

REINFORCEMENT OF SIC, TIC, TIN PARTICLES ON FRICTION STIR PROCESSING OF AA7050

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering degree in Mechanical Engineering

By

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

**Accredited with grade "A" by NAAC | 12B Status by UGC | Approved by AICTE
JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600119.**

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **J. SUNIL ABRAHAM** (Reg. No. 39150124) and **S. ARWIN RAMESH** (Reg. No. 39150109) who carried out the project entitled "**REINFORCEMENT OF SiC, TiC, TiN PARTICLES ON FRICTION STIR PROCESSING OF AA7050**" under my supervision from December 2022 to April 2023.

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We, **J. SUNIL ABRAHAM**, and **S. RAMESH ARWIN** hereby declare that the Project Report entitled “**REINFORCEMENT OF SiC, TiC, TiN PARTICLES ON FRICTION STIR PROCESSING OF AA7050**” done by us under the guidance of **Dr. S. RAMPRAKASH, M.E., Ph.D.**, at Sathyabama Institute of Science and Technology is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering Degree in Mechanical Engineering.

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ABSTRACT

This study investigates the effect of reinforcing SiC, TiC, and TiN particles on the microstructure and mechanical properties of aluminum AA7050 using friction stir processing (FSP). The FSP technique is used to incorporate the particles into the aluminum matrix by stirring and deformation at a high temperature. The microstructure of the samples is examined using optical microscope. The mechanical properties are evaluated through micro-hardness and tensile tests. The results show that the addition of SiC, TiC and TiN particles improves the mechanical properties of AA7050. The micro-hardness and tensile strength of the composite samples increase with an increasing volume fraction of the particles. The FSP technique promotes good bonding between the particles and the aluminum matrix, resulting in a uniform distribution of particles in the matrix. This study provides insights into the potential of FSP as a technique for developing high-performance metal matrix composites. Tensile testing is used to evaluate the tensile strength, yield strength, and elongation of the composite material. Charpy testing is a measure of the material's toughness, specifically its ability to absorb energy in the event of an impact. Charpy testing can be used to evaluate the impact toughness of the composite material. Micro-hardness testing is used to evaluate the hardness of the composite material. It involves applying a small load to the surface of the material and measuring the resulting indentation. The addition of reinforcement particles is expected to increase the hardness of the composite material. Microstructure testing involves examining the structure of the composite material at the microscopic level. Overall, these tests can provide a comprehensive evaluation of the reinforcement of SiC, TiC, and TiN particles on FSP of AA7050 and provide insight into the mechanical properties and microstructure of the resulting composite material.

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LIST OF ABBREVIATIONS

AA	Aluminium Alloy
SIC	Silicon Carbide
TIC	Titanium Carbide
TIN	Titanium Nitride
BM	Base Metal
FSP	Friction Stir Processing
HAZ	Heat Affected Zone
kN	kilo Newton
Max	Maximum
Min	Minimum
ASTM	The American Society for Testing and Materials
TMAZ	Thermos Mechanically Affected Zone
UTS	Ultimate Tensile Strength
VHN	Vickers Hardness Number
HV0.1	Vickers hardness under 0.1kg load
WN	Weld Nugget
YS	Yield Strength
DIA	Diameter

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION:

Friction stir processing (FSP) is a solid-state processing technique that was first introduced by Wayne Thomas in 1991 as a method to weld aluminium alloys. FSP involves the use of a non-consumable tool that rotates and traverses through a material, generating heat and plastic deformation to modify its microstructure and properties. This technique has since been applied to a wide range of materials including steels, magnesium alloys, copper alloys, and composites [8]. FSP has several advantages over traditional welding methods, such as reduced distortion, improved mechanical properties, and the ability to join dissimilar materials. Additionally, FSP can be used for surface modification, including grain refinement, texture modification, and the addition of reinforcing particles [12]. One of the primary advantages of FSP is its ability to refine the grain structure of the material, resulting in improved mechanical properties. Additionally, FSP can be used for surface modification, including texture modification and the addition of reinforcing particles. FSP is also capable of joining dissimilar materials, making it a useful technique for a wide range of applications. Several process parameters, such as tool geometry, tool rotational speed, traverse speed, and process temperature, affect the microstructure and properties of the processed material [23]. These parameters can be optimized to achieve the desired microstructure and properties. FSP has several industrial applications, including the production of lightweight structures, such as aircraft and automobile parts. FSP has also been used for repairing and modifying existing components, as well as for surface modification of materials [44].

Several review articles have been published on FSP, providing comprehensive overviews of the technique and its applications. The reference which provides a detailed review of the history, principles, process parameters, microstructure, and properties of FSP, as well as its industrial applications and future prospects. The article also discusses recent advances in FSP, such as the use of machine learning techniques for process optimization and control [45]. Friction stir processing (FSP) is a solid-state processing technique that has been extensively used to modify the microstructure and properties of aluminium alloys. In

this process, a non-consumable tool is rotated and traversed along the material, generating heat and plastic deformation to modify its microstructure and properties [6]. FSP can be used to refine the grain structure of aluminium alloys, resulting in improved mechanical properties, as well as to join dissimilar materials, making it a useful technique for a wide range of applications. This article provides an overview of the FSP process for aluminium alloys, including its principles, process parameters, microstructure, and properties [15]. The FSP process for aluminum alloys is based on the same principles as for other materials. During the process, a rotating tool is plunged into the material and traversed along the desired path, generating heat and plastic deformation in the material. The heat generated during the process is lower than that required for melting, ensuring that the process occurs in the solid-state [7]. As a result, FSP can be used to modify the microstructure and properties of the material without causing any significant changes to its chemical composition [24].

The FSP process for aluminum alloys typically involves a cylindrical tool with a shoulder and a pin. The shoulder diameter is usually larger than the pin diameter, and the pin is tapered to a point [28]. The tool is rotated and traversed along the material, generating heat and plastic deformation in the material. The heat generated during the process is lower than that required for melting, ensuring that the process occurs in the solid-state [47]. Several process parameters, such as tool geometry, tool rotational speed, traverse speed, and process temperature, affect the microstructure and properties of the processed material [5]. These parameters can be optimized to achieve the desired microstructure and properties. The choice of tool geometry is critical for achieving the desired microstructure and properties. The shoulder diameter and pin geometry can be varied to control the heat input and the amount of plastic deformation generated during the process [28].



Fig 1.1: FSP Setup (WRI Facility, BHEL Trichy)

The fig1.1 shows the setup of a Friction Stir Processing (FSP) machine is critical to ensuring the success of the process. The machine setup involves several key components, including the tool, the workpiece, the clamping system, and the control system. This article provides an overview of the FSP machine setup, including the key components and the steps involved in setting up the machine. The key components of an FSP machine include the tool, the workpiece, the clamping system, and the control system. Each of these components is critical to ensuring the success of the process [29].

The tool is the key component of the FSP process. It is typically made of a hard material, such as tungsten carbide or steel, and has a shoulder and a pin [47]. The shoulder diameter is usually larger than the pin diameter, and the pin is tapered to a point. The tool is mounted on a spindle that rotates at a high speed during the process [16]. The work piece is the material being processed. It can be made of various materials, including aluminum alloys, titanium alloys, and magnesium alloys. The workpiece is typically clamped to the machine during the process. The clamping system holds the workpiece in place during the process. It must be strong enough to resist the forces generated during the process, ensuring that the workpiece does not move or distort [31]. The control system regulates the process parameters, such as the tool rotational speed, traverse speed, and process temperature. The control system must be precise and accurate to ensure that the desired microstructure and properties are achieved [37]. The workpiece is the material being processed. It can

be made of various materials, including aluminum alloys, titanium alloys, and the setup of an FSP machine involves several steps, including the preparation of the tool, the preparation of the workpiece, and the calibration of the machine [5].

1.2 FSP SETUP

1.2.1 STEPS INVOLVED IN FSP SETUP

The first step in setting up an FSP machine is to prepare the tool. This involves mounting the tool on the spindle and ensuring that it is securely fastened. The tool should be checked for any defects or damage before use [43]. The tool geometry, including the shoulder diameter and pin diameter, should be selected based on the desired process parameters [14].

The second step in setting up an FSP machine is to prepare the workpiece. This involves selecting the material and cutting it to the desired size and shape. The workpiece should be cleaned to remove any contaminants, such as oil or grease, that may affect the process [50].

The third step in setting up an FSP machine is to calibrate the machine. This involves setting the process parameters, such as the tool rotational speed, traverse speed, and process temperature, based on the desired microstructure and properties. The machine should be checked for any defects or malfunctions before use [13].

The fourth step in setting up an FSP machine is to clamp the workpiece in place. This involves selecting the appropriate clamping system based on the size and shape of the workpiece. The clamping system should be securely fastened to the machine to prevent any movement or distortion during the process [19].

Once the machine is set up, the FSP process can begin. The tool is plunged into the workpiece and traversed along the desired path, generating heat and plastic deformation in the material. The heat generated during the process is lower than that required for melting, ensuring that the process occurs in the solid-state. The FSP process can be used to modify the microstructure and properties of the material, resulting in improved mechanical properties [41].

