International Journal of General Engineering and Technology (IJGET)
ISSN (P): 2278–9928; ISSN (E): 2278–9936
Vol. 11, Issue 1, Jan-Jun 2022; 1–8

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

POROSITY ANALYSIS OF FRICTION STIR WELDED AL 6061 ALUMINIUM ALLOYS

Preethi K. H.[1], Dharanish J[2], Bheemraj R[3], Rajeshwari[4] & Mahesh G Emmi[5]

[1]Department of IEM, Bangalore Institute of Technology, Bangalore, India

[2,3] Department of Mechanical Engineering, National Institute of Engineering, Mysuru, India

[4]Department of Industrial Engineering and Management, Dr. Ambedkar Institute of Technology, Bengaluru, India

[5]Faculty of Advanced Technologies, Air Force Technical College, Bangalore, India

ABSTRACT

Friction Stir Welding (FSW) is one of the most widely used techniques when welding is carried out to obtain extreme levels of strength. Welded Aluminium alloy structures form the major part of leading industrial technologies used in manufacturing. These friction-stir welded alloys are used in numerous applications like aerospace, military, automobile and related technologies. It is therefore, important to analyse this welded material for all kinds of processing defects. Porosity is one such type of defect which can affect the strength of a welded joint. This paper presents the porosity analysis of Al 6061 Aluminium alloys welded using FSW.

KEYWORDS: *Friction Stir Welding (FSW), Porosity, Aluminium Alloy, Welding*

Article History

Received: 14 May 2022 | Revised: 16 May 2022 | Accepted: 20 May 2022

1. INTRODUCTION

Aluminium if compared with steel has low weld ability due to its characteristics of quick thermal expansion, low rigidity, high brittleness and deterioration of the material structure at high temperatures. To produce optimum quality welds, two approaches can be used; the first involving control of the gases used during welding, as a material like Aluminium is more susceptible to negative affects due to welding gases. The second approach is managing the thermal coefficients and temperatures during the welding process. The first approach will involve use of inert gases like Tungsten, Helium and Oxygen etc.; while the second approach involves use of advanced welding techniques like TIG or MIG welding **[1][2][3]**. Aluminium alloys are basically the improvement of the Aluminium material by addition of certain level of other materials or metals. Aluminium is the base material and low levels of other materials are added to form an Aluminium alloy. The fundamental need of producing these alloys is the exceptional features they offer which are not found in the base metal of Aluminium alone **[4][5]**.Increasing use of Aluminium in the industrial applications is urging researchers to develop light weight materials with more strength. Aluminium alloys form the best materials which can sustain high heat and form a strong solid after welding as compared to steel or other counterparts. Many characteristic changes are observed in the resultant materials after welding which decide the strength of the product. Welding is different from the other material joining techniques like brazing and soldering; in these techniques the base material is not melted **[6][7]**.Therefore, the knowledge of the optimum parameters of a particular welding technique is of importance. Choosing a correct welding technique and its execution under specific operating conditions decides the quality of the resultant welded material.

Aluminium when affected by heat does not glow red before burning, so any visual signs before damage like other materials are not observed. The damage of the microstructure of the Aluminium alloy can go unnoticed. Although the alloy gets affected by heat, the pre welding and post welding heating and cooling arrangements can very well produce strong materials which can exhibit excellent tensile and ultimate and still be comparatively light weight in regards to the other materials **[8][9][10][11].**

(a) Friction Stir Welding

Aluminium can be welded with relative ease, but first and foremost, the correct welding process must be selected**[12][13][14].**Friction Stir Welding (FSW) is one of the most popular techniques used for welding because it does not involve any kind of gases and there is no high-power requirement. **Figure 1** shows the diagrammatic representation of the friction stir welding process. The pictorial representation indicates the development of frictional stress and high temperatures at the surface of the workpiece as the tool rotates and travels along the joining axis. FSW generally involves a rotating tool which moves along the joining axis to produce friction and the materials get connected with recrystallization taking place. This process of joining produces good quality materials, but there can be certain defects which should be resolved. Porosity is one such defect which takes place during welding. High level of porosity will eventually lead to development of cracks in the resultant material.

