

**MECHANICAL PROPERTIES AND MICROSTRUCTURAL
EVALUATION OF SIMILAR & DISSIMILAR FRICTION
STIR WELDS OF AA7075 & AA7050**

Submitted in partial fulfillment of the requirements for the award of

**Bachelor of Engineering degree in
Mechanical Engineering**

BY

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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **VENKADESHWARAN (39150131)** and **MUDUNDI GUNA SAKETHA RAM VARMA (39150086)**, who carried out the project entitled "**MECHANICAL PROPERTIES AND MICROSTRUCTURAL EVALUATION OF SIMILAR & DISSIMILAR FRICTION STIR WELDS OF AA7075 & AA7050**".

The Project work carried out by them under my supervision and guidance during July 2022 to May 2023.



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DECLARATION

We, **VENKADESHWARAN (39150131)** and **MUDUNDI GUNA SAKETHA RAM VARMA (39150086)** , hereby declare that the project report entitled **“MECHANICAL PROPERTIES AND MICROSTRUCTURAL EVALUATION OF SIMILAR & DISSIMILAR FRICTION STIR WELDS OF AA7075 & AA7050”** Done by us under the guidance of **Dr. S. RAM PRAKASH., M.E., Ph.D.**, is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree In Mechanical Engineering.



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ABSTRACT

Aluminium alloy composites are the quickest processing materials for structural applications due to their modulus, high specific weight, high temperature strength and resistance to corrosion and wear. Friction Stir Welding applies its solid state process behavior to join AA7050 and AA7075 . Friction stir welding has shown to be a successful method for combining AA7050 and AA7075 as a solid state joining technique. The situation still exists when joining aluminium alloys by using friction stir welding, though.

To analyze the influence of process parameters on the micro hardness, micro structure, and mechanical properties of dissimilar friction stir welded joints. Welded joints made of the aluminium alloys 7050 and 7075 were characterised using six different combinations of FSW characteristics. The FSW technique was used to weld plates with an 8 mm thickness at dissimilar joints.

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LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviations

AA	-	Aluminium Alloy
BM	-	Base Metal
FSW	-	Friction Stir Welding
HAZ	-	Heat Affected Zone
kN	-	kiloNewton
Max	-	Maximum
Min	-	Minimum
TMAZ	-	Thermo Mechanically Affected Zone
TEM	-	Transmission Electron Microscope
UTS	-	Ultimate Tensile Strength
VHN	-	Vickers Hardness Number
WN	-	Weld Nugget
YS	-	Yield Strength

Symbols

Al	-	Aluminium
Cu	-	Copper
El	-	Elongation
Fe	-	Iron
Mg	-	Magnesium
Mn	-	Manganese
MPa	-	Mega Pascal
mm	-	Millimeter
mm/min	-	Millimeter per minute
rpm	-	Revolutions per minute
RPM	-	Rotational speed
D	-	Shoulder diameter
Si	-	Silicon
Ti	-	Titanium
HV	-	Vickers Hardness
Zn	-	Zinc
Zr	-	Zirconium

CHAPTER 1

INTRODUCTION

Aluminium provides a unique combination of characteristics that may be enhanced and changed by alloying and processing, such as low density, ease of fabrication and adequate strength. Heat-treatable and non-heat-treatable alloys are the two main categories for aluminium alloys. In several industries, including ship building, aerospace and automotive, there has been a growth in interest in aluminium alloys. This trend also holds true for the potential to combine multiple alloys into a single structure. Because distinct materials' benefits may be effectively utilised, joining dissimilar materials is difficult yet necessary for many applications. The present research looks into the way the microstructure characteristics of dissimilar friction stir welds were affected, as well as their mechanical properties like microhardness, impact strength, tensile strength, and bend strength.

FSW is an environmentally friendly solid state welding process that annihilates defects such as distortion, porosity, solidification cracking, oxidation, solute redistribution and liquid cracking related with conventional fusion welding of aluminum alloys. In this technique, Mechanical mixing and forging are used to join items that are below their melting point. Today, aluminum alloys are advised one of the most auspicious engineering materials for marine and aerospace applications due to their corrosion resistance and high strength-to-weight ratio.

1.1 FRICTION STIR WELDING

Friction Stir Welding (FSW) is invented by Wayne Thomas in 1991, The technology of choice for lightweight transport constructions like boats, trains, and aeroplanes is friction stir welding (FSW), a solid-state procedure that generates high-quality welds on challenging materials like aluminium.

FSW is a mechanical method that may produce very high strength welds in a range of materials that is stiff, low-energy, and repeatable, possibly offering an affordable and environmentally friendly answer to these issues. FSW is a solid state joining method that can produce lap or butt joints with excellent quality, high strength and low strain over a variety of material lengths and thicknesses. In this case, the rotating STP tool is locked between two fixed plates. The frictional heat creates an elastic area close to the tool. Along the seam line, the Rotate tool moves. An integrated solid-state seam is formed. FSW avoids several of the flaws connected to melt welding techniques, including shrinkage, porosity and solidification cracking.



FIGURE 1.1

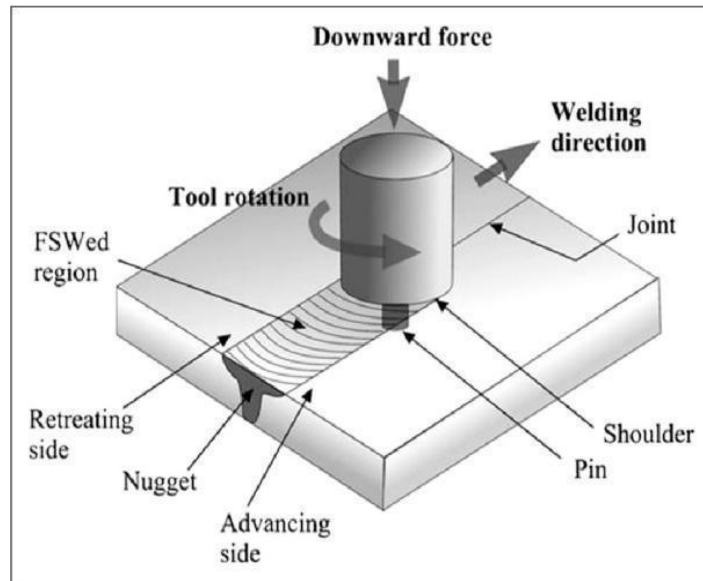


FIGURE 1.2

Figure 1.1 and 1.2 Shows the Process of FRICTION STIR WELDING

1.2 PROCESS PARAMETERS OF FSW

Significant factors that affect the material's temperature distribution, flow pattern, and joint design include the FSW parameters, joint design and tool geometry. These factors also have an impact on how the material changes microstructurally. The various friction stir welding process parameters include the rotational speed of tool, vertical pressure, speed of welding or tool traverse speed , and parameters of tool geometry.

The cylindrical-shaped tool used for the operation of friction stir welding. The term "tool" refers to the entire rotating device connecting the workpiece and the machine spindle. The portion of the tool that is embedded in the welding of the workpiece is known as the "probe." or "pin". The "shoulder" of the tool is the portion that presses on the workpiece's surface. Since there is no edge in a cylindrical tool, the terms "leading face" and "trailing face" can be used instead. In a non-cylindrical tool, the words "trailing edge" (shoulder's rear face during welding) and "leading edge" (the shoulder's front face during welding) are employed. The probe's front during welding is referred to as the "probe leading face." The back face of the probe is referred to as the "probe trailing face" while

welding.

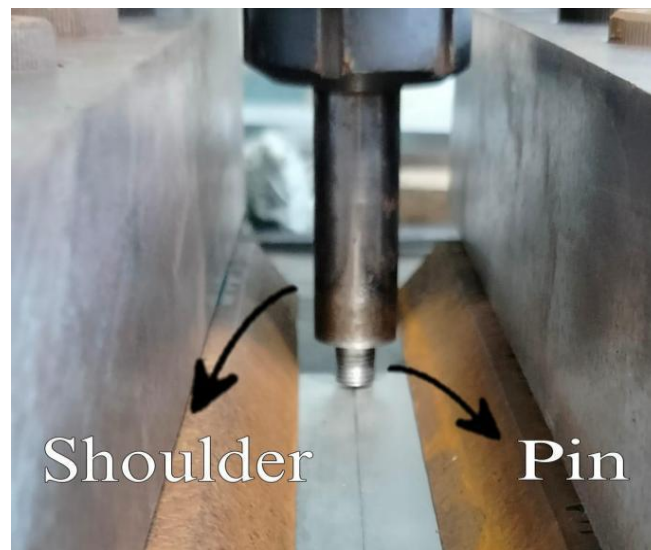


FIGURE 1.3 SHOULDER AND PIN OF CYLINDRICAL TOOL

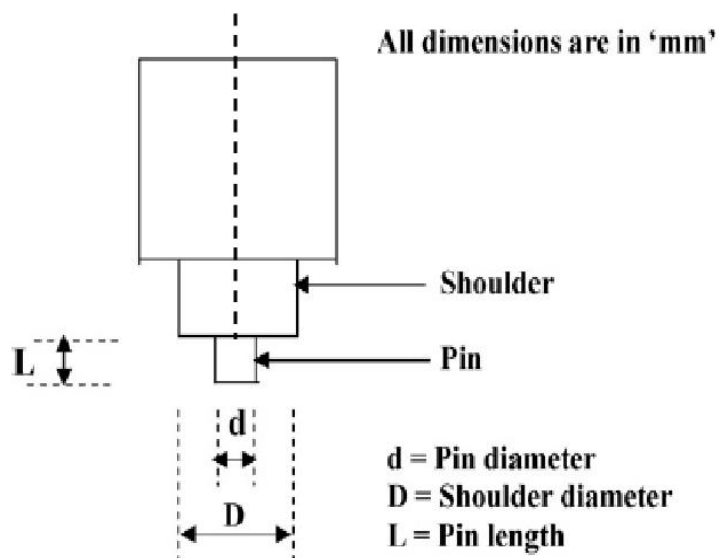


FIGURE 1.4 FSW Tool Dimensions

A portion of the shoulder may become more deeply embedded in the workpiece as a result of the tool sometimes being tilted at a little angle. The

term "heel" refers the portion of the shoulder that penetrates the surface of the workpiece the most, and the "heel plunge depth" is the greatest depth to which the shoulder may penetrate. When referring to the tilt angle, the terms "travel angle" and "tilt angle" are frequently used. In some cases, When a tool is inclined sideways, the angle is referred to as the "work angle" or "sideways tilt angle".

