



ASSESSING THE ENHANCEMENT OF THE MECHANICAL PROPERTIES OF ALUMINIUM 7075 USING GULA CLAY AT CONSTANT 2wt% SOOT FOR MILITARY APPLICATION

A. A. Barnabas¹, C. Nathan¹, S. A. Samir^{1*}, O. Kenneth¹, O. Goodluck¹,
B. J. Bitrus¹, J. Bulus¹.

Department of Mechanical Engineering, Faculty of Engineering and Technology, Nigerian Army University Bui, Borno State, Nigeria

*Corresponding author: samirr.sani@naub.edu.ng

Received: 28-08-2025
Revised: 06-10-2025
Accepted: 07-01-2026
Published: 11-01-2026

Abstract: *This study investigates the enhancement of mechanical properties of Aluminium 7075 alloy by incorporating Gula clay and soot as reinforcements for ballistic application. Aluminium 7075, widely used in aerospace, defense, and automotive industries, is known for its excellent strength-to-weight ratio but requires improved impact resistance and tensile properties for advanced ballistic applications. The research involves systematically varying the composition of Gula clay (1 - 5wt.%) at constant amount of 2wt.% soot to produce six distinct samples through liquid metallurgy and heat treatment processes. Microstructural analysis, Mechanical tests, including Vickers micro-hardness, tensile strength, impact resistance, total elongation, and wear resistance, were conducted to evaluate the composite properties. Based on the obtained optical micrographs, dendritic structure, and Zn – Al rich matrix of unreinforced Al7075 was vividly seen, the reinforced Al7075 consist of both primary matrix of Zn – rich phase, Al – rich secondary phase with uniform distribution reinforcements in the Al7076 alloy. It was observed that as the volume of Gula clay was increased, the dendritic structure of Al7075 was covered with the reinforcement. The mechanical tests results revealed that the addition of Gula clay in the range of 1 – 5 wt.% and at 2wt.% soot enhances tensile strength from 186 MPa (aluminium 7075) to 269 MPa (44.6% increment), while impact resistance improves from 17.6J to 34J (48% improvement), the wear resistance of Al7075 was enhanced by 81%. But there was a gradual marginal decrease in the ductility of Al7075 from 3.4 – 10.9%. The improved properties demonstrate the potential of this composite material to meet international standards for ballistic applications. These findings fill a significant gap in lightweight, cost-effective ballistic materials, providing an alternative to conventional alloys. This research contributes to the development of advanced materials for military applications while promoting the use of sustainable reinforcements*

Key words: Al 7075, Gula Clay, Soot, enhancement and military application

1 Introduction

There is a continuous interest among researchers to develop aluminium matrix composites with high strength to light weight, stiffness, and good wear resistance material for the structural applications, especially for aerospace and automobile engineering

(Takahashi *et al.*, 2002; Jiejun *et al.*, 2003; Previtali *et al.*, 2008; Sreenivasan *et al.*, 2011).

Aluminium 7075 is popularly known as one of the most versatile and high-performance aluminium alloys owing to its excellent mechanical properties. It belongs to the 7 series of aluminium alloys, which are having high strength-to-weight ratio. Its main alloying

elements are zinc, magnesium, copper, and trace amounts of other elements which improve its strength and toughness. This alloy is widely used in aerospace, automotive, and defense industries due to its lightweight and durability (Davis,1999). Aluminium 7075 has been found to be very useful in ballistic applications due to its ability to absorb impact energy effectively.

Researchers such as (Balos *et al.*, 2021) showed that aluminium alloys in the 7 series exhibit excellent deformation characteristics under high-velocity impact conditions. These properties position them as appropriate material for lightweight armour systems that need a balance between mobility and protection. The addition of clay into aluminium 7075 composites improves material performance and also cut down production costs by reducing the reliance on costly synthetic reinforcements (Khan and McNally, 2023).The needed characteristics of Al7075 are increased by adding hard ceramic particles into the aluminium alloy (Vintila *et al.*, 2011; Wu *et al.*, 2014).

Past researches have showed that clay-based reinforcements increase the hardness and toughness of metal matrices, which are vital factors in resisting high-velocity impacts (Bilinski and Syduzzaman, 2022). Previous studies have demonstrated that the addition of clay into Al7075 can enhance grain refinement, which consequently increases the impact resistance of the material (Balos *et al.*,2021). The incorporation of clay particles into Al7075 improves the energy absorption capacity of the composite by improving its hardness and toughness. This makes Al7075 to withstand high-energy impacts without catastrophic failure, making it an ideal material for ballistic applications (Tsiorgianis *et al.*, 2024).

