is no usage of a shielding gas or flux [22].

3.0 FSW Tool

Specially FSW tools consist of two different sections, such as shoulder and pin, as shown in Fig.3. The pin is plunged into the base plate and shoulder. It upholds along with the work surface. This shoulder contact generates frictional heat as the pin "stirs" the material is to be welded. The typical shapes for tool pin may be triangular, cylindrical, square, or conical [23].

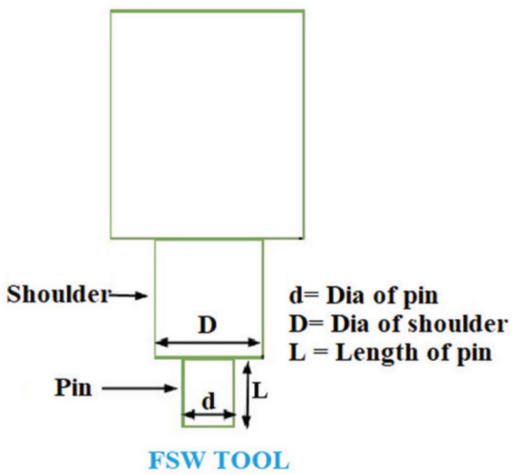

Figure 3: FSW tool nomenclature

4.0 Microhardness characterization

Research on FSW microhardness measurements for various weld joints is reviewed and evidence on reinforcement dispersion and improvement of many phases is provided. Observed that different microhardness profile have been observed. Arora et al [24] suggested a study on AA2219 dissolution of precipitates detected in the thermo-mechanically affected region (TMAZ), while in the heat-affected zone (HAZ), harden (rough) precipitate has observed. Koilraj et al. [25] reported 2219 T87 and AA5083 H321 at the weld nugget region undisturbed base material, there was a gradual decrease in hardness on the advancing side. The microhardness of the weld nuggets region is significantly lower than parent material. Noor et al. [16] reported a FSW study on AA2219 and AA7475 and suggested that there is a definite contact between the TMAZ and stir region. The material flows downward in nugget region, and that grains are elongated in advancing side are under more stress than RS. Various traverse speed along with distance have been considered for plotting the hardness profile as shown in Fig.4.

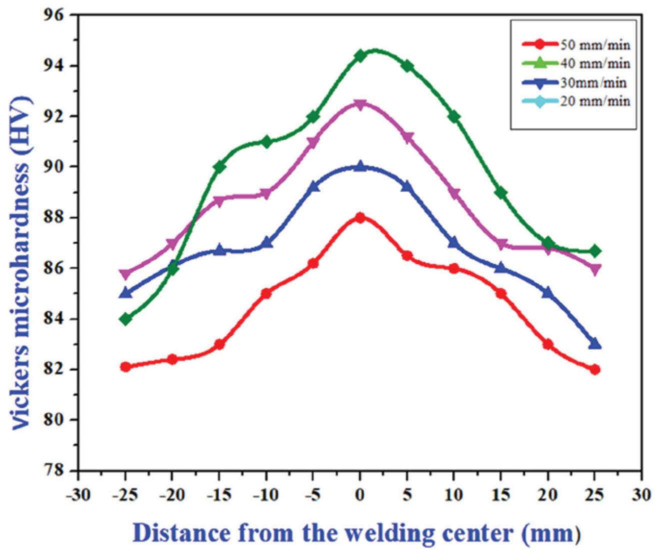

Figure 4: Microhardness variations based on traverse speed

5.0 Tensile Strengths

FSW of tensile characteristics for various weld joints are studied and here are explained a few of them. Initially Liu et al. [15] reported zigzag line had no effect on cracked particles scattered in a dispersion and irregular pattern across the microstructure, the FSW joints made of AA2219 alloy. Further Chen et al. [20] studied FSW properties of AA2219 alloys are significantly impacted by the initial surface qualities. The yield strength is maximum in nugget region than the TMAZ. The characteristics of FSW of aluminum, magnesium, silicon alloy joints were compared and reported to fail at kissing bond in the nugget region/TMAZ. Similarly, Tao et al. [26] suggested that kissing bond had any effect on ultimate tensile strength (UTS). The grains are equally dispersed in the stir region and elongated in TMAZ. They also mentioned that whether the zigzag line affected the failure mode of FSW joints were dependent on two factors. The first was a continuous zigzag line with minimal disturbance. The other was a hardness profile that was fairly uniform, with no noticeable lower hardness zone. Only if both term is fulfilled then a zigzag line fracture occurs during tension.