The weld's "advancing side" is the side where the local tool direction and traversal direction are the same, or the side where the direction corresponds to the shoulder rotation's direction. Similar to this, the area of the weld where the shoulder rotates in a different direction from the travel direction and the shoulder moves locally against the traversing direction is known as the "retreating side".

CHAPTER 2

LITERATURE SURVEY

The properties as well as performance of the dissimilar Friction Stir welded aluminium alloys, AA7050-T7651 and AA5083-H111, are significantly influenced by the tool axis offset. Subrahmanian, Ramachandran K, Rajeev V, Renjith also stated that tool axis shifted by 0.25 mm in favor of the stronger sides with a joint tensile strength (joint efficiency: 96%) of 294 MPa and elongation of 12%, the AA7050 alloy side is determined to be the best. The heat affected zone along the AA5083 alloy side is always least powerful zone for all joints produced at various tool axis offsets, While the stir zone and the thermomechanically impacted zone continue to be stronger.

Lazinska. M.' Mierzynski, J. Analyzed the impact of process parameters on the microhardness, microstructure, and mechanical characteristics of friction stir welded (FSW) butt joints made of dissimilar materials. Both alloys' heat-affected zones throughout, it was seen that the basic materials' hardness did not diminish. The macroscopic observations showed the stir zone to have various shapes and defects resulted on by both are excess and insufficient heat input.

Three plates are arranged in a T-butt configuration, These three plates are successfully used to create T-joints and a large diameter pin (12 mm) FSW tool to alter one track Friction Stir Welding of the three components. All of the T-welds' skin and stringer fracture surfaces show that the joint unsuccessful through a combination of fracture modes, mostly ductile due to a locally deformed aluminium base and somewhat brittle due to hard phase particles. Usually, higher strength aluminium alloys from the 7xxx and 2xxx series are utilized to make ships and aircrafts stringer and skin components is concluded.

According to Sindhuja M & Neelakrishnan S, The yield strength rose as tool rotating speed increased because the durability of the friction stir joint

welding was sensitive to rotating speed. The tensile strength of 179MPa, which was 90.86% and 81.36% of the parent materials AA5052 and AA6062 respectively, is attained at RPM of 1800, 30 mm min⁻¹, 1.5 kN, and a tilt angle of 2°.

With higher feed rates of 20 mm/min and lower rpm, i.e., rpm of 1600, for dissimilar AA6061 and AA5082 weldments, the mechanical characteristics have developed, concluded by Venkat Ramana G, Vishnu Vardhan T, Balram Yelamasetti. By employing taper square pin profiles at a tool speed equal to 1600 rpm, identical AA 5082 FSW joints with better mechanical properties were produced. When compared to similar base materials, the mechanical qualities of weld joints made from AA6061 and AA5082 base materials have improved.

In this experiment, a thorough analysis of the impact of a broad variety of FSW parameters on the aluminium alloy dissimilar junctions' quality has been carried out. The hardness profile produced in the dissimilar AA7020/AA5083 joints demonstrates the FSW hardness profile of these alloys, which reduced in the NG zone due to the depletion of the cold deformation strengthening. However, the structure of the dissimilar AA7020/AA5754 indicated a rise in insensitiveness in the NG because of the close mixture of the alloy's low strength and the alloy's high strength and this research is carried out by Mahdy, A.; Ahmed, E; Alsaleh, N.A.

It was discovered that using the previously mentioned welding parameters made it possible to weld AA1050 and AA5083. It was discovered that the joint's UTS was lower than the parent materials' UTS. When compared to specimens taken from different parts in the weld, The specimen obtained before the weld had the lowest UTS. Velaphi Msomi And Nontle Mbana stated that The joint's ductility fluctuated between the levels found in the parent materials. It was determined that the fracture location corresponded to the one mentioned in the literature.

Agilan Muthumanickam, Phanikumar Gandham, Sivakumar Dhenuvakonda have concluded that Grain size was reduced referable to a slower tool rotational speed and increased travel speed. Tensile characteristics were significantly influenced by travel speed whereas tool rotational speed had only a little impact. As the travel speed to tool rotation speed ratio rose, the tensile characteristics improved. Flash defects were seen at high rotational speeds (1000 rpm). Tunnel flaws were seen at 200 rpm, a low tool rotation speed.

J. Langari and F. Kolahan have reported that Weld heat during the FSW process had an impact on the microstructure of the weld zones by causing precipitates to dissolve, creating porosity, promoting grain development, as well as altering the grain structures. Higher rotational rates or slower welding speeds increased the medium grain size of the WNZ and TMAZ regions as solution of the impacts of heat input. Due to development of fracture and tunnelling defects in WNZ-TMAZ interfaces, ultimate tensile strength rose for the sample welded at lower rotational rates but reduced for those welded at higher welding speeds.

Different FSW is used to create sound joints by placing the delicate 6060 alloy onto the side that is retreating. The nugget clearly displays the bonding interface, and the majority of the SZ is made up of the advancing-side element 7003. The dissimilar junction has an ultimate tensile strength of 159.2 MPa, which is 78.6% of BM 6060-T4, and an elongation of 10.14%. On the 6060 side of the HAZ, there is a weak zone where tensile fracture happens and the lowest hardness is 45HV. Wen Zhang, Weiwen Zhang, and Cheng come to the conclusion that fracture above ground demonstrates a distinctive ductile fracture.

Aluminium alloys AA6101 and AA1350 were examined by R. Ashok kumar, M. R. Thansekhar for the results of the number of passes and offset distance in friction stir welding. The results of the analysis showed that offset distance significantly influences the attributes of joints and contributes, respectively, to bending strength, tensile strength, and weight loss at rates of 87.72%, 96.61%, and 99.54%. When the tool pin offset is placed on the side of the high-strength material, which enhances plastic flow, enough heat input is

achieved for combining the materials. Whenever the tool pin located in the retreating side, insufficient heat input might result in poor material flow.

In this work, Ho-Sung Lee, Kookil Joon-Tae Yoo stated that microstructure characterization and mechanical properties for friction stir welded AA2195 and AA2219 were analyzed. The greatest weld efficiency is about 78%, and the process condition was achieved at rotational speeds of rpm of 600–800 and travel speeds of 170–240 mm/min. The experiment was carried out with the tool moving at a rate of 120-300 mm/min and rotating at a rate of rpm of 400-800. Results reveal that the failure happened at AA2219's somewhat weaker TMAZ/HAZ contact, indicating the need for more study to strengthen this interface.

Landry Giraud & Robe Christophe determined that, under normal industrial settings, they are capable of welding a different setup. According to the temperature measurements, the steady state condition is attained quite rapidly and with little variation in temperature for every material. The process parameters affect the mechanical behaviour, material mixing, and weld integrity. The investigation is based on findings from temperature and effort measurements in a limit of early speed from 310 mm/min to 1200 mm/min and rotation speed from 1k rev/min to 2k rev/min. As the retreating speed increases, the connection between the two base metals gets discontinuous on the cross-sectional weld direction; however it get along cyclical in nature on the direction of welding.

In an extremely wide variety of circumstances, defect-free welds may be produced. However, the only welds that produced a poor weld were those that were performed with the lowest rotational speed, fastest traverse speed, and tool offset towards the side of the AA2219 alloy. The dissimilar friction stir welding of aluminium alloys AA2219 and AA5083 may attain joint efficiencies of over 96.9% on UTS. The friction stir weld joint of the dissimilar aluminium alloys AA5083 and AA2219's tensile characteristics was examined by Abhay Sharma, P. Mastanaiah, G. Madhusudhan Reddy

The friction- stir welding between the aluminium alloys AA6063 and AA2014 is accomplished using various process variables. It was explored how

they affected the created joints' mechanical characteristics. Although material stirred region was minimal at Lowest Pin Diameter, heat generation was significant. Increasing the pin diameter will increase the welded region. When the thickness of the plate is equal to the pin's diameter, the best tensile strength is achieved. The AA6082 and AA5083 aluminium alloys can be welded together on larger pin sizes in the future. Tensile strength improves because of the rapid rate of material interlocking and refilling at a 4 degree tilt angle. Insufficient heat is produced on the retreating side when it tilts towards the AA6063 side. As a result, AA2014's fusion is incomplete. This is concluded by Ranjith. R, Senthil Kumar. B

The mechanical properties and metallurgical characteristics of the welded components were taken into consideration when optimizing the FSW process parameters. The weld quality has also been impacted by the tool pin profile. From this research work, Venkatesh Kannan M, Sadeesh P, Avinash P Rajkumar V, stated that the most effective rotation speed, traverse speed, and ratio of D/D for cylindrical pins are 710 rpm, 28 mm/min, and 3, respectively. Additionally, a 6 mm squared pin with rotational speed of rpm of 1000 and 40 mm/min traversal speed was shown to have higher mechanical qualities.

