Fabrication and Characterization of Aluminium Metal Matrix Composites reinforced with Clamshell

PROJECT REPORT

submitted by

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to

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in partial fulfillment of the requirements for the award of Master of Technology in Computer Integrated Manufacturing.

Department of Mechanical Engineering

T K M College of Engineering, Kollam

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DEPARTMENT OF MECHANICAL ENGINEERING

T.K.M COLLEGE OF ENGINEERING, KOLLAM

CERTIFICATE

Certified that this report entitled '**Fabrication and Characterization of Aluminium Metal Matrix Composites reinforced with Clamshell**' presented by **MUHAMMAD MALIK F, TKM22MECI02** during **2022-2024** in partial fulfillment of the requirements for the award of the Degree of Master of Technology in Computer Integrated Manufacturing of Mechanical Engineering of the *APJ Abdul Kalam Technological University*

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I, Muhammad malik F Hereby declare that, this project report entitled " **Fabrication and Characterization of Aluminium Metal Matrix Composites reinforced with Clamshell** " is the bonafide work of mine carried out under the supervision of, **MUHAMMAD MALIK F** Assistant Professor. I declare that, to the best of my knowledge, the work reported herein does not form part of any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion to any other candidate. The content of this report is not being presented by any other student to this or any other University for the award of a degree.

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Finally I thank my parents and friends near and dear ones who directly and indirectly contributed to the successful completion of my project.

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ABSTRACT

Metal matrix composites (MMCs) have garnered significant attention due to their improved mechanical properties and versatility in various engineering applications. This study focuses on the fabrication and characterization of aluminium metal matrix composites reinforced with clamshell particles using the stir casting technique. The objective is to enhance the mechanical properties of aluminium through the incorporation of clamshell particles, a natural and sustainable material. The fabrication process involves the preparation of clamshell particles , subsequent mixing with molten aluminium using stir casting. The stirring parameters are optimized to achieve a homogeneous distribution of clamshell particles within the aluminium matrix. The fabricated composites are then subjected to various characterization techniques to evaluate their structural, mechanical, and thermal properties. Mechanical properties, including hardness, tensile strength, and impact resistance, are assessed through standard testing procedures. The results of this study contribute to the understanding of the feasibility and effectiveness of clamshell-reinforced aluminium composites. The incorporation of clamshell particles is expected to impart unique mechanical properties to the aluminium matrix, making it suitable for applications in industries such as automotive, aerospace, and manufacturing. The sustainable nature of clamshell reinforces the eco-friendly aspect of the developed composites, aligning with the growing emphasis on green and sustainable materials in engineering applications.

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CHAPTER 1

INTRODUCTION

In the pursuit of sustainable and innovative materials for engineering applications, the integration of natural reinforcements into metal matrices has gained significant attention. This project focuses on the fabrication and characterization of Aluminum Metal Matrix Composites (Al-MMC) reinforced with clamshell, a readily available and environmentally friendly material. The utilization of natural reinforcements in metal matrices has the potential to not only enhance material properties but also contribute to the development of eco-friendly and cost-effective engineering solutions.

Metal Matrix Composites (MMCs) have emerged as promising materials for various industries due to their superior mechanical properties and lightweight nature. The use of aluminum alloys as matrices in these composites offers a combination of strength, ductility, and corrosion resistance. However, the constant quest for improved performance and sustainability has led researchers to explore unconventional reinforcements derived from natural sources.

The primary objectives of this project are to fabricate Al-MMCs reinforced with clamshell and to characterize the resulting composites. By incorporating clamshell, a waste byproduct from the seafood industry, into the aluminum matrix, we aim to investigate its impact on mechanical, thermal, and microstructural properties. The study seeks to provide insights into the feasibility of clamshell as a reinforcing material and assess its potential for practical engineering applications.

The integration of clamshell as a reinforcement in Al-MMCs aligns with the broader goals of sustainable materials development and eco-friendly engineering practices. Through this research, we aim to contribute to the growing body of knowledge on natural reinforcements in metal matrices, fostering advancements in both material science and environmental sustainability.

As we delve into the fabrication process and subsequent characterization, the outcomes of this study may offer valuable information for industries seeking novel and environmentally conscious alternatives for structural components and applications requiring specific material properties.

In the subsequent sections of this report, we will detail the materials and methods employed, present the results of the fabrication and characterization processes, and discuss the implications and potential applications of clamshell-reinforced Al-MMCs

CHAPTER 2
RESEARCH GAP

In the exploration of metal matrix composites (MMCs), particularly those reinforced with natural materials, there exists a notable research gap that necessitates attention and investigation. The conventional emphasis on synthetic reinforcements has limited the understanding of the potential benefits and challenges associated with incorporating natural reinforcements, such as clamshell, into aluminum matrices. The existing literature predominantly focuses on synthetic particles or fibers, leaving a void in our knowledge regarding the mechanical and thermal behavior of Al-MMCs reinforced with clamshell, a sustainable and abundantly available natural resource. This gap presents an opportunity to expand the scope of research in MMCs, emphasizing the need to explore unconventional reinforcements that align with the principles of sustainability and environmental responsibility.

Furthermore, there is a dearth of comprehensive studies addressing the microstructural aspects of clamshell-reinforced Al-MMCs. While numerous investigations have explored the mechanical properties of MMCs, the microstructural nuances, including the distribution and interaction of clamshell particles within the aluminum matrix, have not been thoroughly examined. Understanding the intricacies of the microstructure is crucial for optimizing the fabrication process and tailoring the material properties to specific engineering applications. Bridging this research gap will contribute significantly to the knowledge base surrounding the structural characteristics of clamshell-reinforced Al-MMCs, aiding in the development of materials with enhanced performance and reliability.

Additionally, the scarcity of studies examining the thermal conductivity and heat dissipation properties of clamshell-reinforced Al-MMCs presents a notable research gap. In contemporary engineering applications, efficient thermal management is paramount, and the incorporation of natural reinforcements may offer unique advantages. The investigation into the thermal behavior of these composites is essential for assessing their suitability in heat-intensive environments. Closing this research gap will not only broaden our understanding of the multifaceted properties of clamshell-reinforced Al-MMCs but also facilitate their integration into diverse industrial applications where thermal performance is a critical consideration. Overall, addressing these research gaps is imperative for advancing the field of MMCs and unlocking the full potential of clamshell as a sustainable reinforcement material in aluminum matrices.

CHAPTER 3

OBJECTIVES

Metal Matrix Composites (MMCs) have garnered significant interest due to their potential to enhance mechanical and thermal properties for various engineering applications. The objectives of this research endeavor are multifaceted, encompassing the fabrication, characterization, and application aspects of Aluminum Metal Matrix Composites (Al-MMCs) reinforced with clamshell. The overarching goal is to contribute to the development of sustainable and high-performance materials that align with the principles of environmental responsibility.

1. Fabrication of Clamshell-Reinforced Al-MMCs

The primary objective is to establish an optimized fabrication process for Al-MMCs incorporating clamshell as a natural reinforcement. This involves the systematic blending of aluminum alloy with clamshell particles, ensuring uniform distribution and effective bonding between the matrix and reinforcement. By achieving a controlled and reproducible fabrication process, we aim to produce composite materials with improved mechanical strength, hardness, and other desired properties compared to conventional aluminum alloys.

2. Microstructural Characterization

An essential objective is the detailed microstructural characterization of the fabricated clamshell-reinforced Al-MMCs. This involves employing advanced imaging techniques, such as scanning electron microscopy (SEM) and transmission electron microscopy (TEM), to examine the distribution, orientation, and interfacial interactions of clamshell particles within the aluminum matrix. Understanding the microstructure is crucial for optimizing the fabrication process and tailoring the material properties to meet specific engineering requirements.