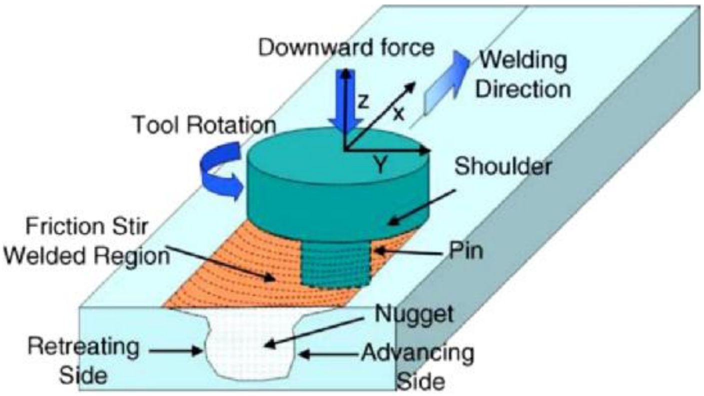

Figure 1: Diagrammatic Representation of the Friction Stir Welding Process [6].

2. Experimental Process: FSW Process

The Friction Stir Welding (FSW) process was carried out on Al 6061 Aluminium alloy. **Figure 2** shows the conical shaped tool that was used. The tilt angle was adjusted to 2° because it gives good rotational and traverse speeds. Different samples of Al 6061 were welded using different rotational and traverse speed.

Figure 2: FSW Tool.

Following are the different combinations of rotational speed (denoted by S) and traverse speed (denoted by F) used:

1. S = 1000 rpm, F = 63 mm/min
2. S = 1000 rpm, F = 80 mm/min
3. S = 1000 rpm, F = 100 mm/min

The regions of base metal, weld zone and heat affected zone were analysed.

3. RESULTS AND DISCUSSIONS

The micrographs for the base metal, the weld zone and the heat affected zones were analysed. The grain formation and the recrystallization in the resultant materials were considered to determine the quality of strength with different rotational and traverse speeds..

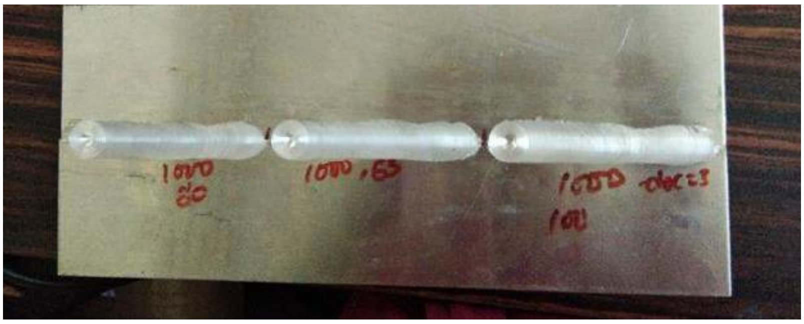

Figure 3: Resultant Al 6061 Alloys after Welding.

(a) Analysis of the Base Metal

The microstructures of the base metal were obtained and analysed. The grain growth and boundary formation of all the samples were studied.

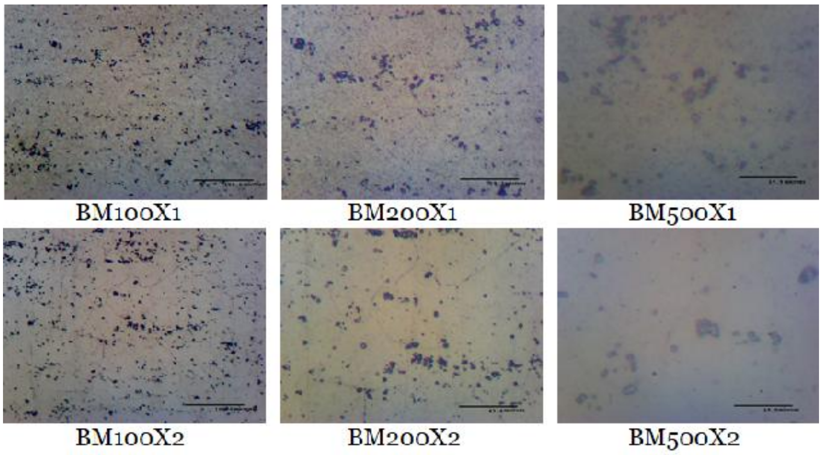

Figure 4: 6061 FSW Base Metal S=1000 F = 63.

