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Synthesis and Characterization of ZrO_2 Reinforced Al7075 MMC's: A Study on Mechanical Property Enhancement

Vishal Yallappa Kenchannavar[1*], Raghu Yogaraju[1], B. K. Pavan Kumar[2], M. K. Venkatesh[3], R. Suresh[4], L. Ravikumar[1] and S. N. Divya[5]

[1]*Department of Mechanical Engineering, BMS College of Engineering, Bangalore - 560019, Karnataka, India; vishalyk361999@gmail.com*

[2]*Department of Mechanical Engineering, Ballari Institute of Technology and Management, Ballari - 583104, Karnataka, India*

[3]*Department of Mechanical Engineering, Dayananda Sagar College of Engineering, Bangalore - 560078, Karnataka, India*

[4]*Department of Mechanical Engineering, M.S. Ramaiah University of Applied Sciences Bangalore - 560058, Karnataka, India*

[5]*Department of Mechanical Engineering, Government polytechnic, Tumkur - 572103, Karnataka, India*

Abstract

The current research involves synthesis of zirconium oxide (ZrO_2) nanoparticles using sol-gel process and focuses on investigating the effect of Zirconium particulate size varied between 30-40 nm on various mechanical properties. Al7075 Metal matrix Composites (MMC's) with variable weight percentage (Wt. %) ZrO_2 nano particles fabricated using the stir casting technique. The castings were created by altering the weight percentage of the reinforced particles at 1, 2, and 3 weight fractions in volume. Scanning Electron Microscope and microstructural analysis were conducted on all composite samples including the fractured surface of tensile specimens. The microstructural study revealed a homogenous distribution of ZrO_2 reinforcement particles throughout the Al7075 metal matrix composites. Results from mechanical tests revealed an enhancement in hardness, toughness and tensile strength with an increase in Zirconium dioxide particles in the weight percentage of composites. As anticipated, the percentage elongation decreased with the increased weight percentage of reinforcement in the aluminum matrix (Al). Al7075 with 3 % ZrO_2 shows higher tensile strength (187Mpa), Hardness (101HBN), Impact strength (0.28J/mm^2) and lower wear rate. Energy Dispersive X-ray Spectroscopy (EDS) analysis was conducted on all composite samples, which reveals the presence of ZrO_2 in Al- ZrO_2 Metal Matrix composites (MMC's).

Major Findings: *Zirconium oxide (ZrO_2) nanoparticles with a size range of 30-40 nm were synthesized using the sol-gel process. A significant improvement in hardness was observed as the percentage of ZrO_2 increased. The tensile strength was highest for the composite with 3 % ZrO_2, measuring 187 MPa. Microstructural examination of tensile specimen fractures confirmed this homogeneity. The composite with 3 % ZrO_2 exhibited higher impact strength compared to others, indicating improved impact resistance.*

Keywords: *Energy Dispersive X-Ray Spectroscopy, Microstructure Analysis, Metal Matrix Composites, Sol-Gel Process, Stir-Casting*

**Author for correspondence*

1.0 Introduction

Metal Matrix Composites (MMC's) have attracted considerable attention in research owing to their exceptional thermal, mechanical, electrical and aerospace properties which are considerably higher than those of traditional ceramic-based composites[1-4]. These are made of a strong metal matrix that is embedded with extremely hard ceramic nanoparticles and provide nearly singular mechanical traits as opposed to standard metals. Nanoparticles are added, and there is an enhancement in tensile strength, yield strength properties, ductility as well creep resistance and fatigue life. Improved mechanical properties of Metal Matrix Composites (MMC's) such as Magnesium (Mg)–Copper (Cu) alloys reinforced by silicon carbide particles mixture of magnesia/carbon black powders and Cu-graphene composites. Since Aluminum Matrix Composites (AMMC's) possess many beneficial properties, such as higher ductility combined with good strength and low weight per volume compared to conventional monolithic aluminum alloys besides improvements in hardness, wear resistance that can be applied for high technological industries including aviation, transportation industry; marine devices manufacturing etc., also increases the number of concerns on processing. In general, these AMMC's are synthesized using distinct reinforcements such as silicon carbide (SiC), aluminum oxide, titanium dioxide, boron carbide, silicon nitride, and graphite (*Gr*)[5].

Zirconium oxide (ZrO_2) is a white crystalline oxide, has the properties of thermal shock stability and glaze melt fluidity because it does not have color in high temperature as much due to its rare structure with surface tension. One of the crucial reinforcements for Aluminum Metal Matrix Composites (AMMC's) is ZrO_2, which improves mechanical and surface properties[3], making these composites well suited for applications where corrosion inhibition as well resistance is essential, also keeping density to a minimum.

Zirconium nanoparticles are prepared using different methods like Sol-gel method, Coprecipitation and Hydrothermal method. Out of those numerous techniques, Sol-gel method is aimlessly used for synthesizing nanoparticles due to its cost-effective and straightforward nature; moreover, a low-temperature or pressure can be utilized in this technique. The experimental Circumstances and processing parameters that are used during the sol-gel synthesis can have an influence on the materials characteristics.

The liquid-state method is of the commonly used fabrication methods and has shown a great performance in fabricating metal matrix composites utilizing stir casting technique due to it cost effective, simplicity and flexibility[5]. Some previous investigation has been conducted on ZrO_2 particle reinforced aluminum alloys.

To reinforcement by ZrO_2, Vida Khalili *et al.* carried out an examination in 2020 utilizing stir casting making Al6061 matrix composites having wt %with zirconium oxide ranging from 0 to 6. % ZrO_2 particles. The presence of ZrO_2 led to a more homogenous distribution and the resulting finer grain size made it less porous. Mechanical testing confirms the higher ZrO_2 content materials (6 wt. % Best action % ZrO_2 composite). There is also a rise in the resistance to corrosion due to a layer of oxide that will form on the surface. The above study reveals the capability of stir casting in developing Al6061- ZrO_2 composites with improved near-surface characteristics for manufacturing purposes[1-3].