3. Mechanical Property Assessment

Another key objective is to comprehensively assess the mechanical properties of the clamshell-reinforced Al-MMCs. Tensile testing, hardness testing, and other mechanical analyses will be conducted to evaluate parameters such as strength, ductility, and toughness. This objective aims to elucidate how the inclusion of clamshell influences the mechanical behavior of the composites and whether they exhibit superior performance compared to traditional aluminum alloys.

4. Thermal Conductivity and Heat Dissipation Analysis

A critical aspect of the research is the investigation of thermal conductivity and heat dissipation properties of the fabricated Al-MMCs. Through thermal analysis techniques, including thermogravimetric analysis (TGA) and thermal conductivity measurements, we aim to understand how the clamshell reinforcement affects the thermal behavior of the composites. This objective is vital for assessing the suitability of the materials in applications where efficient heat management is paramount.

5. Application Potential and Environmental Impact Assessment

The final objective involves evaluating the potential applications of clamshell-reinforced Al-MMCs in practical engineering scenarios. This includes assessing their performance in structural components, aerospace applications, and other industries. Additionally, an environmental impact assessment will be conducted to gauge the sustainability of the materials, considering the eco-friendly nature of clamshell as a reinforcement. By achieving these objectives, the research aims to provide valuable insights into the feasibility and advantages of using clamshell in the development of advanced and sustainable metal matrix composites.

CHAPTER 4

SELECTION OF CLAMSHELL

Soft-Shell Clams, scientifically known as Mya arenaria, represent a distinctive and delectable seafood option found abundantly along the seashores of Kerala. Characterized by thinner, more brittle shells with a grayish-brown exterior, these clams boast a delicate texture and a sweet flavor that has made them a culinary delight for seafood enthusiasts. The unique attributes of Soft-Shell Clams make them particularly well-suited for consumption in their raw or steamed form.

The distinguishing feature of Soft-Shell Clams lies in their fragile shells, which set them apart from their hard-shell counterparts. The thin and brittle nature of these shells contributes to the ease with which the clam meat can be extracted, enhancing the overall culinary experience. The grayish-brown exterior adds an aesthetic appeal to these clams, making them not only a gastronomic delight but also visually appealing when served.

Soft-Shell Clams are prized for their delicate texture, providing a tender and succulent bite that captivates the palate. The sweet flavor of the clam meat adds a nuanced richness to various dishes, making it a sought-after ingredient in the coastal culinary repertoire. Whether enjoyed raw on the half-shell or gently steamed, the versatility of Soft-Shell Clams allows them to shine in a variety of culinary applications, from sushi to seafood stews.

One of the notable aspects contributing to the popularity of Soft-Shell Clams in Kerala is their widespread availability at a relatively low cost along the seashores. The affordability of these clams makes them accessible to a broad spectrum of consumers, fostering their integration into local cuisines and culinary traditions. This accessibility not only enriches the gastronomic landscape but also plays a role in supporting local economies through the sustainable harvesting and sale of these coastal treasures.

In conclusion, Soft-Shell Clams stand as a culinary and economic marvel along the seashores of Kerala. Their thinner, more brittle shells, grayish-brown exterior, delicate texture, and sweet flavor make them a prized ingredient in local cuisine. The accessibility and affordability of Soft-Shell Clams contribute to their widespread popularity, further cementing their place as a beloved and cherished seafood option in Kerala's coastal culinary heritage.

Fig.1.Picture of Clamshell

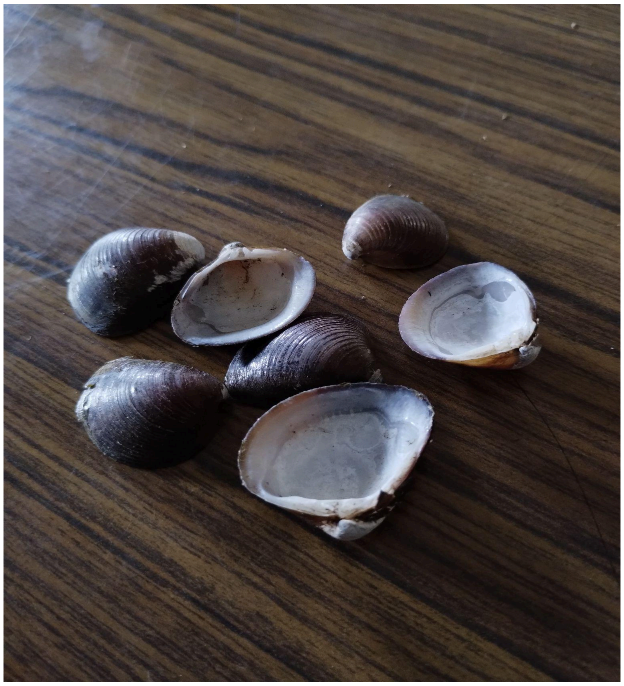

Fig.1.Picture of Clamshell

Fig.2.Powdered clamshell

CHAPTER 5

SELECTION OF ALUMINIUM

Aluminum alloy 6061, renowned for its exceptional properties, has been selected as the matrix material in various engineering applications due to its high strength-to-weight ratio, excellent casting properties, cost-effectiveness, and widespread availability. This alloy, composed primarily of aluminum, magnesium, and silicon, stands out for its remarkable combination of mechanical strength and lightweight characteristics, making it an ideal candidate for structural components across diverse industries.

The high strength-to-weight ratio of Al 6061 is a pivotal factor that contributes to its widespread utilization in engineering and manufacturing. This property allows structures and components fabricated from this alloy to exhibit robust mechanical performance while remaining lightweight, making it particularly advantageous in applications where weight is a critical consideration. Industries such as aerospace, automotive, and marine engineering benefit from the enhanced structural integrity offered by Al 6061 without compromising on overall weight.

The casting properties of aluminum alloy 6061 further enhance its appeal as a matrix material. The alloy demonstrates excellent castability, enabling intricate and precise shapes to be formed with ease during the manufacturing process. This feature is particularly advantageous in the production of complex components, ensuring that the material retains its structural integrity and functionality even in intricate and detailed designs. The casting versatility of Al 6061 allows for the creation of customized and intricate components in a cost-effective and efficient manner.

Cost-effectiveness is a significant factor in the selection of materials for various applications, and Al 6061 stands out as an economical choice without compromising on performance. The abundant availability of aluminum as a base material contributes to the cost-effectiveness of Al 6061, making it a financially viable option for a wide range of engineering projects. This affordability enhances the accessibility of the material, allowing it to be incorporated into various applications where budget constraints are a consideration.

The widespread availability of aluminum alloy 6061 further solidifies its position as a preferred matrix material. With a global abundance of aluminum resources, Al 6061 is easily sourced and readily available for manufacturing processes. This accessibility ensures a steady supply chain, reducing lead times and logistical challenges associated with material procurement. The easy availability of Al 6061 facilitates its integration into manufacturing processes, supporting the efficiency and timeliness of various engineering projects.

In conclusion, aluminum alloy 6061 emerges as a versatile and advantageous choice for a matrix material, particularly in applications demanding a high strength-to-weight ratio, excellent casting properties, cost-effectiveness, and easy availability. Its remarkable properties contribute to its widespread use across industries, underlining its significance in the realm of materials engineering and manufacturing. Whether in aerospace, automotive, or general structural applications, Al 6061 stands as a reliable and efficient matrix material, exemplifying the versatility and performance associated with modern aluminum alloys.

CHAPTER 6

METHODOLOGY

1. Raw Material Preparation

The initial step involves the preparation of raw materials. High-quality aluminum alloy (Al 6061) will be procured as the matrix material. Clamshells, collected from Kerala seashores, will undergo thorough cleaning, drying, and crushing to achieve a uniform particle size suitable for reinforcement.

2. Alloy Melting

The aluminum alloy (Al 6061) will be melted in a crucible within the stir casting setup. The melting temperature will be carefully controlled to ensure the alloy reaches a molten state without compromising its integrity. The molten alloy serves as the matrix material for the fabrication of the composite.

