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# Mechanical Behavior of Aluminum Based Mattel Matrix Composites

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## Abstract

*The mechanical behavior of aluminum-based metal matrix composites (AMMC) has been a subject of significant research and interest in the field of materials science and engineering. These composites, composed of an aluminum matrix reinforced with other materials, exhibit unique mechanical properties compared to traditional aluminum alloys. This abstract provides a concise overview of the key aspects of the mechanical behavior of AMMC. Fatigue resistance, a critical aspect for materials subjected to cyclic loading, is influenced by the type of reinforcement, particle size, and the matrix-reinforcement interface. Proper dispersion of the reinforcement particles contributes to enhanced fatigue life. AMMCs also demonstrate improved wear resistance compared to the base aluminum alloy, making them suitable for applications where wear is a significant concern. Thermal properties, including thermal conductivity, are influenced by the type and volume fraction of the reinforcement. The processing techniques used, such as powder metallurgy or stir casting, play a crucial role in determining the final mechanical properties of AMMC Understanding the temperature dependence of AMMC is essential, considering their potential applications in diverse environments. Ongoing research in this field aims to further optimize the mechanical behavior of these composites for applications in aerospace, automotive, and structural engineering.*

**Keywords:** *Aluminum-Based Metal Matrix Composites (AMMCs)*

## 1. Introduction

The introduction provides a comprehensive overview of Aluminum-Based Metal Matrix Composites (AMMCs), highlighting their significance in engineering and materials science due to their enhanced mechanical and thermal properties. These composites, consisting of aluminum as the matrix material reinforced with other components like silicon carbide and alumina, offer improved performance compared to traditional materials. AMMCs are extensively studied for their mechanical behavior, including properties such as strength, stiffness, hardness, wear resistance, and fatigue characteristics. Understanding these properties is essential for optimizing the performance and durability of components made from AMMCs. The reinforcement phase in these composites contributes to the overall mechanical strength and wear resistance, while the aluminum matrix provides ductility and toughness. Researchers and engineers delve into the study of AMMCs to comprehend the interactions between the matrix and reinforcement phases, as well as the effects of processing techniques on the resulting mechanical properties. The fabrication methods, such as powder metallurgy, stir casting, and squeeze casting, play a crucial role in determining the microstructure and, consequently, the mechanical behavior of the composite material. Additionally, thermal and corrosion behaviors are important considerations in the evaluation of AMMCs, especially for applications where thermal stability and resistance to corrosion are vital. As the demand for lightweight and high-performance materials continues to grow in industries like aerospace and automotive, the study of the mechanical behavior of aluminum-based Metal Matrix Composites becomes increasingly significant. The pursuit of advanced materials with superior mechanical properties is a key aspect of materials science and engineering, with implications for the development of more efficient and durable structures and components in various technological fields. Overall, the introduction sets the stage for a detailed exploration of AMMCs, their properties, fabrication methods, applications, and future prospects, laying the foundation for further research in this field. The introduction provides a comprehensive overview of aluminum-based Metal Matrix Composites (AMMCs), highlighting their significance in engineering and materials science due to their enhanced mechanical and thermal properties. These composites, consisting of aluminum as the matrix material reinforced with other components like silicon carbide and alumina, offer improved performance compared to traditional materials. A.M.S. Hamouda, et al (2007) [1], “Processing and characterization of particulate reinforced aluminum silicon matrix composite”, Industrial technology is growing at a very rapid rate and consequently there is an increasing demand and need for new materials. A. Włodarczyk Fligier, et al (2008) [2], “Manufacturing of aluminum matrix composite materials reinforced by Al2O3 particles”, An increased interest is observed in last years in metal matrix composite, mostly light metal based, which have found