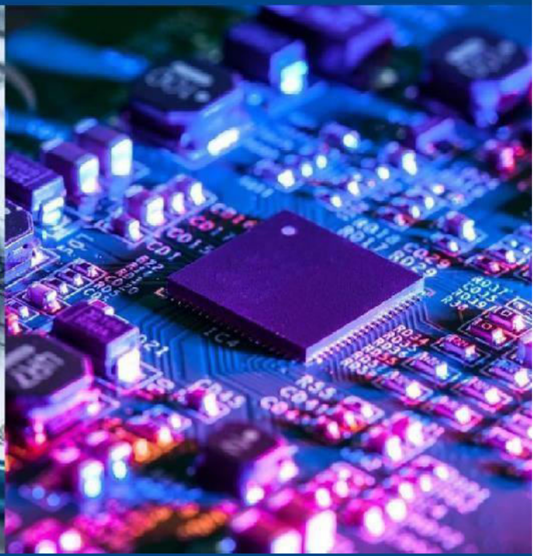
ISSN: 2582-7219





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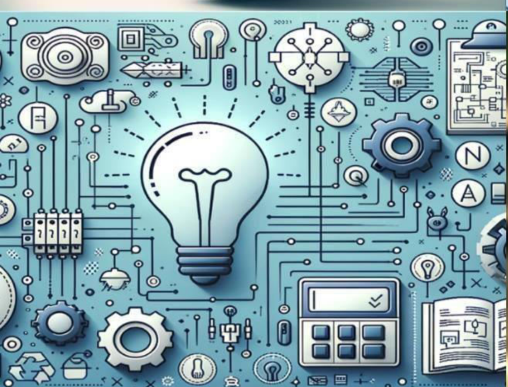

Impact Factor: 8.206

Volume 8, Issue 8, August 2025

© 2025 IJMRSET | Volume 8, Issue 8, August 2025| DOI:10.15680/IJMRSET.2025.0808001

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Effect of Al_2O_3 on Mechanical Properties of Aluminium Metal Matrix Composites

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ABSTRACT: The present research work aims to investigate the mechanical properties of Al6063 composite reinforced with aluminium oxide (Al_2O_3). In this research, metal-matrix composites of aluminium matrix reinforced with Al_2O_3 (alumina) particles were fabricated by stir casting technique. Aluminium is selected as the matrix material and Al_2O_3 as reinforced particles are mixed in different weight percentages (0, 2.5, 5 and 7.5 wt %). The composites were subjected to tensile, hardness and impact tests. The experimental result reveals that the tensile strength and hardness increases with the increase in Al_2O_3 percentage, whereas impact strength decreases with the increase in Al_2O_3 percentage.

KEYWORDS: aluminium, Al 6063, Al_2O_3, aluminium oxide, alumina, mechanical properties, aluminium metal matrix composites

I. INTRODUCTION

In modern technology, the demand for materials that are both lightweight and strong is crucial for various industries. A metal matrix composite is a combined product of matrix phase and reinforcement phase. The combination of matrix phase of aluminium and reinforcements phase denotes aluminium MMC. Aluminium matrix composites are used in many industries, including aerospace (aircraft, helicopters, and spacecraft), automotive (brake rotors, pistons, cylinder liners, and other engine parts), construction (building facades, interior cladding, signage, and building rehabilitation), sports (golf clubs and bicycles)**,** defense weapons etc, due to their superior properties such as low density, high strength to weight ratio, better corrosion resistance, excellent thermal and electrical conductivity etc. The properties of the metals can be improved by the addition of more elements to the parent metal. The alloys of metals reinforced with particulate ceramics to achieve combined properties and formed as metal matrix composites. But the mechanical behavior of the composite depends on the matrix material composition, size, and weight fraction of the reinforcement and method utilized to manufacture the composite. Figure-1 shows the most commonly used matrix materials in metal matrix composites (MMCs). Steel based metal matrix composites are suitable for aerospace, biomedical and automotive applications due to their superior mechanical properties such as high strength, stiffness, and wear resistance etc. Copper matrix composites are suitable for a variety of applications, such as heat sinks, connectors, electrical contacts, circuit breakers, electronic packaging, sports equipment, welding electrodes, etc., due to the thermal and electrical conductivity, good mechanical strength, wear resistance and corrosion resistance. Titanium matrix composites are used in many industries, including aerospace, automobiles, biomedical, defense weapons etc, due to their superior properties such as high-temperature strength**,** high stiffness**,** high strength-to-weight ratio, good corrosion resistance etc. Magnesium-based metal matrix composites are finding increasing applications due to their light weight, high strength-to-weight ratio, wear behaviour, damping behaviour and good corrosion resistance. They are used in structural applications, hydrogen energy storage applications, biomedical applications, aerospace, automotive, electronics, and sports equipment industries. Nickel metal matrix composites are suitable for aerospace, military, gas turbines and automotive applications due to their superior mechanical and tribological properties.

