JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Study on Mechanical Properties of Friction Stir Welded LM5, and LM22 Aluminium alloys

[1]Manigandan Krishnan,[2]Senthilkumar Subramaniam
[1]Associate Professor,[2]Professor
[1]Department of Mechanical Engineering,
[1]P.S.V College of Engineering and Technology, Krishnagiri, India.
[2]Vellore Institute of Technology, Vellore, India.

Abstract

The mechanical properties of friction stir-welded aluminum alloys LM5 and LM22, which are produced using the lost foam casting technique, are examined in this study in relation to various tool pin profiles. Tool pin profiles that were taken into consideration were square, triangle, thread, taper, and straight cylindrical. Due to microstructure refinement and porosity reduction, the Friction Stir Welded LM5 and LM22 Aluminum alloys' Ultimate Tensile Strength increased by 15% to 30% for different tool pin geometries, and their percentage elongation also increased significantly. Because of the improved stirring action, it was discovered that the cylindrical threaded tool pin geometry had a greater effect on Friction Stir Weld than other pin profiles.

Keywords: Friction stir welding, Tool pins, Aluminium alloys, Tensile strength, Microhardness

1. Introduction

A solid state welding method for microstructural alteration of metallic materials is called friction stir processing. In order to improve mechanical qualities, friction stir processing has been used to alter the microstructure of cast aluminum alloy plates. Lost foam casting is a casting technique that uses a foamed polystyrene design encircled by unbounded dry sand. The metal takes on the shape of the design after it has evaporated when it is poured. The process recognized by variety of names such as “Foam Pattern”, “Evaporative Process.” Through a "stirring" movement, a revolving tool creates significant plastic deformation during friction stir welding. Localized heating occurs due to the friction between the tool shoulder and the upper surface of the sheet, along with the plastic deformation of the material in contact with the tool. This process creates a stirred zone characterized by a very fine grain size in a single pass. Research has been conducted on the development of the fine-grained structure in aluminum processed by friction stir welding (FSW) using a technique that involves plunging and extracting a rotating tool. These experiments demonstrated that the rotating tool caused significant deformation in the initial grain structure, including substantial alteration of the existing sub-grains. FSW can be broadly defined as an in situ extrusion process, where the stirring and mixing of material occurs primarily at the surface layer of the weld adjacent to the rotating shoulder, leading to a notable increase in temperature within and around the weld area. The research article conducts an extensive literature review to examine the mechanical properties of LM5 and LM22 aluminum alloys that have been produced using the Lost Foam Casting method, focusing on various tool pin profiles in the context of friction stir welding.

2. Materials and Methods

A foamed pattern measuring 175mm x 120mm x 10mm was created from an Expanded Polystyrene board through a hot wire cutting technique and a sharp knife. The necessary dimensions for the sprue cup, sprue, and runner were cut out individually. The gating system was then adhered to the pattern to form a complete pattern assembly, utilizing a bottom gating system. This assembly was uniformly coated with a water-based zircon coating material and allowed to dry. It was then left to air dry for an entire day. Subsequently, the coated pattern assembly was placed within a CI moulding box, which was filled with dry, unbounded silica sand. This setup was then subjected to a vibrating machine for compaction, ensuring that the moulding sand level was maintained at the top of the sprue cup. Five kilograms of Aluminium alloy LM5 were melted in a plumbago crucible using an LPG gas-fired crucible furnace. Once the metal reached the desired molten temperature, slag was removed by adding flux, followed by the addition of a degasser to eliminate dissolved gases. The pouring temperature for the molten metal was kept between 700°C and 720°C. The molten metal was poured into the sprue cup, causing the foam to vaporize and the metal to take its place. After solidification, the rectangular castings were detached from the gating assembly and thoroughly cleaned.

A total of three castings were produced from LM5 and LM22 alloys using the same method. The castings were machined to dimensions of 150mm x 100mm x 5mm using a center lathe. A vertical milling machine was employed for Friction Stir Welding, as illustrated in Figure 1. Tensile test specimens were prepared in the transverse direction of the FSW plate in accordance with ASTM standards. Each specimen had a gauge length of 50mm, with three specimens produced from each FSW plate. Rectangular specimens were cut from the FSW plate in the transverse direction, and after surface polishing, microhardness was assessed using a Vickers microhardness tester.