Different zones, including the weld zone (WZ), the thermo mechanically affected zone (TMAZ), the heat affected zone (HAZ) and are observed in the dissimilar joint. Three different types of micro structures, including an unmixed region, a mechanically combined area, and a combined flow region, compose the weld zone. The speed of the welding process affects the creation of the elastic flow area. The joints produced at the greatest and lowest welding speeds demonstrate the lack of a combined flow region. Better tensile characteristics may be seen in joints created at a welding speed of 63 mm/min. A ductile fibrous fracture is the failure mechanism that has been noticed. Analysis was done on the impact of welding speed on mechanical and metallurgical characteristics. It is discovered that compared to other welding rates, 63 mm/min generates higher mechanical and also metallurgical qualities.

In this study, Beytullah Gungor, Erdinc Kaluc observed that aluminum

alloys that are often used in the shipbuilding industry, AW 6082 and AW 5083, were successfully welded jointly to form a 6 mm thick structure. The most effective performance achieved by AW5083, which is easily welded using all common fusion welding techniques, included an 86% joint effectiveness, a bending stress limit which was near to the base metal, and acceptable ductility and bending. Then, with respect to the joint efficiency, dissimilar welding of 6082 and 5083 with 65 percent and comparable welding of 6082 by 62 percent.

Successful friction stir welding of the disparate materials AA5052 and AA6061 was accomplished. It was found that the spindle torque and normal load requirements reduced as rotational speed increased. According to the micro structural analyses, the two elements were not thoroughly mixed together to form the nugget. The micro hardness of the nugget's surface abruptly changed throughout. Therefore, the alloying elements' mutual dispersion as well as the nugget's attainment of identical orientations may have influenced its favourable mechanical characteristics. These materials' mechanical qualities were evaluated by tensile testing and found to be satisfactory. Using electron probe microanalysis, the degree of interdiffusion of alloying components at the contact was investigated by N. T. Kumbhar and K. Bhanumurthy.

CHAPTER 3

AIM, OBJECTIVES AND SCOPE

3.1 AIM

The aim of this work is to obtain the defect free, single pass and full penetration of similar and dissimilar friction stir welds of AA7075 and AA7050

3.2 OBJECTIVES

- Optimization of friction stir welds process parameters to achieve full penetration and defect free weldments.
- To examine the metallurgical changes on different locations of weldments [i.e., Base material (BM), Heat affected zone (HAZ), Stir zone (SZ), Thermo-mechanically affected zone (TMAZ)] using an optical microscope.
- To evaluate the mechanical properties (i.e., Microhardness, Tensile strength, Impact strength) of joint weldments.

3.3 SCOPE

3.3.1 Materials

The aluminum alloys 7075 and 7050 plates were used for this study as the base materials. 8mm thick plates were considered to analyze the friction stir welding.

3.3.2 Welding processes

In order to join the thick plates AA7075 and AA7050, friction stir welding was employed. A detailed investigation has been carried out for understanding the changes in microstructures, mechanical properties of the welds, as the change in RPM.

3.3.3 Metallurgical characterizations

Microstructural studies using optical microscopy is considered mandatory in this work. Optical microstructural studies were intended to investigate the grain structure in different zones of weld region.

3.3.4 Mechanical properties

Tensile tests at room temperature are advised in the scope of mechanical behavior evaluation. The weld region hardness was evaluated using Vickers hardness tests . Impact tests were also carried out to understand toughness of the joint.

CHAPTER 4

EXPERIMENTAL WORK

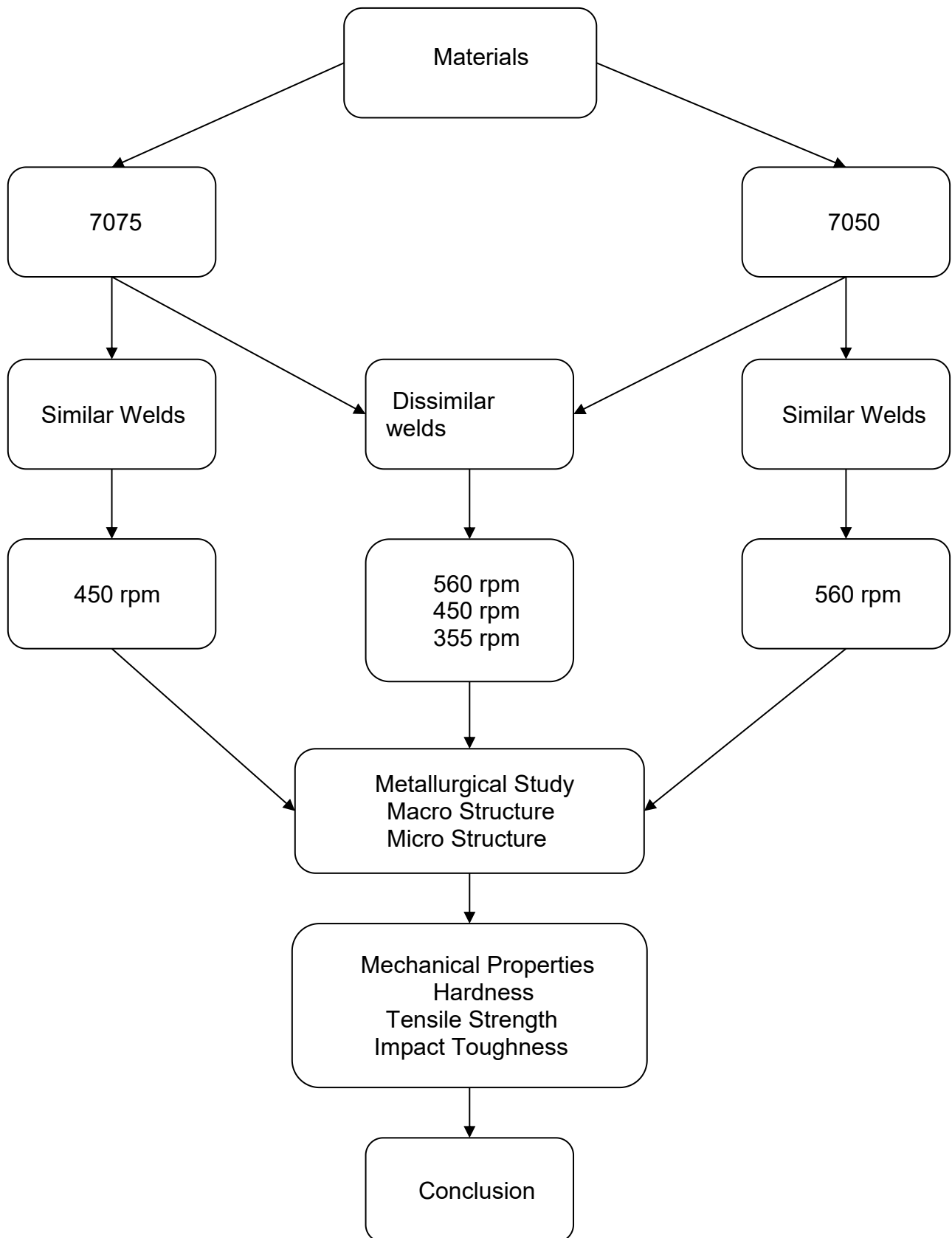
The experiments carried out for this investigation are described in this chapter. This chapter covered the materials utilised, the welding procedures, and the welding settings. The methods used to evaluate the welds for characterisation, mechanical testing, and corrosion testing were also explained in depth. Flow chart explaining the entire gamut of the present work is shown in Figure 4.1.

4.1 CHEMICAL COMPOSITION OF MATERIALS USED IN THIS STUDY

In this study, the material was aluminum alloy 7075 and 7050 different Parameters. 8mm thick plates were used to make friction stir welds. Table 4.1 lists the chemical composition of the components employed in this investigation. The numbers in the table represent the minimum average of three X-ray spectrum analysis studies.

Table 4.1 Chemical composition of the base material (weight %)

Material	Zn	Mg	Cu	Si	Cr	Fe	Ti	Mn	AL
7075	5.8	2.5	1.4	0.04	0.18	0.14	0.075	0.03	89.875
7050	7.09 1	1.9	1.12	0.064	0.009	0.073	0.051	0.005	89.467



Flowchart 4.1 Flow Chart of experimental procedure

4.2 FSW of 8mm Thick AA7075 and AA7050 plates

The experiments were carried out using plates of AA7075 aluminium alloy and AA7050 aluminium alloy, both of which were 8 mm thick and had the chemical composition shown in Table 4.1. The dimensions of base metal plates were 100 mm width by 300 mm length. Base metal plates had dimensions of 100 mm in width by 300 mm in length. As illustrated in Figures 4.2, 4.3, and 4.4, the plates were longitudinally butt-welded utilising a friction stir welding equipment that is readily available in the market. A typical friction stir welding tool used to make welds in this process. Table 4.21 lists the procedure variables for friction stir welding. After several tests with the goal of producing welds with complete penetration and no defects, these criteria were established.