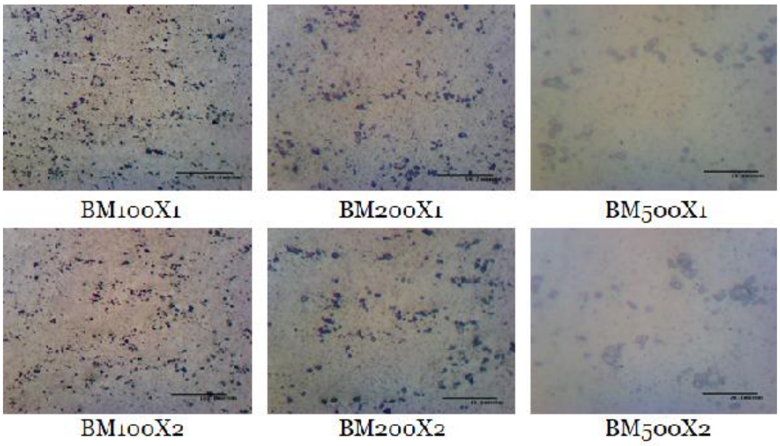

Figure 5: 6061 FSW S=1000 F = 80 Base Metal.

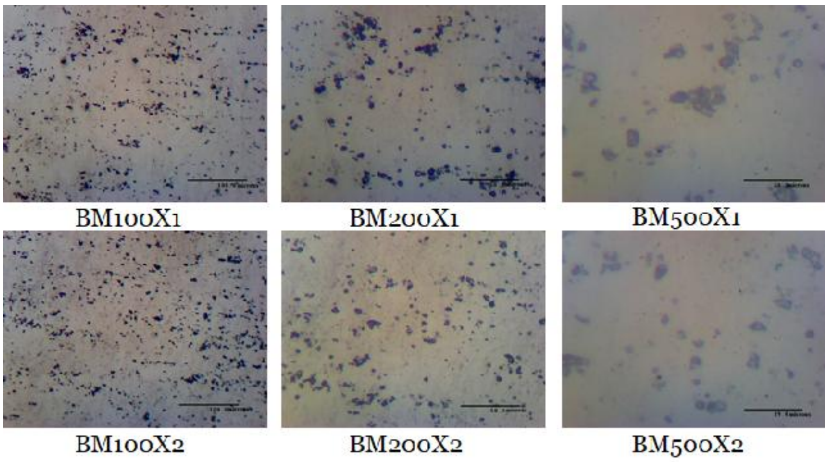

Figure 6: 6061 FSW S=1000 F = 100 Base Metal

Figure 4, 5 and 6 show the micrographs for the base metal with FSW performed on Al 6061 at a rotational speed of 1000 rpm, traverse speed of 63 mm/min and a rotational speed of 1000 rpm, traverse speed of 80 mm/min and a rotational speed of 1000 rpm, traverse speed of 100 mm/min respectively. No unique microstructural change is observed, the grains formed are equiaxed, homogeneous and away from the boundaries. Also, it is observed that, as the traverse speed is increased the number of grains increase, at the traverse speed of 100 mm/min, maximum number of grains are found on a careful examination of the microstructure.

(b) Analysis of the Weld Zone

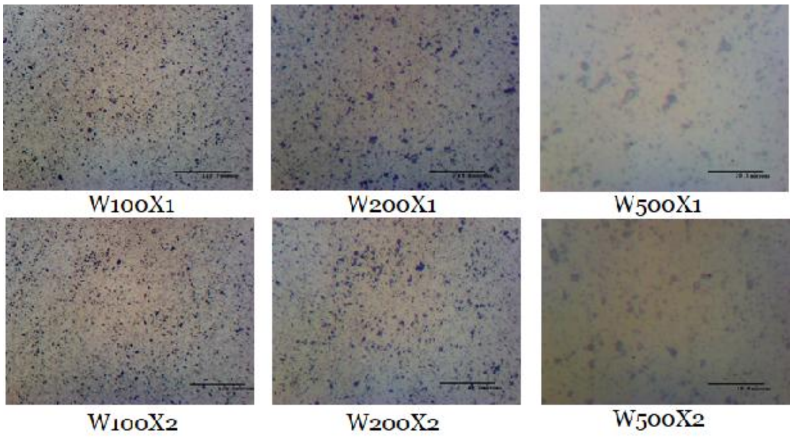

Figure 7: 6061 FSW Weld Portion S=1000 F = 63.