Figure. 1 Vertical Milling Machine

3. Results and Discussion

3.1 .Mechanical Properties

3.1.1 Tensile Properties

The tensile characteristics of the LM5 and LM22 alloys showed considerable enhancement following Friction Stir Welding (FSW), as illustrated in Tables 1 and 2. The Ultimate Tensile Strength (UTS) of the castings treated with FSW was observed to surpass that of the as-cast samples, which contained large Si particles and exhibited casting imperfections such as porosity. The presence of these large Si particles in the as-cast state contributed to premature cracking during tensile deformation, leading to reduced tensile strength and ductility. In contrast, FSW facilitated the refinement of Si particles and the removal of porosity, resulting in a more uniform microstructure that enhanced both UTS and elongation.

Table 1 UTS Vs Tool Pin Geometry

Sl. No.	Tool Pin Geometry	UTS (MPa)
1.	Square	163
2.	Triangle	154
3.	Cylindrical Thread	168
4.	Taper	138
5.	Straight cylindrical	129

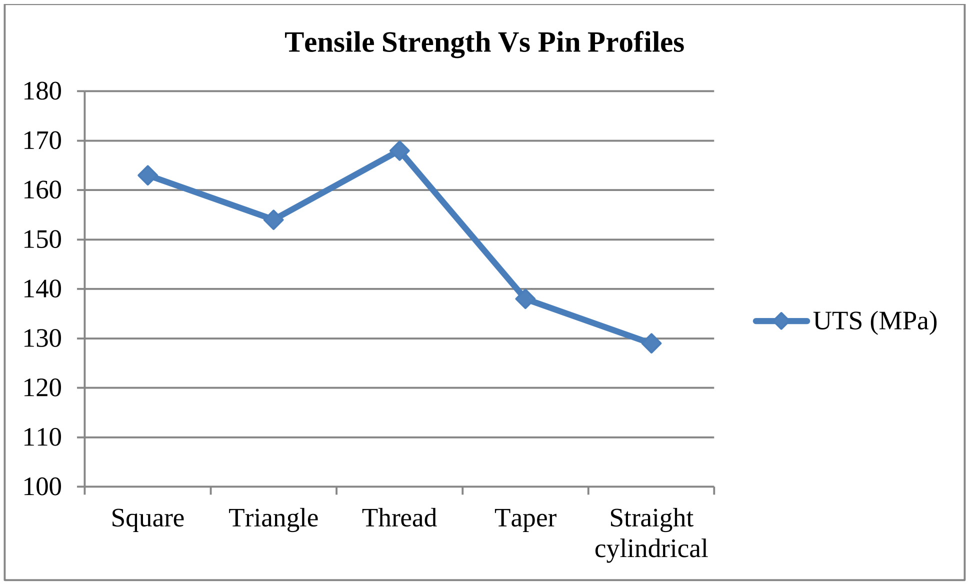

Figure 2 Tensile Strength Vs Pin Profiles

In LM5, the ultimate tensile strength (UTS) rose from 129 MPa in its as-cast state to 168 MPa when subjected to cylindrical pin friction stir welding (FSW). Concurrently, the elongation increased from 1.55% to 6.5%, as illustrated in Figures 2 and 3. The cylindrical threaded pin design yielded the most significant enhancements in both tensile strength and elongation. These advancements can be attributed to the even distribution of smaller silicon particles, the removal of porosity, and the refinement of grains within the aluminum matrix.

Table 2 UTS Vs Tool Pin Geometry

Sl. No.	Tool Pin Geometry	UTS (MPa)
1	Square	144
2	Triangle	131
3	Cylindrical Threaded	149
4	Taper	122
5	Straight Cylindrical	118

In a similar manner, LM22 exhibited a notable enhancement in both tensile strength and elongation following friction stir welding (FSW). The ultimate tensile strength (UTS) improved from 103 MPa in its as-cast state to 149 MPa when using a cylindrical pin for FSW. Additionally, the percentage elongation rose from 1.53% to 6.7%. Once again, the cylindrical threaded pin configurations yielded the most favorable outcomes regarding tensile strength and ductility.