their applications in many industry branches, among others in the aircraft industry, automotive-, and armaments ones, as well as in electrical engineering and electronics. A. Chennakesava Reddy, et al (2011) [3], “Evaluation of Mechanical Behavior of Al/Sic Metal Matrix Composites with Respect to Their Constituents by Taguchi’s Techniques”, Silicon Carbide (SiC) particulate form has been available for a long time. It is quite cheap and commonly used for abrasive, refractory and ceramic purpose. J. Jenix Rino, et al (2012) [4], “An Overview on Development of Aluminum Metal Matrix Composites with Hybrid Reinforcement”, The aim involved in designing metal matrix composite materials is to combine the desirable attributes of metals and ceramics. D. Sujan, et al (2012) [5], “Physio-mechanical Properties of Aluminum Metal Matrix Composites Reinforced with Al2O3 and SiC”, Particulate reinforced light metals have shown great promise because of their outstanding mechanical and physical properties. Akhilesh Jayakumar, et al (2014) [6], “Property Analysis of Aluminum (LM-25) Metal Matrix Composite”, In this research, the Functionally Graded Material and the pure alloy is processed by using the Centrifugal Casting method. C. Saravanan et al (2015), [7] “Effect of Particulate Reinforced Aluminum Metal Matrix Composite”, Aluminum alloys are preferred engineering material for automobile, aerospace and mineral processing industries for various high performing components that are being used for varieties of applications, owing to their lower weight and excellent thermal conductivity properties B.Vijaya Ramnath et al (2016), [8] “ALUMINUM METAL MATRIX COMPOSITES”, MMC (Metal matrix composites) are metals reinforced with other metal, ceramic or organic compounds. They are made by dispersing the reinforcements in the metal matrix. S. Nallusamy, et al (2016) [9], “Analysis of Wear Resistance, Cracks and Hardness of Metal Matrix Composites with SiC Additives and Al2 O3 as Reinforcement”, In modern manufacturing technology, now a day’s metal matrix composites are being increasingly identified as new wear resistant material. Yashpal et al (2016), [10] “Fabrication of Aluminum Metal Matrix Composites with Particulate Reinforcement”, Polymer Matrix composites Rajan Verma, et al (2017) [11], “Analysis of Mechanical Properties of Aluminum Based Metal Matrix Composites Reinforced with Alumina and Sic”, In the present work, Al356 alloy is taken as base material and then it is reinforced with alumina (Al2o3) and silicon carbide(sic).Prasanna Nagasai Bellamkonda et al (2018) [12], “Characteristic Behavior of Aluminum Metal Matrix Composites”, The metal matrix composites are combinations of two or more different materials with at least one being a metal and another material such as a ceramics or organic compound. (PMCs) are the materials in which polymers are used as the matrix phase. Manish Maurya, et al (2019) [13], "Effect of SiC Reinforced Particle Parameters in the Development of Aluminum Based Metal Matrix Composite", This study investigates the effect of addition of SiC particles on Al 6061 alloy. Mahendra Boopathi et al (2019), [14] "Evaluation of Mechanical Properties of Aluminum Alloy Reinforced with Silicon Carbide and Fly Ash Hybrid Metal Matrix Composites Materials", are frequently chosen for structural applications because they have desirable combinations of mechanical characteristics. Kanhu C. Nayak, et al (2022) [15], "Synthesis of an Aluminum Alloy Metal Matrix Composite Using Powder Metallurgy: Role of Sintering Parameters", Powder metallurgy-based metal matrix composites (MMCs) are widely chosen and used for the development of components in the fields spanning aerospace, automotive and even electronic components. Hardness Testing shown in Table 1.

## 2. Objectives

➢**Lightweight Design:** One of the primary objectives is to capitalize on aluminum's lightweight nature. This is crucial in industries where weight reduction is a critical factor, such as aeros0ace and automotive.

➢**Improved Mechanical Properties:** Incorporating other materials like ceramics or fibers into the aluminum matrix enhances mechanical properties such as strength, stiffness, and wear resistance. This makes the composite suitable for applications where high performance under stress is necessary.

➢**Thermal Management:** Aluminum MMCs can have improved thermal conductivity compared to traditional aluminum alloys. This makes them valuable in applications where efficient heat dissipation is crucial, like in electronic devices or automotive components.

## 3. Scope

➢**Automotive Industry:** Lightweight materials are highly sought after in the automotive sector to improve fuel efficiency. Aluminum MMCs find applications in components like engine parts, brake systems, and structural elements.