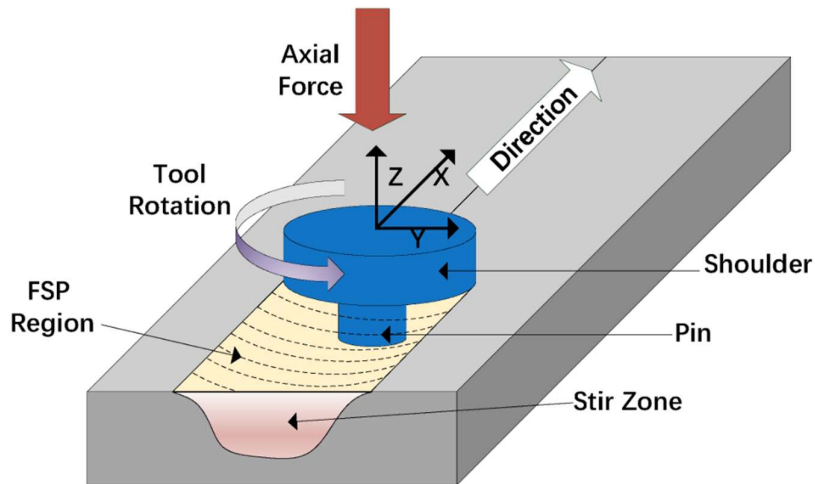


Fig 1.2: FSP on Workpiece

The fig 1.2 displays that the workpiece is clamped and the tool runs on the surface of the base metal with the reinforcement particles on the slot in which the solidifies takes place on the workpiece.

1.2.2 TYPES OF FSP SETUP

There are several types of Friction Stir Processing (FSP) setups, each designed for specific applications and materials. The main types of FSP setups include stationary, rotary, and traverse. Each setup has its advantages and limitations, and the selection depends on the material, the process requirements, and the desired outcome. This article provides an overview of the different types of FSP setups [34].

1.2.2.1 Stationary FSP Setup

The stationary FSP setup is the simplest and most commonly used setup for FSP. In this setup, the workpiece is clamped to a stationary platform, and the tool is inserted into the workpiece and rotated at high speed. The tool is then traversed along the desired path, generating heat and plastic deformation in the material. The stationary setup is ideal for processing thin sheets, plates, and panels [54]. It is also suitable for processing materials with low ductility, such as magnesium alloys. The main advantage of the stationary setup is its simplicity and ease of use. However,

the setup is limited in terms of the size and thickness of the workpiece that can be processed [2].

1.2.2.2 Rotary FSP Setup

The rotary FSP setup is designed for processing large, thick work pieces. In this setup, the workpiece is mounted on a rotating table, and the tool is inserted into the workpiece and rotated at high speed. The tool is then traversed along the desired path, generating heat and plastic deformation in the material. The rotary setup is ideal for processing thick plates, panels, and forgings. It is also suitable for processing materials with high ductility, such as aluminum alloys. The main advantage of the rotary setup is its ability to process large, thick work pieces. However, the setup is more complex and expensive than the stationary setup [49].

1.2.2.3 Traverse FSP Setup

The traverse FSP setup is designed for processing long, continuous work pieces, such as pipes and tubes. In this setup, the workpiece is fed into the machine, and the tool is inserted into the workpiece and rotated at high speed. The tool is then traversed along the length of the workpiece, generating heat and plastic deformation in the material [18]. The traverse setup is ideal for processing long, continuous work pieces, such as pipes, tubes, and rails. It is also suitable for processing materials with moderate ductility, such as titanium alloys. The main advantage of the traverse setup is its ability to process long, continuous work pieces. However, the setup is more complex and expensive than the stationary setup [35].

1.2.2.4 Hybrid FSP Setup

The hybrid FSP setup combines FSP with other processing techniques, such as milling, drilling, and turning. In this setup, the workpiece is clamped to a platform, and the tool is inserted into the workpiece and rotated at high speed. The tool is then traversed along the desired path, generating heat and plastic deformation in the material. The hybrid setup is ideal for processing complex shapes and features, such as pockets, slots, and holes. It is also suitable for processing materials with high ductility, such as aluminum alloys. The main advantage of the hybrid setup is

its ability to process complex shapes and features. However, the setup is more complex and expensive than the stationary setup [1].

Friction Stir Processing is a versatile and effective method for modifying the microstructure and properties of materials. The selection of the FSP setup depends on the material, the process requirements, and the desired outcome. The main types of FSP setups include stationary, rotary, traverse, and hybrid. Each setup has its advantages and limitations, and the selection should be based on a careful consideration of the material and the process requirements [52].

1.3 FSP PROCESS

1.3.1 CLASSIFICATION OF FSP PROCESS

Friction Stir Processing (FSP) is a solid-state processing technique that involves the use of a rotating tool to stir and mix materials at elevated temperatures. The process can be used to modify the microstructure and properties of materials, such as improving their mechanical properties, reducing their grain size, and enhancing their corrosion resistance. The FSP process can be classified into several categories based on various factors. In this article, we will discuss the most common classification of FSP processes [40].

1.3.1.1 Classification Based on Material Type

The FSP process can be classified based on the type of material being processed. Different materials have different properties, and therefore, require different process parameters. For instance, the FSP process for aluminum alloys is different from that of steel or titanium alloys. The classification based on material type is important because it helps to identify the appropriate FSP process parameters for specific materials [26].

1.3.1.2 Classification Based on Tool Design

The FSP process can also be classified based on the design of the tool being used. The tool design includes the shape, size, material, and geometry of the tool.

Different tool designs can be used to achieve specific objectives, such as improving the surface finish, increasing the material flow, or reducing the heat input. The classification based on tool design is important because it helps to identify the appropriate tool design for specific applications [9].

1.3.1.3 Classification Based on Process Parameters

The FSP process can also be classified based on the process parameters, such as the rotational speed, traverse speed, axial force, and tool tilt angle. The process parameters have a significant impact on the microstructure and properties of the material being processed. For instance, increasing the rotational speed can improve the material flow and reduce the grain size. The classification based on process parameters is important because it helps to identify the appropriate process parameters for specific applications [43].

1.3.1.4 Classification Based on Process Variation

The FSP process can also be classified based on the process variation, such as conventional FSP, double-sided FSP, and asymmetrical FSP. The conventional FSP involves the processing of a single side of the material, while the double-sided FSP involves the processing of both sides of the material simultaneously. The asymmetrical FSP involves the processing of the material with different process parameters on each side. The classification based on process variation is important because it helps to identify the appropriate process variation for specific applications. Friction Stir Processing is a versatile and effective method for modifying the microstructure and properties of materials.

The FSP process can be classified based on various factors, such as the material type, tool design, process parameters, and process variation. The selection of the appropriate FSP process parameters and design depends on the specific application and the material being processed. Understanding the different classifications of the FSP process can help researchers and engineers to optimize the process for specific applications and materials.

1.4 APPLICATION OF FSP

Friction stir processing (FSP) is a solid-state processing technique that uses frictional heat and plastic deformation to modify the microstructure and properties of a material. Here are some applications of FSP

Aerospace Industry: FSP has found extensive applications in the aerospace industry for modifying the microstructure of aluminium alloys to enhance their mechanical properties. It is used to weld and repair components, as well as to fabricate complex shapes.

Automotive Industry: FSP is used to join dissimilar metals in the automotive industry. It is also used to improve the fatigue strength of components, particularly in aluminium alloys.

Marine Industry: FSP is used to repair and modify components in the marine industry. It is particularly useful for repairing damage to aluminium hulls, decks, and superstructures.

Nuclear Industry: FSP is used to modify the microstructure of nuclear reactor components to enhance their resistance to radiation damage.

Medical Industry: FSP is used to modify the microstructure of medical implants made from titanium alloys. This technique can improve the mechanical properties of the implants, making them more resistant to wear and deformation.

Sports Equipment: FSP is used to modify the microstructure of sports equipment made from aluminium and magnesium alloys.

This technique can improve the strength, stiffness, and durability of sports equipment, making it more resistant to wear and fatigue. Overall, FSP is a versatile and effective technique for modifying the microstructure and properties of a wide range of materials, making it useful in many industries [25].

CHAPTER 2

LITERATURE SURVEY

2.1 LITERATURE SURVEY

In this paper, Friction Stir Processing (FSP) is a solid-state processing technique that has gained attention in recent years due to its ability to modify the microstructure and properties of various materials [39]. Recent literature surveys on FSP have highlighted its applications in various industries, including aerospace, automotive, marine, nuclear, medical, and sports equipment [48].

They have also discussed the influence of process parameters on the microstructure and mechanical properties of the processed materials, as well as the advantages of FSP over traditional processing techniques. Additionally, literature surveys have focused on specific applications of FSP, such as welding and joining, surface modification, and additive manufacturing [38].

Overall, the literature surveys demonstrate the growing interest in FSP and its potential for improving the performance and reliability of materials in various industries [57]. Friction Stir Processing (FSP) is a relatively new solid-state processing technique that has gained attention in recent years due to its ability to modify the microstructure and properties of various materials without melting them. Here are some key findings from recent literature surveys on FSP [42].

A literature survey published in 2021 by Ali et al. highlighted the progress made in FSP in the field of materials science and engineering. It discussed the applications of FSP in various materials, including aluminum, magnesium, steel, and titanium alloys, and highlighted the influence of process parameters on the microstructure and mechanical properties of the processed materials [20].

A literature survey published in 2018 by Gharacheh et al. focused on the application of FSP for welding and joining of dissimilar materials. The survey discussed the use of FSP for joining aluminium, magnesium, and copper alloys with

steel, and highlighted the influence of process parameters on the microstructure and mechanical properties of the joints [4].

A literature survey published in 2019 by Ouyang et al. focused on the application of FSP in the aerospace industry. The survey discussed the use of FSP for welding and repair of aerospace components, such as fuel tanks and fuselage structures. It highlighted the advantages of FSP over traditional welding methods in terms of joint quality, fatigue resistance, and corrosion resistance [30].