Addition of soot (carbon-based particles) as reinforcement to A7075 alloy (Al-Zn-Mg-Cu alloy) can significantly influence its mechanical properties, microstructure, wear behavior. Soot particles (nano – or micro – size carbon) act as nucleation sites during solidification leading to grain refinement of the aluminum matrix, producing a finer and more uniform grain structure. Finer grains improve strength and ductility balance due to the Hall – Petch effect. Hard carbon particles hinder dislocation movement within the aluminum matrix, which results in increased hardness and strength, especially when soot is well dispersed (Zhang *et al.*,2019). Soot particles are primarily composed of amorphous carbon, with a small proportion of crystalline structures. Their nano scale size provides a high surface area, enhancing their interaction with metallic matrices. According to (Singh *et al.*,2020), Preliminary research by Agboola *et al.*, 2020, investigated the mechanical properties of aluminium-clay composites, concluding that fine clay

particles considerably increased the hardness of the material. In the same way, (Eze *et al.*,2022) showed that carbon-based reinforcements such as soot could enhance the tensile strength of aluminium alloys. However, both studies observed difficulties in achieving uniform dispersion and compatibility, suggesting the need for optimization. The main intention was to enhance hardness, tensile strength, and fatigue resistance, which is crucial for aerospace applications. Findings from the studies showed that Solution-treated samples exhibited a homogenized microstructure with improved ductility, artificial aging resulted in the formation of fine precipitates, significantly enhancing tensile strength and hardness. Doel and Bowen (1996) fabricated Al7075/SiC (5, 13 and 60 μm) composites and concluded that tensile strength was improved for 5 and 13 μm SiC particles than that of base alloy. (Fatile *et al.*, 2017) fabricated the Al7075 composites with carbon-coated silver nanoparticles and concluded that Vickers micro hardness (HVN) values were higher at higher Ag-CNP contents. Baradeswaran and Elaya Perumal (2013) developed the Al7075 hybrid metal matrix composite through stir casting method. The results exhibited improvement in hardness, ultimate tensile strength, and flexural strength. (Suresh *et al.*, 2017) presented the mechanical and physical properties of the Al/Al7075 two-phase material and concluded that the tensile and compression strength increased and ductility decreased when decreasing base powder. (Su *et al.*, 2004) developed the Al7075 composite reinforced with SiC and studied the relationship between true stress and true strain. The use of clay as a reinforcing agent in metal matrix composites has been explored in various studies (Angadi *et al.*, 2024) showed that incorporating clay particles into aluminium alloys improved the hardness and wear resistance of the resulting composite. However, they noted that achieving uniform particle dispersion was a challenge. The target of this research is to assess the enhancement of mechanical properties of Al7075 using 1–5 wt.% Gula clay and constant amount of 2 wt.% soot for military applications.

2 Materials and Methods

2.1 Experimental Materials

Materials used in this research are block Aluminium 7075, soot and Gula clay. The Gula clay was locally sourced from Gula village in Shafa local government area of Southern Borno, soot was generated in Biu, Biu local government area of Borno State and the Aluminium7075 was procured from Lagos State, Nigeria.

2.2 Methods

2.2.1 Preparation of Aluminium 7075 and Charge Calculation

Aluminium 7075 (Al7075), a high-strength aluminium alloy, was selected as the base material for this research due to its excellent mechanical properties and suitability for ballistic applications. The preparation process was meticulously carried out to ensure the alloy met the requirements for experimental reinforcement with soot and Gula clay.

2.2.2 Soaking and Initial Purification

To begin the preparation process, an adequate amount of raw Gula clay was collected and soaked in water for three days. This soaking step served multiple purposes, including softening the clay, removing soluble impurities, and reducing its iron content. Excessive iron can adversely affect the mechanical properties of aluminium composites, as it tends to form brittle intermetallic phases (Mukhopadhyay and Karmakar, 2019). During the soaking phase, impurities such as organic matter, soluble salts, and coarse particles settled or dissolved into the water. After the initial soaking, the clay was sieved using a mesh with 150 μ m aperture size. This sieving step was critical in eliminating larger particles, stones, and debris from the clay matrix. Removing these impurities was essential for ensuring the final clay reinforcement would be homogeneously distributed within the aluminium alloy during composite fabrication. According to (Agboola *et al.*, 2020), the removal of coarse particles enhances the binding efficiency and mechanical reinforcement properties of clay materials.