It is presented in the research of T. Gunasekaran *et al.* that Al7075 matrix composites dispersed with 1-5 weight percentage (wt. %) ZrO_2 particles. Were produced via stir casting. The inclusion of ZrO_2 had a positive impact on the microstructure by means of refining grain structures and reducing porosity. Mechanical testing indicated that the 5 weight percentage (wt. %) ZrO_2 composite had the highest enhancements, with hardness, tensile strength, and yield strength increasing by 12%, 15%, and 10%, respectively. Assessment through scanning electron microscope and X-ray diffraction analysis verified these improvements. This study draws attention to the role of ZrO_2 in the method of improving mechanical properties in Al7075, which is showing the interest of using stir casting for creating advanced composites[2]. During one of their studies, B. Prasanna Nagasai and his colleagues used stir casting to create a composite material of Al-6061 alloy reinforced with 2-6 weight percentage (wt. %) ZrO_2 nanoparticles. The uniform particle distribution was revealed in the results that led to the improvement of the grain structure and reducing porosity. The composites with 6 weight percentage (wt. %) ZrO_2 exhibited the most significant improvements as seen from the mechanical testing results: where hardness increased by 10%, tensile strength by 15%, and wear resistance by 8%. On the other hand, the SEM and XRD outcomes delivered key

insights into the bonding mechanisms. They also identify the future potential of such Al-6061- ZrO_2 systems for the lightweight materials with preferred mechanical characteristics in different fields[3].

P. Vignesh, S.V. Alagarsamy, P. Raveendran, *et al.* researched the Al7050 alloy containing 1-5 weight percentage (wt. %) ZrO_2 using the stir-casting method. The homogeneous ZrO_2 distribution resulted in grain refined structures and a decrease in porosity. Mechanical testing proved that better ZrO_2 distribution increased the hardness (10 %), tensile strength (15 %), and wear resistance (8 %). The mechanical properties of bonding between ZrO_2 and Al7050 were evaluated through SEM and XRD. The paper is based on the potential uses of ZrO_2-reinforced Al7050 to enhance mechanical properties in applications[3].

G. Karthikeyan and G. R. Jinu probed into a LM6 aluminum matrix dispersed with ZrO_2, in the weight fraction range of 2-6 % via stir-casting. The uniform dispersion of nanoparticles leads to an 18% rise in the tensile strength, and the ductility and fracture toughness are also increased. The detailed SEM fractography shows the formation of ZrO_2 dislocation bands as well as the interrupted, non-uniform crack at the interface between ZrO_2 and LM6 matrix. The paper outlines the role of ZrO_2 in improving the mechanical behaviour of LM6 for high strength-to-weight as well as improved fracture resistance[4].

Metal Matrix Composites (MMCs) have gained significant attention due to their superior mechanical properties and adaptability for various applications. Among these, Al7075 alloy, known for its high strength-to-weight ratio, has been extensively used in aerospace, automotive, and defense industries. Lim *et al.*, showed the addition of zirconium oxide (ZrO_2) as a reinforcement in Al7075 enhances mechanical properties such as tensile strength, hardness, and wear resistance due to its high thermal stability and hardness. The sol-gel technique is a preferred method for synthesizing ZrO_2 nanoparticles, offering uniform particle size and controlled morphology. Additionally, Ahmad and Hamzah depicted the distribution of ZrO_2 particles in the Al7075 matrix plays a crucial role in achieving improved properties. Studies have shown that uniform dispersion minimizes the formation of voids and improves the load-bearing capacity[5]. ZrO_2 nanoparticles are widely used in medicine and pharmacy for their anticancer, antibacterial, and antioxidant properties, as well as in tissue engineering and biomimetic scaffolds due to their high strength, biocompatibility, and chemical stability. This review critically explores their biomedical applications and synthesis methods[6].

This study investigates the wear and mechanical properties of Al7075 MMCs reinforced with micro and nano SiC using stir casting[7]. The obtained results show improved grain refinement and mechanical properties with increasing SiC content, with nano-SiC composites performing better than micro-SiC. Wear resistance was higher in nano composites, and fracture surfaces were analyzed using SEM. Similarly, author authors examine the impact of Sr/Ca nano partiles on the microstructure, mechanical, and wear properties of A357 aluminum alloy using stir casting. They observed that the improved hardness and uniform dispersion of Sr/Ca, enhancing silicon structure[8,9]. Wear behaviour was analysed and revealing that Sr/Ca nano particles significant effect[9]. Aluminium (Al2219) was used as the matrix, with n-B4C and MoS_2 as reinforcements. Hybrid and un-hybrid nano metal matrix composites were fabricated using the stir casting technique. They observed that the nano particles reinforcement has enhanced the microstructure, mechanical, and wear properties of A357 alloy[10].

Earlier research review has shown that the use of the Aluminum Matrix Composites (AMMC's) has become of great importance when it comes to replacing monolithic materials in various applications. The novelty of the research work is to investigate the effect of ZrO_2 particles reinforcements on the microstructure and mechanical properties of the aluminum (Al7075) alloy composite[11-14]. The present research work is mainly orientated at fabricating new composites whose Al7075 is the matrix material. They are to be mixed with different amounts of ZrO_2 particles (0, 1, 2, and 3 wt. %) produced by the stir casting process. The zirconia nanoparticles play a crucial role in enhancing the mechanical, thermal, and wear properties of MMCs, making them valuable in automotive, aerospace, biomedical, and industrial applications. Further, investigated the mechanical properties and fracture analysis of the fabricated MMCs.