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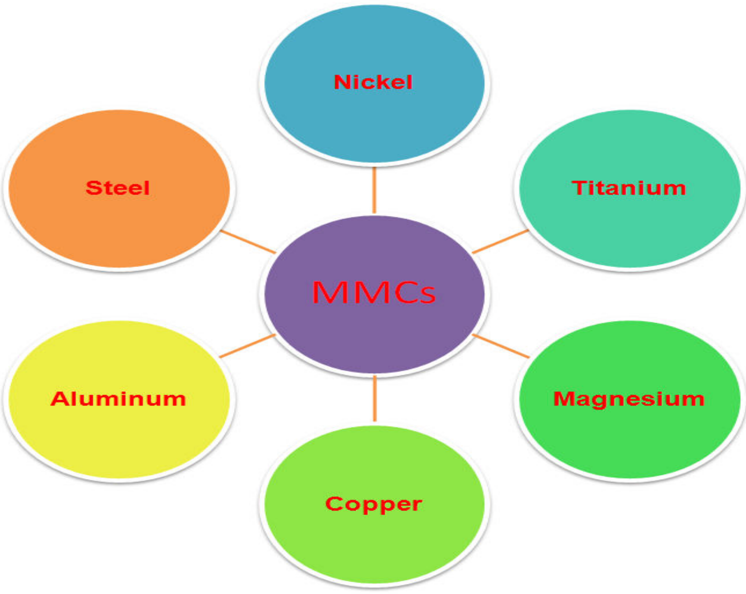