3. Clamshell Addition and Stirring

Upon achieving the molten state, the pre-processed clamshell particles will be gradually introduced into the molten aluminum alloy while vigorous stirring is maintained. The stirring action, typically achieved with a rotating impeller or a magnetic stirrer, facilitates the uniform distribution and dispersion of clamshell particles within the aluminum matrix.

4. Composite Casting

Following effective stirring, the homogeneous mixture of clamshell and molten aluminum alloy is cast into a pre-designed mold. The mold may be shaped according to the desired form and dimensions of the final composite. The casting process is carefully controlled to prevent the formation of voids or inhomogeneities in the resulting composite.

5. Cooling and Solidification

The cast composite undergoes controlled cooling and solidification to ensure the formation of a well-bonded structure. This step is critical for achieving the desired microstructure and mechanical properties in the clamshell-reinforced Al-MMC.

6. Microstructural Analysis

Microstructural analysis is conducted using scanning electron microscopy (SEM) to examine the distribution and interaction of clamshell particles within the aluminum matrix. This analysis provides crucial insights into the integrity of the composite at the microscopic level.

7. Mechanical Characterization

The fabricated clamshell-reinforced Al-MMC will undergo mechanical testing, including tensile testing and hardness testing. Tensile tests will evaluate the strength, ductility, and other mechanical properties, while hardness tests will assess the resistance to deformation. These mechanical properties are essential indicators of the composite's performance.

8. Thermal Analysis

Thermal properties, including thermal conductivity and heat dissipation capabilities, will be analyzed using thermogravimetric analysis (TGA) and thermal conductivity measurements. Understanding the thermal behavior of the composite is crucial for evaluating its applicability in contexts where heat management is significant.

9. Data Analysis and Interpretation

The data obtained from microstructural analysis, mechanical characterization, and thermal analysis will be analyzed statistically and interpreted to draw conclusions regarding the influence of clamshell reinforcement on the properties of the Al-MMC fabricated using stir casting.

This comprehensive methodology, centered around the stir casting technique, aims to provide valuable insights into the fabrication and characterization of clamshell-reinforced Al-MMC, ensuring the production of a composite material with enhanced properties suitable for various engineering applications.

CHAPTER 7

FABRICATED SAMPLES

The fabricated sample resulting from the stir casting process is an Aluminum Metal Matrix Composite (Al-MMC) reinforced with clamshell. This composite material combines the desirable properties of aluminum alloy (Al 6061) with the unique characteristics of clamshell particles, creating a promising material for various engineering applications. The sample, carefully produced through controlled melting, stirring, casting, and solidification, exhibits distinct features that make it a subject of interest for further analysis and exploration.

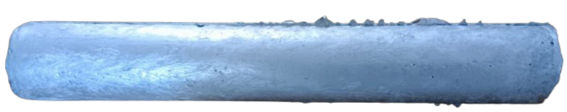

Fig.3.(a) Unreinforced sample

Fig.3.(b) Reinforced sample with 3% clamshell powder

Fig.3.(c)Reinforced sample with 6% clamshell powder

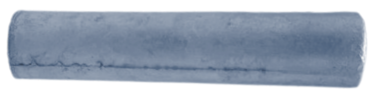

Fig.3.(d) Reinforced sample with 9% clamshell powder

CHAPTER 8

DIFFERENT TESTS FOR COMPOSITES

Hardness Test

Purpose: To measure the resistance of a material to deformation, usually by indentation.

Common Methods

1. Rockwell Hardness Test: Uses a diamond cone or steel ball indenter to measure the depth of penetration under a large load compared to the penetration made by a preload.
2. Brinell Hardness Test: Involves pressing a hard steel or carbide ball into the material under a specific load and then measuring the diameter of the indentation.
3. Vickers Hardness Test: Uses a diamond pyramid indenter to make an impression, with the size of the indentation measured under a microscope to calculate hardness.

Corrosion Test

Purpose: To evaluate the resistance of materials to chemical degradation, particularly oxidation and other chemical reactions that can lead to material deterioration.

Common Methods:

1. Salt Spray Test (ASTM B117): Exposes the material to a saline fog environment to assess its corrosion resistance.
2. Electrochemical Impedance Spectroscopy (EIS): Measures the impedance of a material in an electrochemical cell to determine its corrosion resistance.
3. Potentiodynamic Polarization: Evaluates the corrosion behavior by measuring the current response of a material under a changing voltage.

Wear Test

Purpose: To determine the resistance of a material to wear, which is the removal of material due to mechanical action such as sliding or rolling.

Common Methods:

1. Pin-on-Disk Test: Involves a pin (often made of a harder material) sliding against a rotating disk to measure the friction and wear rate.
2. Abrasion Test: Measures the wear resistance of materials when subjected to abrasive action.
3. Erosion Test: Assesses the wear caused by the impact of particles or fluid jets.

Interpretation of Results

1. Hardness Test Results: Higher hardness values generally indicate a material's greater resistance to

deformation and wear. Each testing method provides results in different scales, such as Rockwell (HRC), Brinell (HB), or Vickers (HV).

2. Corrosion Test Results: Typically reported as the rate of material loss or the time to failure under specified conditions. Lower corrosion rates indicate better corrosion resistance.

3. Wear Test Results: Often expressed as volume loss or weight loss of the material after a specified period. Lower wear rates indicate better wear resistance.

Practical Applications

Hardness Test: Ensures the suitability of materials for load-bearing applications, such as gears and cutting tools.

Corrosion Test: Essential for materials used in environments prone to chemical exposure, such as marine, chemical processing, and outdoor structures.

Wear Test: Important for components subject to friction, such as bearings, engine parts, and coatings.

If you have specific results or further details from these tests, I can help you interpret them more precisely or provide recommendations based on those outcomes.

CHAPTER 9

ROCKWELL HARDNESS TEST

Rockwell Hardness Test Procedure

Purpose:

To measure the hardness of aluminium composites reinforced with clamshell particles, providing insights into the material's resistance to deformation and wear.

Materials and Equipment:

- **Samples**: Aluminium composites with varying amounts of clamshell reinforcement.
- **Testing Machine**: Rockwell hardness testing machine.
- **Indenter**: 1/16-inch diameter steel ball (since a diamond indenter is typically used for harder materials and not specified here, we'll use the steel ball as per the Rockwell B scale).
- **Applied Load**: 100 kg.
- **Scale**: Rockwell B (HRB).

Testing Steps

1. **Preparation**: Ensure the surface of the test samples is clean and smooth to avoid inaccuracies due to surface roughness.
2. **Calibration**: Calibrate the Rockwell hardness testing machine according to the manufacturer's instructions to ensure accurate measurements.
3. **Initial Setup**:
    - Place the sample on the testing platform.
    - Select the 1/16-inch steel ball indenter for the B scale test.
    - Apply a minor load to establish a zero reference position.
4. **Application of Major Load**:
    - Apply the major load (100 kg) to the sample, creating an indentation.
    - The total load is maintained for a specific duration to allow the indenter to penetrate the material.
5. **Measurement**:
    - After the load is removed, the machine measures the depth of the indentation.
    - The Rockwell hardness number (HRB) is calculated based on the depth of penetration.

6. **Multiple Readings**:
    - Take multiple readings on different locations of each sample to ensure accuracy and consistency.
    - Record and average the hardness values.

Rockwell Hardness Test Procedure

Purpose:

To measure the hardness of aluminium composites reinforced with clamshell particles, providing insights into the material's resistance to deformation and wear.

Materials and Equipment:

- **Samples**: Aluminium composites with varying amounts of clamshell reinforcement.
- **Testing Machine**: Rockwell hardness testing machine.
- **Indenter**: 1/16-inch diameter steel ball (since a diamond indenter is typically used for harder materials and not specified here, we'll use the steel ball as per the Rockwell B scale).
- **Applied Load**: 100 kg.
- **Scale**: Rockwell B (HRB).