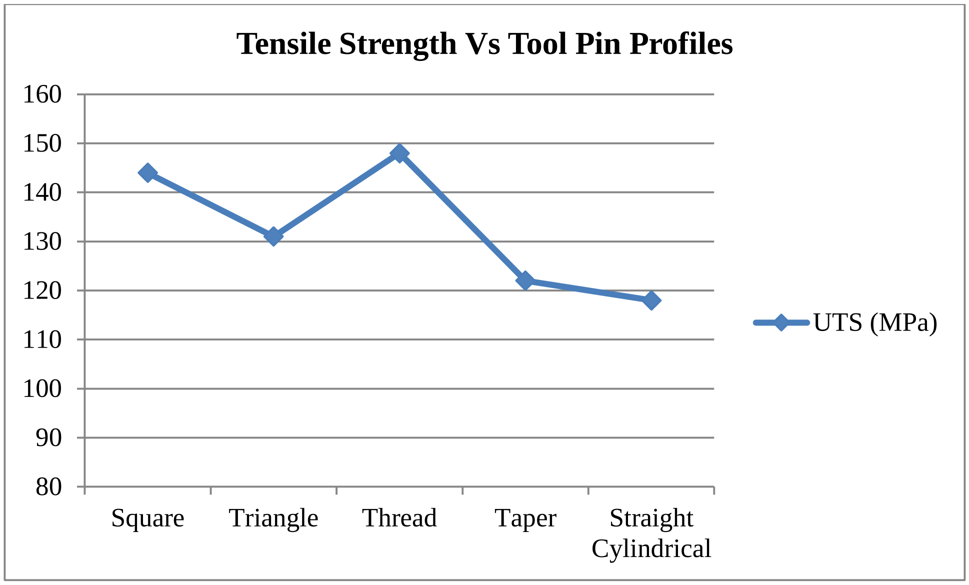

Figure 3 Tensile Strength Vs Pin Profiles

3.1.2 Microhardness

The microhardness of the samples treated with Friction Stir Welding (FSW) was marginally lower than that of the as-cast samples, as illustrated in Figure 4. This decrease in hardness can be attributed to the distribution of smaller silicon particles within the aluminum matrix during the FSW process, which diminishes the overall microhardness in comparison to the larger silicon particles found in the as-cast state. Despite the slight reduction in hardness, the enhancement in other mechanical properties, including tensile strength and ductility, more than compensated for this minor loss in hardness.

Table 3.3 Microhardness Vs Tool Pin Geometry

Sl. No.	Tool Pin Geometry	Microhardness (HV)
1.	Square	171
2.	Triangle	154
3.	Thread	163
4.	Taper	142
5.	Straight Cylindrical	137

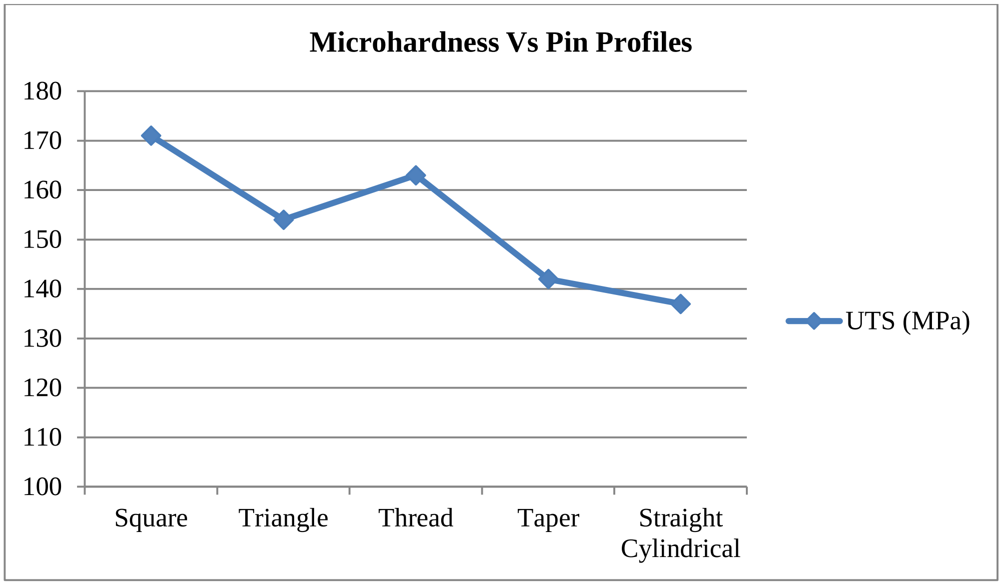

Figure 3.3 Tensile Strength Vs Pin Profiles

3.2Tool Pin Geometry on FSW

3.2.1 LM5 Alloy

The selection of tool pin geometry is vital in the Friction Stir Welding (FSW) process, as it influences the stirring action and subsequently the mechanical characteristics of the processed material. The threaded pin design resulted in the most pronounced refinement of silicon particles and achieved optimal distribution of these particles within the aluminum matrix. In contrast, the square pin creates a pulsating stirring effect due to its four corners, while the threaded pin effectively traps the metal between its threads, resulting in a more vigorous stirring action. Both geometries contributed to improved tensile strength and elongation, as illustrated in Figures 2 and 3. The stirring action generated by these designs aids in breaking down larger silicon particles and facilitates better material flow, thereby enhancing the mechanical properties of the LM5 alloy.