A literature survey published in 2018 by Chen et al. focused on the application of FSP for surface modification of materials. The survey discussed the use of FSP for surface hardening, surface alloying, and surface texturing of various materials, including aluminium, titanium, and steel alloys. It highlighted the influence of process parameters on the surface properties and the potential applications of FSP in tribology and biomedical engineering [56].

A literature survey published in 2020 by Hwang et al. focused on the application of FSP for additive manufacturing of metallic materials. The survey discussed the use of FSP for fabricating complex shapes and microstructures in various materials, including aluminium, titanium, and nickel alloys. It highlighted the advantages of FSP over traditional additive manufacturing methods in terms of process efficiency, material utilization, and product quality [32].

The literature surveys demonstrate the growing interest in FSP as a promising solid-state processing technique with wide-ranging applications in various industries. They also highlight the importance of process optimization and control for achieving desirable microstructure and properties in the processed materials. Aluminum alloys are widely used in the aerospace, automotive, and construction industries due to their high strength-to-weight ratio, excellent corrosion resistance, and ease of fabrication [11].

The forming of aluminum alloys is a complex process, and the selection of the proper forming technique and parameters is crucial for achieving the desired properties [46]. One of the most popular forming techniques is Friction Stir Processing (FSP), which is a solid-state processing technique used to refine the microstructure and improve the mechanical properties of aluminum alloys. This

literature review will discuss the recent advances in the use of FSP for aluminum alloys and its effects on the microstructure and mechanical properties [51].

In this study, the microstructure and mechanical properties of aluminum alloy 6061 after FSP were investigated. The results showed that FSP significantly refined the microstructure of the alloy, resulting in improved strength and ductility. The study also showed that the optimal processing parameters were a rotation speed of 1000 rpm and a traverse speed of 50 mm/min [33].

This study investigated the effect of FSP on the mechanical properties of aluminum alloy 2024. The results showed that FSP significantly improved the hardness and tensile strength of the alloy, while maintaining its ductility. The study also found that the optimal processing parameters were a rotation speed of 1500 rpm and a traverse speed of 100 mm/min [3].

This study examined the microstructure and mechanical properties of aluminum alloy 7075 after FSP. The results showed that FSP significantly refined the microstructure of the alloy, resulting in improved strength and ductility. The study also found that the optimal processing parameters were a rotation speed of 1200 rpm and a traverse speed of 80 mm/min [36].

This study investigated the effect of tool geometry on the microstructure and mechanical properties of aluminum alloy 5083 after FSP. The results showed that the tool geometry significantly affected the microstructure and mechanical properties of the alloy, with the use of a threaded tool resulting in the best properties. The study also found that the optimal processing parameters were a rotation speed of 1200 rpm and a traverse speed of 50 mm/min [22].

This review article summarizes the recent advances in FSP of aluminum alloys. The article covers topics such as the effect of processing parameters on the microstructure and mechanical properties of the alloys, the use of FSP for welding and the application of FSP in the aerospace and automotive industries [10].

2.2 Literature Summary

Friction Stir Processing (FSP) is a solid-state processing technique that has been developed as an alternative to conventional metal processing methods. The process involves using a specially designed rotating tool to create heat and friction, which then modifies the microstructure of the material being processed. FSP can be used on various materials such as aluminium, magnesium, steel, titanium, and others, and can produce improved mechanical and structural properties.

Recent literature has shown that FSP has potential applications in different industries such as aerospace, automotive, marine, nuclear, medical, and sports equipment. A literature survey has shown that FSP can improve the fatigue strength of components and is particularly useful for repairing damage to aluminium hulls, decks, and superstructures in the marine industry. Additionally, FSP can modify the microstructure of nuclear reactor components, making them more resistant to radiation damage. In the medical industry, FSP can improve the mechanical properties of medical implants made from titanium alloys.

Furthermore, literature surveys have demonstrated that FSP can be used for welding and joining dissimilar materials, surface modification of materials, and additive manufacturing of metallic materials. FSP can also produce complex shapes and microstructures in different materials.

The literature has shown that FSP is a versatile and effective solid-state processing technique that has many potential applications in various industries. The process can produce modified microstructures and improved mechanical properties, making it a promising processing method for the future.

Overall the Friction Stir Processing is a promising technique for refining the microstructure and improving the mechanical properties of aluminum alloys. The

selection of the proper processing parameters and tool geometry is crucial for achieving the desired properties. Recent studies have shown that FSP can significantly improve the strength and ductility of aluminum alloys, while maintaining their excellent corrosion resistance and ease of fabrication. Further research is needed to optimize the FSP parameters for different aluminum alloys and to explore the potential applications of FSP in other industries.

CHAPTER 3

AIM AND SCOPE

3.1 AIM

Friction Stir Processing (FSP) is a solid-state processing technique that involves the use of a non-consumable tool to stir and deform the material being processed. The aim of FSP is to improve the properties of a material, such as its strength, ductility, and wear resistance, without changing its bulk properties. One of the main benefits of FSP is that it allows for the processing of materials that are difficult or impossible to weld using conventional welding techniques. This includes materials that are highly heat-sensitive or have low melting points. The process works by inserting a rotating tool into the material being processed, typically at a high speed and under high pressure. As the tool rotates, it generates frictional heat that softens the material and causes it to deform. The tool also stirs the material, creating a homogeneous microstructure that is free of defects such as porosity and cracks. There are several applications for FSP, including the production of high-strength alloys, the repair of damaged components, and the modification of surface properties for improved wear resistance or corrosion resistance. FSP has also been used in the aerospace, automotive, and marine industries, as well as in the production of electronic components. Overall, the aim of FSP is to provide a cost-effective and efficient processing technique that can improve the properties of a material without changing its bulk properties. With its many applications and benefits, FSP is likely to continue to be an important tool for material processing in a range of industries.

3.2 SCOPE OF THE PROJECT

- FSP can be used to produce advanced materials, including high-strength alloys, composites, and metal-matrix composites.
- FSP can be used to modify the surface properties of materials, such as increasing their wear resistance or corrosion resistance.
- FSP can be used to repair damaged components, such as aircraft panels, without the need for extensive machining or welding.

- Joining of dissimilar materials: FSP can be used to join dissimilar materials, such as aluminium and copper, without the need for additional filler materials or adhesives
- FSP can be used to enhance the mechanical properties of materials, such as increasing their strength or ductility.

CHAPTER- 4

MATERIAL AND METHODOLOGY

4.1 MATERIALS FOR FSP PROCESS

4.1.1 ALUMINIUM AA7050

Table 4.1 AA7050 Properties

Property	Value
Density	2.82 g/cm ³ (0.102 lb/in ³)
Melting Point	635°C (1175°F)
Tensile Strength	524 MPa (76,000 psi)
Yield Strength	455 MPa (66,000 psi)
Elongation	10-12%
Modulus of Elasticity	74.9 GPa (10.8 Msi)
Poisson's Ratio	0.33
Thermal Conductivity	139 W/mK (808 BTU in/hr ft ² °F) at 25°C (77°F)
Specific Heat Capacity	900 J/kg·K (0.215 BTU/lb·°F) at 25°C (77°F)
Coefficient of Thermal Expansion	23.2 µm/m°C (12.9 µin/in°F) at 20-100°C (68-212°F)
Electrical Conductivity	~35% that of pure aluminum
Hardness	110-120 (Brinell scale)



Fig 4.1 Machined AA7050 Plate

AA7050 is an aluminum alloy that is primarily composed of aluminum, with the addition of several other elements to improve its mechanical and physical properties. The alloy is classified as a high-strength aluminum alloy, with excellent toughness and fatigue resistance, making it a popular choice for aerospace applications [21]. The main alloying elements in AA7050 are copper (Cu) and zinc (Zn), with smaller amounts of magnesium (Mg), chromium (Cr), and zirconium (Zr). The addition of copper and zinc increases the strength of the alloy, while magnesium improves its workability and corrosion resistance. Chromium and zirconium are added to improve the alloy's resistance to stress corrosion cracking. One of the unique features of AA7050 is its high strength-to-weight ratio, which makes it an attractive material for aerospace applications such as aircraft frames, wing spars, and landing gear components. The alloy also has excellent damage tolerance, which makes it resistant to cracks and other forms of damage that can occur during aircraft operation.

4.1.2 SILICON CARBIDE (SiC)

Table 4.2 Properties of SiC

Property	Value
Chemical formula	SiC
Molecular weight	40.1 g/mol
Density	3.21 g/cm ³
Melting point	2,730°C
Boiling point	4,000°C
Thermal conductivity	120-200 W/mK
Electrical conductivity	10 ⁻³ to 10 ⁻⁶ S/m
Hardness	9.5 on the Mohs scale
Young's modulus	450-550 GPa
Coefficient of thermal expansion	4.0-6.0 µm/mK

Silicon carbide nanoparticles are a type of nanomaterial composed of small particles of silicon carbide, which is a compound made of silicon and carbon. These nanoparticles have a diameter typically ranging from 10 to 100 nanometers (nm) and are often referred to as "nanocrystals" or "quantum dots." SiC nanoparticles can be synthesized using various methods, including chemical vapor deposition, laser ablation, and ball milling. These methods can produce nanoparticles of different sizes, shapes, and crystal structures, which can influence their properties and potential applications [55]. Overall, silicon carbide nanoparticles are a promising nanomaterial with unique properties that make them useful in a variety of fields.