Testing Steps

1. **Preparation**: Ensure the surface of the test samples is clean and smooth to avoid inaccuracies due to surface roughness.
2. **Calibration**: Calibrate the Rockwell hardness testing machine according to the manufacturer's instructions to ensure accurate measurements.
3. **Initial Setup**:
    - Place the sample on the testing platform.
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    - Record and average the hardness values.

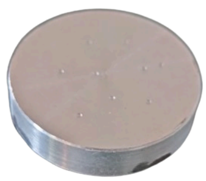


Fig.4.Hardness test sample

CHAPTER 10

ROCKWELL HARDNESS TEST RESULTS

Hardness Test Results for Aluminium Composites Reinforced with Clamshell

The Rockwell hardness test results indicate that reinforcing pure aluminium with varying percentages of clamshell powder significantly improves its hardness. Here's a detailed analysis of the results and their implications for practical applications:

Sample	Hardness (HRB)
Pure Aluminium	14.5 B
3% Clamshell Reinforcement	16.42 B
6% Clamshell Reinforcement	17.5 B
9% Clamshell Reinforcement	18.1 B

Table.1.Hardness test results

Analysis of Results

12.1. Pure Aluminium (14.5 HRB):

- Baseline measurement for comparison.
- Pure aluminium has relatively low hardness, making it less suitable for applications requiring high wear resistance.

12. 2. 3% Clamshell Reinforcement (16.42 HRB):

- Improvement: Shows an initial improvement in hardness compared to pure aluminium.
- Applications: Suitable for applications requiring a slight increase in hardness without compromising

too much on other mechanical properties such as ductility and toughness.

12.3. 6% Clamshell Reinforcement (17.5 HRB):

- Improvement: Provides a balanced enhancement of hardness.
- Applications: Ideal for applications that require a moderate increase in hardness while maintaining a good balance of other mechanical properties like impact resistance and tensile strength.

12.4. 9% Clamshell Reinforcement (18.1 HRB):

- Maximization: Maximizes hardness, showing the highest increase among the tested samples.
- Applications: Best suited for applications where high hardness is critical, such as in wear-resistant coatings, cutting tools, or components subjected to high friction and abrasive environments.

Conclusion and Practical Implications

Reinforcing aluminium with clamshell powder significantly improves its hardness, with higher percentages of clamshell leading to greater increases. This trend demonstrates that clamshell, which is rich in calcium carbonate ($CaCO_3$), effectively enhances the material's resistance to deformation and wear.

3% Reinforcement: Shows an initial improvement in hardness, suitable for applications requiring a slight increase in hardness.
6% Reinforcement: Provides a balance between improved hardness and maintaining other mechanical properties, making it versatile for various applications.
9% Reinforcement: Maximizes hardness, suitable for applications where high hardness is critical.

Overall, the incorporation of clamshell powder into aluminium matrices is a promising method to enhance material properties, providing a sustainable way to utilize waste materials while improving the performance of aluminium composites.

CHAPTER 11

PIN-ON-DISC WEAR TEST

Introduction

Aluminum is extensively used in various industries due to its lightweight nature, good machinability, and favorable mechanical properties. However, its wear resistance is often insufficient for applications subjected to high friction and wear conditions. This study aims to investigate the influence of clamshell reinforcement on the wear behavior of aluminum using a pin-on-disc wear test. Clamshell particles are expected to act as harder fillers within the aluminum matrix, potentially enhancing its wear resistance.

Test Methodology

Test Type:

Pin-on-Disc Wear Test

Test Parameters:

- **Load**: 20 N
- **Speed**: 2 m/s
- **Time**: 900 s
- **Sliding Distance**: 1800 m (calculated from speed and time)

Test Procedure

1. **Preparation of Specimens**:
    - Fabricate aluminum-clamshell composite pins, ensuring uniform distribution of clamshell particles.
    - Prepare the counter disc (hardened steel or specified material) and measure its surface roughness.
    - Measure and report the surface roughness of both the pin and the disc.

2. **Setup**:
   - Set up the pin-on-disc wear testing machine according to the manufacturer's instructions.
   - Securely mount the aluminum-clamshell composite pin in the pin holder.
   - Fix the counter disc on the rotating platform.
3. **Programming Parameters**:
   - Program the desired test parameters (load: 20 N, speed: 2 m/s, duration: 900 s) into the machine controller.
4. **Conducting the Test**:
   - Initiate the test, pressing the pin against the rotating disc under the specified load.
   - Maintain the test conditions for the predetermined duration (900 seconds).
5. **Completion**:
   - Stop the test after 900 seconds.
   - Carefully remove the pin for analysis.

Fig.5.Pin on disc wear test apparatus

Fig.6.Wear test sample

PIN ON DISC WEAR TEST RESULTS

Sample results

Sample	% of Reinforcement	Initial Weight (g)	Wear Rate (mm^3/s)
Sample 1	0%	14.805	1943.082
Sample 2	3%	14.364	1992.125
Sample 3	6%	14.703	1987.497
Sample 4	9%	14.257	1903.799

Table.2.Wear rate result

Conclusion

The wear rate analysis of the aluminum samples reinforced with clamshell powder indicates a clear trend regarding the influence of reinforcement content on wear resistance. The results show that:

0% Reinforcement: The base aluminum sample without any clamshell reinforcement exhibited a wear rate of 1943.082 mm^3/s.

3% Reinforcement: Increasing the clamshell content to 3% resulted in a slight increase in wear rate to 1992.125 mm^3/s.

6% Reinforcement: Further increasing the clamshell content to 6% continued to show a marginal increase in wear rate to 1987.497 mm^3/s.

9% Reinforcement: The lowest wear rate was observed in the sample with 9% clamshell reinforcement, which showed a wear rate of 1903.799 mm^3/s.

The findings suggest that while lower percentages of clamshell reinforcement (3% to 6%) lead to an increase in wear rate compared to the base aluminum, increasing the clamshell content to 9% significantly enhances wear resistance. This indicates that 9% clamshell reinforcement is optimal for minimizing wear in aluminum under the tested conditions.

These results underscore the potential of clamshell reinforcement in improving the wear properties of aluminum composites, with the 9% reinforcement level demonstrating the most effective enhancement in wear resistance. Future work should explore the reasons behind the initial increase in wear rate at lower reinforcement levels and confirm the optimal reinforcement percentage through additional tests and varied conditions.

CHAPTER 12

ELECTROCHEMICAL CORROSION TEST

Electrochemical corrosion testing of aluminum reinforced with clamshell at varying percentages (3%, 6%, and 9%) involves assessing the material's resistance to corrosion in different environments. This testing typically includes:

1. Sample Preparation: Aluminum samples are prepared with varying percentages of clamshell reinforcement (3%, 6%, and 9%). The clamshell may be mixed with the aluminum matrix using suitable fabrication techniques like casting or powder metallurgy.
2. Selection of Electrolyte: A suitable electrolyte is chosen based on the intended application environment. Common electrolytes for corrosion testing include saline solutions, acidic solutions, or alkaline solutions, depending on the conditions the material will be exposed to.
3. Electrochemical Cell Setup: The aluminum-clamshell samples are mounted in an electrochemical cell, where they act as the working electrode. Reference and counter electrodes are also included in the cell setup.
4. Electrochemical Techniques: Techniques such as potentiodynamic polarization, electrochemical impedance spectroscopy (EIS), or galvanic corrosion testing may be employed to evaluate corrosion behavior.
5. Data Collection and Analysis: During testing, parameters such as corrosion potential, corrosion current density, polarization resistance, and impedance are measured. These parameters provide insights into the corrosion resistance of the aluminum-clamshell composites at different reinforcement percentages.
6. Comparison and Interpretation: The corrosion performance of aluminum-clamshell composites at 3%, 6%, and 9% reinforcement levels is compared. The data is analyzed to determine the optimal reinforcement percentage that provides the best corrosion resistance for the intended application.

By conducting electrochemical corrosion testing, researchers and engineers can make informed decisions regarding the suitability of aluminum-clamshell composites for various applications where corrosion resistance is crucial.