Table 4.21 Friction stir welding process parameters to weld 8 mm thick AA7075- AA7050 plates

Nomenclature	Process Parameters
Tool Geometry	M2 tool steel Tapered threaded pin Diameter of pin : 7mm Length of the Pin: 9 mm Diameter of shoulder : 22 mm
Tool rotational speed	560 rpm, 450 rpm, 355rpm
Welding speed	160 mm/min



FIGURE 4.1 Friction Stir Welding Machine



FIGURE 4.2 FSW of AA7075 and AA7050 at 355rpm



FIGURE 4.3 FSW of AA7075 and AA7050 at 450 rpm



FIGURE 4.4 FSW of AA7075 and AA7050 at 560rpm

4.3 FSW of 8mm Thick AA7075 plates

The experiments were carried out using plates of AA7075 aluminium alloy, both plates of which were 8 mm thick and had the chemical composition shown in Table 4.1. The dimensions of base metal plates were 100 mm width by 300 mm length. Base metal plates had dimensions of 100 mm in width by 300 mm in length. As illustrated in Figures 4.5, the plates were longitudinally butt-welded utilising a friction stir welding equipment that is readily available in the market. A typical friction stir welding tool used to make welds in this process. Table 4.22 lists the procedure variables for friction stir welding. After several tests with the goal of producing welds with complete penetration and no defects, these criteria were established.

Table 4.22 Friction stir welding process parameters to weld 8 mm thick AA7075 plates

Nomenclature	Process Parameters
Tool Geometry	M2 tool steel Tapered threaded pin Diameter of Pin : 7mm Length of Pin : 9 mm Diameter of Shoulder : 22 mm
Tool rotational speed	450 rpm
Welding speed	160 mm/min



FIGURE 4.5 FSW of AA7075 at 450rpm

4.4 FSW of 8mm Thick AA7050 plates

The experiments were carried out using plates of AA7050 aluminium alloy, both of which were 8 mm thick and had the chemical composition shown in Table 4.1. The dimensions of base metal plates were 100 mm width by 300 mm length. Base metal plates had dimensions of 100 mm in width by 300

mm in length. As illustrated in Figure 4.6 the plates were longitudinally butt-welded utilising a friction stir welding equipment that is readily available in the market. A typical friction stir welding tool used to make welds in this process. Table 4.23 lists the procedure variables for friction stir welding. After several tests with the goal of producing welds with complete penetration and no defects, these criteria were established.

Table 4.23 Friction stir welding process parameters to weld 8 mm thick AA7050 plates

Nomenclature	Process Parameters
Tool Geometry	M2 tool steel Tapered threaded pin Diameter of Pin : 7mm Length of Pin : 9 mm Diameter of Shoulder : 22 mm
Tool rotational speed	450 rpm
Welding speed	160 mm/min

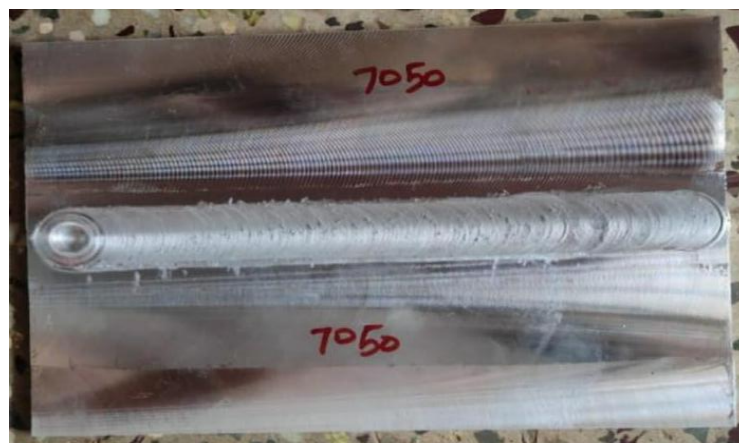


FIGURE 4.6 FSW of AA7050 at 450 rpm

CHAPTER 5

RESULT AND DISCUSSION

5.1 BASE MATERIAL

5.1.1 CHEMICAL COMPOSITION OF MATERIALS USED IN THIS STUDY

In this study, the material was aluminum alloy 7075 and 7050 different Parameters. 8mm thick plates were used to make friction stir welds. The material's chemical compositions utilized in this study was given in Table 5.1. The values shown in the table represent the minimum average of three X-ray spectrum analysis studies.

Table 5.1 Chemical composition of the base material (weight %)

Material	Zn	Mg	Si	Cu	Cr	Fe	Ti	Mn	AL
7075	5.8	2.5	0.04	1.4	0.18	0.14	0.075	0.03	89.875
7050	7.091	1.9	0.064	1.12	0.009	0.073	0.051	0.005	89.467

5.1.2 TENSILE PROPERTIES

Tensile properties refer to the mechanical activity of the material under tension, or when it is being pulled apart. Ultimate tensile strength (UTS), yield strength (YS), and elongation are the three major characteristics that are commonly determined in tensile testing.

Ultimate Tensile Strength(UTS) : This is the maximum stress that a

material can withstand before it fails under tension. Units of force per unit of cross-sectional area are used to measure it (e.g., MPa or psi). For AA7050, the UTS ranges about 542.2 MPa, while for AA7075, it ranges about 532.08 MPa.

Elongation: This is a measure of how much a material stretches or deforms under tension before it breaks. Typically, it is reported as a percentage of the sample's original length. For AA7050, the elongation ranges about 10.67%, while for AA7075, it ranges about 4.8 %.

In general, both AA7050 and AA7075 are high-strength aluminum alloys that are commonly utilized in ship building, aerospace and other high-performance applications. AA7075 is generally considered to be stronger than AA7050, with a higher UTS and YS, but it also tends to be more brittle and less ductile. AA7050, on the other hand, has better toughness and resistance to crack growth, which makes it a good choice for applications that require high fatigue resistance.

It's also worth noting that the specific tensile properties of these alloys can vary depending on factors such as the manufacturing process, heat treatment, and the specific alloy composition. So while the values given here are generally representative, it's always important to consult the specific material data sheet for the alloy being used to ensure that the properties meet the requirements of the intended application.

Material	Ultimate Tensile Strength	Percentage of elongation
7075	532.08	4.8
7050	542.2	10.67

Table 5.2 Tensile properties of AA7075 and AA7050 base material plates

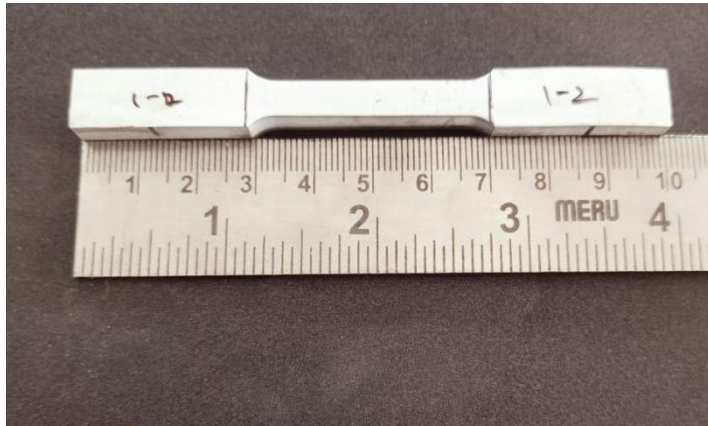


FIGURE 5.1 Tensile Test sample according ASTM B557

5.1.3 IMPACT STRENGTH

A material's capacity to endure abrupt shocks or shock loading is measured by its impact strength. A wide range of variables, such as the specific alloy composition, microstructure, heat treatment, and manufacturing process, can have an influence on an aluminium alloy's impact strength. For AA7050, the impact strength ranges about 10.32 joule, while for AA7075, it ranges about 6.71 joule.

Studies have shown that FSW can improve the impact strength of these alloys by producing a refined microstructure with improved grain structure and distribution of strengthening particles. In particular, FSW has been shown to improve the impact strength of AA7075 and AA7050 by producing a more homogeneous and refined microstructure with smaller grain sizes and more uniform particle distributions. This can result in better energy absorption and resistance to crack propagation under impact loading.

MATERIAL	IMPACT STRENGTH (JOULE)
AA7075	6.71
AA7050	10.32

Table 5.3 Impact test results of FSW on base material plates



FIGURE 5.2 Impact test specimens of FSW on base material plates

5.2 MICROSTRUCTURAL ANALYSIS

5.2.1 Microstructural analysis of AA7050 at 450 rpm

The Stir Zone (SZ), the Thermo- Mechanically Affected Zone (TMAZ) and the Heat Affected Zone (HAZ) are only a few of the different zones that make up the microstructure in an FSW of AA7050 that is similar welds at 450 rpm.

During the FSW process, the Stir Zone (SZ) is the area that receives significant plastic deformation. High shear and deformation of the material in this zone produces a highly refined grain structure with elongated and aligned grains in the tool travel direction. Because of the substantial plastic deformation experienced during the procedure, the SZ also displays a homogenised microstructure and fine precipitates distribution, and its mechanical characteristics are often higher than those of base metals.

The area around the SZ that suffers heat cycles during FSW is called as the Heat Affected Zone (HAZ). The heat produced during the procedure has an impact on the HAZ, however minimal elastic deformation will not occur. Due to the heat-affected microstructure in this zone, which is coarser than the base metal, the strength and ductility are reduced.

The Thermo-Mechanically Affected Zone (TMAZ) is the region between the SZ and HAZ that is sensitive to heat and mechanical influences during the FSW process. The TMAZ has a microstructure that is somewhat more refined than the SZ, and its characteristics are intermediate between those of the SZ and HAZ.