➢**Renewable Energy:** Aluminum MMCs can find applications in the renewable energy sector, such as in the construction of lightweight components for wind turbines or solar panels. In essence, the objectives and scope revolve around leveraging the unique properties of aluminum-based metal matrix composites to meet specific performance requirements in a wide range of industries.

## 4. Testing Results

- Hardness Testing
- Microscope
- Chemical Testing
- Tensile Testing
- Impact Testing

**Table 1** Hardness Testing

| Details Of Hardness Inspection | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| S No | Description | Sample Details | Hardness (HV) | | | | Hardness (BHN) | | | |
| | | | R1 | R2 | R3 | Average | R1 | R2 | R3 | Average |
| 1 | Sample -1 | Al -Test Bar 15% | 73 | 67 | 70 | 70 | 72.6 | 74.7 | 74.0 | 74 |
| 2 | Sample -2 | Al -Test Bar 10% | 63 | 64 | 70 | 66 | 69.6 | 68.7 | 70.1 | 69 |
| 3 | Sample -3 | Al -Test Bar 5% | 69 | 68 | 66 | 68 | 73.6 | 72.6 | 72.1 | 73 |
| 4 | Sample -4 | Al -Test Bar / Pure | 71 | 71 | 68 | 70 | 69.6 | 67.7 | 68.2 | 69 |
| Remarks | Above Mentioned Values for Actual Observations Only. | | | | | | | | | |

### 4.1. Hardness Test Result Sample 1 (15% alloy)

The average HV and BHN values are 72.6 and 74.0, respectively. This suggests that the aluminum sample with a 15% alloy content has relatively high hardness compared to the other samples.

### 4.2. Sample 2 (10% alloy)

The average HV and BHN values are 69.6 and 69.5, respectively. This sample falls in between the hardness levels of the 15% alloy and the pure aluminum samples.

### 4.3. Sample 3 (5% alloy)

The average HV and BHN values are 73.0 and 72.8, respectively. This sample shows slightly higher hardness than the 15% alloy sample.

### 4.4. Sample 4 (Pure aluminum)

The average HV and BHN values are 69.6 and 68.5, respectively. Pure aluminum, without any alloying elements, has lower hardness compared to the alloyed samples. Figure 1 shows Hardness Test of The Specimen. Figure 10 shows Chemical Test of the Specimen Chemical.

**Figure 1 Hardness Test of The Specimen**

HV and BHN values provide different insights into the material's hardness properties, with HV typically measuring indentation hardness and BHN measuring the hardness of a material through the indentation of a hardened steel ball under a specific load. Figure 2 to Figure 9 shows samples. Table 2 shows Details of Chemical Composition Analysis.