Figure-1: Matrix materials in MMCs

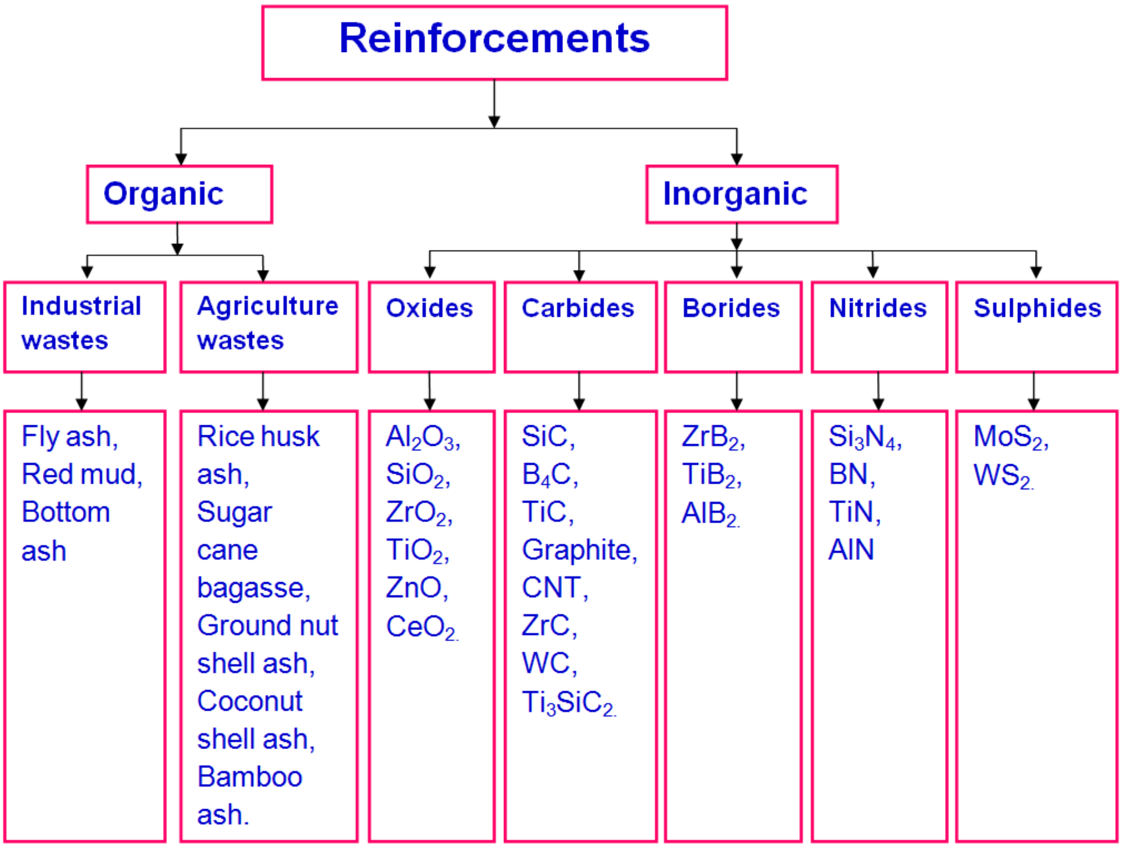

Figure-2: Commonly used reinforcements in MMCs

Figure-2 shows the most commonly used reinforcements in metal matrix composites. Figure-3 shows the various types of processes for fabrication of a composite. Different methods like powder metallurgy, compo casting, squeeze casting and stir casting are used to fabricate the aluminium metal matrix. Amongst various processing routes stir casting is one of the promising liquid metallurgy technique utilized to fabricate the composites. The process is simple, flexible, and applicable for large quantity production. Most commonly, the manufacturing of AMMCs has utilised aluminium alloys from the 2000, 5000, 6000, and 7000 series range as a matrix.

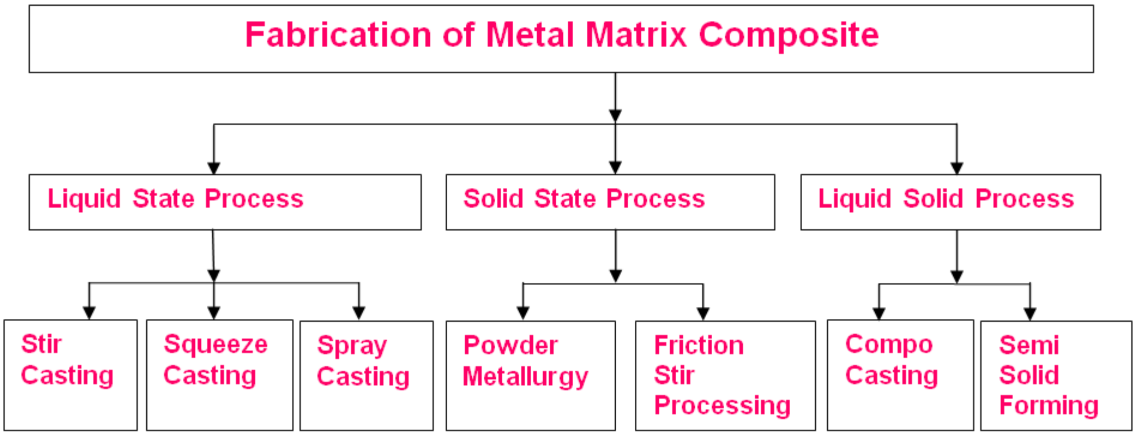

Figure-3: Methods of fabrication.

II. LITERATURE REVIEW

M. Sambathkumar et al [1] fabricated and investigated the effect of reinforcement on the mechanical properties of aluminium metal matrix composite. Metal matrix composites prepared using Al7075 alloy as a matrix, silicon carbide and titanium carbide as reinforcement particles. Two step stir casting process was used to fabricate the composites by varying volume fractions of silicon carbide and titanium carbide (0 to 15 vol. %). Vickers micro hardness tests were performed and the hardness values were increased with an increase in reinforcement from 0 to 15 vol.%. The tensile strength of the 10 vol. % of aluminum hybrid matrix composite was better than that of the base alloy.

Temitayo M. Azeez et al [2] fabricated the aluminium – egg shell ash composite by stir casting to investigate the mechanical properties. Percentage of eggshell ash was varied from 0 to 10wt% in steps of 2wt%. Results indicated that the tensile strength, hardness and impact strength of the composite is higher than the base matrix. Also, the tensile strength, hardness and impact strength of the composite increased with increase in weight percent of eggshell ash in the matrix.

Ch Hima Gireesh et al [3] have prepared a hybrid metal matrix composites by using aluminium 6061 as the matrix material and silicon carbide (SiC), alumina (Al_2O_3) and fly ash as the reinforcing material. The composite is produced by conventional stir casting in which the weight fraction of the silicon carbide and alumina is varied (from 5%, 7.5%, and 10%) by fixing the fly ash weight fraction (5%). The experimental investigation revealed that the proposed hybrid composite with 20% of total reinforcement material exhibits high hardness and high yield strength. Also, the tensile strength of the composite increased with increase in weight percent of reinforcement in the matrix.