In conclusion, the SZ shows the most refined microstructure in the dissimilar FSW of AA7050 and AA7050 at 450 rpm, whereas the HAZ shows the coarsest microstructure. Between the SZ and HAZ, the TMAZ has a somewhat refined microstructure. These areas' mechanical characteristics vary, with the SZ displaying the maximum strength and ductility.

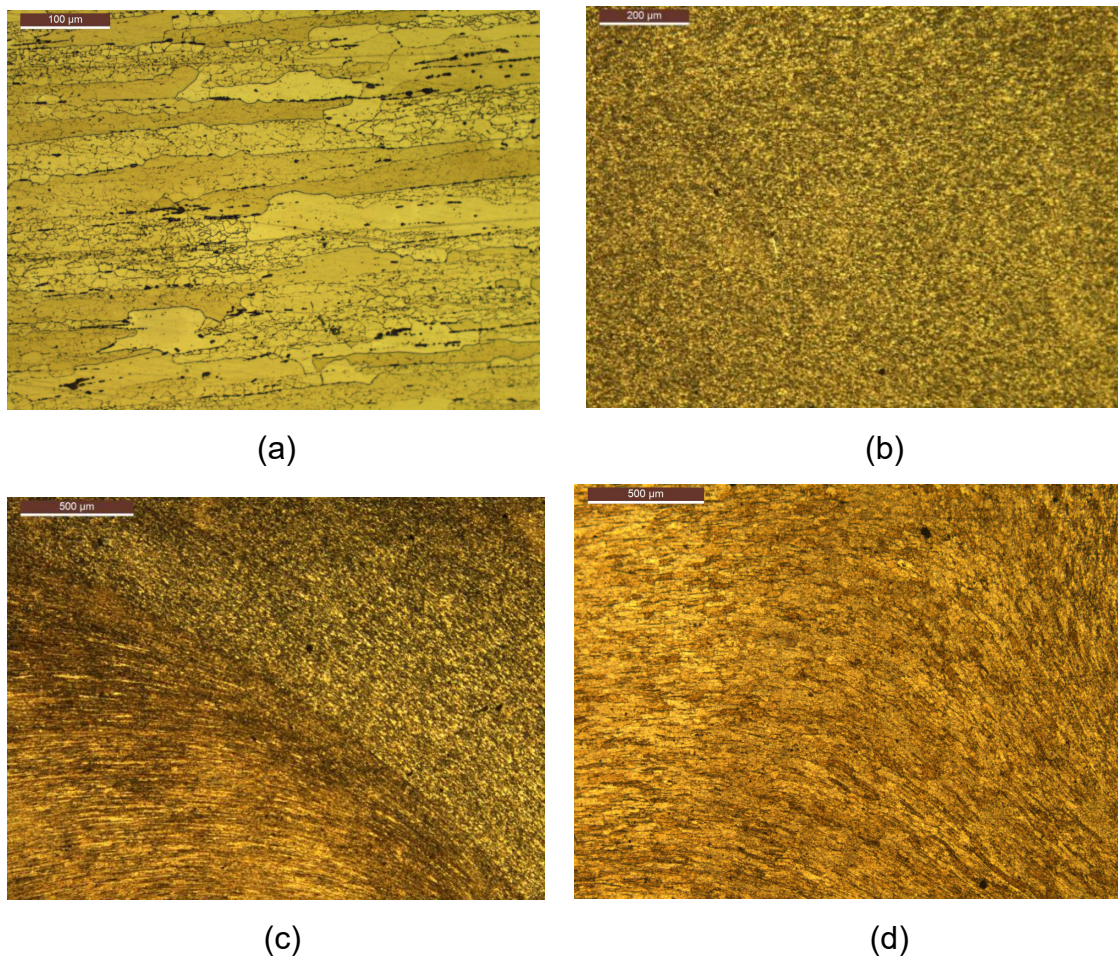


FIGURE 5.3 (a)BM AA7050, (b)Weld nugget, (c)TMAZ, (d)HAZ

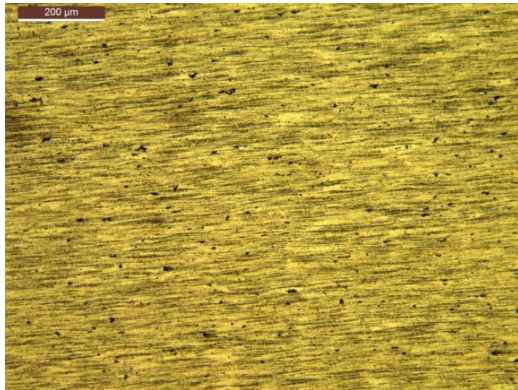
5.2.2 Microstructural analysis of AA7075 at 450 rpm

The microstructure of the weld may be divided into three unique zones when welding comparable materials like AA7075 using friction stir welding (FSW) at 450 RPM: the stir zone (SZ), the thermo-mechanically affected zone (TMAZ) and the heat-affected zone (HAZ).

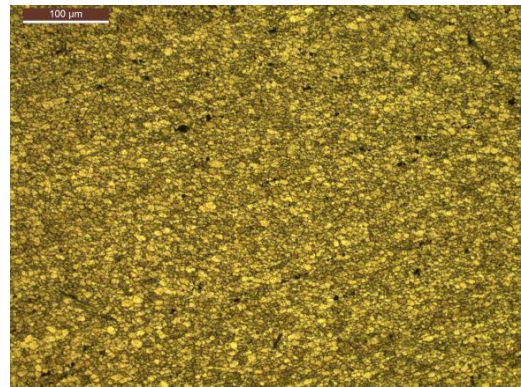
Stir Zone: The material undergoes extreme deformation and high temperatures during FSW, producing a streamlined and homogenised microstructure. The microstructure in the SZ of AA7075 welds often consists of an equiaxed, fine grain structure that is perpendicular to the weld direction. The dynamic recrystallization that occurs during welding results in grain sizes that are frequently smaller in the SZ than in the base material.

Heat Affected Zone: Depending on the welding settings, the microstructure of AA7075 welds in the HAZ may contain grains that have partially or completely undergone recrystallization. Due of the slower cooling rate and less deformation present in the HAZ compared to the SZ, the grain size may be greater. This area of the AA7075 and AA7075 welds may have a combination of recrystallized and deformed grains in the microstructure. Based on the welding settings, the size of grain in the TMAZ may fall wherever between the SZ and HAZ.

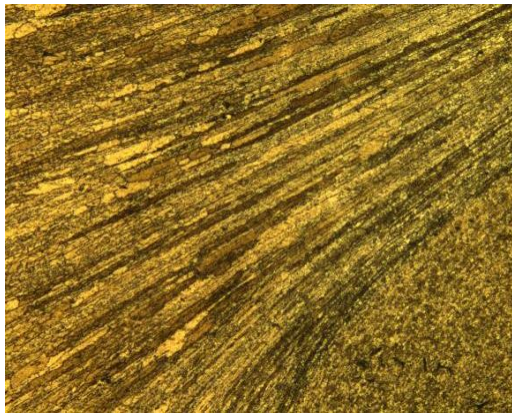
In conclusion, the microstructure of comparable AA7075 and AA7075 welds at 450 RPM FSW it is distinguished by a fine and balanced structure of grains in the SZ, partially or totally recrystallized grains in the HAZ, and a mixture of recrystallized and deformed grains in TMAZ.



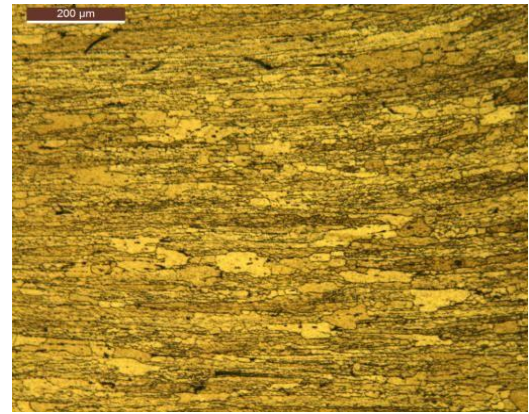
(a)



(b)



(c)



(d)

FIGURE 5.4 (a)BM AA7075, (b)Weld nugget, (c)TMAZ, (d)HAZ

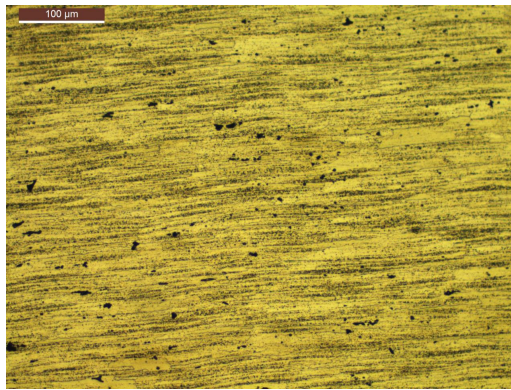
5.2.3 Microstructural analysis of AA7075 and AA7050 at 450 rpm

Friction stir welds of AA7075 and AA7050 at 450 RPM are affected by a number of variables, including the welding parameters, tool geometry, and base material characteristics. Between the two alloys, there are some distinctions.