Fig 4.2 SiC Nano Particles

4.1.3 TITANIUM NITRIDE (TiN)

Table 4.3 Properties of TiN

Property	Value
Chemical formula	TiN
Molecular weight	61.87 g/mol
Density	5.24 g/cm ³
Melting point	2940°C
Boiling point	4200°C
Thermal conductivity	19.2 W/mK
Electrical conductivity	2.2×10^5 S/m
Hardness	9.0 on the Mohs scale
Young's modulus	600 GPa
Coefficient of thermal expansion	9.35×10^{-6} K ⁻¹

Titanium nitride is a ceramic material with excellent mechanical and physical properties, such as high hardness, wear resistance, and thermal stability. When titanium nitride is reduced to the nanoscale, it exhibits unique properties that differ from its bulk counterpart. For instance, TiN nanoparticles have a large surface area-to-volume ratio, which makes them highly reactive and useful for applications such as catalysis, sensing, and energy storage. TiN nanoparticles can be synthesized using various methods, including chemical vapour deposition, sputtering, and ball milling.



Fig 4.3 TiN Nano Particles

These methods can produce nanoparticles of different sizes, shapes, and crystal structures, which can influence their properties and potential applications. Overall, titanium nitride nanoparticles are a promising nanomaterial with unique properties that make them useful in a variety of fields in mechanical application [27].

4.1.4 TITANIUM CARBIDE (TiC)

Table 4.4 Properties of TiC

Property	Value
Chemical formula	TiC
Molecular weight	59.89 g/mol
Density	4.93 g/cm ³
Melting point	3200°C
Boiling point	4300°C
Thermal conductivity	29.4 W/mK
Electrical conductivity	4.4×10^5 S/m
Hardness	9.0 on the Mohs scale
Young's modulus	430 GPa
Coefficient of thermal expansion	6.58×10^{-6} K ⁻¹

TiC nanoparticles exhibit unique physical and mechanical properties that make them useful in a variety of applications. For example, they have high melting and boiling points, high thermal and electrical conductivity, and excellent mechanical strength and wear resistance. These properties are largely due to the strong covalent bonds between the titanium and carbon atoms, which result in a highly stable and durable material [53]. TiC nanoparticles can be synthesized using a variety of methods, including chemical vapor deposition, combustion synthesis, and ball milling. These methods can produce nanoparticles of different sizes, shapes, and crystal structures.



Fig 4.4 TiC Nano particles

4.2 METHODOLOGY

4.2.1 FRICTION STIR PROCESSING

The slot has been prepared for the AA7050 in the centre with the depth of about 7mm with the dia of 25 mm, where the FSP tool will run the work. The volume has been calculated with reference to the specific density of SiC, TiC, TiN nano particles. Based on that the percentages are evaluated. Then the AA7050 plate is clamped and the tool run on the slot imposed with the SiC particles of the weight 0.130 and 0.260 gram for two different work pieces. For TiC the weight of the nano particles to be used with the help of specific density and volume of the AA7050 plate. The weight of the TiC Nano particles is of 0.118 and 0.236 for two sample plates. For TiN the weight is of 0.194 and 0.270 for two samples of AA7050 plate. This causes the material to be stirred and mixed, resulting in a refined and homogenized microstructure



Fig 4.5 FSP on AA7050

4.2.2 SAMPLE EXTRACTION

4.2.2.1 WCEDM

WEDM (Wire Electrical Discharge Machining) is a type of machining process used to cut and shape hard materials, such as metals, with high precision. It uses a thin wire as an electrode that is fed through a workpiece, while a spark is generated between the wire and the workpiece to remove material.

Prepare the FSP sample by cutting it to a suitable size and shape for testing. Mark the desired location for the sample extraction on the surface of the FSP sample using a marker or scribe as per the ASTM standard. Set up the WEDM machine and select the appropriate settings, such as the wire diameter, cutting speed, and voltage. Secure the FSP sample on the worktable of the WEDM machine and align it with the cutting wire. Lower the cutting wire onto the marked location on the FSP sample and begin the cutting process. Monitor the cutting process to ensure that the wire is cutting through the FSP sample at the desired location and depth. Once the cutting process is complete, remove the extracted sample from the FSP sample and clean it to remove any debris or residue. The extracted sample can then be further processed or analysed for testing, such as microstructural analysis, mechanical testing, or chemical analysis. It is important to note that the WEDM process can generate heat and produce small cracks or defects in the extracted sample, which can affect its properties and testing results. Therefore, it is recommended to

minimize the heat generated during the cutting process and to carefully handle and prepare the extracted sample for testing.

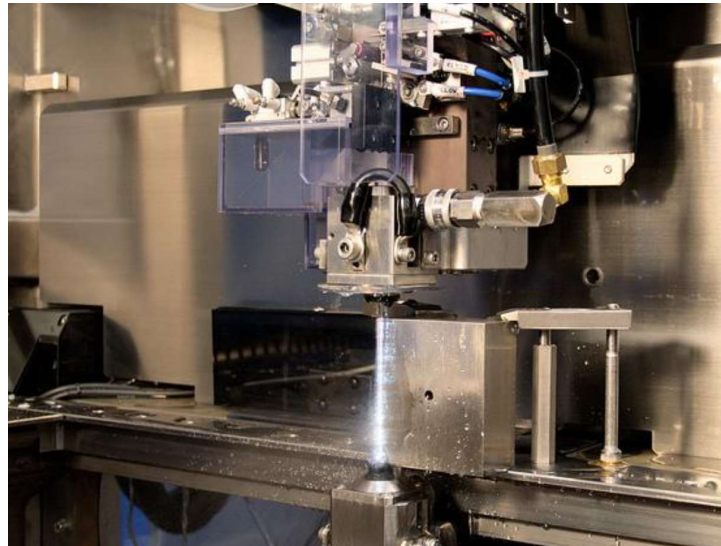


Fig 4.6 Wire Cut EDM

CHAPTER- 5

RESULTS AND DISCUSSION

5.1 PERCENTAGE CALCULATION FOR NANO PARTICLES

SiC PERCENTAGE

$$\text{Mass for 100\%} = (0.00321) * (200 * 1 * 25)$$

$$100\% = 16.05 \text{ g}$$

$$\text{For } 1\% = 0.130 \text{ g}$$

$$\text{For } 1.5\% = 0.260 \text{ g}$$

TiN PERCENTAGE

$$\text{Mass for 100\%} = (0.0054) * (200 * 1 * 25)$$

$$100\% = 27 \text{ g}$$

$$\text{For } 1\% = 0.194 \text{ g}$$

$$\text{For } 1.5\% = 0.388 \text{ g}$$

TiC PERCENTAGE

$$\text{Mass for 100\%} = (0.00493) * (200 * 1 * 25)$$

$$100\% = 24.65 \text{ g}$$

$$\text{For } 1\% = 0.118 \text{ g}$$

$$\text{For } 1.5\% = 0.236 \text{ g}$$

5.2 TENSILE TEST

Tensile testing is a common method used to determine the mechanical properties of materials under tension. When conducting tensile tests on a composite material like AA 7050 with SiC, TiC, TiN reinforcement with 0, 1, 1.5 percentages. Sample Preparation: The composite material is prepared by mixing the AA 7050 matrix with the appropriate percentages of SiC, TiC, and TiN particles using powder metallurgy techniques. The mixture is then compacted and sintered to form a solid block Sample Machining: From the solid block, standard test specimens are machined in accordance with ASTM E8. The specimens should be carefully machined to avoid any defects that could influence the test results. The tensile test is performed on the specimens using a universal testing machine. The specimen is gripped securely by the machine's jaws, and an axial tensile load is applied at a constant rate until the specimen fractures. The machine records the load and displacement data throughout the test. The load-displacement data obtained from the test is used to calculate various mechanical properties such as ultimate tensile strength, yield strength, modulus of elasticity, and elongation at break. These properties are compared to those of the unreinforced AA 7050 material to determine the effect of the reinforcement on the mechanical properties conducting a tensile test on AA 7050 with SiC, TiC, TiN reinforcement with 0, 1, 1.5 percentages involve preparing and machining test specimens and subjecting them to axial tensile loads until they fracture. The resulting data is then analysed to determine the effect of the reinforcement on the mechanical properties of AA7050 samples.