S. Thirumalvalavan et al [4] investigated the mechanical properties of SiO_2 reinforced aluminium metal matrix composites. The aluminum alloy (LM25) is used as the matrix metal for the fabrication of the composites that has been reinforced with 0 wt. %, 4 wt. %, 8 wt. % and 12 wt. % of SiO_2. The result of this investigation showed that the tensile strength, rockwell hardness and impact strength is increased with increased addition of fused silica particulates up to 8 wt% and then decreases with increasing wt% of SiO_2.

Mohamad Reda A. Refaai et al [5] have chosen aluminum as the matrix material and 2.5 to 15wt% of peanut shell ash as the reinforcement to produce the composite by double stir casting technique. The effect of reinforcement on the hardness, tensile strength and impact strength of composites was investigated. The result of this test showed that the hardness increases with the increase in ash percentage, whereas the tensile strength and impact strength decreases with the increase in ash percentage.

Objective of the work

In this research, experimental analysis is done to find tensile strength, hardness and impact strength by varying the weight percentage of Al_2O_3 in Al6063 composite.

III. MATERIAL AND METHODS

Matrix and Reinforcement

Matrix is the base material in the composite. Among the various matrix materials available, aluminium and its alloys are widely used in the production of metal matrix composites. Generally, Aluminium 6061 alloy, Aluminium 6063 alloy, Aluminium 7075 alloys are used. In the present work, Al6063 has been chosen as the matrix material for preparing metal matrix composite. Aluminium alloy 6063 is a commercial aluminum alloy. It's used in aerospace and automobile manufacturing because of its high strength-to-weight ratio, low density, and high stiffness. The chemical composition of the Al 6063 is shown in table-1.

Table-1: Chemical composition of Al6063

Element	Weight %	
	Minimum	Maximum
Mg	0.45	0.90
Si	0.2	0.6
Fe	0.0	0.35
Cu	0.0	0.10
Cr	0.0	0.10
Zn	0.0	0.10
Ti	0.0	0.10
Mn	0.0	0.10
Others	0.0	0.15
Al	97.5%	99.35%

Aluminium oxide, also known as alumina, is a chemical compound of aluminium and oxygen with the chemical formula Al_2O_3. It's a white, odorless and crystalline powder. Aluminum oxide (Al_2O_3) has very good mechanical properties and is comparatively cheaper than silicon carbide (SiC). Al_2O_3 provides excellent impact resistance, chemical resistance, abrasion resistance, and high temperature properties.

Stir casting

Stir casting process is most widely used to prepare MMCs of low melting point material because it is economical, simple, flexible and suitable for mass production. In this method, the reinforcement phase is mixed with the molten

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matrix metal by means of mechanical stirring. The molten composite slurry is then cast by conventional casting methods. The properties of the metal matrix composites produced using stir casting methods will depend on the processing parameters such as temperature of melt, stirring speed, stirring duration, geometry of the stirrer and size of crucible which will affect the distribution of the reinforcements in the matrix.

Preparation of Composites

In the present investigation, commercially available aluminium (Al 6063) is used as matrix reinforced with alumina (Al_2O_3) particulates. Initially the weighed aluminium 6063 ingots for a particular composition was placed inside a graphite crucible and melted in a muffle furnace. The temperature of the furnace was made to reach 750°C. Alumina will be preheated to remove moisture. Alumina was added in 0%, 2.5%, 5% and 7.5% weight percentages to the molten metal as a reinforcement material. Mechanical stirring is used to distribute reinforcement into molten aluminium matrix. The molten metal is then poured into the metal mould and solidified to room temperature.

IV. RESULTS AND DISCUSSION

The prepared aluminium metal matrix composite samples are investigated for their mechanical properties and are compared with the pure aluminium. The mechanical properties of the composite specimens are presented in table-2.

Table-2: Mechanical properties of composites.