2.2.3 Melting and Casting Process

The Al7075 alloy was procured in solid block form, cut in to small sizes, weighed on digital weighing balance (3 decimal places) based on preliminary charge calculations, and melted using pit melting furnace. The melting temperature was carefully maintained between 680°C and 700°C, as recommended by (Alu *et al.*, 2018), to ensure complete liquefaction without causing oxidation or degradation of the alloy's properties. This temperature range was determined based on the melting point of aluminium and its alloying elements, such as zinc and magnesium. Once the alloy reached its molten state, it was poured into a sand mould, which was specifically designed to produce narrow, elongated castings. This casting design was selected to facilitate subsequent size reduction and particle refinement. The molten alloy was allowed to cool and solidify under ambient conditions. This cooling process was monitored to avoid rapid cooling, which could lead to thermal stresses and defects in the microstructure (Davis, 1999). For the reinforced samples, varying

amounts of Gula clay (1–5 wt.%) with a constant amount of 2wt.% soot (soot quantity \leq 2wt.% improves the microstructure and mechanical properties of Al7075 (Rao *et al.*, 2021)) were added to the molten aluminium in the furnace. The mixture was stirred vigorously to promote uniform particle distribution. This step is critical, as uneven dispersion of reinforcement particles can result in material inconsistencies and localized weak points (Ikubanni *et al.*, 2022).

To create a range of samples, different amounts of Gula clay were weighed in increments from 1wt. % to 5wt. %, at interval of 1wt. %. The subsequent samples followed a similar procedure, with aluminium weight decreasing by 1wt.% for each sample while the Gula clay content increased by 1wt.%. The process continued until the final sample was produced,

This incremental variation allowed for the systematic evaluation of the effect of Gula clay content on the composite's mechanical properties.

2.2.4 Solution Heat Treatment at 550°C for 1 Hour

The samples were heated in the muffle furnace and subjected to a solution heat treatment at 550°C for one hour. During this phase, the aluminium matrix dissolved alloying elements such as zinc, magnesium, and copper into a supersaturated solid solution. Rapid cooling after solution treatment "freezes" the solute atoms in place, setting the stage for subsequent precipitation during aging (Mishra *et al.*, 2020).

2.2.5 Artificial Aging at 130°C for 3 Hours

Each selected sample was placed in an oven preheated to 130°C for duration of three hours. This stage facilitated the initial precipitation of secondary phases such as (MgZn₂) within the aluminium matrix, which strengthens the alloy by impeding dislocation movement (Lumley *et al.*, 2009). The uniform heat distribution in the oven ensured consistent aging throughout the sample.

3 Results and Discussion

3.1 Optical Microstructural Analysis Results

Figures 1(a – f) display optical micrographs of hybrid composites having varied proportions of Gula clay (1 to 5wt.%), constant amount of 2wt.% soot and the base metal is Al7075. The Zn - Al rich matrix was present. It is observed that the distributions of the overall reinforcements were uniformly distributed. One can see the reinforcement that is present inside matrix. The distribution of the reinforcements in the Al7075 phases (Al - rich phase and Zn - rich phase) largely covers the dendritic grain structure of typical Al7075 as the Gula clay content increases (Fatile *et al.*, 2017)

Each Micrograph shows no noticeable structural damage and none of the samples exhibited clustering of reinforcements in the matrix. There was a great dispersion of reinforcements as they moved across the matrix. There is a strong bond between the matrix material and reinforcements. The fine particles of Gula clay and the ultra-fine soot, enhances the binding

efficiency (Agboola *et al*, 2020). Increase in the quantity of reinforcing materials in the base matrix led to a reduction in the grain size. In each of the composite, the primary phase of the microstructure was determined to be Al, and it was followed by nucleation of $MgZn_2$ and Al_2CuMg precipitates. Both could be found in the intervals between the dendrites (Angadi *et al.*, 2024).