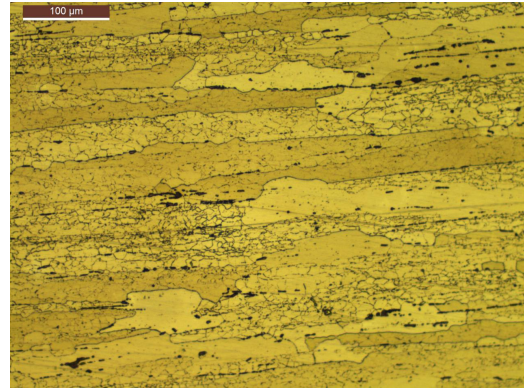
Both AA7075 and AA7050 generally have a fine-grained microstructure with elongated grains that are aligned perpendicular to the action of the welding tool. This is a consequence of the FSW process's high deformation and temperature, which cause recrystallization and grain refinement.

Stir Zone: In this area, the material is in a highly dynamic state with a homogeneous and fine-grained microstructure in this area. Due to the several elastic deformation and the existence of dynamic recrystallization, the grains in this area are smaller than those in the area of base material.

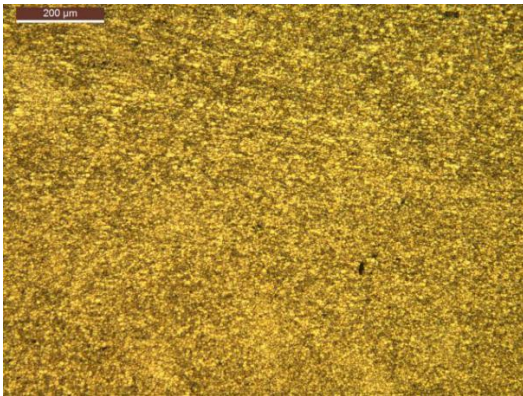
Heat Affected Zone: The HAZ contains bigger grains than the SZ, and the temperature cycle that it goes through when welding affects its characteristics. The microstructure in this area often exist of a mixture of grains that are recrystallized and elongated. The temperature and mechanical cycles experienced during welding have an impact on the TMAZ's characteristics.



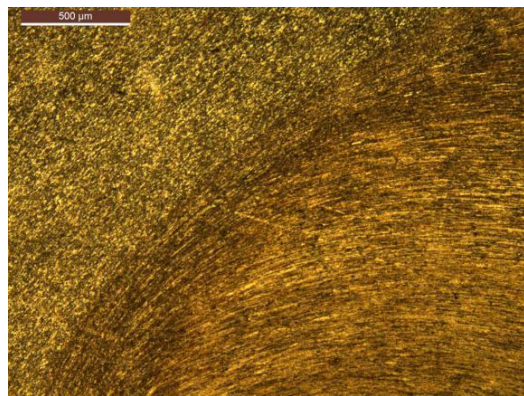
(a)



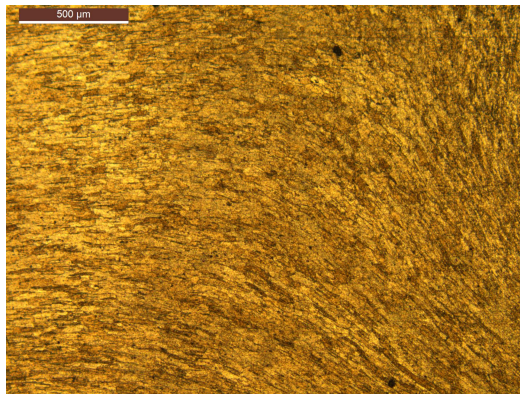
(b)



(c)



(d)



(e)

FIGURE 5.5 (a)BM AA7050, (b)BM AA7075, (c)Weld nugget, (d)TMAZ, (e)HAZ

5.2.4 Microstructural analysis of AA7075 and AA7050 at 560 rpm

High-strength alloys of aluminium Both AA7075 and AA7050 are often employed in high-performance applications in the aerospace and automotive industries. The AA7075 and AA7050 friction stir welds' microstructures at 560 rpm would normally be divided into a number of separate zones.

Stir Zone: With very tiny grains and significantly smaller component particle sizes, the microstructure in this area is highly honed. Any precipitates are broken up and redistributed, and the alloying components are homogenised.

Heat affected Zone: The area, which is near the stir zone, certain microstructural alterations have been brought about by welding process heat. Typically, the HAZ is separated into three sub-zones: the overaged zone (OA), the partially annealed zone (PAZ), and the completely annealed zone (FAZ). The PAZ has a more refined but still equiaxed grain structure, in contrast to the FAZ's coarse, equiaxed grain structure. Because the alloying elements were overaged, the OA zone is distinguished by a highly fine, elongated grain structure.

Overall, the AA7075 and AA7050 friction stir welds' microstructure at 560 rpm would be distinguished by a highly refined and homogenised microstructure in the stir zone, with some microstructural variations in the HAZ.

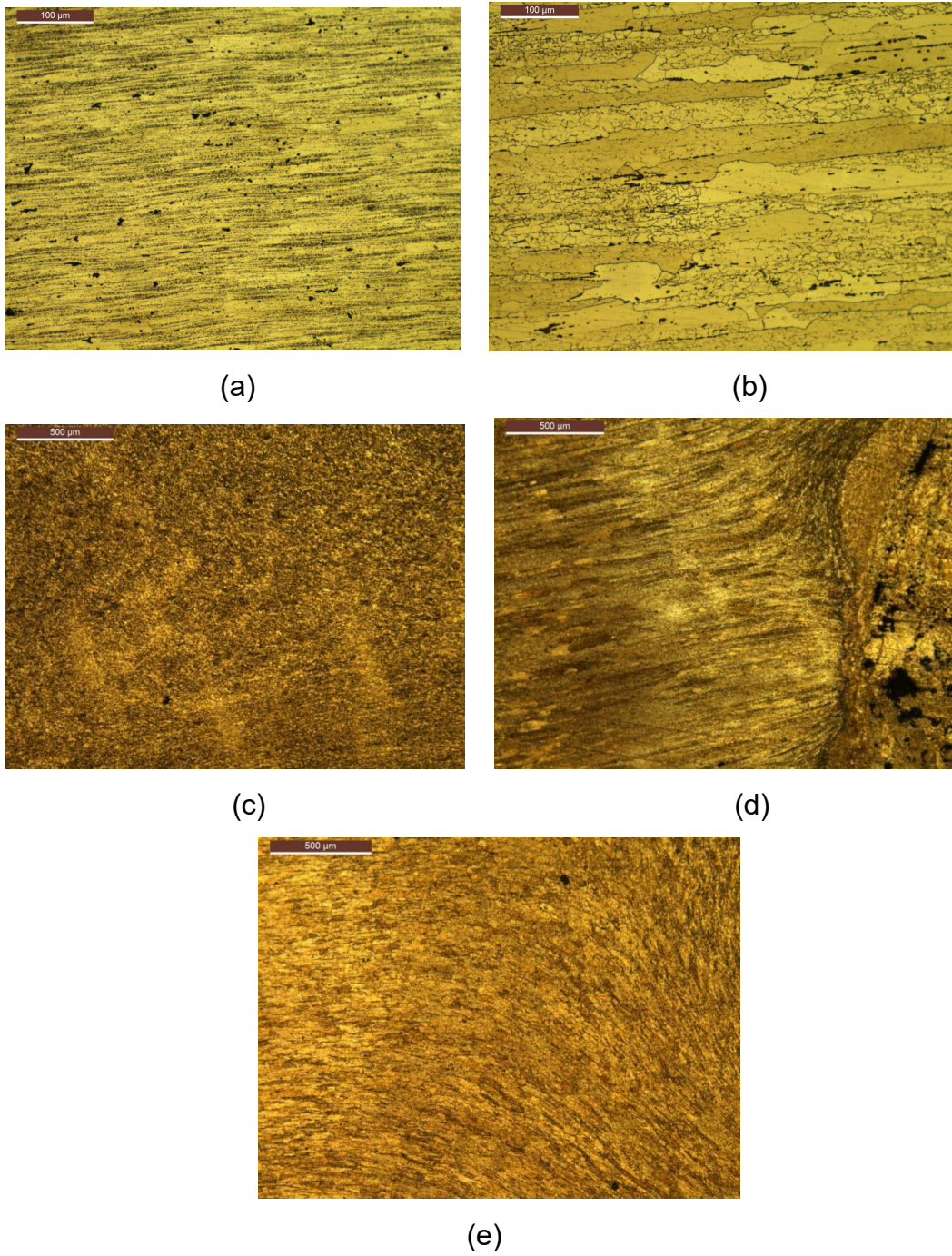


FIGURE 5.6 (a)BM AA7050, (b)BM AA7075, (c)Weld nugget, (d)TMAZ, (e)HAZ

5.3 MICROHARDNESS ANALYSIS

In order to determine any potential differences in microstructure or quality across the different zones of the weldment, Mid-thickness Vickers microhardness tests were performed on the weld. Figure 5.2 clearly displayed the example hardness distributions. As shown, the distributions display a "W"-shaped curve typical of friction stir-welded heat treatable aluminium alloys, and particularly so with 7xxx series alloys. The main cause of this is the welding heat, which causes the nugget temperature to rise above the recrystallization temperature. In this area, fine equiaxed grains form, giving the material a harder value than in the solution-treated state but a little less than in the heat-treated condition. Weld displays hardness that is almost equal to T6 hardness in the weld nugget area. The hardness minimum in the HAZ is situated 15 to 20 mm away from the weld centre line.