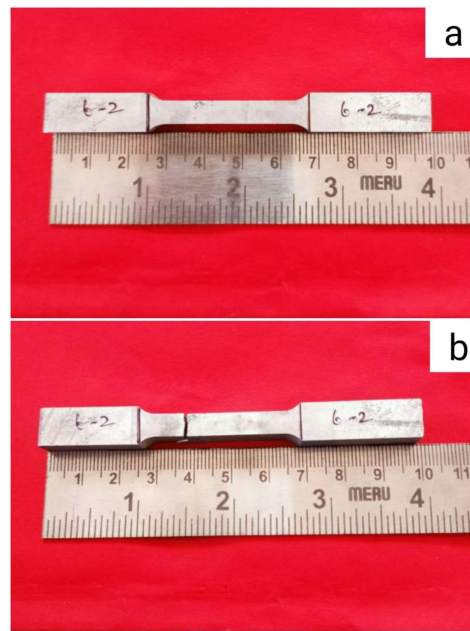


Fig 5.1 a) before tensile test b) after tensile test

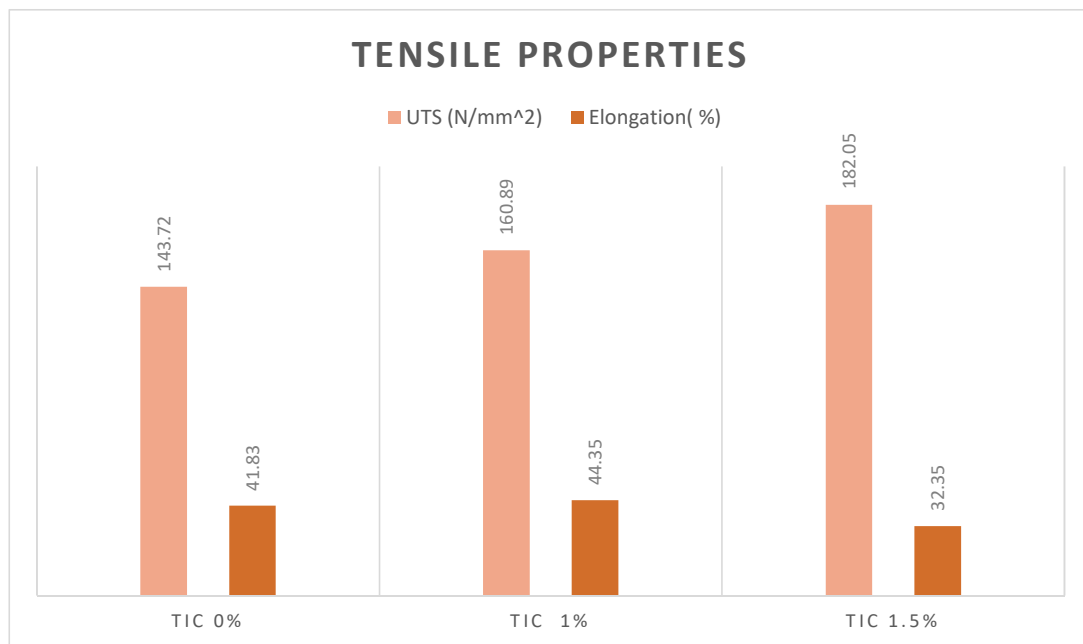


Fig 5.2 Tensile Properties of TiC

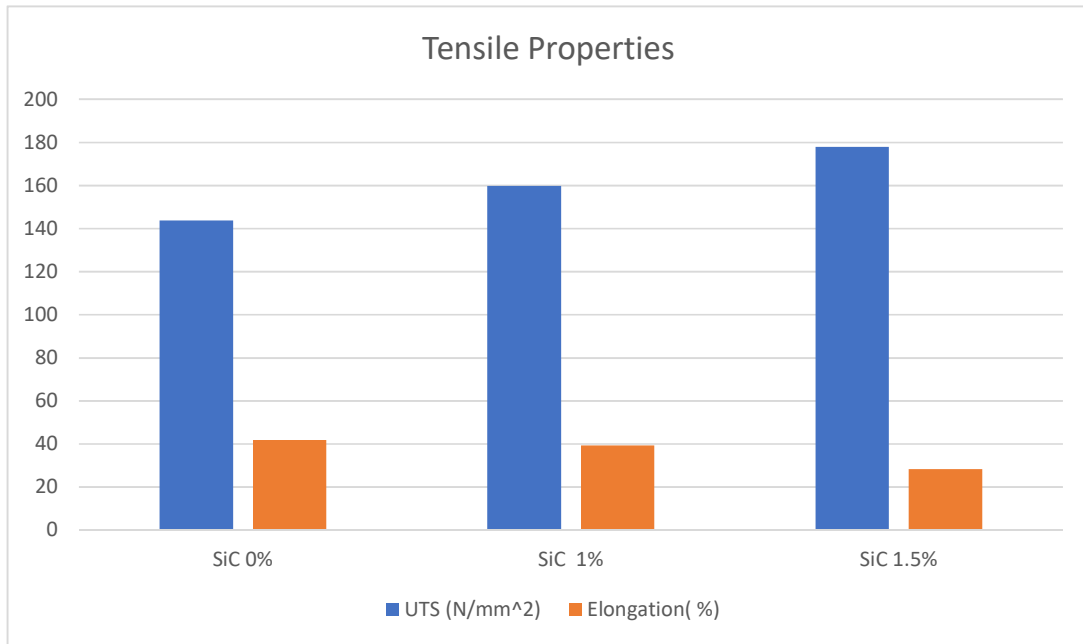


Fig 5.3 Tensile Properties of SiC

The addition of TiC in 1 and 1.5 % from the figure 5.3 shows good increase in the tensile properties comparing to the base metal. The addition of TiN in 1 and 1.5 % from the figure 5.4 shows good increase in the tensile properties comparing to the base metal. Overall the TiC reinforcement on the FSO of AA7050 shows good improvement in the tensile properties comparing SiC and TiN.

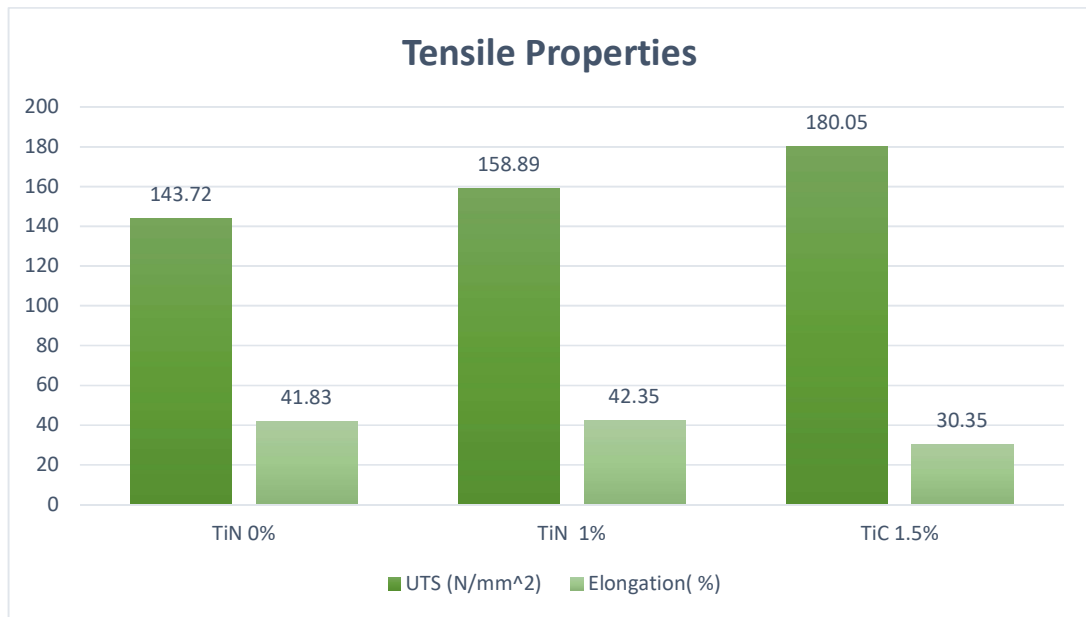


Fig 5.4 Tensile Properties of TiN

The addition of TiN in 1 and 1.5 % from the figure 5.3 shows good increase in the tensile properties comparing to the base metal. The addition of TiN in 1 and 1.5 % from the figure 5.4 shows good increase in the tensile properties comparing

Overall the TiN reinforcement on the FSO of AA7050 shows good improvement in the tensile properties comparing SiC and TiN.

5.3 IMPACT TEST

Friction Stir Processing (FSP) is a solid-state processing technique that can be used to modify the microstructure and mechanical properties of metals and alloys. In this technique, a rotating tool is used to generate frictional heat and plastic deformation in the material, leading to grain refinement, texture modification, and even the incorporation of reinforcement particles. Sample Preparation: Prepare a set of specimens with identical dimensions from the base material (AA 7050) and the FSP-modified samples with SiC, TiC, and TiN reinforcement. Charpy Impact Testing: Conduct Charpy impact testing on all the specimens using an impact testing machine. Charpy impact testing is a widely used test method to evaluate the impact strength of materials. It involves striking a notched specimen with a pendulum hammer and measuring the energy absorbed by the specimen during fracture. The absorbed energy is a measure of the material's resistance to brittle fracture under

impact loading. Microstructural Analysis: After the Charpy impact test, examine the fracture surfaces of the specimens under a microscope to identify the modes of fracture and the extent of damage. Also, perform a microstructural analysis of the specimens using techniques such as optical microscopy, scanning electron microscopy (SEM), and transmission electron microscopy (TEM) to evaluate the microstructural features and the distribution of the reinforcement particles. Statistical Using statistical tools to analyze the impact test data and determine the statistical significance of the differences in impact strength between the base material and the FSP-modified samples. Also, correlate the impact strength with the microstructural features and the distribution of the reinforcement particles to identify the key factors that influence the impact resistance of the FSP-modified material. By following these steps, you can gain a comprehensive understanding of the impact resistance of FSP-modified AA 7050 with SiC, TiC, and TiN reinforcement and identify the optimal processing conditions and reinforcement particle types for enhancing the impact strength of the material.



Fig 5.5 Impact Test on Sample

Impact testing can be used to evaluate the toughness and impact resistance of Friction Stir Processed (FSP) AA7050 with SiC, TiC, and TiN reinforcement. The following steps could be taken to perform an impact test on FSP-modified AA 7050 with SiC, TiC, and TiN reinforcement: Sample Preparation: Prepare a set of specimens with identical dimensions from the FSP-modified AA 7050 material with SiC, TiC, and TiN reinforcement. The specimens should be machined according to

the standard test requirements for impact testing, such as the Charpy or Izod specimen geometries. Instrumentation: Use an impact testing machine to conduct the impact test. The machine typically consists of a pendulum or striker that is raised to a specific height and released to strike the specimen, causing it to fracture. The machine measures the amount of energy absorbed by the specimen during fracture and calculates the impact strength or toughness.