3.2.2 LM22 Alloy

The influence of tool pin geometry was also notably impactful in the LM22 alloy. Among the various designs, the cylindrical threaded pin geometries proved to be the most efficient in enhancing the microstructure and mechanical characteristics, especially in terms of tensile strength and elongation, as illustrated in Figures 2 and 3. Additionally, the square pin geometry facilitated a more consistent distribution of smaller silicon particles, leading to a significant enhancement in tensile properties and microhardness.

4. Conclusions

The following conclusions were derived from result of this investigation:

1. FSW minimizes the porosity intrinsic in Lost Foam Castings.

2. The Ultimate Tensile Strength (UTS) of the FSW castings showed an enhancement ranging from 10% to 35% across different tool pin geometries, with a significant increase in percentage elongation as well. This improvement can be attributed to the reduction in porosity and the refinement of the microstructure.

3. It was observed that the cylindrical tool pin geometry for FSW had a greater impact compared to other tool pin designs.

REFERENCES

1. Prakash kumar Sahu & Sukhomay Pal, Multi-response optimization of process parameters in friction stir welded AM20 magnesium alloy by Taguchi grey relational analysis, *Journal of Magnesium and Alloys*, **3** (2015) 36-46.
2. Sanjay kumar & sudir kumar, Multi-response optimization of process parameters for friction stir welding of joining dissimilar Al alloys by gray relation analysis and Taguchi method, *Journal of the Brazilian Society of Mechanical Sciences and Engineering* **37** (2015) 665-674.
3. Martin J P, Stanhope C, Gascoye S. Novel techniques for corner joints using friction stir welding. *TMS Annual Meeting & Exhibition*. 2011. 27 Feb. - 3 Mar.
4. Şefika K, Multi-response optimization using the Taguchi-based grey relational analysis: a case study for dissimilar friction stir butt welding of AA6082-T6/AA5754-H111, *The International Journal of Advanced Manufacturing Technology*, **68** (2013) 795-804.
5. Kamal J, Neeraj S, Rajesh K & Deepak M, An experimental investigation and optimization of friction stir welding process for AA6082 T6 (cryogenic treated and untreated) using an integrated approach of Taguchi grey relational analysis and entropy method, *Proceedings of Mech. Engg. Part L: J Materials: Design and Application* **2** (2015) 454-469.
6. Manas Ranjan P, Parametric Investigation of Friction Stir Welding on AA6061 Using Taguchi technique, *Materials Today*, **2** (2015) 2399-2406.
7. Kesharwani R K, Panda S H & Pal S K, Multi Objective Optimization of Friction Stir Welding Parameters for Joining of Two Dissimilar Thin Aluminum Sheets, *Procedia Materials Science*, **6** (2014) 178-187.
8. Esther Akinlabi, Anthony Andrews & Stephen Akinlabi, Effects of processing parameters on corrosion properties of dissimilar friction stir welds of aluminium and copper, *Trans. Nonferrous Met. Soc. China*. **24** (2014) 1323-1330.
9. Byung-Wook, Don-Hyun & Yong-Hwan, Fabrication of SiCp/AA5083 composite via friction stir welding, *Trans. Nonferrous Met. Soc. China*, **22** 2012 s634−s638.
10. Dinaharan I & Murugan N, Effect of friction stir welding on microstructure, mechanical and wear properties of AA6061/ZrB2 in situ cast composites, *Materials Science and Engineering*. **A543** (2012) 257-266.

11. Kalaiselvan K & Murugan N, Role of friction stir welding parameters on tensile strength of AA6061−B_4C composite joints, *Trans. Nonferrous Met. Soc. China*, **23** (2012) 616-624.
12. Fahimpour V, Sadrnezhaad S K & Karimzadeh F, Corrosion behavior of aluminum 6061 alloy joined by friction stir welding and gas tungsten arc welding methods, *Materials and Design*. **39** (2012) 329-333.
13. Ilangovan M, Rajendra boopathy S & Balasubramanian V, Effect of tool pin profile on microstructure and tensile properties of friction stir welded dissimilar AA6061-AA5086 aluminium alloy joints, *Defence Technology*, **11** (2015) 174-184.
14. Guo J F, Chen H C, Friction stir welding of dissimilar materials between AA6061 and AA7075 Al alloys effects of process parameters, *Mat. and Design*, **56** (2014) 185-192.