Sample Composition	Tensile Strength (MPa)	Hardness (VHN)	Impact Strength (J/mm^2)
100% Al	102.9	81.0	0.40
Al with 2.5%Al_2O_3	140.2	85.1	0.32
Al with 5%Al_2O_3	148.0	90.0	0.24
Al with 7.5%Al_2O_3	157.8	96.7	0.14

Tensile strength

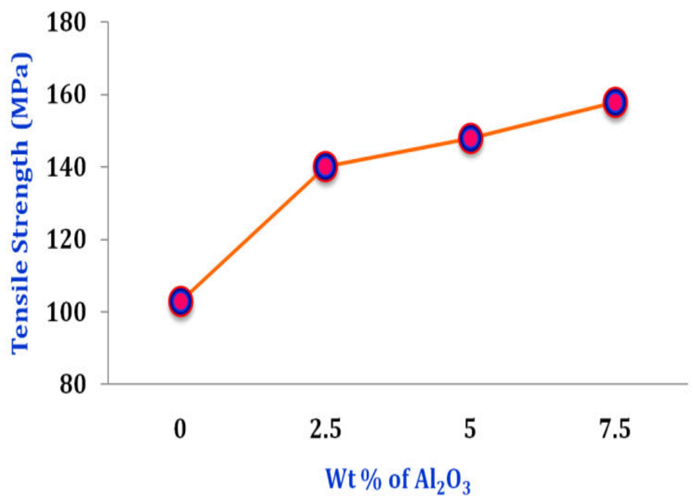

Figure-4: Tensile strength of composites

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The graph plotted between tensile strength versus different weight percentages of Al_2O_3 particulates is shown in figure-4. From figure-4 it can be observed that, with the inclusion of Al_2O_3 particles, the tensile strength of composites increased than the matrix material. Furthermore, increment in the reinforcement weight percentage increases the tensile strength. The tensile strength of Al6063- 7.5%Al_2O_3 composite is 157.8 N/mm^2, which is 53.35% higher than that for Al6063 alloy. The strength improvement of composites can be attributed to the good bonding between the matrix and reinforcement material. R. Arunkumar [6] fabricated and investigated the effect of reinforcement on the mechanical properties of aluminium metal matrix composite. In the present case, the boron carbide (B_4C) content is varying in composition of (0, 2.5, 5 and 7.5 wt %) in aluminum matrix, fabricated by stir casting technique. Results indicated that the tensile strength of the composite is higher than the base matrix. Also, the tensile strength of the composite increased with increase in weight percent of boron carbide in the matrix. Priyaranjan Samal et al [7] fabricated and analysed the mechanical properties of titanium carbide (TiC) reinforced aluminium composites. Aluminium metal matrix composites were fabricated by considering aluminium alloy 5052 reinforced with various weight percentage (5, 7, and 9) of titanium carbide (TiC) through stir casting method. The authors reported that the tensile strength of the composites is higher than the unreinforced matrix metal and the tensile strength of the cast composites increases linearly with increasing the weight fraction of titanium carbide.