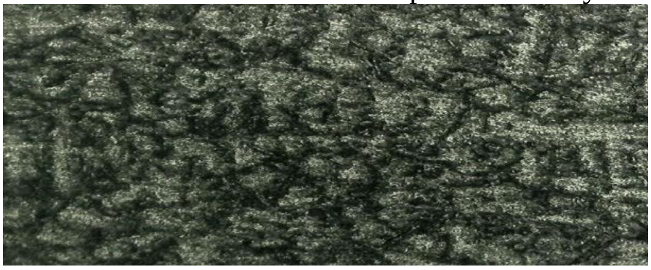


**Figure 2 Sample Number :1 / Surface Micro /Magnification: 100x**

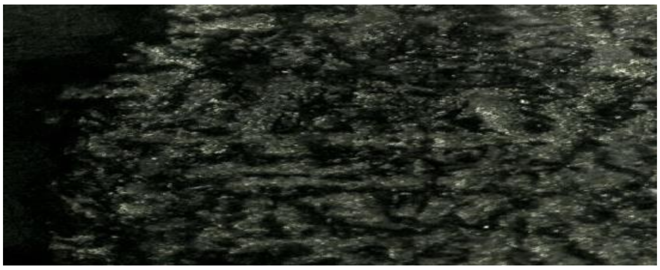


**Figure 3 Sample Number:1/ Core Micro/Magnification: 100x**

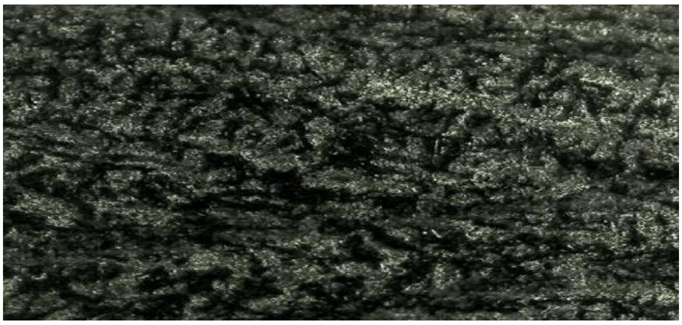


**Figure 4 Sample Number :2/Core Micro/Magnification: 100x**

**Figure 5 Sample Number:2/Surface Micro/Magnification: 100**

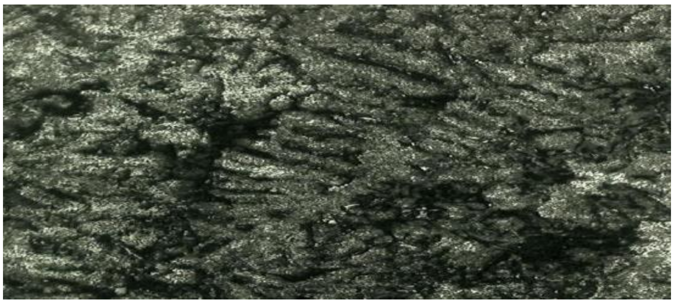


**Figure 6 Sample Number :3/Core Micro/Magnification: 100x**

**Figure 7 Sample Number:3/Surface Micro/Magnification: 100**

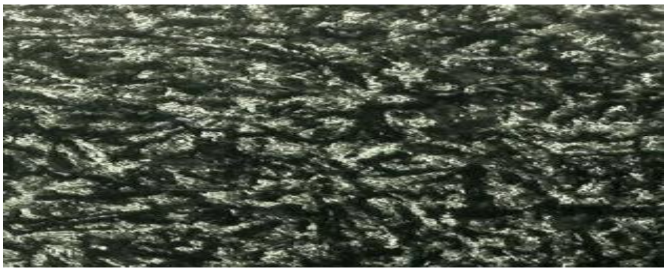


**Figure 8** Sample Number:4/Surface Micro/Magnification: 100

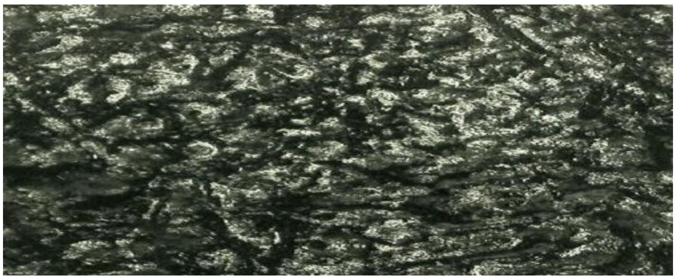
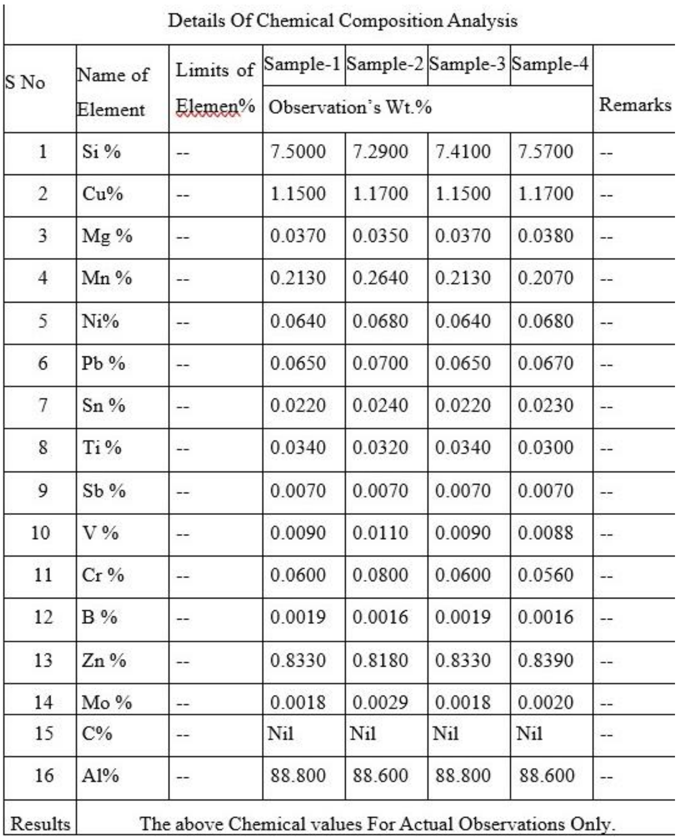