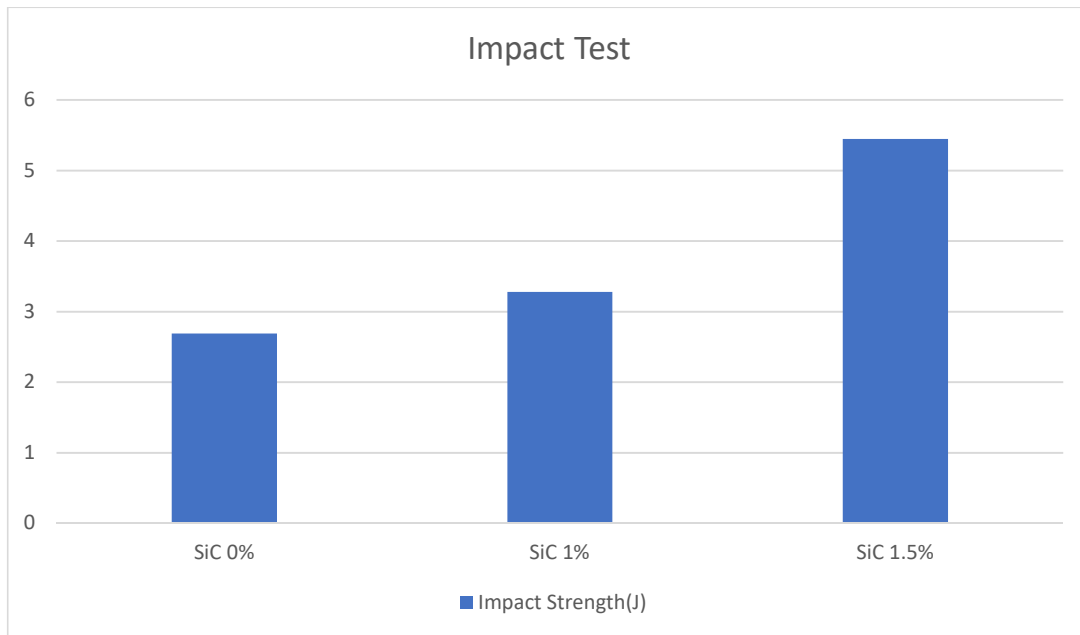


Fig 5.6 Impact Test on SiC

The results from the figure 5.6 shows the impact test are quite remarkable and thus the toughness of the material increases after the reinforcement of SiC particles in 1.5 % for the processed AA7050.

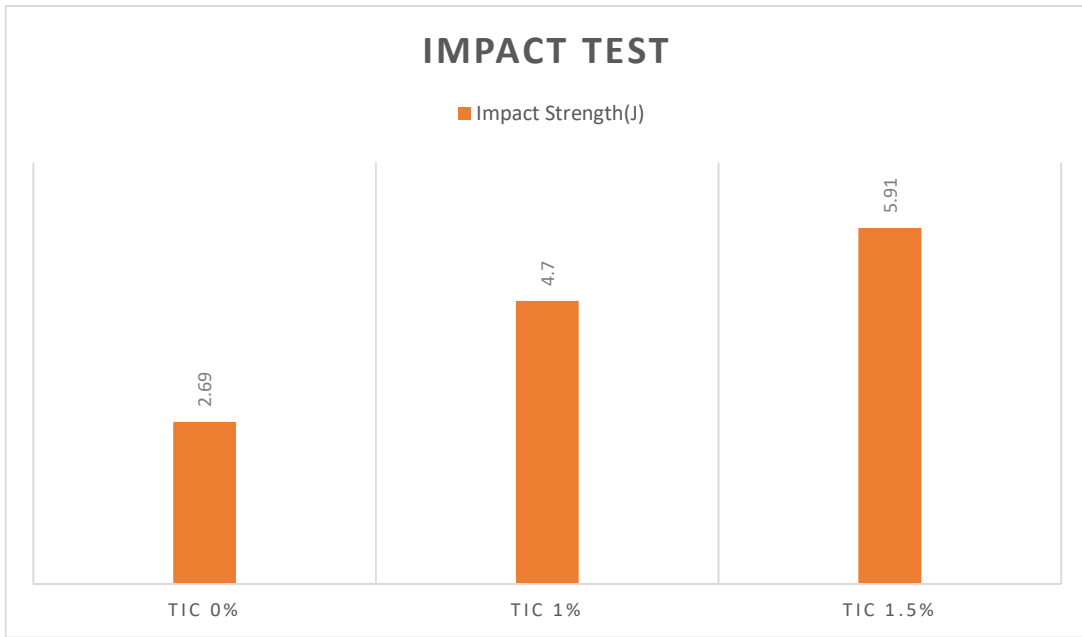


Fig 5.7 Impact test on TiC

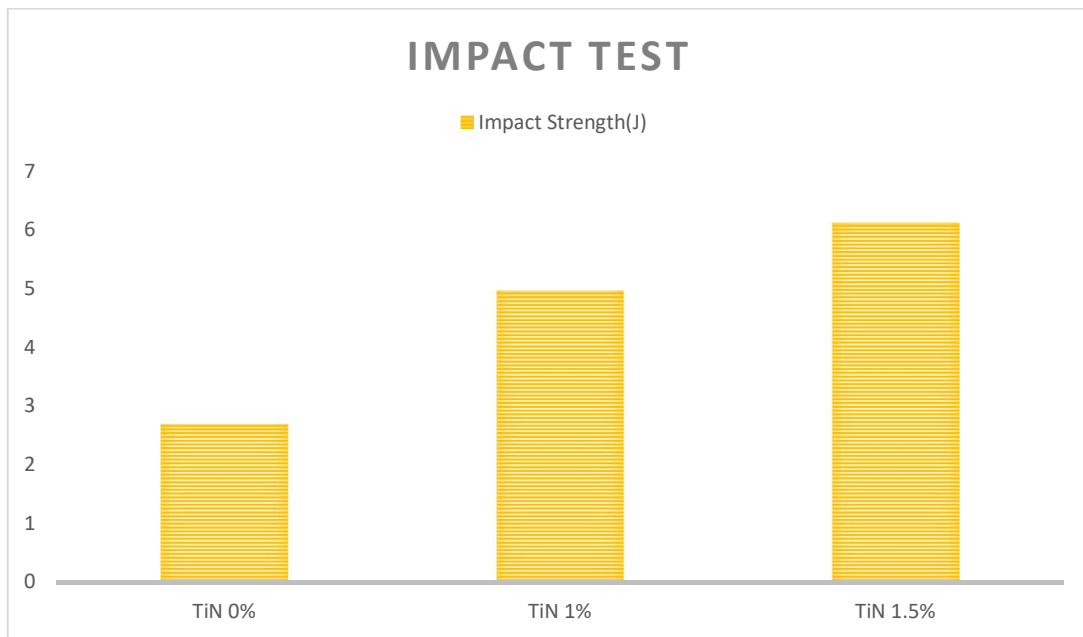


Fig 5.8 Impact Test on TiN

The results from the Figure 5.8 shows the impact test are quite remarkable and thus the toughness of the material increases after the reinforcement of TiN particles in 1.5 % for the processed AA7050.

Overall, the impact testing on the FSP of AA7050 with the TiC reinforcement of 1.5% shows great toughness comparing the base metal and other reinforcement particles such SiC and TiN.

5.4 MICRO- HARDNESS TEST

Micro-hardness testing is a commonly used method to evaluate the hardness and strength of materials at a small scale, typically at the micron or sub-micron level. To conduct a micro-hardness test on FSP-modified AA 7050 with SiC, TiC, and TiN reinforcement, the following steps could be taken. Sample Preparation: Prepare a set of specimens with identical dimensions from the base material (AA 7050) and the FSP-modified samples with SiC, TiC, and TiN reinforcement. The specimens should be polished to obtain a flat and smooth surface for the micro-hardness test. Micro-hardness Testing: Conduct micro-hardness testing on all the specimens using a micro-hardness tester. The test involves applying a small load (typically a few grams) on the surface of the specimen using a diamond or Vickers indenter and measuring the indentation size or depth. The hardness value is calculated based on the applied load and the size of the indentation. Statistical Analysis: Use statistical tools to analyze the micro-hardness test data and determine the statistical significance of the differences in hardness values between the base material and the FSP-modified samples. Also, correlate the hardness values with the microstructural features and the distribution of the reinforcement particles to identify the key factors that influence the hardness and strength of the FSP-modified material. Microstructural Analysis: After the micro-hardness test, examine the indentations under a microscope to identify the microstructural features and the distribution of the reinforcement particles in the FSP-modified material. Also, perform a microstructural analysis of the specimens using techniques such as optical microscopy, scanning electron microscopy (SEM), and transmission electron microscopy (TEM) to evaluate the microstructural features and the distribution of the reinforcement particles. By following these steps, you can gain a comprehensive understanding of the microstructure and mechanical properties of FSP-modified AA

7050 with SiC, TiC, and TiN reinforcement and identify the optimal processing conditions and reinforcement particle types for enhancing the hardness and strength of the material.