The tensile specimens may be more likely to fracture in this region, according to this. As can be observed in the next section, the strength values likewise increase as the hardness profiles of the welds do. Transmission electron microscopy is used to explore and then show the causes of this low hardness at this distance in the HAZ.

All of the welds that have been tested for hardness often exhibit what is known as a "W" curve, where hardness is highest at the weld centre, or in the nugget, at around 90 HV, and rapidly drops as the survey travels out away to the weld centre into the HAZ. Hardness decreases to as low a value as 57–75 HV in dissimilar welds and 94–107 in comparable welds at a distance of approximately 15 mm away to the weld centre line, as can be seen from the hardness surveys shown below.

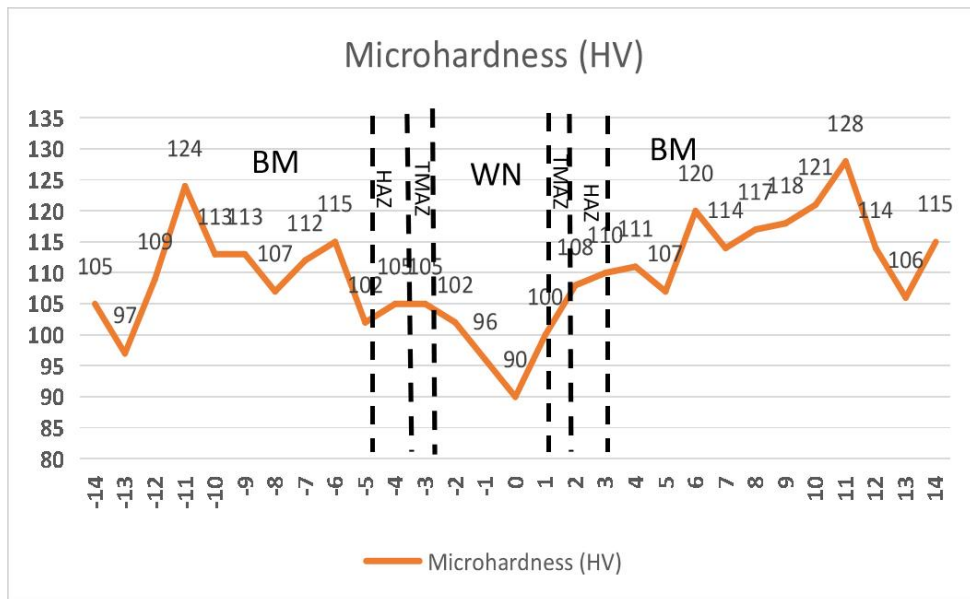


FIGURE 5.7 Micro Hardness plot for AA7050 at 450 rpm

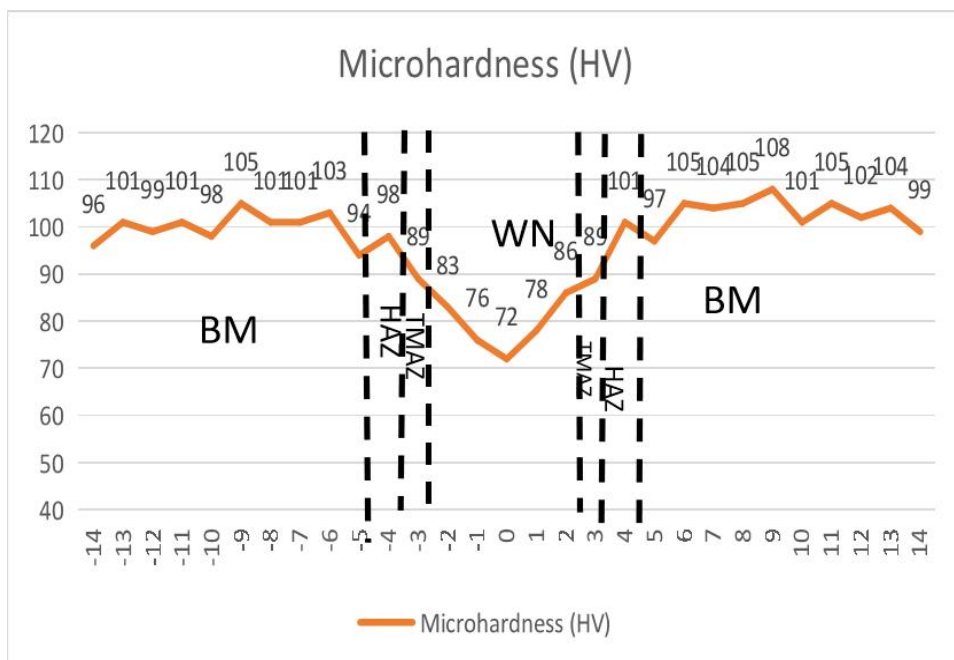


FIGURE 5.8 Micro Hardness plot for AA7075 at 450 rpm

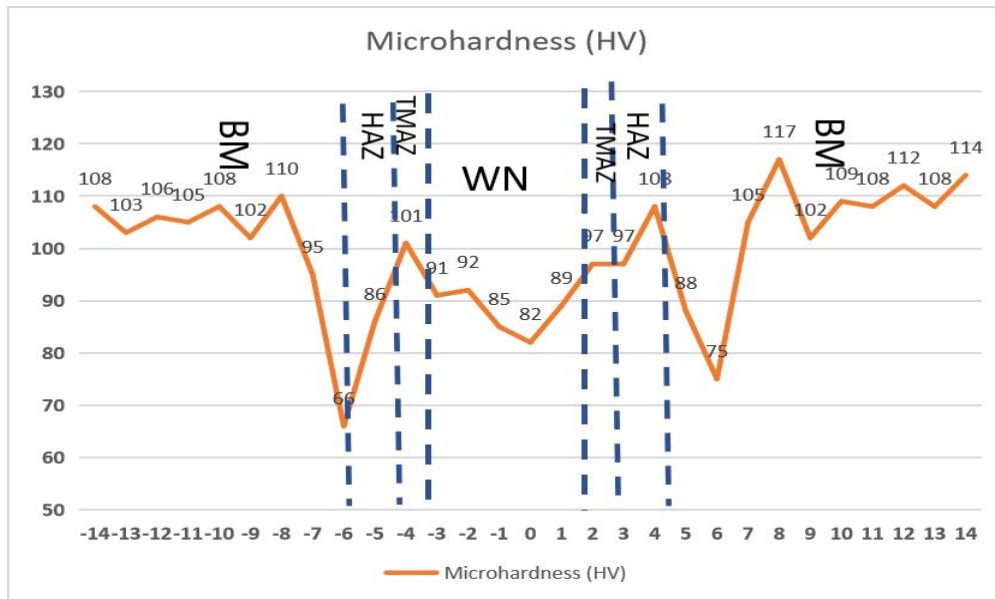


FIGURE 5.9 Micro Hardness plot for AA7075 - AA7050 at 450 rpm

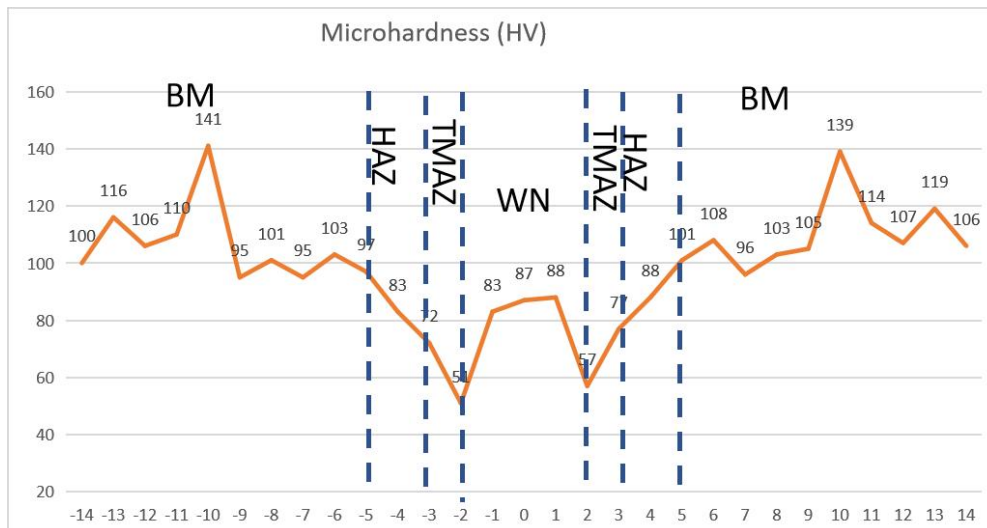


FIGURE 5.10 Micro Hardness plot for AA7075 - AA7050 at 560 rpm

5.4 MECHANICAL PROPERTIES OF WELD JOINTS

5.4.1 TENSILE PROPERTIES

Prepare test specimens according to a standard, such as ASTM E8/E8M, which specifies the dimensions and geometry of tensile test specimen. Install the test specimen in a tensile testing machine, which will apply a gradually increasing load to the specimen until it fails. Record the load and the corresponding elongation of the specimen at regular intervals, typically using an extensometer attached to the specimen. Based on the results of the tests, determine the yield strength, tensile strength, and other mechanical parameters of the material.

Welded similar and dissimilar joints using different parameter were tensile tested and the results are given in the below chart. From the below chart, it is clear that welds made using lower tool rotation speed, in the case 355 RPM, exhibited better tensile properties, both strength and ductility values, than those made using 450 and 560 RPM. As welding speed increases for a given RPM, so does the joint's strength. For all of the measured RPM numbers, this is more or less accurate. Welds made using higher tool rotation speed particularly at 560RPM, exhibited very poor joint ductility, reasons for this are formation and widening of precipitate free zones (PFZ) in the HAZ, as established .