6.0 Microstructure Characterization

Many researchers are carried out FSW study on AA2219 alloy and broadly explained about changes in microstructural region such as nugget region, TMAZ, HAZ and parent

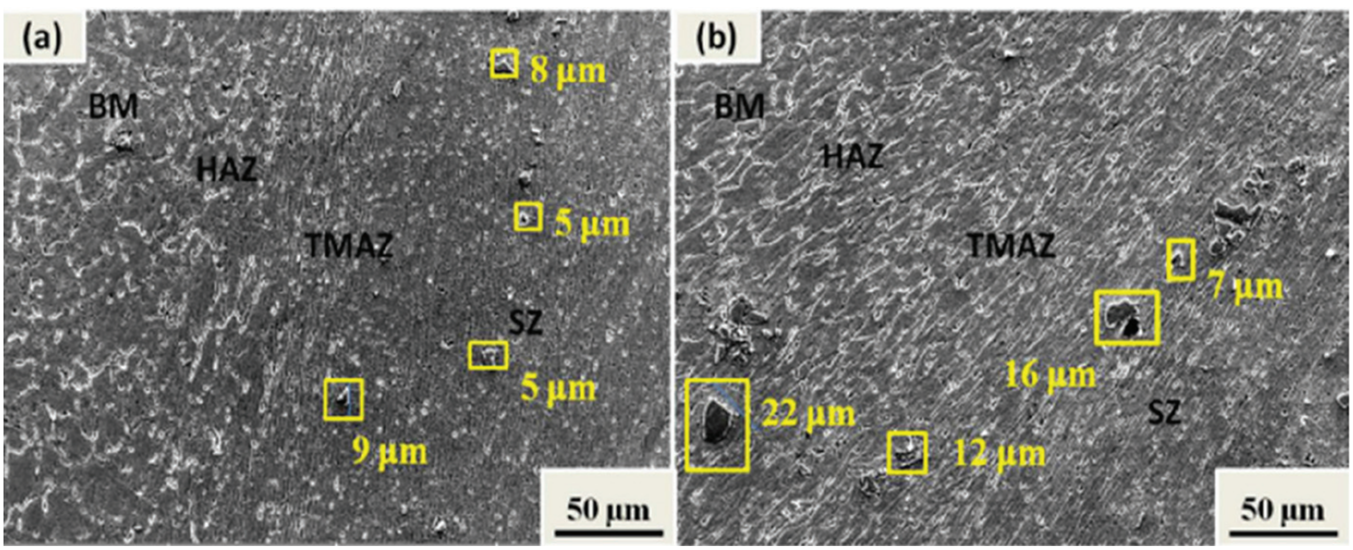

Figure 5: SEM micrograph of various zones are shown on the (a) advancing (b) retreating side respectively [2]

material. So here are discussed a few of the researcher's opinion on microstructure characterization.

Li et al. [27] reported FSW study of AA2219-T6 and observed, the pin tool with respect to their shoulder diameter dominate the microstructural deformation of weld formation. The main function of the centered non-rotational shoulder is to keep plasticized materials out of the stirring zone and to maintain the weld's contour. The rotation speed rises from 500 to 1000 rpm, the weld width at the upper surface of the weld almost same. Further, Arora et al. [24] explained a study on AA2219. The nugget zone is made up of fine equiaxed grains that dynamically recrystallize, and it was discovered that the nugget zone has a higher hardness than the base material. Fig.5 shows SEM micrograph of various zones are shown on the advancing and retreating side respectively. Koilaraj et al. [25] reported a study on AA2219 alloy. There were a lot of precipitate second phase intermetallic particles in the basic materials. On the advancing side, TMAZ causes strongly irregular grains in TMAZ/HAZ, with little change in grain structure in the weld nugget region.

Moreover, Yanying et al. [28] investigated the high strength AA2219 alloy and improves the properties in nugget region. The fracture occurs at TMAZ. Arunkumar et al. [29] discussed $CuAl_2$ dissolution precipitates and separates the high density of grain boundaries, resulting in sound joint quality. Many studies have shown that welding input parameter are the major effect on the weld joint properties.