2.0 Materials and Methods

The base matrix selected in the present experimental study was Al7075, and its chemical composition is given as Table 1. The method of work flowchart is shown in the Figure 1. Based on the literature review, industrial expert's opinion and automotive application of MMCs and in order

Table 1. Elements of Al7075 alloy

Elements	Percentage
Zn	5.5 %
Mg	2.5 %
Cu	1.5 %
Fe	0.3 %
Si	0.08 %
Al	90.02 %

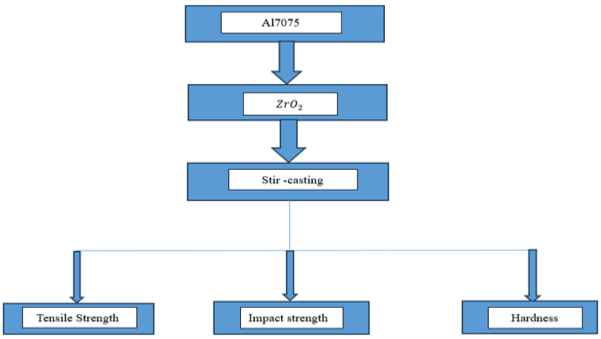


Figure 1. Methodology of Al- ZrO_2 MMC's.

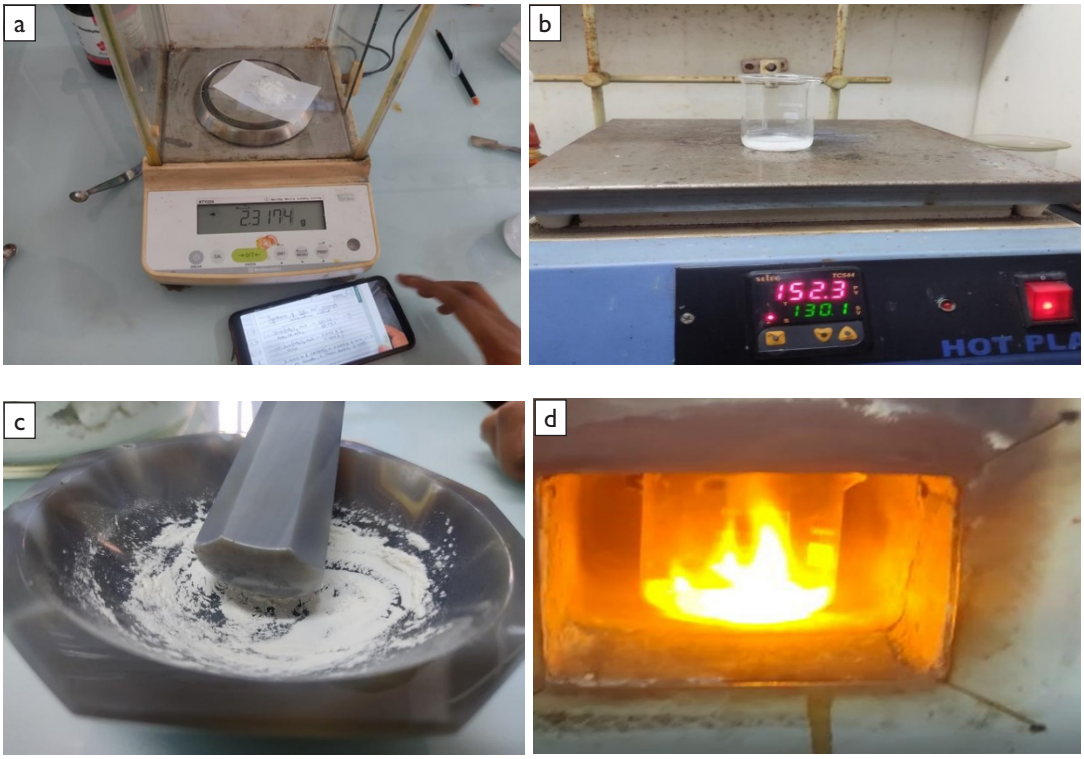


Figure 2. Steps in Sol-gel process, **(a)** Balancing weighing equipment, **(b)** Precursor hydrolysis on hot plate, **(c)** Hand grinding ZrO_2 nanoparticles, **(d)** Flashing of reactants in the furnace.

to improve wear resistance, high-temperature stability, and mechanical strength and also, maintaining a balance of toughness and machinability in the in MMCs, ZrO_2 particles were selected has reinforcement and varied with 1, 2, and 3 weight fractions in volume. Moreover, Zirconia (ZrO_2) nanoparticles were used as a reinforcement material due to their high hardness, chemical inertness, and excellent wettability with matrix materials, while also considering cost. ZrO_2 nano particles (30–40 nm) were synthesized by the sol-gel process is depicted in Figure 2. Figure 2 shows step in sol-gel process.

Initially, 2.3123 g of Zirconyl nitrate is taken along with 0.606 g of Urea in a beaker with a small quantity of distilled water. Further the beaker is transferred to a flat hot plate for around 10-15 min till it form white viscous gel like formation. Once it forms into gel like formation, the entire thing is transferred to furnace whose temperature is maintained at 550°C, and the mixture is kept for a duration of 12-15 minutes. The final product obtained is Zirconium oxide along with the release of carbon dioxide. The oxide of zirconium is synthesized into two different samples i.e, Sample-Z and Sample-YZ. Sample-Z is Pure

Zirconium and Sample-YZ is Zirconium with Yittrium (III) nitrate hexa-hydrate as a catalyst.

$$2.3123 \text{ gram of } ZrO(NO_3)_2 + 0.606 \text{ gram of } CH_4N_2O + H_2O = X \text{ gram of } ZrO_2 \quad (1)$$

The combination solutions of urea and zirconia nitrate were stirred continuously. The urea will act as a complexing agent, promoting the formation of zirconium oxide nanoparticles. After combining the solutions, continue stirring the mixture at 150°C temperature or slightly elevated temperature. The hydrolysis reaction will occur, leading to generation of zirconium hydroxide gel. The gelation process will proceed as the zirconium hydroxide particles connect and form a three-dimensional network. Allow the gel to age for a specific period. Aging is typically carried out at a controlled temperature, around 60-80 °C, *for several hours (2-3 hours).* This step promotes the growth and stabilization of zirconium oxide nanoparticles within the gel matrix. After the aging process, the gel needs to be dried to detach the solvent and convert the gel into a solid material. This is done by air drying and oven drying methods. The specific drying conditions will depend on the desired properties of the nanoparticles such as size and shape[7]. The XRD results, including the identified peaks, peak positions, peak intensities, and diffraction angle are depicted in Figure 3. Interpret the data in the context of the crystal structure, particle size, and other relevant properties of the ZrO_2 nanoparticles.