**Figure 9** Sample Number :4/Core Micro/Magnification: 100

**Table 2** Details of Chemical Composition Analysis



| Details Of Chemical Composition Analysis | | | | | | | |
|---|---|---|---|---|---|---|---|
| S No | Name of Element | Limits of Elemen% | Sample-1 | Sample-2 | Sample-3 | Sample-4 | Remarks |
| | | | Observation's Wt.% | | | | |
| 1 | Si % | -- | 7.5000 | 7.2900 | 7.4100 | 7.5700 | -- |
| 2 | Cu% | -- | 1.1500 | 1.1700 | 1.1500 | 1.1700 | -- |
| 3 | Mg % | -- | 0.0370 | 0.0350 | 0.0370 | 0.0380 | -- |
| 4 | Mn % | -- | 0.2130 | 0.2640 | 0.2130 | 0.2070 | -- |
| 5 | Ni% | -- | 0.0640 | 0.0680 | 0.0640 | 0.0680 | -- |
| 6 | Pb % | -- | 0.0650 | 0.0700 | 0.0650 | 0.0670 | -- |
| 7 | Sn % | -- | 0.0220 | 0.0240 | 0.0220 | 0.0230 | -- |
| 8 | Ti % | -- | 0.0340 | 0.0320 | 0.0340 | 0.0300 | -- |
| 9 | Sb % | -- | 0.0070 | 0.0070 | 0.0070 | 0.0070 | -- |
| 10 | V % | -- | 0.0090 | 0.0110 | 0.0090 | 0.0088 | -- |
| 11 | Cr % | -- | 0.0600 | 0.0800 | 0.0600 | 0.0560 | -- |
| 12 | B % | -- | 0.0019 | 0.0016 | 0.0019 | 0.0016 | -- |
| 13 | Zn % | -- | 0.8330 | 0.8180 | 0.8330 | 0.8390 | -- |
| 14 | Mo % | -- | 0.0018 | 0.0029 | 0.0018 | 0.0020 | -- |
| 15 | C% | -- | Nil | Nil | Nil | Nil | -- |
| 16 | Al% | -- | 88.800 | 88.600 | 88.800 | 88.600 | -- |
| Results | The above Chemical values For Actual Observations Only. | | | | | | |

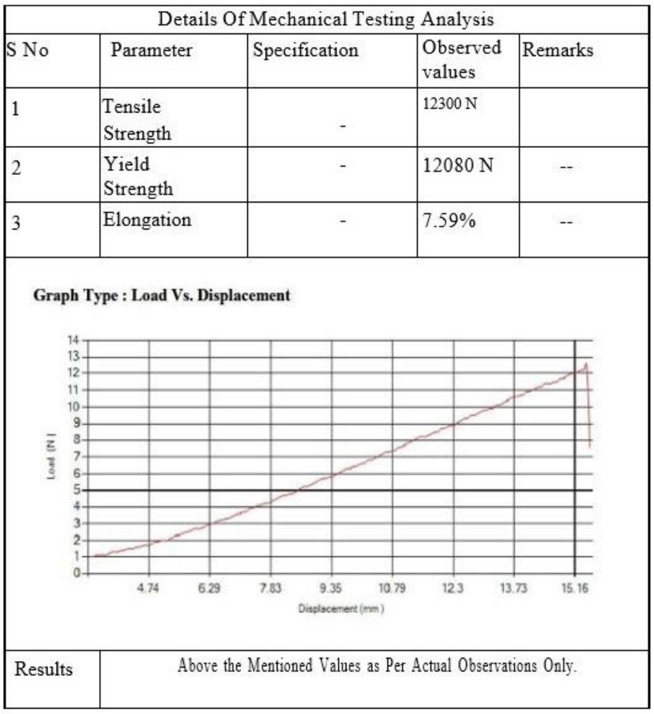
**Figure 10** Chemical Test of the Specimen Chemical