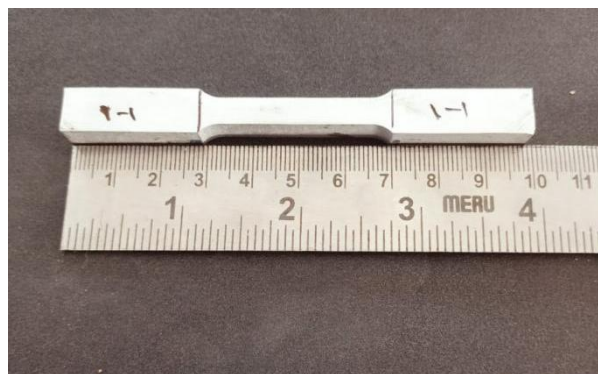
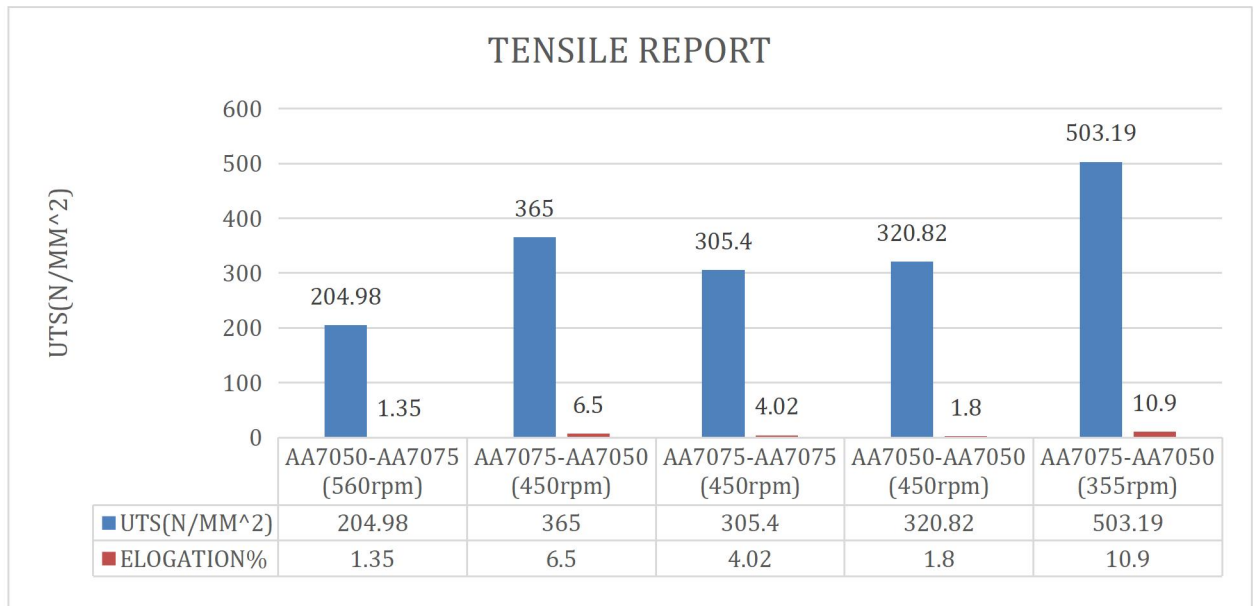


FIGURE 5.11 Tensile Test sample before testing

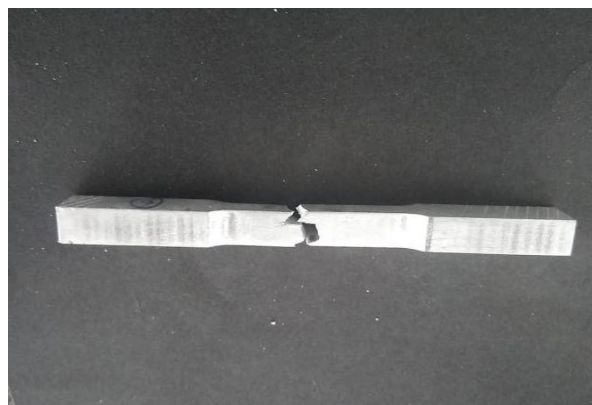


FIGURE 5.12 Tensile Test sample after testing

It is safe to advise utilising lower RPM while making welds and greater welding speeds since they would provide less heat input and less HAZ damage by way of minimizing the formation and widening of 61 PFZs and TMAZ in terms of dissolution of strengthening precipitates. Plates of 10 mm thickness can be successfully welded without any defect using a wide range of parameters. However, strength and ductility of the joints are higher for welds made using low RPM (355) and welding speed (160 mm/min).

Summary

To summarize, this study found that AA7075 -AA7050 (355 RPM) welds show superior tensile properties than the AA7075 -AA7050 (450 RPM), AA7075 -AA7075 (450 RPM), AA7075 -AA7050 (560 RPM), AA7050 -AA7050 (450 RPM) weld plates. Welds made using higher tool rotation speed particularly at 560RPM, exhibited very poor tensile properties.

5.4.2 IMPACT STRENGTH

In a study comparing the impact toughness of dissimilar friction stir welds between AA7075 and AA7050, The impact toughness of this joint was found to be lower compared to that of the base metals. However, the AA7050 side of the joint had a higher impact hardness than the AA7075 side. This is explained by the fact that AA7050 has a higher fracture toughness than AA7075, which allows it to absorb more energy before fracturing.

On the other hand, in a study comparing the impact toughness of similar friction stir welds between AA7075 and AA7050, it was discovered that the joint's impact toughness was greater than that of the base metals. This is because of the FSW process can refine the microstructure of the material, which can increase its toughness. In this case, the AA7075 side's impact toughness was determined to be greater than the AA7050 side. This is explained by the reality that AA7075 has a higher work-hardening rate than AA7050, which can improve its toughness.

Table 5.4 Results of Impact testing of all the FS welds Material

MATERIAL	PARAMETER	IMPACT STRENGTH (J)
7075		6.71
7050		10.32
7050-7075	560	5.69
7050-7075	450	7.62
7075-7075	450	4.34
7050-7050	560	9.68
7050-7075	355	9.27



FIGURE 5.13 Impact test specimens after testing

SUMMARY

In summary, Friction stir welds between AA7075 and AA7050's impact toughness can be affected by a number of variables, such as the chemical composition, microstructure, and welding process parameters. Impact toughness is often less in dissimilar friction stir welds than in base metals, but can be improved by using a higher-toughness material on one side. Due to the microstructural refinement in comparable friction stir welds, the impact toughness may be greater compared to other types of base metals.

CHAPTER 6

CONCLUSION

In similar welds, microhardness recorded in the different zones of weld because variation in microstructure extended to the different zones of microhardness values. In similar welds, microhardness recorded in the different zones of weld because variation in microstructure extended to the different zones of microhardness values.

During dissimilar welds, microhardness in the AA7075 slides has recorded high microhardness values whereas AA7050 slight reduction in the other side. However, impact toughness of the material is higher in 7050 compared to 7075 because 7075 has a rolled condition. It has higher tensile and hardness properties whereas 7050 having higher impact toughness.

This study found that AA7075-AA7050 (355 RPM) welds show superior tensile properties than the AA7075-AA7050 (450 RPM), AA7075-AA7075 (450 RPM), AA7075-AA7050 (560 RPM), AA7050-AA7050 (450 RPM) weld plates. Welds made using higher tool rotation speed particularly at 560 RPM, exhibited very poor tensile properties.

Friction stir welds between AA7075 and AA7050's impact toughness can be affected by a number of variables, such as the chemical composition, microstructure, and welding process parameters. Impact toughness is often less in dissimilar friction stir welds than in base metals, but can be improved by using a higher-toughness material on one side. Due to the microstructural refinement in comparable friction stir welds, the impact toughness may be greater compared to other types of base metals.

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<https://doi.org/10.1007/s00170-018-2147-y>
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APPENDIX - I

 SRI SIVASUBRAMANIYA NADAR COLLEGE OF ENGINEERING (AN AUTONOMOUS INSTITUTE, AFFILIATED TO ANNA UNIVERSITY, CHENNAI) KALAVAKKAM, CHENNAI-603110	 ASM INTERNATIONAL CHENNAI CHAPTER
 DEPARTMENT OF MECHANICAL ENGINEERING	
International Conference on Processing and Performance of Materials (2 nd & 3 rd , Mar 2023)	
<u>CERTIFICATE OF PRESENTATION</u>	
This is to certify that Dr./Mr./Ms./Mrs. MUDUNDI GUNA SAKETHA RAM VARMA, VENKADESHWARAN, S RAM PRAKASH, R PRAVEEN has presented the	
paper titled "STUDY ON MECHANICAL PROPERTIES AND MICROSTRUCTURAL EVALUATION OF DISSIMILAR FRICTION STIR WELDS OF ALUMINIUM ALLOYS" (ICPPM_156) in the International Conference on Processing and Performance of Materials (ICPPM-2023) held at Sri Sivasubramaniya Nadar College of Engineering, Kalavakkam, Chennai – 603 110, Tamil Nadu, India during 2-3, March 2023.	
 Convener Dr. K. K. Babu	 HoD/Mechanical Dr. K.S. Vijay Sekar
	 Principal Dr. V.E. Annamalai

APPENDIX - II

APPENDIX - III