Figure 4(a) and (b) depicts a stir casting setup used to synthesize the composite, an electrical arc furnace and a stirrer assembly. The detailed procedure is shown in the Figure 5. Aluminum composites was gradually heated from room temperature until it reached 350°C, where

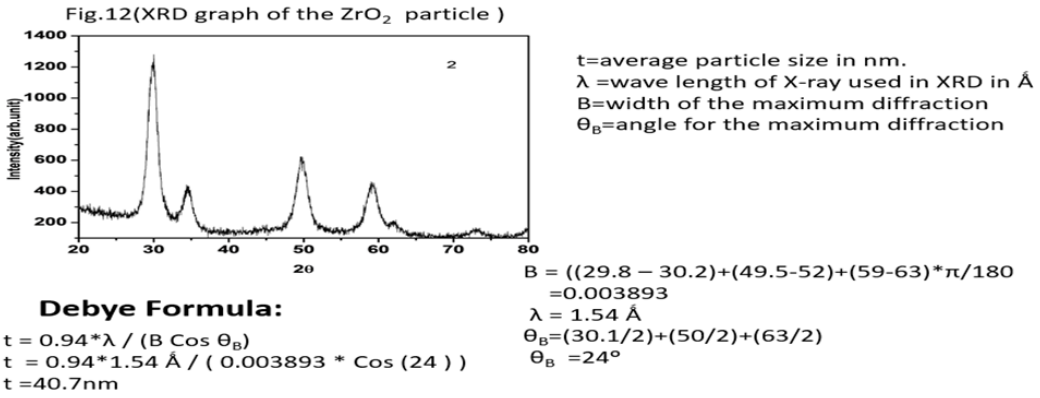


Figure 3. XRD graph of ZrO_2 particle.

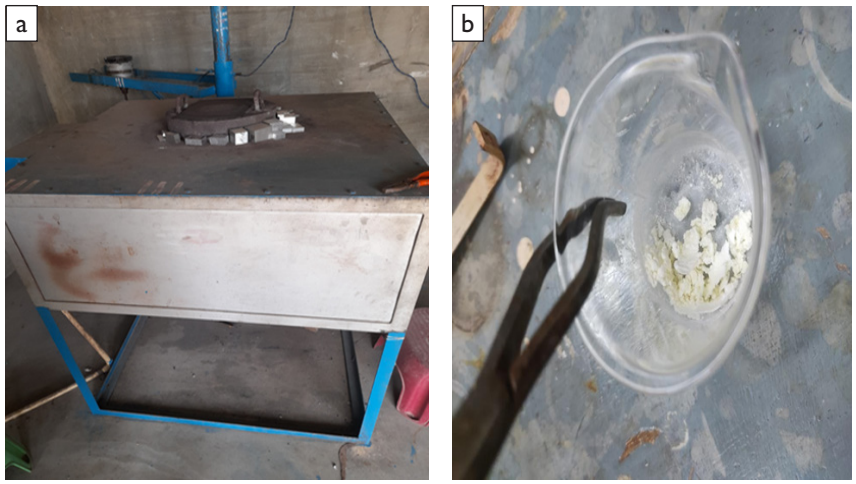


Figure 4. **(a)** Stir-casting set up. **(b)** Synthesis of ZrO_2 nanoparticles by Sol-gel process.

melting initiated and continued up to about 800°C, as shown in Figure 5(a). After adding ZrO_2, which had been heated to about 350 °C to remove moisture, the molten liquid was stirred for eight minutes at 1200 rpm using a motor.

Figure 5(b) illustrates another 8 minutes of stirring after the introduction of preheated ZrO_2, and the temperature was maintained at 800°C after which the mixture turned molten. Hexachloroethane was added to assist in vortex creation and the removal of impurities in the molten mixture. The melted material was transfered into the mould and allowed to cool to the desired size as shown in Figure 5(c). Later on, it was machined and underwent various tests as shown in Figure 5(d) and (e) : 1 st Al7075 99 % + 1 % ZrO_2, 2nd Al7075 98 % + 2 % ZrO_2, 3rd Al7075 97 % + 3 % ZrO_2.

3.1 Tensile Test

Mechanical properties can be determined by tensile testing, where the material is subjected to uniaxial stretching until it fractures. According to the ASTM-E8 standard, specimens are machined and tested on a Universal Testing Machine (UTM) as depicted in Figure 6(a) and (b). The UTM is utilized to apply tensile force slowly and continually at the same time measure of applied load as well as corresponding elongation. Ultimate tensile strength, yield strength, and elongation at break are among the characteristics that are tested. Figure 6(c) shows a tensile specimen subjected to a tensile load, with its break point observed at a load of 5.088 KN. The weight percentage of zirconium dioxide's effect on the ultimate strength of Al7075 matrix composites is depicted