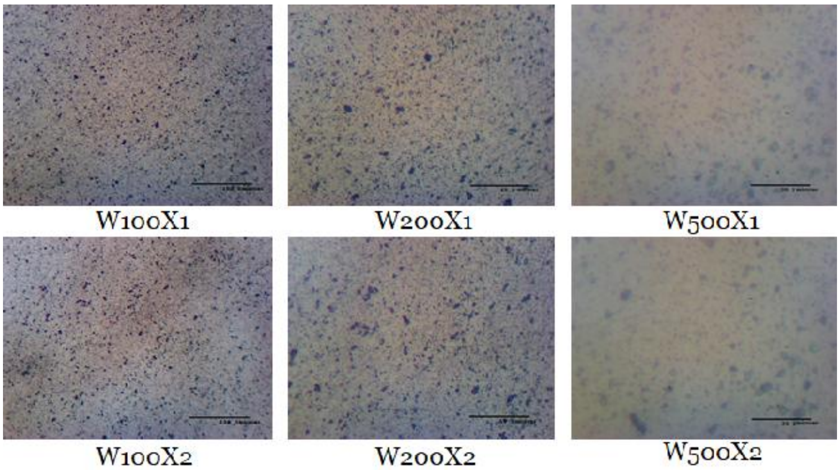

Figure 8: 6061 FSW S=1000 F = 80 Weld Portion

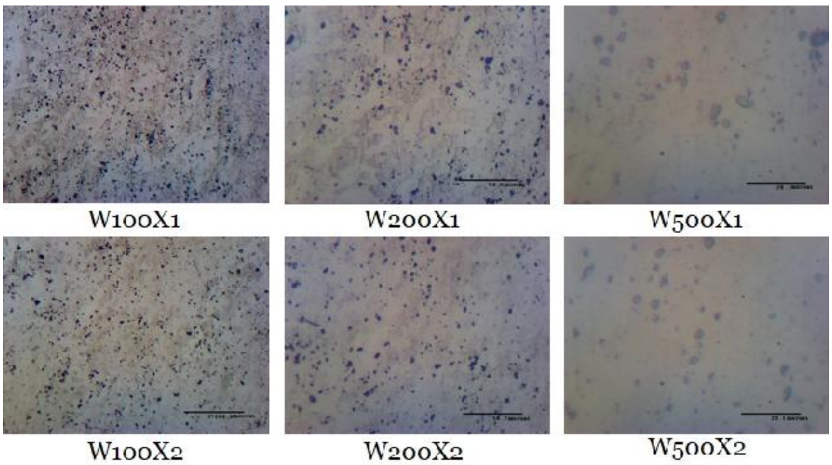

Figure 9: 6061 FSW S=1000 F = 100 Weld Portion.

Figure 7, 8 and 9 show the micrographs for the weld portion with FSW performed on Al 6061 at a rotational speed of 1000 rpm, traverse speed of 63 mm/min and a rotational speed of 1000 rpm, traverse speed of 80 mm/min and a rotational speed of 1000 rpm, traverse speed of 100 mm/min respectively. It is seen that recrystallization has taken place. The number of grains is more as compared to the base metal zone. It is also observed that as the traverse speed is increased the number of grains is also increased. Due to recrystallization, a new microstructure has been formed.