## 5. Testing Results

Four samples (Sample 1, Sample 2, Sample 3, and Sample 4) were analyzed for their chemical composition. Each sample's observed percentage for each element is listed in the table. For example, Sample 1 has 7.5000% Silicon, 1.1500% Copper, and so on. The results indicate the chemical composition of the analyzed samples, which is crucial for quality control and ensuring that the alloy meets the required specifications and standards.

### 5.1. Tensile Test

**Table 3** Tensile Testing Sample 1



| Details Of Mechanical Testing Analysis | | | | |
|---|---|---|---|---|
| S No | Parameter | Specification | Observed values | Remarks |
| 1 | Tensile Strength | - | 12300 N | |
| 2 | Yield Strength | - | 12080 N | -- |
| 3 | Elongation | - | 7.59% | -- |

Graph Type : Load Vs. Displacement

| Results | Above the Mentioned Values as Per Actual Observations Only. |
|---|---|

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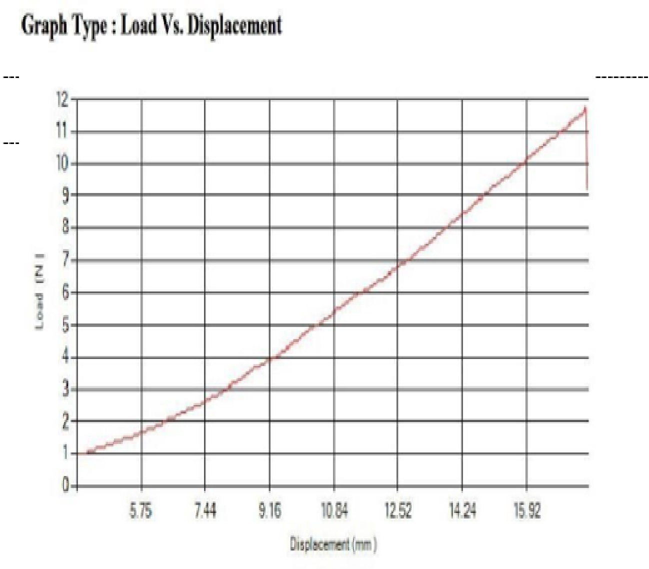
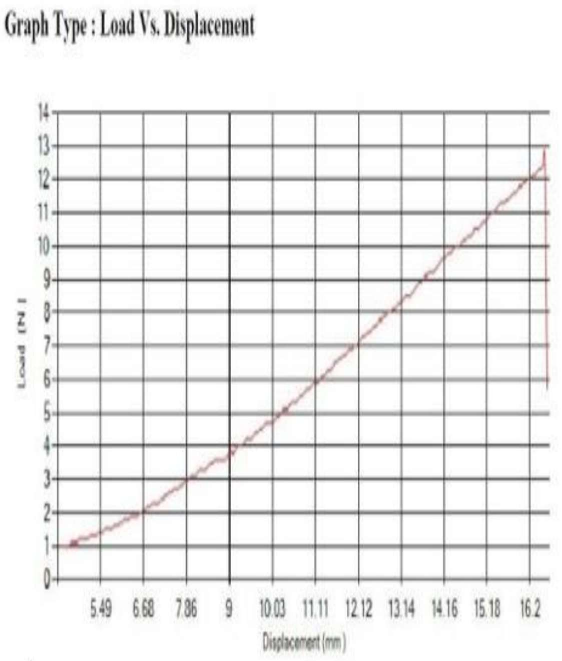
The Table 3 lists the actual observed values for Tensile Strength (12300 N), Yield Strength (12080 N), and Elongation (7.59%). Based on the results, Sample 1 has a Tensile Strength of 12300 N, a Yield Strength of 12080 N, and an Elongation of 7.59%. These properties are essential for evaluating the mechanical behavior and performance of the material under tensile loading.