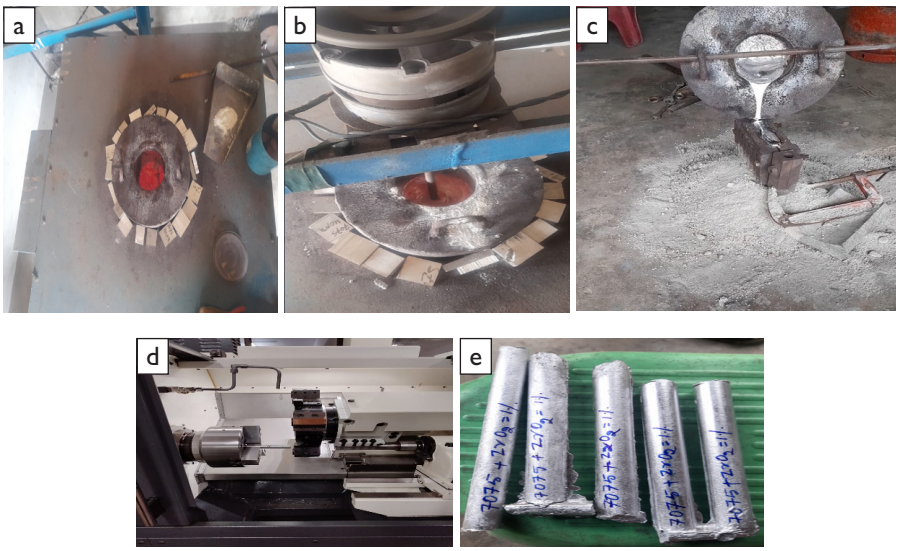


Figure 5. Steps in Stir-casting. **(a)** Melting of Al7075. **(b)** Stirring. **(c)** Pouring molten matrix into mould. **(d)** Machining of samples for various tests. **(e)** Fabricated Al- ZrO_2 metal matrix composites.

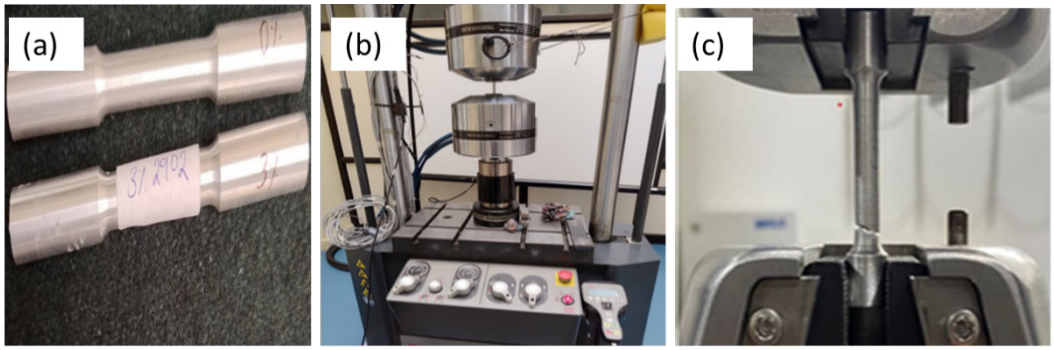


Figure 6. **(a)** Specimen according to ASTM-E8 standard. **(b)** Universal Testing Machine **(c)** Fracture of Tensile Specimen.

in Figure 7 and tensile test results are tabulated in the Table 2.

To make a comparison, 1%, 2% and 3% ZrO_2 aluminum reinforced composites are available, and all these specimens of aluminum have been analyzed with a specimen of aluminium without any reinforcement. Figure 7 developed above clearly reveals that there is a better trend on the ultimate tensile strength of composites with nanoparticle reinforcement than the composites without nanoparticles. For the examination of the mechanical behaviour of Al7075 and its composite, the weight fraction of reinforcement is keep varying in the range of (0%-3%).

Thus, at 3% of ZrO_2 reinforcement, Al7075+3% ZrO_2 composite has greater ultimate strength compared to other weight percentages of reinforcement.

Table 2. Results of Tensile Test.

Metal Matrix Composites	Ultimate Tensile Strength (MPA)
Al7075 base Alloy	92
Al7075+1 % ZrO_2	118
Al7075 +2 % ZrO_2	121
Al7075+3 % ZrO_2	187

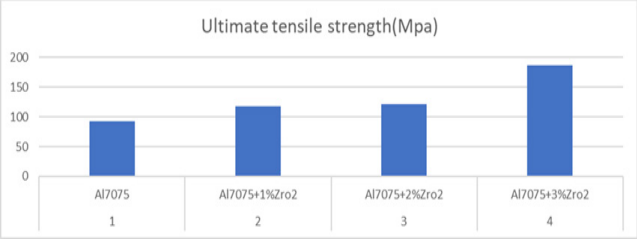


Figure 7. Effect of weight percentages on ultimate tensile strength of Al-ZrO_2 metal matrix composites.

From the Table 2 it is visible that the 0 % ZrO_2 Aluminum metal matrix composite has the lowest stress with standing capacity and as the percentage of ZrO_2 increases the stress with standing capacity increases, namely 1%, 2% and 3%. Result supports the fact that mechanical strength of Aluminum metal matrix composite increases with the inclusion of ZrO_2 reinforcement because the reinforcement provides different co-efficient of thermal expansion than that of matrix material. This results in increased dislocation densities and strength, thus increasing the capability of the composite to tolerate it. The increased strength of the composite is also due to better distribution and wetting of reinforcement, and better particle packing of the hard reinforcement in the soft aluminium matrix that in summarize the interfacial bonding characteristics[2].

3.2 Brinell Hardness Test

Brinell hardness testing is done by pressing a hardened steel or carbide ball into the test specimen under a specific load. The resulting indentation diameter is determined using a microscope, and the hardness value determined. Figure 8(a) shows the Brinell hardness test equipment while Figure 8(b) shows the specimens prepared as per ASTM E10-15a. Figure 8 (c) shows an indentation on the specimen surface, resulting from the pressing of a hardened steel ball under a specific load.