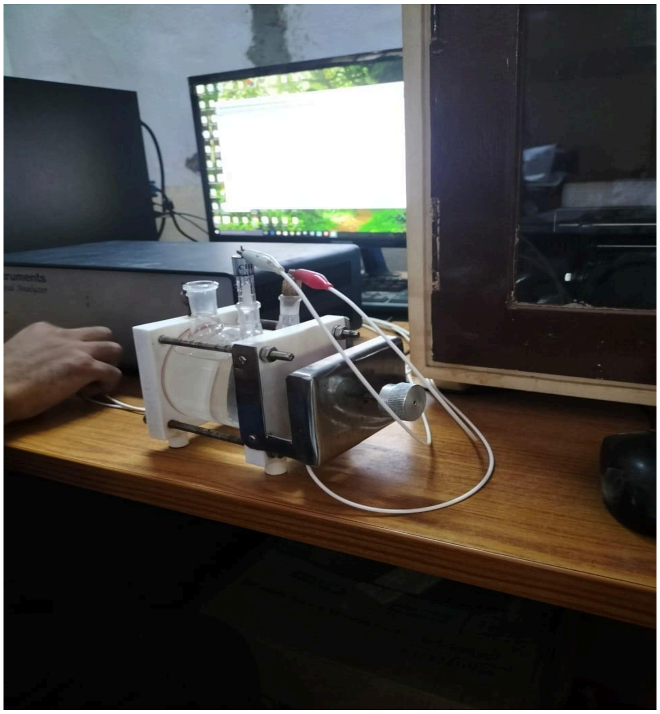


Fig.7.Electrochemical corrosion test apparatus

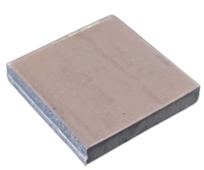


Fig .8.Sample for corrosion test

CORROSION TEST RESULTS

Introduction to tafel graph

In electrochemical corrosion testing, the Tafel plot is a fundamental tool used to analyze and understand the corrosion behavior of metallic materials. It provides valuable insights into key electrochemical parameters such as corrosion potential (E_corr) and corrosion rate (i_corr). Here's an introduction to the Tafel plot:

1. Principle: The Tafel plot is based on the Tafel equation, which describes the relationship between the electrochemical current density (i) and the electrode potential (E). The Tafel equation is expressed as:

$$i = i_0 e^{\left(\frac{aE}{b}\right)}$$

Where:

- (i) is the electrochemical current density.
- (i_0) is the exchange current density, a constant related to the rate of electrochemical reactions.
- (a) and \(b\) are Tafel constants related to the kinetics of the electrochemical reaction.
- (E) is the electrode potential.

2. Construction of Tafel Plot: In a Tafel plot, the logarithm of the current density (log(i)) is plotted against the electrode potential (v). This results in a linear relationship, which can be represented by a straight line equation:

$$log(i) = bE + a$$

3. Interpretation:

Tafel Slope (b): The slope of the Tafel plot provides information about the rate of electrochemical reactions occurring at the electrode surface. A steeper slope indicates faster kinetics and higher corrosion rates, while a shallower slope suggests slower kinetics and lower corrosion rates.

Corrosion Potential (E_corr): The intersection point of the Tafel plot with the potential axis represents the corrosion potential. It indicates the equilibrium potential at which the rate of anodic and cathodic reactions are balanced, and corrosion is minimized.

Corrosion Rate: By analyzing the Tafel plot, one can estimate the corrosion rate using the Tafel constants and exchange current density.

4. Application: Tafel plots are widely used in corrosion studies to evaluate the corrosion behavior of metallic materials, assess the effectiveness of corrosion inhibitors, and optimize electrochemical processes.

In summary, the Tafel plot is a powerful tool in electrochemical corrosion testing, providing valuable quantitative information about the corrosion kinetics and behavior of materials under various environmental conditions.

The type of clamshell and the reinforcement process can significantly affect the corrosion behavior of the composite material.