(c) Analysis of the Heat Affected Zone (HAZ)

The Heat Affected Zone (HAZ) is the area of the workpiece that has not been melted but has undergone significant structural changes due to high temperatures. **Figure 10, 11 and 12** show the micrographs for the Heat Affected Zone with FSW performed on Al 6061 at a rotational speed of 1000 rpm, traverse speed of 63 mm/min and a rotational speed of 1000 rpm, traverse speed of 80 mm/min and a rotational speed of 1000 rpm, traverse speed of 100 mm/min respectively. Some unique observations of this zone at high speeds are:

- Enormous change in the microstructure
- Increase in grain size
- Formation of large grains near the boundaries

An increase in the grain size is seen at a traverse speed of 100 mm/min which makes the structure porous. Also, these grains are formed near the boundaries, which will with time develop into cracks and result in cracking of the resultant material.

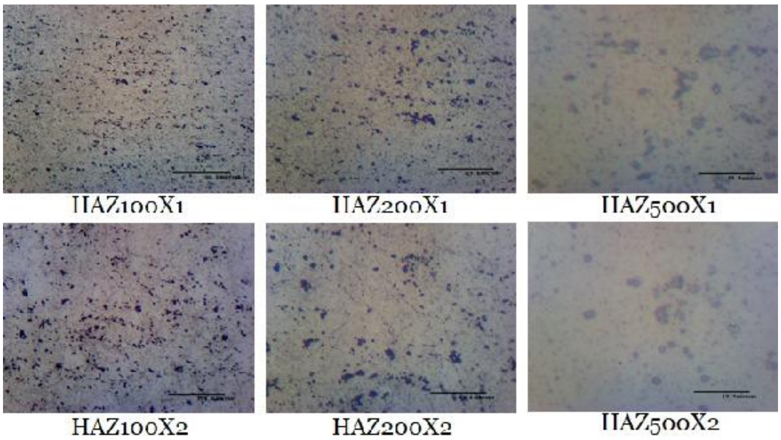

Figure 10: 6061 FSW S=1000 F = 63 HAZ Portion.

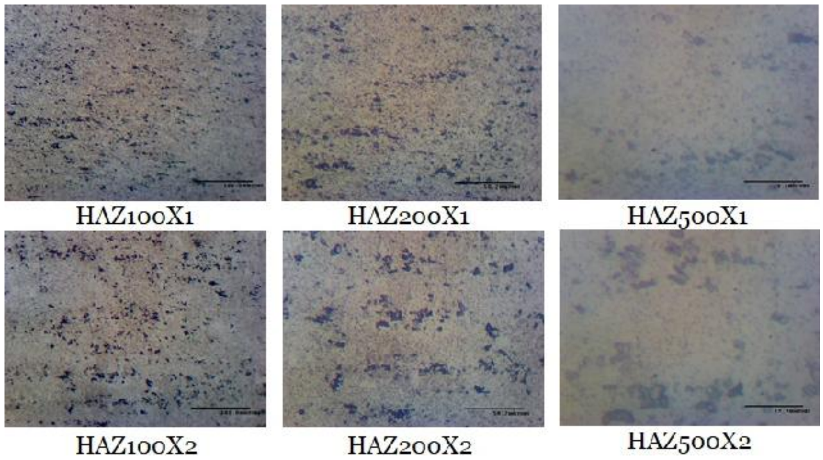

Figure 11: 6061 FSW S=1000 F = 80 HAZ Portion.

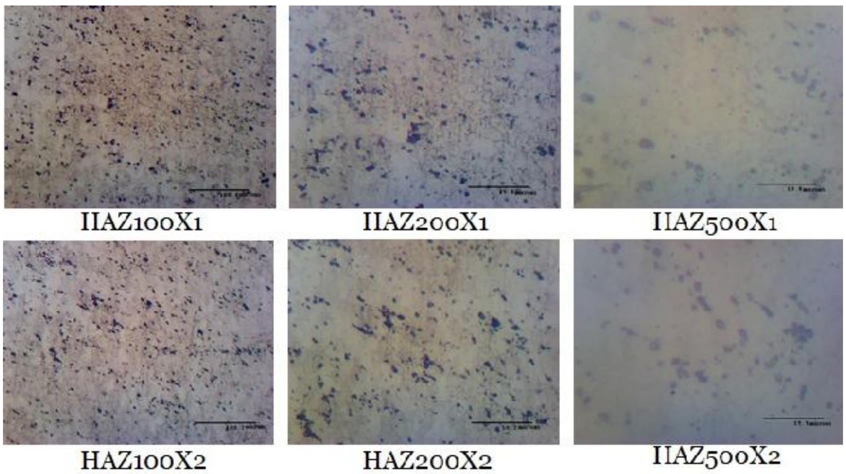

Figure 12: 6061 FSW S=1000 F = 100 HAZ Portion.