7.0 Conclusion

In this review, for AA2219 and its various tempering conditions of FSW were effectively utilized. FSW has been proven to an innovative method for improving grain structure. The grain structure at the nugget region was characterised by fine and uniform distribution of particles. Joints created at various traverse speeds exhibit different macrostructures. There are various traverse speeds that results in defect-free sound joints. Microstructural zone are classified into nugget region, TMAZ, HAZ and parent material. The grains are equally dispersed throughout the nugget and thermo mechanical affected region.

References

1. Fawad Tariq, Nausheen Naz, Rasheed Ahmed Baloch, Faisal (2012), "Characterization of Material Properties of 2xxx Series Al-Alloys by Non-Destructive Testing Techniques", *J Non-destructive Eval*, 31:17–33
2. Sachin Kumar, Narendranath, S. & Chakradhar, D (2019), "Microstructure, Hardness and Tensile Properties of Friction Stir Welded Aluminum Matrix Composite Reinforced with SiC and Fly Ash", Silicon 11(6): 2557–2565
3. Sachin Kumar, Narendranath S. & Chakradhar D (2020), "Characterization and Evaluation of Joint Properties of FSWed AA6061/SiC/FA Hybrid AMCs Using Different Tool Pin Profiles", *The Indian Institute of Metals* 73(9):2269-2279
4. Sachinkumar Patil & Dasharath. S. M & Lakshmi Narayana. K. S (2018), "Application of taguchi technique to optimize the cutting parameters for turning of aa6351 with and without heat treatment", *International Journal of Mechanical and Production Engineering Research and Development* 8(6):921-927
5. D. Bakavos, P.B. Prangnell, B. Bes, F. Eberl (2008), "The effect of silver on microstructural evolution in two 2xxx series Al-alloys with a high Cu:Mg ratio during ageing to a T8 temper", *Materials Science and Engineering* A 491: 214–223
6. Yuming Xie, Xiangchen Meng, Feifan Wang, Yimeng Jiang, Xiaotian Ma, Long Wan, Yongxian Huang (2021), "Insight on corrosion behaviour of friction stir welded AA2219/AA2195 joints in astronautical engineering", *Corrosion Science* 192:109800
7. Sachin Kumar, Chakradhar D & Narendranath S. (2018), "Process parameter optimization for FSW of AA6061/SiC/fly ash AMCs using Taguchi technique", *Emerging materials research* 7(3):1-35
8. Sachinkumar, S. Narendranath, D. Chakradhar (2020), "Effect of traverse speed on joint characteristics of FSWed HAMCs", Material today proceedings, 45 :1-4
9. P. Mastanaiah, Abhay Sharma, G. Madhusudhan Reddy (2018), "Role of hybrid tool pin profile on enhancing welding speed and mechanical properties of AA2219-T6 friction stir welds", *Journal of Materials Processing Tech*, 257: 257-269
10. Sachinkumar, Narendranath, S., & Chakradhar, D. (2018). Effect of FSW on microstructure and hardness of AA6061/SiC/fly ash MMCs. Materials Today: Proceedings, 5(9) :17866-17872.
11. Sachinkumar, Narendranath, S., & Chakradhar, D. (2018, April). *Study on microstructure and tensile properties of fly ash AMCs welded by FSW.* In AIP Conference Proceedings (Vol. 1943, No. 1, p. 020118). AIP Publishing LLC
12. Sachinkumar, Nagamadhu, M., Badiger, R. I., & Babu, K. A. (2021). Analysis of effect of friction stir welding parameters on joint hardness and tensile strength of AA3003/SiC composites. Materials Today: Proceedings, 45: 115-119
13. J.Q. Li, H.J. Liu (2013), "Effects of tool rotation speed on microstructures and mechanical properties of AA2219-T6 welded by the external non-rotational