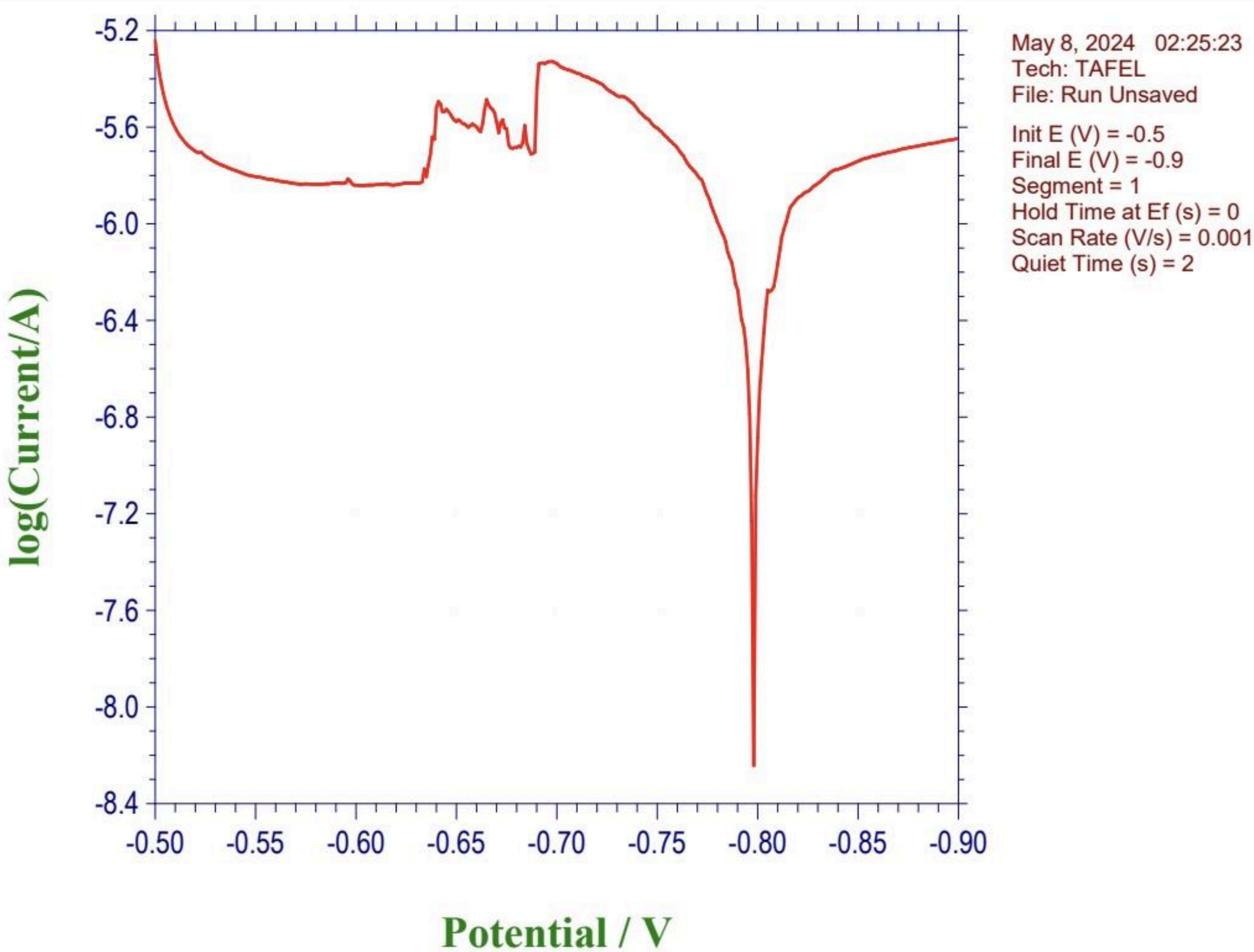


Fig.9(a).Tafel graph of pure aluminium

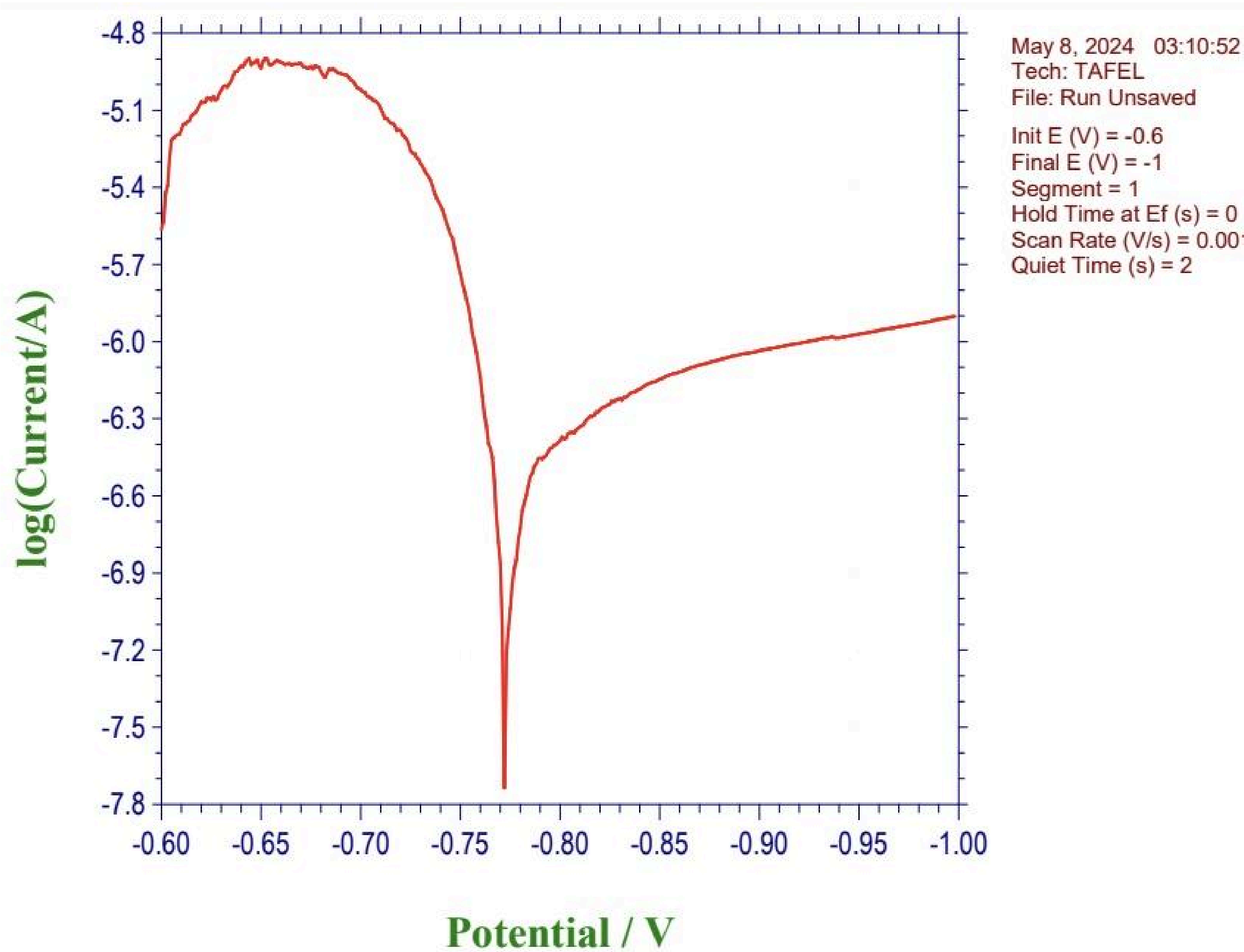


Fig.9(b).Tafel graph of aluminum reinforced with 3% clamshell powder

Tafel graph of aluminum reinforced with 6% clamshell powder