Aluminium matrix with no reinforcements is compared to specimens containing 1%, 2% and 3% ZrO_2 Aluminum 7075 reinforced composites. The weight percentage of zirconium dioxide's effect on the hardness of Al7075 matrix composites is depicted in Figure 9 and Table 3. The Figure 9 clearly indicates that Al-7075 matrix composites with ZrO_2 nanoparticle reinforcement have

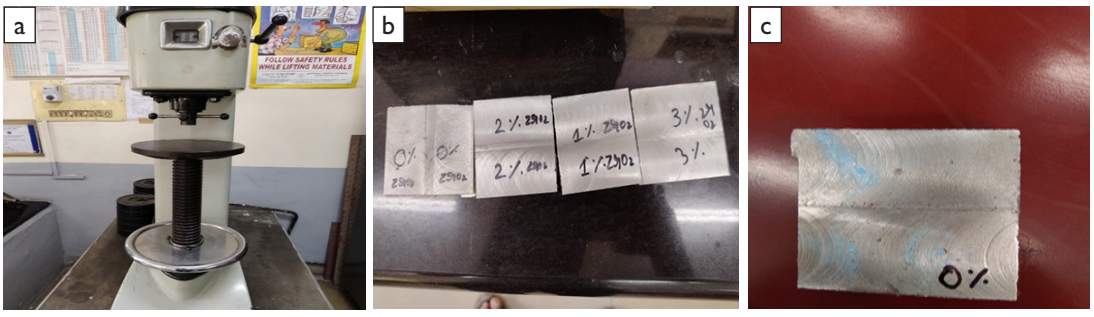


Figure 8. **(a)** Specimen according to ASTM-E10-15a standard and **(b)** Brinell hardness testing equipment. **(c)** Indentation on specimen.

more hardness compared to metal matrix composites without nanoparticles. According to the Figure 9, which showed the hardness samples for different percentages of reinforcement, and Table 3, which provided the determined hardness values for varied percentages of refinement. It is worth noting that there is a steady rise in the value of hardness as it goes from one percentage of ZrO_2 reinforcement to another. Dislocations occurring during solidification lead to increased matrix hardness, but most of this extra hardness is contributed by the higher reinforcement's own strength. Al7075 +3% ZrO_2 has greater hardness compared to other mass proportions of enhancements[2].

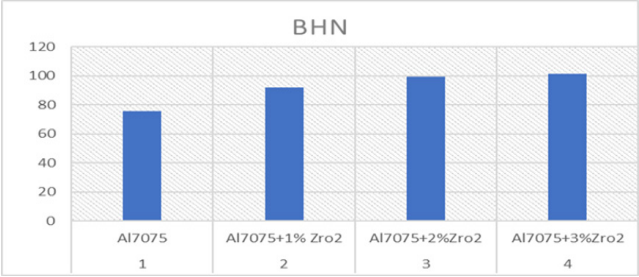


Figure 9. Effect of weight percentages of ZrO_2 on hardness of Al matrix composites.

Table 3. Results of Brinell hardness Test

Metal Matrix Composites	Dia. of Indentation (mm)	BHN
Al7075 alloy	2.8,3.3,2.6	75.62
Al7075+1 % ZrO_2	2.5,3.0,2.4	91.78
Al7075+2 % ZrO_2	2.5,2.4,2.6	99.19
Al7075+3 % ZrO_2	2.4,2.4,2.6	101.38
Time	30 sec	
Dia of Indenter	10 mm	
Load	500 kg	

3.3 Izod Impact Test

The Izod impact test is a procedure for evaluating the toughness of materials by measuring the amount of energy absorbed in fracture. A pendulum hammer strikes a notched specimen and the energy absorbed is measured. Figure 10(a) demonstrates an Izod Impact testing machine, while Figure 10(b) presents specimens fabricated in accordance with ASTM E23 standards.

Figure 10(c) shows a fractured notched specimen from the Izod test, highlighting the break point and fracture surface. It illustrates the impact direction and resulting fracture pattern from the pendulum hammer. The weight ratio of zirconium dioxide's effect on the impact strength of Al7075 matrix composites is depicted in Figure 11 and results are tabulated in the Table 4.

Specimen with 1%, 2% and 3% ZrO_2 Aluminum dispersed composites are analyzed with aluminum without any reinforcement. From the Figure 11, it is very clear that metal matrix composites with nanoparticle reinforcement has higher Impact strength as compared to metal matrix composites without nanoparticles. Al7075+3% ZrO_2 shows higher impact strength as compared with another weight percentages of reinforcement. Table 4 displays that the impact strength of aluminum metal matrix composite with 0% ZrO_2 is the lowest, followed by that of 1%, 2%, and 3%. The outcome validates that the addition of

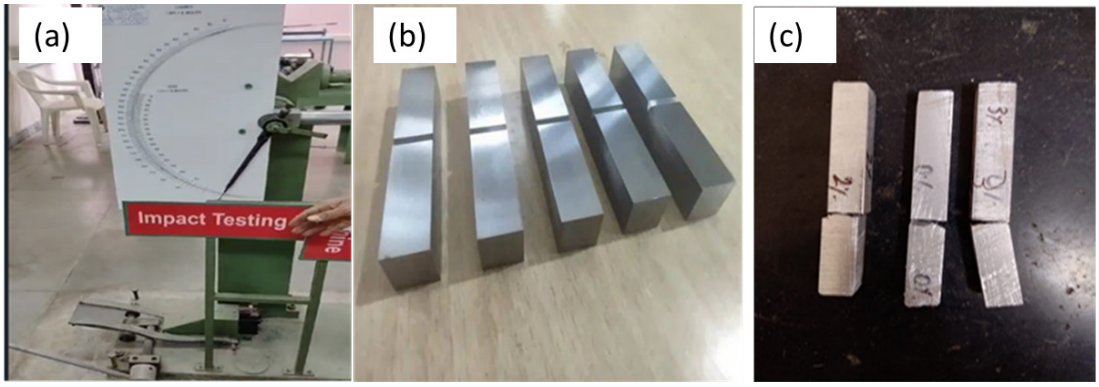


Figure 10. **(a)** Izod Impact testing equipment, **(b)** Specimen according to ASTM-E23 standard and **(c)** Fracture of specimen. **(d)** Effect of weight percentages of ZrO_2 on hardness of Al matrix composites.