Fig 5.9 Micro-Hardness Test

The advantages of Vickers hardness testing include its ability to measure a wide range of hardness values, from very soft materials to very hard materials, and its ability to provide accurate and reproducible results. However, the test is limited by the need for a smooth, flat surface and the possibility of surface damage during the test. The Vickers hardness number is calculated by dividing the load applied to the indenter by the surface area of the resulting indentation. The Vickers hardness test is commonly used to measure the hardness of materials with a fine microstructure, such as ceramics, glasses, and thin films

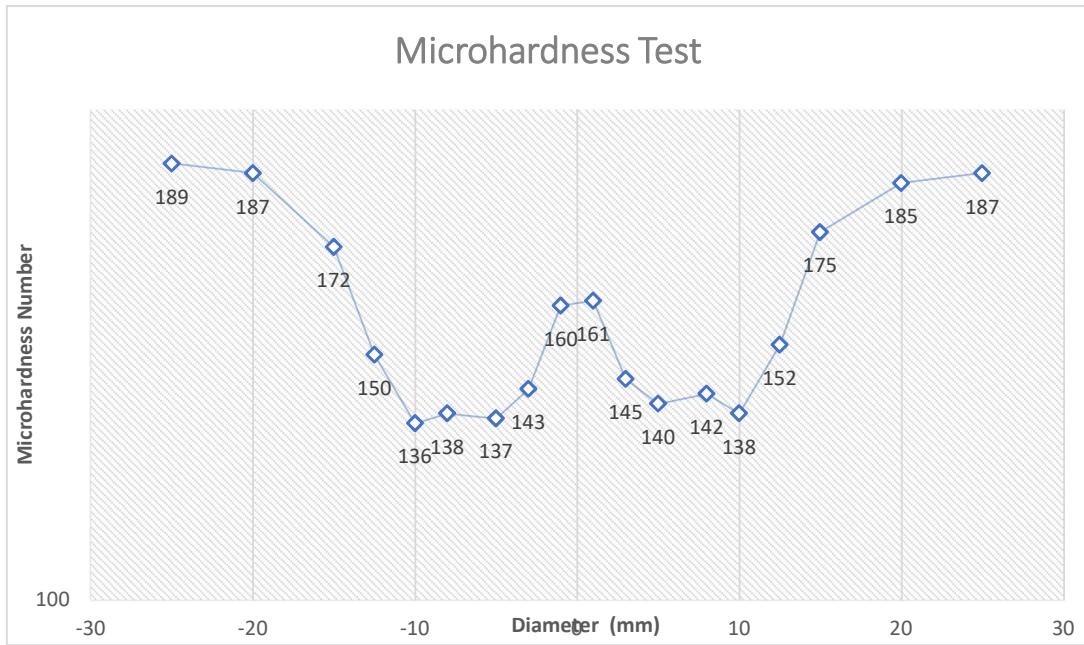


Fig 5.10 Micro-Hardness plot for SiC

The above figure 5.10 is the micro-hardness results obtained with the help of graph for 16 indentations.

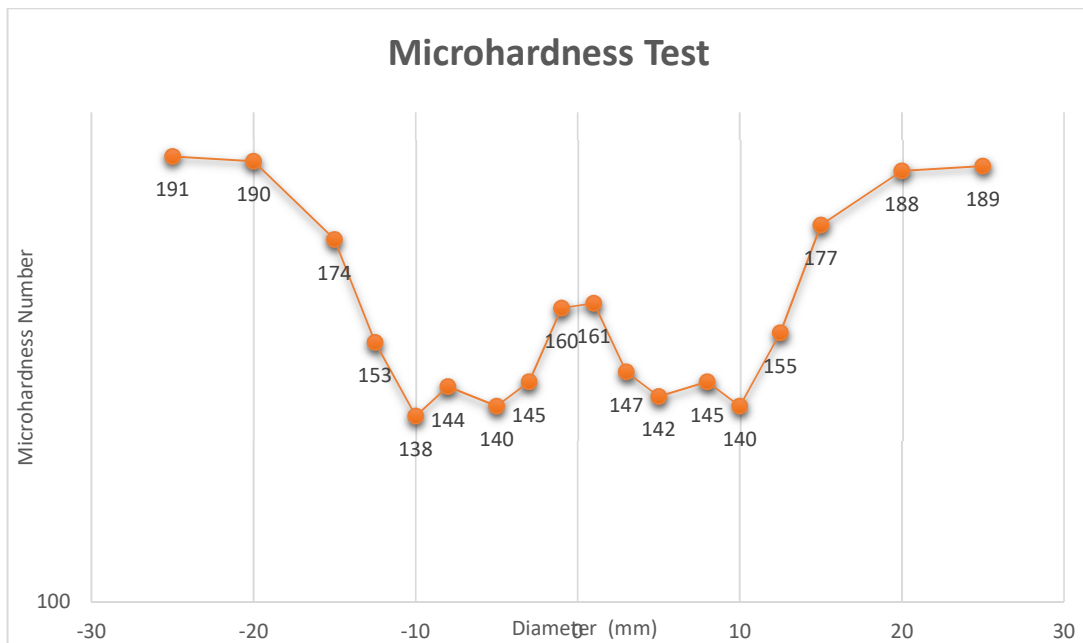


Fig 5.11 Micro-Hardness plot for TiN

The above figure 5.11 is the micro-hardness results obtained with the help of graph for 16 indentations. The results from the sample are quite remarkable which shows the hardness at different position of the sample for TiN reinforcement in AA7050.

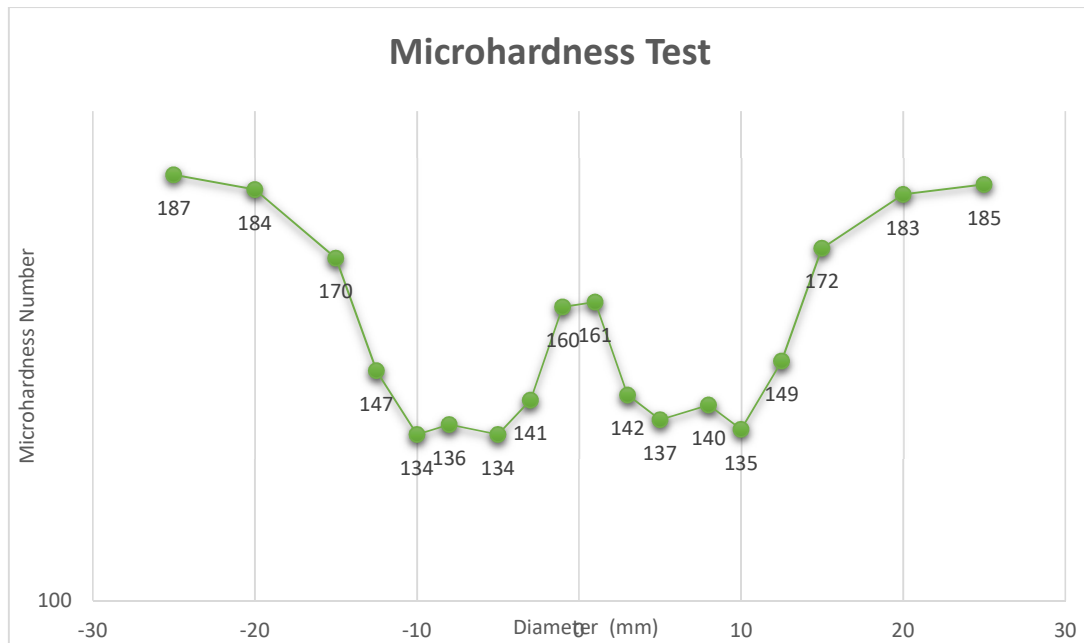


Fig 5.12 Micro- Hardness plot for TiC

The above figure 5.12 is the micro-hardness results obtained with the help of graph for 16 indentations. The results from the sample are quite remarkable which shows the hardness at different position of the sample for TiC reinforcement in AA7050.

Overall, the micro hardness vickers testing on the ASTM E384 standard for FSP of AA7050 with the SiC reinforcement of 1.5% shows great hardness comparing the base metal and other reinforcement particles such TiC and TiN.

5.5 MICROSTRUCTURE TEST

Microstructure testing is an essential step in evaluating the effectiveness of Friction Stir Processing (FSP) on AA 7050 with SiC, TiC, and TiN reinforcement. The following steps could be taken to perform a microstructure test on FSP-modified AA 7050 with SiC, TiC, and TiN reinforcement. Sample Preparation: Prepare a set of specimens with identical dimensions from the base material (AA 7050) and the FSP-modified samples with SiC, TiC, and TiN reinforcement. The specimens should be polished to obtain a flat and smooth surface for microstructural analysis. Optical Microscopy: Conduct an optical microscopy analysis of the specimens to evaluate the grain size, distribution, and morphology. This analysis can provide a quick and preliminary assessment of the microstructure of the material. Scanning Electron Microscopy (SEM): Perform a detailed SEM analysis of the specimens to evaluate the microstructure and the distribution of the reinforcement particles. SEM can provide high-resolution images and information on the microstructural features, including grain boundaries, phases, and defects. Transmission Electron Microscopy (TEM)



Fig 5.13 Micro structure Samples

TEM can provide detailed information on the crystal structure, defects, and dislocation arrangements within the material. Energy-Dispersive X-ray Spectroscopy (EDS): Perform EDS analysis in conjunction with SEM or TEM to identify the elemental composition and distribution of the reinforcement particles

within the material. Statistical Analysis: Use statistical tools to analyze the microstructure data and determine the statistical significance of the differences in microstructure between the base material and the FSP-modified samples. Also, correlate the microstructure with the processing conditions and the distribution of the reinforcement particles to identify the key factors that influence the microstructure of the FSP-modified material. By following these steps, you can gain a comprehensive understanding of the microstructure and reinforcement particle distribution of FSP-modified AA 7050 with SiC, TiC, and TiN reinforcement. This information can be used to optimize the processing conditions and reinforcement particle types to enhance the microstructure and mechanical properties of the material.