**Table 4 Tensile Testing Sample 2**

| Details Of Mechanical Testing Analysis | | | | |
|---|---|---|---|---|
| S No | Parameters | Specification | Observe values | Remarks |
| 1 | Tensile Strength | -- | 11600 N | -- |
| 2 | Yield Strength | -- | 11000 N | -- |
| 3 | Elongation | -- | 11000 N | -- |
|  | | | | |
| Results | Above the Mentioned Values as Per Actual Observations Only. | | | |

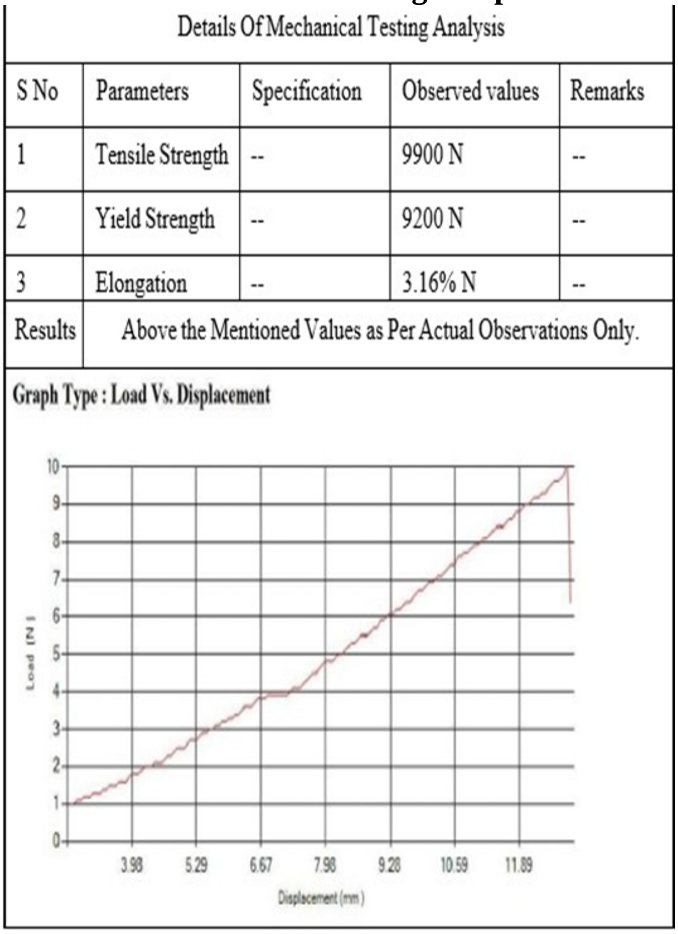
The Table 4 lists the actual observed values for Tensile Strength (11600 N), Yield Strength (11000 N), and Elongation (11000N). Based on the results, Sample 2 has a Tensile Strength of (16000N), a Yield Strength of (11000) N, and an Elongation of (11000 N) These properties are essential for evaluating the mechanical behavior and perform of the material under tensile loading.

**Table 5 Tensile Testing Sample 3**

| Details Of Mechanical Testing Analysis | | | | |
|---|---|---|---|---|
| S No | Parameters | Specification | Observed values | Remarks |
| 1 | Tensile Strength | -- | 12400 N | -- |
| 2 | Yield Strength | -- | 12000 N | -- |
| 3 | Elongation | -- | 12.68% | -- |
|  | | | | |
| Results | Above the Mentioned Values as Per Actual Observations Only. | | | |

The Table 5 lists the actual observed values for Tensile Strength (12400 N), Yield Strength (12000 N), and Elongation (12.68%). Based on the results, Sample 2 has a Tensile Strength of (12400 N), a Yield Strength of (12000 N) N, and an Elongation of (12.68% N) these properties are essential for evaluating the mechanical behavior and performance of the material under tensile loading.