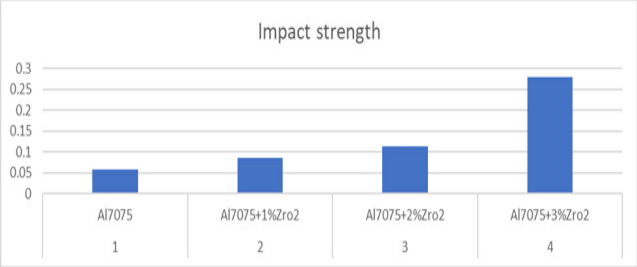


Figure 11. Effect of weight percentages of ZrO_2 on impact strength of Al matrix composites.

Table 4. Results of Izod Impact Test

Metal Matrix Composites	Energy Absorbed (I.R-F.R)	Impact strength(J/mm^2)
Al7075 base alloy	4J	0.0057
Al7075+1 % ZrO_2	6J	0.0085
Al7075+2 % ZrO_2	8J	0.11
Al7075+3 % ZrO_2	10J	0.28

ZrO_2 reinforcement increases the impact strength of the aluminum metal matrix composite[11,12].

3.4 SEM and Tensile Fractography Analysis

The homogenous dispersion of the ceramic reinforcements was determined by microstructure study. Figure 12(a) shows the Scanning Electron Microscope (SEM). The specimens were prepared to the dimensions of 10 mm × 10 mm × 10 mm. The specimens shown in Figure 12(b) was carefully polished before an optical analysis was performed to provide high-quality results. Figure 13 shows Scanning electron micrographs of composites reinforced with 1%, 2%, and 3% ZrO_2 particles in Al7075 matrix. The SEM image of pure Al7075 matrix showed a clearly visible microstructure with well-defined grain boundaries that were free from particles, voids, and any kind of casting defects. In contrast, the existence of ZrO_2 particles in the micrographs of Al7075 composites containing 1wt. % ZrO_2, 2 wt. % ZrO_2, and 3 wt. % ZrO_2 is clearly shown in Figure 13. The ZrO_2 particles are distributed uniformly in the composite without any form of agglomeration. This is because the fabrication of the composites employs a novel two-step stir casting process[4,13].

Tensile fractography is the characterization of fracture surfaces in tensile loading mode (or occasionally under uniaxial bending), allowing for such information to be obtained as dimples, cleavage planes, intergranular cracks and voids. They provide some reports on deformation, fracture behaviour and mechanical properties failure mechanisms of the material. Tensile fractography of Al- ZrO_2 MMC's is shown in Figure 14. SEM images of tensile fractography for Al7075 composites containing different weight % of ZrO_2 show characteristic features of ductile fracture mechanisms. The fractography consists of a large number of small dimples on the fracture surface, which is typical behavior of ductile material deforming before it fractures[14-16]. Furthermore, features of cleavage and intergranular cracks can also be found in the fractography, indicating local areas where the brittle fracture mechanisms may have initiated or propagated. Furthermore, small voids have been identified at certain points on the fracture surface, which therefore can indicate local stress concentrations or poorly bonded areas that might be present in the composite material. Briefly, these observations represent a combination of ductile and brittle fracture behaviours in Al7075- ZrO_2 composites, bringing out a rather complex mechanical response under tension loading conditions[4].



Figure 12. **(a)** SEM equipment **(b)** Al MMCs specimens.

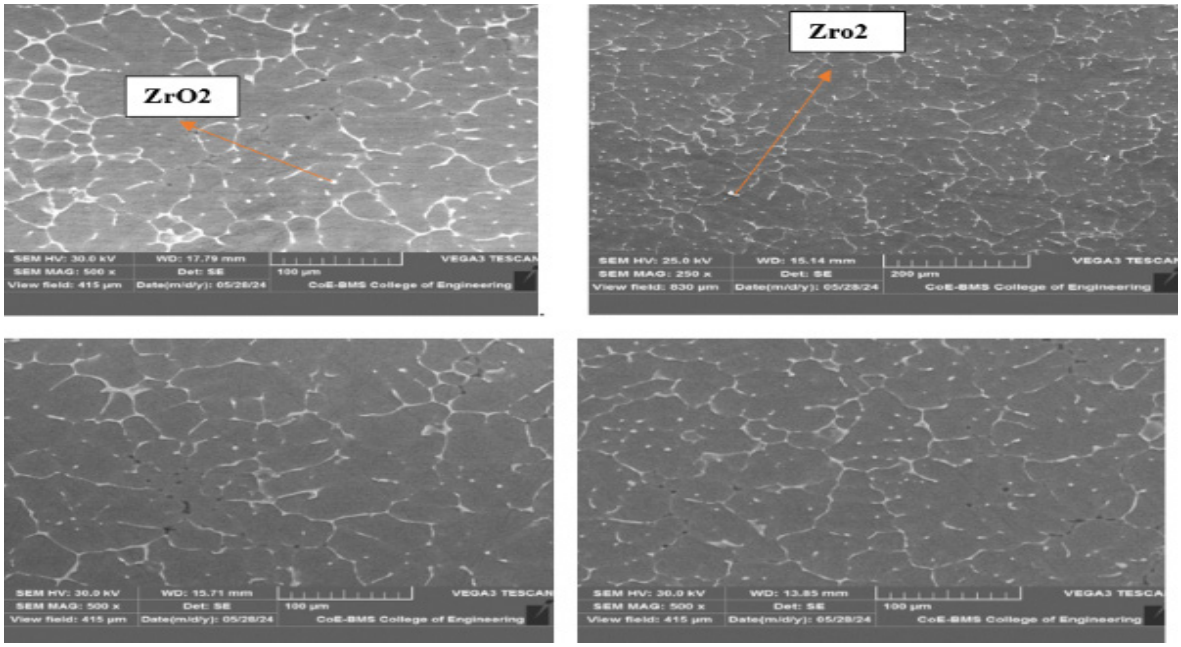


Figure 13. Microstructures of Al7075 with various weight percentages of ZrO_2.