shoulder assisted friction stir welding", *Materials and Design, 43:299-306*

14. P. Ashwatha and M. Anthony Xavior (2016), "Processing methods and property evaluation of Al_2O_3 and SiC reinforced metal matrix composites based on aluminium 2xxx alloys", *Journal of Materials Research Society*.1-19
15. Liu Hui-jie, ZHANG Hui-jie, HUANG Yong-xian, YU Lei (2010), "Mechanical properties of underwater friction stir welded 2219 aluminum alloy", *Transactions of nonferrous metals society of China* 20 :1387-1391
16. Noor Zaman Khan, Arshad Noor Siddiquee, Zahid A. Khan, Ashim K. Mukhopadhyay, (2016), "Mechanical and microstructural behaviour of friction stir welded similar and dissimilar sheets of AA2219 and AA7475 aluminium alloys", *Journal of alloys and compounds,* 12:1-10
17. K. Kamal Babu, K. Panneerselvam, P. Sathiya, A. Noorul Haq, S. Sundarrajan, P. Mastanaiah, C.V. Srinivasa Murthy (2018), "Influences of metastable q_0 and stable q intermetallics formed during cryorolling and friction stir welding process on AA2219", *Journal of Alloys and Compounds* 732:624-629
18. K. Anderson-Wedge, G. Stubblefield, N. Zhu, B. Long, S.R. Daniewicz, P. Allison, J. Sowards, O. Rodriguez, R. Amaro, (2021), "Characterization of the evolution of 2219-T87 aluminum as a function of the friction stir welding process", *International Journal of Fatigue*, 142 :105954
19. P. Bala Srinivasana, K.S. Arora, W. Dietzel, S. Pandey, M.K. Schaper (2010), "Characterisation of microstructure, mechanical properties and corrosion behaviour of an AA2219 friction stir weldment", *Journal of Alloys and Compounds*, 492:631-637
20. H.B. Chen, J.F. Wang, G.D. Zhen, S.B. Chen, T. Lin (2015), "Effects of initial oxide on microstructural and mechanical properties of friction stir welded AA2219 alloy", *Materials and design* 18:26-32
21. Sachinkumar, S. Narendranath, D. Chakradhar (2020), "Studies on microstructure and mechanical characteristics of as-cast AA6061/SiC/fly ash hybrid AMCs produced by stir casting" Materials today proceedings, 20(2): A1-A5
22. Sachinkumar, S. Narendranath, D. Chakradhar (2021), "Analysis of the Effect of Friction Stir Welding Parameters on Characteristics of AA6061 Composites using Response Surface Methodology", *Trans Indian Inst Met,* 74:1303–1319
23. Sachinkumar, Nagamadhu, M., Badiger, R. I., & Babu, K. A. (2021). Analysis of effect of friction stir welding parameters on joint hardness and tensile strength of AA3003/SiC composites. Materials Today: Proceedings, 45:115-119.
24. K.S. Arora, S. Pandey, M. Schaper, and R. Kumar (2010), "Microstructure Evolution during Friction Stir Welding of Aluminum Alloy AA2219", *J. Mater. Sci. Technol*., 2010, 26(8): 747-753
25. M. Koilraj, V. Sundareswaran, S. Vijayan, S.R. Koteswara Rao (2012), "Friction stir welding of dissimilar aluminum alloys AA2219 to AA5083 – Optimization of process parameters using Taguchi technique", *Materials and Design* 42:1-7
26. Y. Tao, D.R. Ni, B.L. Xiao, Z.Y. Ma, W. Wu, R.X. Zhang, Y.S. Zeng (2017), "Origin of unusual fracture in stirred zone for friction stir welded 2198-T8 Al-Li alloy joints", *Materials Science & Engineering A*, 693 :1-13
27. J.Q. Li, H.J. Liu (2013), "Effects of tool rotation speed on microstructures and mechanical properties of AA2219-T6 welded by the external non-rotational shoulder assisted friction stir welding", *Materials and design* 43:299-306.
28. Yanying Hu, Huijie Liu, Shuaishuai Du (2021), "Achievement of high-strength 2219 aluminum alloy joint in a broad process window by ultrasonic enhanced friction stir welding", *Materials Science & Engineering* A 804:140587
29. S. Arunkumar, P. Sathiya, K. Devakumaran, and S. Ramesh Kumar (2018), "Microstructural and Mechanical Characterization of as Weld and Aged Conditions of AA2219 Aluminium Alloy by Gas Tungsten Arc Welding Process", *Russian Journal of Non-Ferrous Metals,* 5(1): 93–101.