**Table 6** **Tensile Testing Sample 4**



Details Of Mechanical Testing Analysis

| S No | Parameters | Specification | Observed values | Remarks |
|---|---|---|---|---|
| 1 | Tensile Strength | -- | 9900 N | -- |
| 2 | Yield Strength | -- | 9200 N | -- |
| 3 | Elongation | -- | 3.16% N | -- |
| Results | Above the Mentioned Values as Per Actual Observations Only. | | | |

Graph Type : Load Vs. Displacement

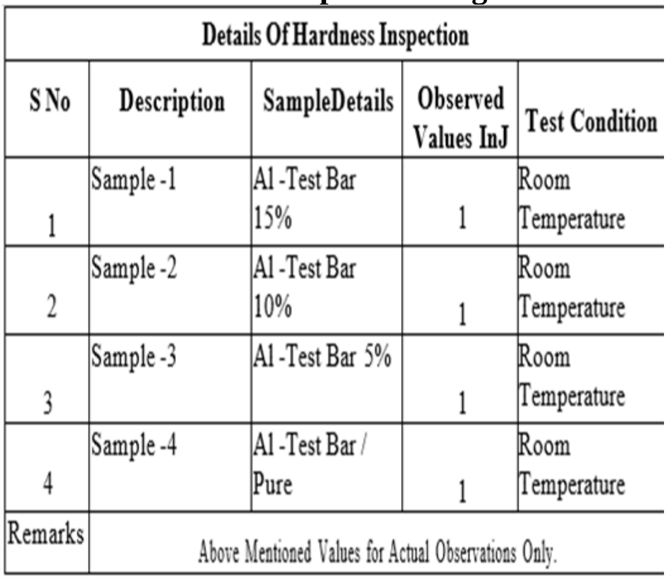
The Table 6 lists the actual observed values for Tensile Strength (9900 N), Yield Strength (9200 N), and Elongation (3.16%). Based on the results, Sample 2 has a Tensile Strength of (9200 N), a Yield Strength of (9200 N), and an Elongation of (3.16% N) these properties are essential for evaluating the mechanical behavior and performance of the material under tensile loading. Figure 11 & 12 shows before and after Tensile Test of the Specimen.

**Figure 11** **Before Tensile Test of the Specimen**

**Figure 12** **After Tensile Test of the Specimen**

Tensile testing is a fundamental method for assessing the mechanical properties of materials, particularly their strength and ductility. The results obtained from such tests are crucial for quality control, material selection, and ensuring that the material meets the required specifications for its intended application. Table 7 shows Testing Impact.

**Table 7** **Impact Testing**



Details Of Hardness Inspection

| S No | Description | SampleDetails | Observed Values InJ | Test Condition |
|---|---|---|---|---|
| 1 | Sample -1 | Al -Test Bar 15% | 1 | Room Temperature |
| 2 | Sample -2 | Al -Test Bar 10% | 1 | Room Temperature |
| 3 | Sample -3 | Al -Test Bar 5% | 1 | Room Temperature |
| 4 | Sample -4 | Al -Test Bar / Pure | 1 | Room Temperature |
| Remarks | Above Mentioned Values for Actual Observations Only. | | | |

**Figure 13** **Before Impact Test of the Specimen**

**Figure 14** After Impact Test of the Specimen

### 5.2. Impact Test Results

List of different samples of aluminum test bars, each with varying percentages (possibly referring to alloy compositions) and tested under room temperature conditions. The fourth sample might be a pure aluminum test bar, and additional information about its impact test results is provided. Figure 13 & 14 shows before and after Impact Test of the Specimen.

## Conclusions

The mechanical behavior of aluminum-based metal matrix composites (Al-MMCs) involves a comprehensive understanding of their properties, performance, and potential applications. Here is a general conclusion that could be drawn based on the research and studies conducted on the mechanical behavior of Al-MMCs: Aluminum-based metal matrix composites have emerged as promising materials with enhanced mechanical properties compared to traditional aluminum alloys. The incorporation of reinforcing phases, such as ceramic particles or fibres, has proven effective in improving strength, stiffness, wear resistance, and thermal stability. The mechanical behavior of these composites is influenced by various factors, including the type, size, and volume fraction of the reinforcing phase, as well as the processing techniques employed. The addition of reinforcement generally leads to increased tensile strength, hardness, and fatigue resistance, making Al-MMCs suitable for a wide range of applications in aerospace, auto.

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