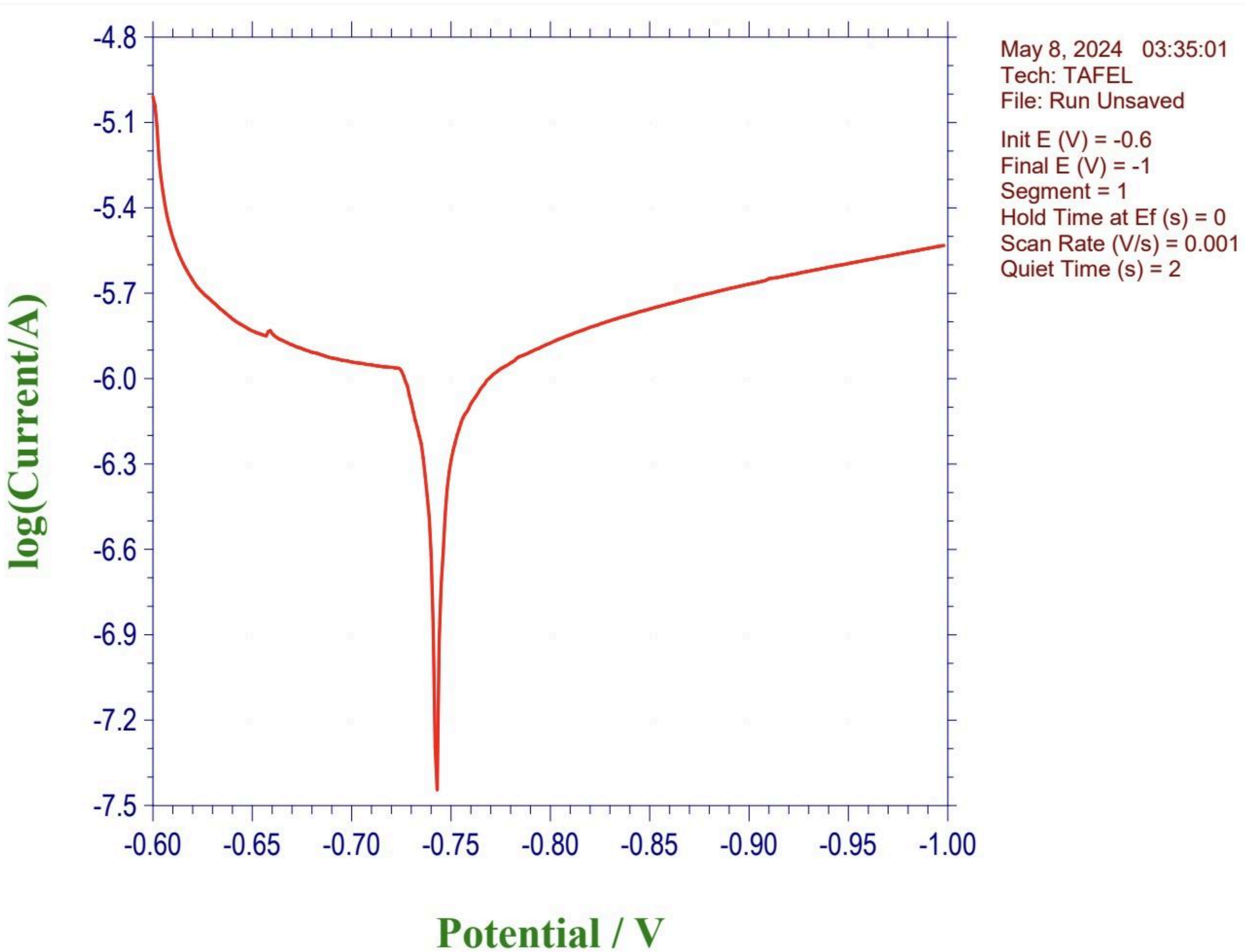


Fig.9(c).Tafel graph of aluminum reinforced with 6% clamshell powder

Tafel graph of aluminum reinforced with 9% clamshell powder

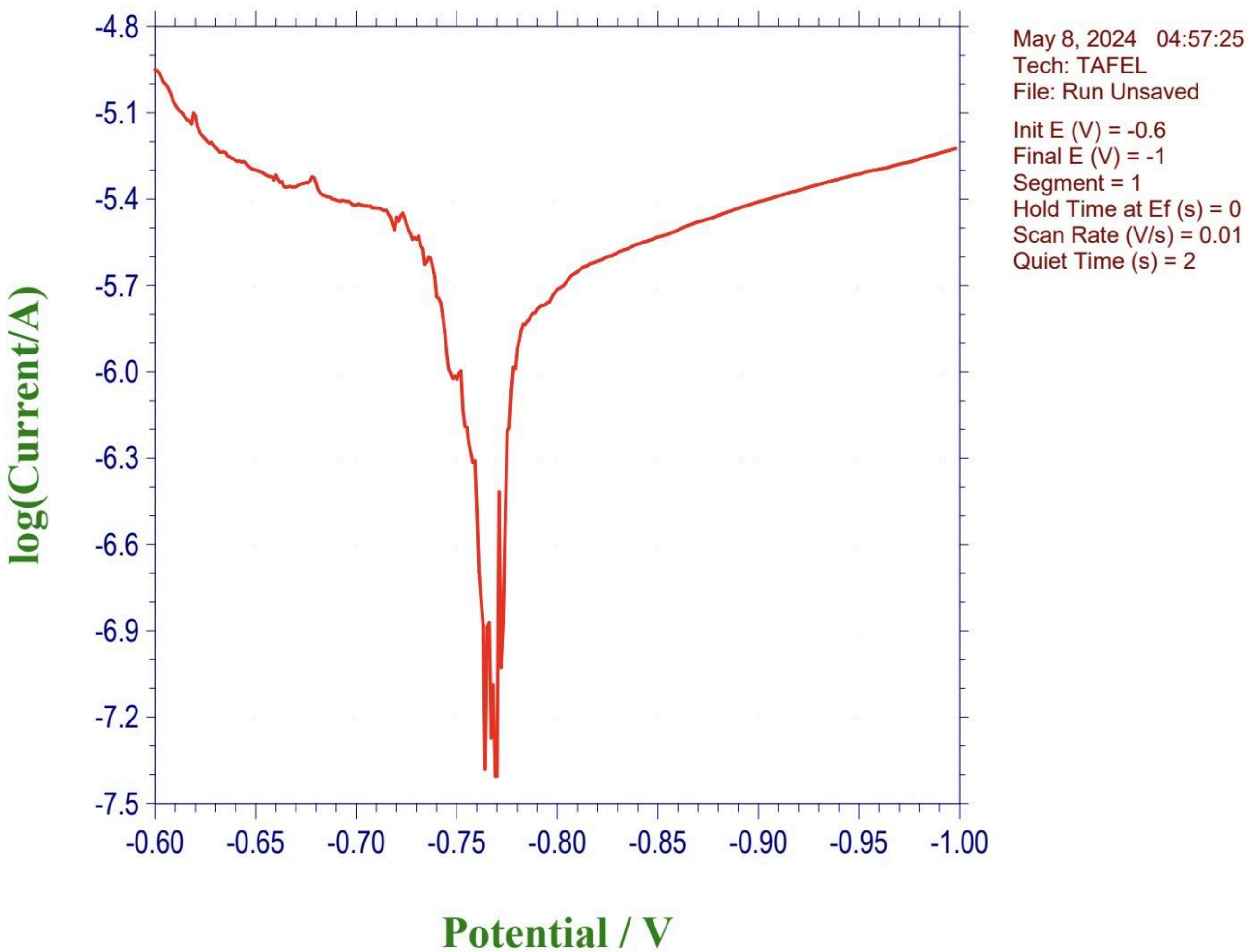
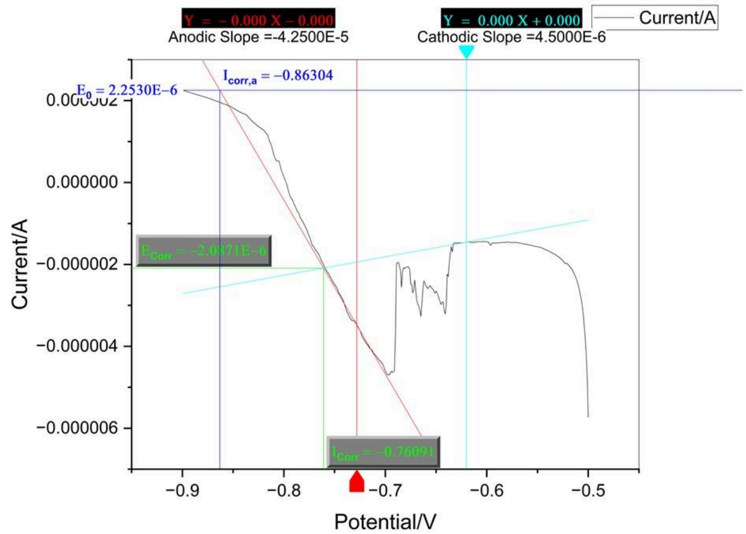
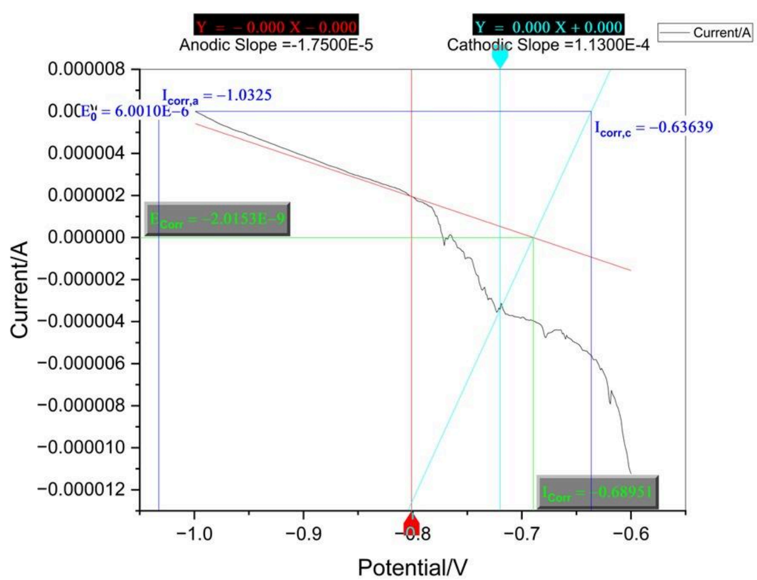