CONCLUSIONS

Friction Stir Welding can be readily used as a simple welding technique of most of the Aluminium alloys. There is no requirement of expensive set ups for involvement of gases or any intense current controlling equipment. For Al 6061, it is observed that if an optimum speed range is maintained according to the thickness of the workpiece, the problems of porosity are not encountered. There can be some level of edge formation but it seems to be under the tolerance limits. Al 6061 friction stir welded materials due to their extraordinary mechanical and chemical properties are extensively used in marine applications for joining of decks and parts in high-speed vessels.

ACKNOWLEDGEMENTS

The present work was supported by department of Industrial Engineering and Management, Bangalore institute of Technology, Bengaluru, India.

REFERENCES

1. *T. Senthil Kumar, V. Balasubramanian, M.Y. Sanavullah, Influences of Pulsed Current Tungsten Inert Gas Welding Parameters on the Tensile Properties of AA6061 Aluminium Alloy, Materials and Design 28 (2007) 2080-209.*

2. *Rajesh Manti, D.K. Dwivedi, A. Agarwal, Microstructure and Hardness of Al-Mg-Si Weldments Produced by Pulse TIG Welding, International Journal of Advanced Manufacturing Technology (2008) 36: 263-269*

3. *V. Balasubramanian, V. Ravishankar, G. Madhusudan Reddy, Effect of Pulse Current Welding on Fatigue Behaviour of High Strength Aluminium Alloy Joints, Materials and Design 29 (2008) 492-500.*

4. *Kumar, S. Sundarajan, Selection of Welding Process Parameters for the Optimum Butt Joint Strength of an Aluminium Alloy, Materials and Manufacturing Processes, 21: 779-782,2006.*

5. *Wang Xi-he, Niu Ji-tai, Guan Shao-kang, Wang Le-jun, Cheng Dong-feng, Investigation on TIG Welding of SiCp –Reinforced Aluminium Matrix Composite using Mixed Shielding Gas and Al-Si Filler, Material Science and Engineering A 499 (2009) 106-110*

6. *Rajesh Manti, D.K. Dwivedi, Microstructure of Al-Mg-Si Weld joints Produced by Pulse TIG Welding, Materials and Manufacturing Processes, 22: 57-61 ,2007.*

7. *Kumar, S. Sundarajan, Optimization of Pulsed TIG Welding Process Parameters on Mechanical Properties of AA5456 Aluminium Alloy Weldments, Materials and Design 30 (2009) 1288-1297.*

8. *K Elangovan V. Balasubramanian et al. studied the influence of pin profile and rotational speed of the tool on the formation of friction stir processing in aluminium alloy Material Science and Engineering A 459 (2007) 7-18.*

9. *A.H. Feng, B.L. Xiao et al. the effect of micro structural evolution on mechanical properties of friction stir welded AA2009/Si-Cp composite, Composite science and technology 68 (2008) 2141-2148*

10. *X-G Chen, M. da Silva et al, micro structure and mechanical properties of FSW AA6063-B4c metal matrix composites, Material Science and Engineering (2009)*

11. *Rebecca Brown, Wei Tang et al, multi pass FSW in alloy 7050-T7451: Effects on weld response variables and weld properties. Material Science and Engineering A513-514 (2009)115-121*

12. *Weifeng Xu, Jinhe Liu et al., the temperature Evolution, microstructure and mechanical properties of FSW aluminium alloy joints. Materials and Design 30 (2009) 1886-1893*

13. *Hakan Aydin, Ali Bayram et al, The Tensile properties of FSW of 2024 aluminium alloys in different heat-treated state. Materials and Design 30 (2009) 2211-2221*

14. *S. Gopalakrishnan, N Murugan et al. the prediction of tensile strength of FSW aluminium matrix Ti-Cp particulate re in forced composite. Materials and Design 32(2011) 462-467*