Hardness

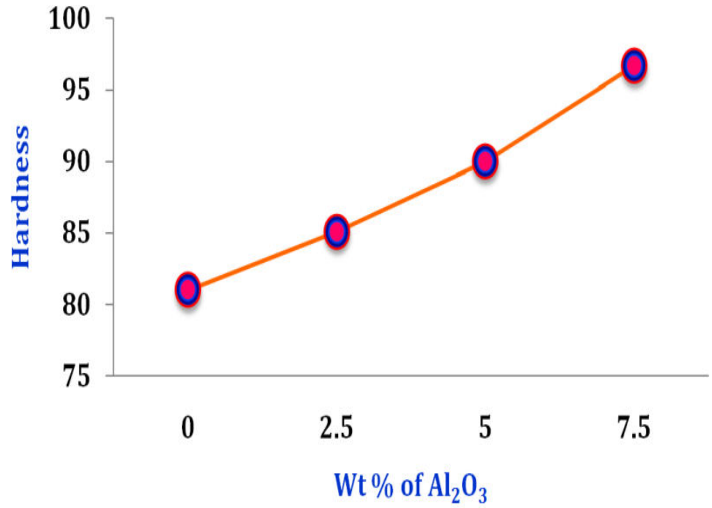

Figure-5: Hardness of composites

Figure-5 represents the variation in hardness of Al6063- Al_2O_3 composites with respect to weight percentage of Al_2O_3 particles. From figure-5 it can be observed that, with the inclusion of Al_2O_3 particles, the hardness of composites increased than the matrix material. Furthermore, increment in the reinforcement weight percentage increases the hardness. The hardness of Al6063- 7.5%Al_2O_3 composite is 96.7 VHN, which is 19.38% higher than that for Al6063 alloy. The hardness of Al6063- Al_2O_3 composites increases because of the high hardness of the aluminum oxide (Al_2O_3) particles and the strong bonding between the aluminum matrix and the Al_2O_3 particles. Manish Maurya et al [8] investigated the mechanical behavior of a new composite, which was manufactured by stir casting method where matrix as Al 6061 alloy used and reinforced with SiC. In the processing of composites, silicon carbide particles have been used as reinforcement materials with different weight percentages (0, 2, 4, 6 and 8). The researchers observed that the hardness of the composites is higher than the unreinforced matrix metal and the hardness of the cast composites increases linearly with increasing the weight fraction of silicon carbide. R. Arunkumar et al [9] investigated the effect of titanium diboride (TiB_2) particles on mechanical properties of aluminum metal matrix composites. The fabrication of aluminum composites with different weight percentage of titanium diboride particles up to 0-10% was processed by stir casting process. The result shows that the hardness of the composites is higher than the unreinforced matrix metal and the hardness of the composites increases with increasing the weight percentage of titanium diboride.

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Impact strength

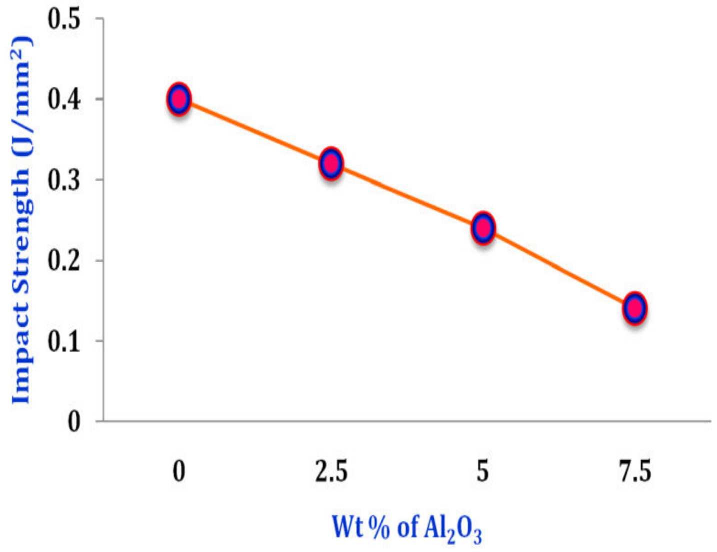

Figure-6: Impact strength of composites

Impact strength of the Al6063 matrix alloy and the prepared composites are shown in figure-6. From the figure, it can be observed that the impact strength of the composites is lesser than that of the matrix alloy. Further, from the graph, the trends of the impact strength can be found to be decreased with increase in Al_2O_3 content in the composites. A maximum decrease of 65% was observed in case of the Al6063- 7.5%Al_2O_3 composites as compared with the alloy. The impact strength decreased in the composite as compared to base metal because of reduced ductility of the composite. The microstructure and mechanical properties of an MMC based on AA 7075 and strengthened through silicon carbide (SiC) aswell as boron carbide (B4C) elements were investigated by HassabAlla M. A. Mahmoud et al [10]. The (SiC + B4C) combination was used in various weight percentages of 4, 8, 12, and 16% to create the hybrid composites utilizing the traditional stir casting procedure. The results showed that the impact strength of composites decreased with an increase in weight percentage of particle in the matrix material. Priyaranjan Samal et al [11] investigated the effect of titanium carbide (TiC) particles on impact strength of Al 5052 alloy metal matrix composites. The fabrication of Al 5052 composites with different weight percentage of TiC particles up to 0-9% was processed by stir casting process. The authors have revealed that the impact strength of composites decreased with an increase in weight percentage of titanium carbide in the matrix material.

V. CONCLUSION

This paper investigates the effect of Al_2O_3 content on the mechanical properties of aluminum matrix composites. From the experimental results, the following conclusions have been made.

- In the tensile test, the composite containing 7.5 wt% Al_2O_3 showed the maximum strength of 157.8 MPa increased by about 54.9 MPa (53.35 %) compared to the base alloy.
- Considering the result of hardness test, the hardness of Al6063- 7.5%Al_2O_3 composite is 96.7 VHN, which is 19.38% higher than that for Al6063 alloy.
- The wt% of Al_2O_3 reinforcement has increased the impact strength of aluminum matrix composites reduced from 0.40J/mm^2 to 0.14J/mm^2. A maximum decrease of 65% was observed in case of the Al6063- 7.5%Al_2O_3 composites as compared with the alloy.

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