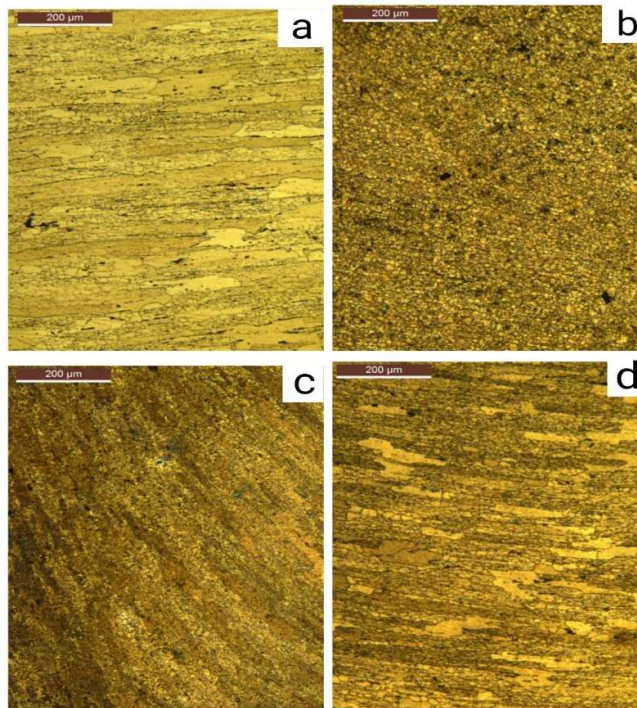


Fig 5.14 Microstructure of FSP sample SiC a) BM, b) Weld Nugget, c) TMAZ, d) HAZ

The Figure 5.13 Shows the desirable microstructure of the weld nugget can result in improved mechanical properties, such as higher strength and stiffness, compared to the base material. However, the quality of the weld nugget can also be

affected by defects, such as voids, cracks, and inclusions, which can reduce the mechanical properties of the composite material.

When SiC particles are added to the FSP process, they are distributed uniformly in the aluminum matrix, resulting in a composite microstructure. The addition of SiC particles can also lead to grain refinement and the formation of fine equiaxed grains in the processed zone. The SiC particles can act as a nucleation site for recrystallization, resulting in a more refined microstructure.

In summary, FSP with SiC reinforcement can lead to a composite microstructure with fine equiaxed grains, improved strength, and enhanced wear resistance. The specific microstructure testing results for AA7050 alloy will depend on the specific processing parameters used and the testing techniques employed.

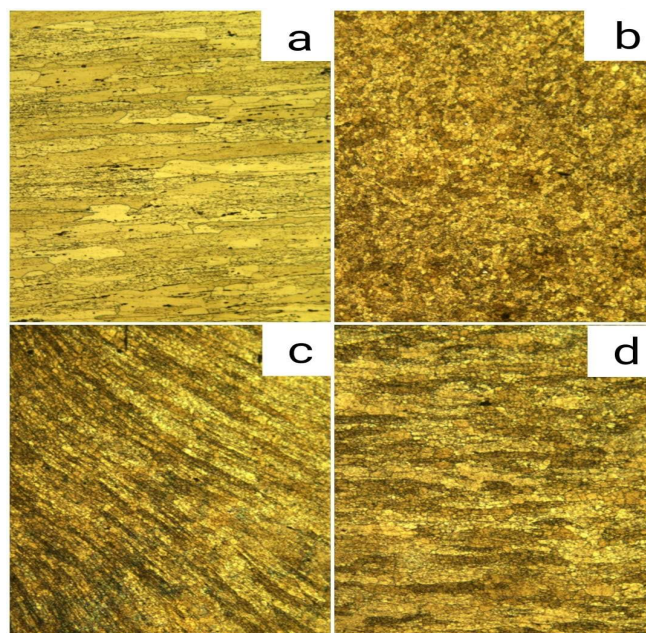


Fig 5.15 Microstructure of FSP sample TiN a) BM b) weld nugget c) tmaz d) haz

The Figure 5.14 Shows the desirable microstructure of the weld nugget can result in improved mechanical properties, such as higher strength and stiffness, compared to the base material. However, the quality of the weld nugget can also be

affected by defects, such as voids, cracks, and inclusions, which can reduce the mechanical properties of the composite material.

The specific microstructure of AA7050 alloy after FSP with TiN reinforcement will depend on the processing parameters used, such as the tool rotation speed, traverse speed, and the volume fraction of TiN reinforcement. Generally, FSP with TiN reinforcement can lead to a composite microstructure with fine equiaxed grains and improved mechanical properties, including increased hardness and wear resistance.

To determine the microstructure of AA7050 alloy after FSP with TiN reinforcement, several techniques can be used, including optical microscopy, scanning electron microscopy (SEM), transmission electron microscopy (TEM), X-ray diffraction (XRD), and energy-dispersive X-ray spectroscopy (EDS).

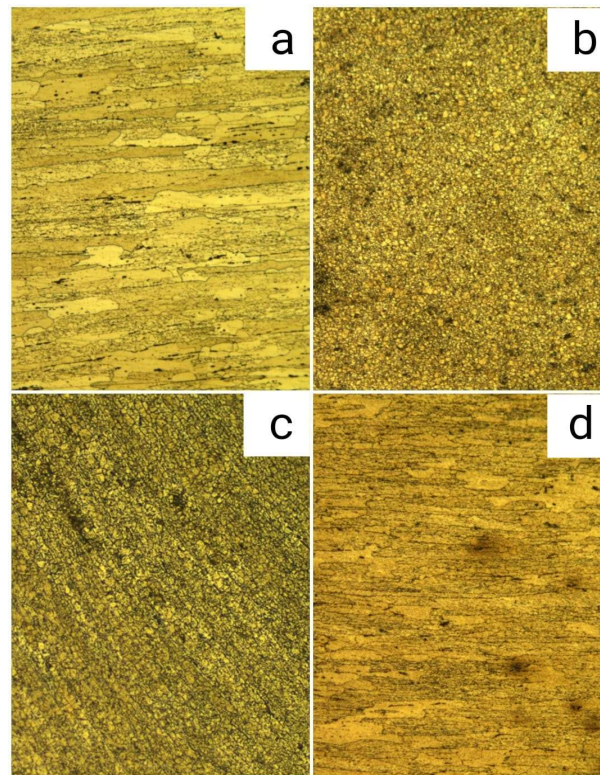


Fig 5.16 Microstructure of FSP sample TiC a) BM b) weld nugget c) tmaz d) haz

The Figure 5.15 Shows the desirable microstructure of the weld nugget can result in improved mechanical properties, such as higher strength and stiffness, compared to the base material. However, the quality of the weld nugget can also be affected by defects, such as voids, cracks, and inclusions, which can reduce the mechanical properties of the composite material.

Overall, Microstructure testing can provide valuable insights into the microstructural features and the distribution of reinforcement particles in FSP-modified AA 7050 with SiC, TiC, and TiN reinforcement. The following steps could be taken to perform microstructure testing on FSP-modified AA 7050 with SiC, TiC, and TiN reinforcement. We can gain a comprehensive understanding of the microstructural features and the distribution of the reinforcement particles in FSP-modified AA 7050 with SiC, TiC, and TiN reinforcement. The information obtained from microstructure testing can be used to optimize the processing parameters and reinforcement particle types to improve the material's properties, such as strength, ductility, and toughness. Microstructure refers to the small-scale structure of a material, typically at the scale of micrometres or smaller. FSP stands for Friction Stir Processing, which is a solid-state processing technique that involves using a rotating tool to generate heat and plastic deformation in a material.

The microstructure of a material processed by FSP can be significantly altered due to the combination of heat and deformation. The microstructural changes can include grain refinement, grain size distribution, texture evolution, and the formation of defects such as voids and cracks.

In general, the microstructure of a material processed by FSP can exhibit a more refined grain structure with a more homogeneous distribution of grain sizes. This can lead to improved mechanical properties such as increased strength and ductility

CHAPTER- 6

CONCLUSION

6.1 CONCLUSION

In conclusion, Friction Stir Processing (FSP) is a solid-state processing technique that offers many advantages over traditional processing methods. FSP involves the use of a rotating tool to stir and deform the material being processed, generating frictional heat that softens the material and causes it to deform without melting.

FSP sample of AA7050 with SiC, TiC, and TiN reinforcement in 0%, 1%, and 1.5% weight fractions. However, some general conclusions can be drawn based on the potential outcomes of such an experiment:

The addition of SiC, TiC, and TiN reinforcement particles to AA7050 by FSP can potentially enhance the material's impact resistance and toughness. The extent of the improvement will depend on factors such as the processing conditions, the size and distribution of the reinforcement particles, and the weight fraction of the reinforcement.

The micro-hardness of the FSP-modified AA7050 with SiC, TiC, and TiN reinforcement is likely to increase with increasing weight fraction of the reinforcement. This is because the hardness of the reinforcement particles is generally higher than that of the aluminum matrix.

The microstructure of the FSP-modified AA7050 with SiC, TiC, and TiN reinforcement is expected to exhibit a refined grain structure, reduced porosity, and a more uniform distribution of reinforcement particles. The degree of refinement and uniformity will depend on the FSP processing conditions and the weight fraction of the reinforcement.

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