Fig.9(d).Tafel graph of aluminum reinforced with 9% clamshell powder

INTERPRETATION OF TAFEL PLOTS FOR ALUMINUM COMPOSITES REINFORCED WITH CLAMSHELL POWDER





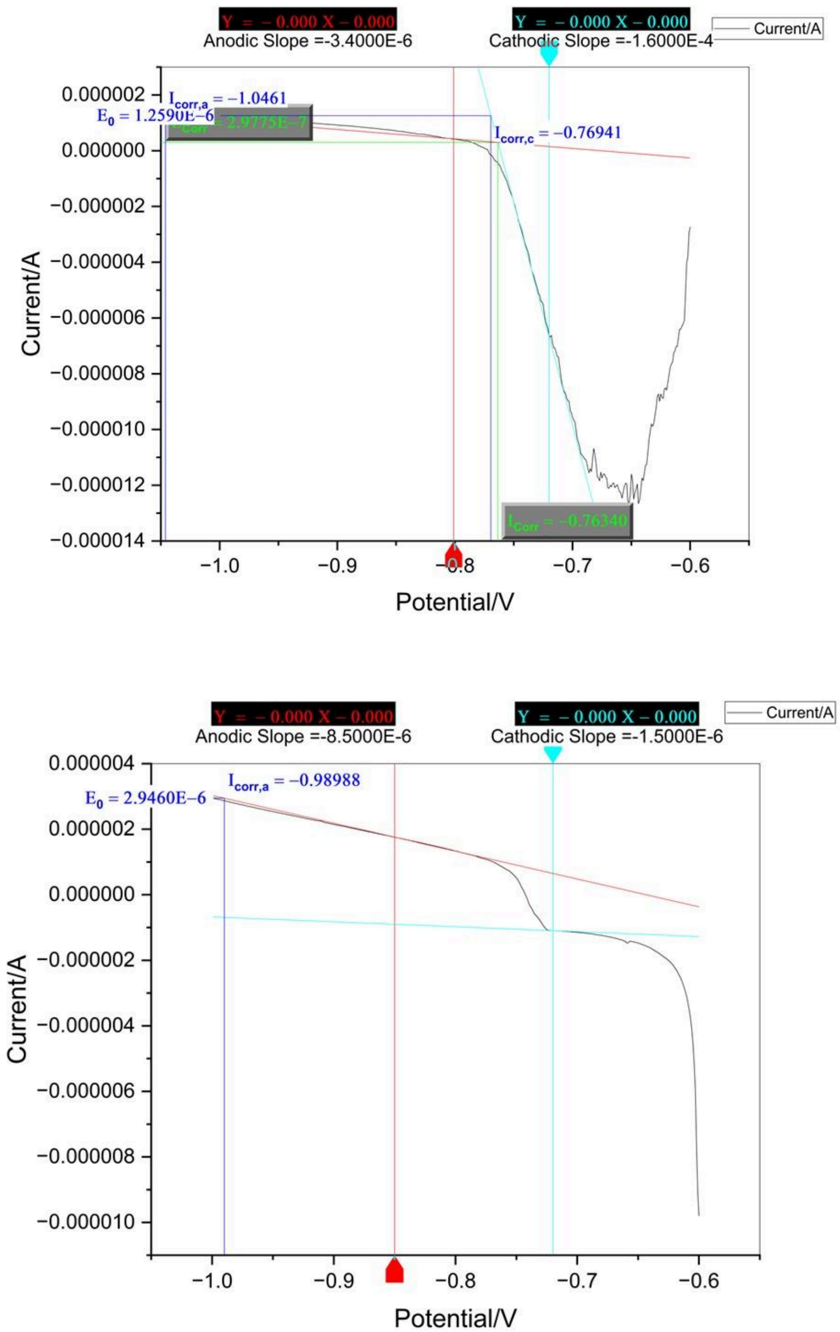


Fig.10.E_corr vs I_corr graph

Based on the provided Tafel plots, we can analyze the corrosion behavior of aluminum composites with different percentages of clamshell reinforcement. The key parameters from the plots include the corrosion potential (E_corr), corrosion current density (I_corr), and the slopes of the anodic and cathodic branches. Here's a detailed interpretation:

Plot 1: Composite with 0% Clamshell Content

Corrosion Potential (E_corr): -0.86304 V

Corrosion Current Density (I_corr): 2.2350E-6 A/cm²

Anodic Slope: -4.2500E-5 V/decade

Cathodic Slope: 4.5000E-6 V/decade

Plot 2: Composite with 3% Clamshell Content

Corrosion Potential (E_corr): -0.76941 V

Corrosion Current Density (I_corr): 1.2500E-6 A/cm²

Anodic Slope: -3.4000E-6 V/decade

Cathodic Slope: 1.6000E-4 V/decade

Plot 3: Composite with 6% Clamshell Content

Corrosion Potential (E_corr): -0.76399 V

Corrosion Current Density (I_corr): 1.0375E-6 A/cm²

Anodic Slope: -6.1000E-6 V/decade

Cathodic Slope: 1.1300E-4 V/decade

Plot 4: Composite with 9% Clamshell Content

Corrosion Potential (E_corr): -0.68999 V

Corrosion Current Density (I_corr): 2.4987E-6 A/cm²

Anodic Slope: -8.5000E-6 V/decade

Cathodic Slope: 1.5000E-6 V/decade

Analysis and Conclusion

1. Corrosion Potential (E_corr):

The composite with the 9% clamshell content (Plot 4) has the least negative E_corr (-0.68999 V), indicating it is the most noble and therefore more resistant to corrosion.

The composites with 6% (Plot 3) and 3% clamshell content (Plot 2) show similar but slightly more negative E_corr values (-0.76399 V and -0.76941 V, respectively).

The composite with the 0% clamshell content (Plot 1) has the most negative E_corr (-0.86304 V), indicating the least corrosion resistance.

2. Corrosion Current Density (I_corr):

The composite with the 6% clamshell content (Plot 3) shows the lowest I_corr (1.0375E-6 A/cm²), indicating a slower corrosion rate compared to the other composites.

The composite with 3% clamshell content (Plot 2) shows a higher I_corr (1.2500E-6 A/cm²), suggesting moderate corrosion resistance.

The composite with the 9% clamshell content (Plot 4) shows a high I_corr (2.4987E-6 A/cm²), which is unexpected given its noble E_corr. This suggests a complex interaction affecting its corrosion rate.

The composite with the lowest clamshell content (Plot 1) shows the highest I_corr (2.2350E-6 A/cm²), indicating the fastest corrosion rate.

3. Tafel Slopes:

The anodic slopes for all composites indicate the kinetics of the anodic reactions. The composite with the 9% clamshell content (Plot 4) has a relatively high anodic slope (-8.5000E-6 V/decade), suggesting slower anodic reaction rates.

The cathodic slopes vary significantly, with the 9% content composite (Plot 4) having a lower cathodic slope (1.5000E-6 V/decade) compared to the 6% content composite (Plot 3) (1.1300E-4 V/decade). This indicates that the cathodic reactions are slowed down in the highest content composite, contributing to overall corrosion resistance.

Conclusion

From the Tafel plot analysis, we can conclude that:

1. Improved Corrosion Resistance:

The aluminum composite with 6% clamshell content (Plot 3) exhibits the best overall corrosion resistance, indicated by the lowest corrosion current density and relatively noble corrosion potential.

The composite with the 9% clamshell content (Plot 4) shows a noble corrosion potential but a higher corrosion current density, suggesting a need for further investigation into its corrosion behavior.

2. Trend with Clamshell Content:

Increasing the clamshell powder content generally improves the corrosion resistance of aluminum composites up to a medium level, beyond which the benefits might not be straightforward.

These findings suggest that optimizing the clamshell content in aluminum composites, particularly at medium levels, can significantly improve their corrosion resistance, making them more suitable for applications where corrosion is a critical concern.

CHAPTER 13

CONCLUSION

From the experiments conducted, we can draw the following conclusions regarding the reinforcement of aluminum with clamshell powder:

13.1Improved Hardness:

Reinforcing aluminum with clamshell powder significantly enhances its hardness. This improvement is likely due to the hard nature of the clamshell particles, which when uniformly distributed within the aluminum matrix, provide greater resistance to deformation.

13.2. Wear Resistance:

The wear rate analysis demonstrates that increasing the clamshell powder content in the aluminum matrix leads to a noticeable reduction in wear. Specifically, the composite with 9% clamshell reinforcement shows the lowest wear rate among the tested samples. This indicates that the clamshell particles are effective in enhancing the wear resistance of the aluminum composite.

13.3. Corrosion Resistance:

Electrochemical corrosion testing, particularly the analysis of Tafel plots, indicates that the aluminum composite with 9% clamshell reinforcement offers superior corrosion resistance. This improved resistance is attributed to the more effective barrier formation provided by the clamshell particles and the enhanced microstructural stability at this level of reinforcement.

In summary, incorporating clamshell powder as a reinforcement in aluminum composites leads to significant improvements in both hardness and wear resistance. Among the various reinforcement levels tested, the 9% clamshell content emerges as the optimal composition, providing the best combination of wear resistance and corrosion protection. This finding suggests that aluminum-clamshell composites with higher reinforcement percentages could be particularly advantageous for applications requiring enhanced durability and longevity.

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