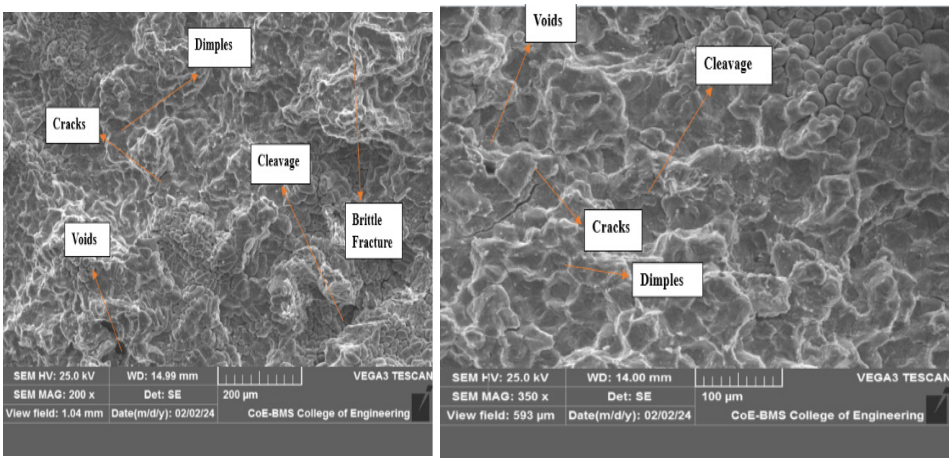


Figure 14. Tensile Fractography of Al7075-various wt % ZrO_2. composites.

3.5 EDS Analysis

Energy Dispersive X-ray Spectroscopy (EDS) is a method which determines the Constituent elements of materials by stimulating them with electron beam irradiation to produce Properties of X-rays emitted by the sample. An EDS detector can measure these x-rays and produces a spectrum which identifies elements in addition to providing quasi-quantitative identification. It is a common technique used in integration with scanning electron microscopy (SEM) to identify materials for research and quality assurance purposes. The EDS test results is in Figure15, correctly predicted a mixture of various elements such as aluminium, zirconium, iron, copper, magnesium, and zinc in Al7075/ZrO_2 composites which is confirmed to be true by the SEM view. Above all, the EDS analyses indicate presence of aluminium and ZrO_2 particles as illustrated in Figure 15 by select point of analysis from SEM photographs display in Left Hand side.

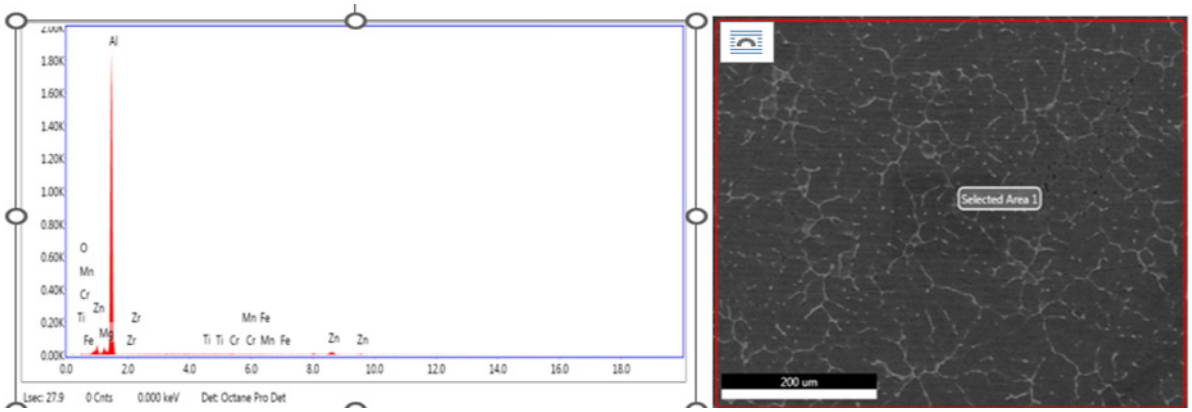


Figure 15. EDS of Al- ZrMetal matrix composites.

4.0 Conclusion

The study includes preparation of Zirconium dioxide nanoparticles and Al7075- ZrO_2 Metal Matrix Composites (MMC's). The Al7075 metal matrix with variable weight percentage of ZrO_2 are casted and specimens prepared according to ASTM standards and tested for Tensile strength, Impact strength, Hardness. The concluded as follows:

1. ZrO_2 nanoparticles (30–40 nm) were produced with high uniformity and purity by sol-gel process.
2. Al7075 matrix composites were developed by stir casting route with different ZrO_2 content, namely 0 %, 1 %, 2 % and 3 weight percentage (wt. %). Here, the technique was proved successful in integrating ZrO_2 particles efficiently with aluminium matrix that lead to systematic investigation of it's mechanical properties.
3. This gave evidence for SEM that ZrO_2 particles have well-dispersed in the Al7075 matrix without any agglomeration. Uniform dispersion within matrix is a key property for consistent material properties and improved performance.
4. Though hardness testing revealed an increasing up to 101 BHN at a ZrO_2 content level of 3 weight percentage (wt %) in Al7075 matrix, which significantly influence the deformation. 3 weight percentage (wt %) addition of ZrO_2 in Al7075 matrix recorded peak tensile strength of 187 MPa also proven useful in reinforcement. While the tensile strength raised this was at a cost of elongation decrease demonstrating a typical trade-off between high-strength and ductility.
5. From the impact testing, the highest value of Impact strength (0.28 J/mm²) was obtained for Al7075 matrix reinforced with 3 weight percentage (wt. %) ZrO_2 revealing its increased toughness and it should well deserve in applications requiring resistance to sudden shock or dynamic loading nature.
6. Results also presented many dimples and voids as well some cracks or cleavage in the SEM fractography of tensile test samples, indicating ductile relative to brittle fracture properties.

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6.0 References

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