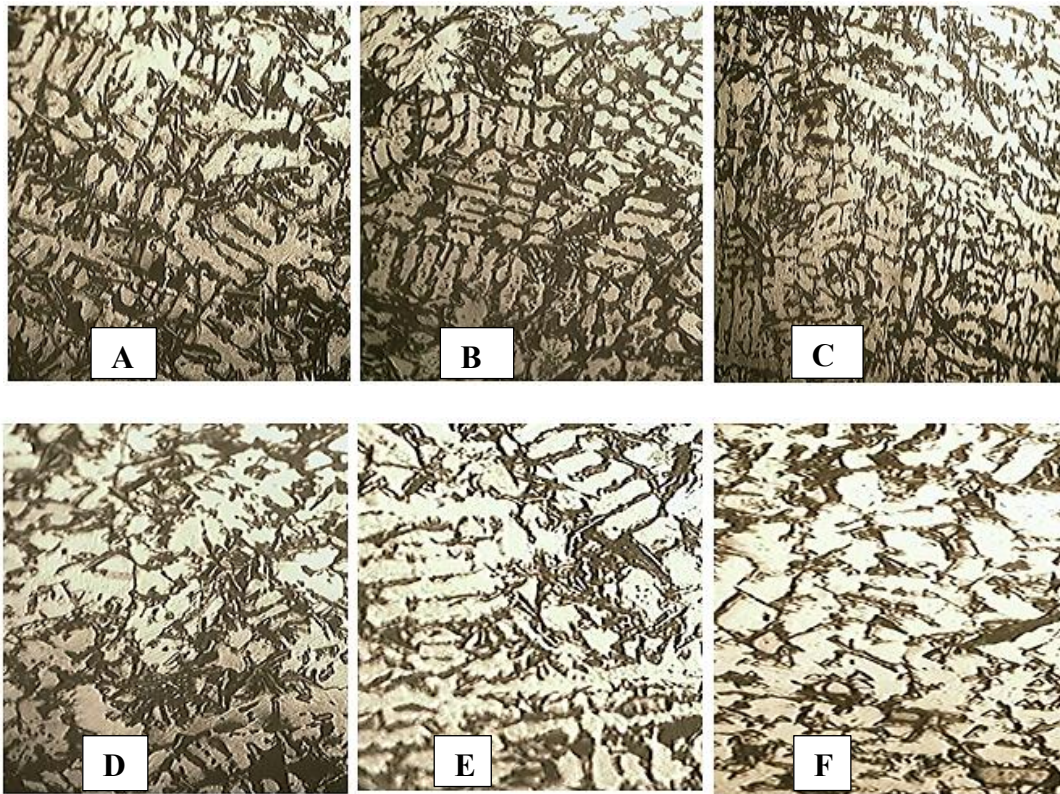


Figure 1: (a) As – Received Al7075 (b): 1wt. % Gula clay + 2wt. % Soot + Al7075 (c): 2wt. % Gula clay + 2wt. % Soot + Al7075. (d): 3wt % Gula clay + 2wt. % Soot + Al7075 (e): 4 wt. % Gula clay + 2 wt. % Soot + Al7075 (f): 5wt% Gula clay + 2wt. %Soot + Al7075

3.2 Hardness Test Results

Hard Gula clay and soot is included into the mixture, resulting in a progressive rise in the hardness values of the samples from 136HV to 187 HV showing that 37.5% improvement in hardness of Al7075 was achieved as shown in Figure 2. Controlled soot addition (less or equal 2 wt. %) can increase hardness, wear resistance, and microstructural stability but excessive or uneven soot can reduce tensile properties (Ravikumar, *et al.*, 2018). The effect of clay on the hardness of Al7075 depends on how the clay is introduced, the type of clay, dispersion of clay particles in the Al7075 matrix, and, adding clay particles into Al7075. The results of this study emphasized the proportionate increase in

hardness that occurs with increasing Gula clay at 2wt. % soot particle reinforcement in the Al7075 metal matrix composite. During the casting process, the molten aluminium 7075 undergoes solidification, a phase transformation from liquid to solid. The rate of solidification and the presence of reinforcements (1 - 5wt.% Gula clay and 2wt.% soot) influence the microstructure of the alloy. According to the theory of grain refinement, the addition of fine particles during solidification promotes heterogeneous nucleation, resulting in a finer grain structure and improvement in hardness (Suresh and Srivastava 2018).

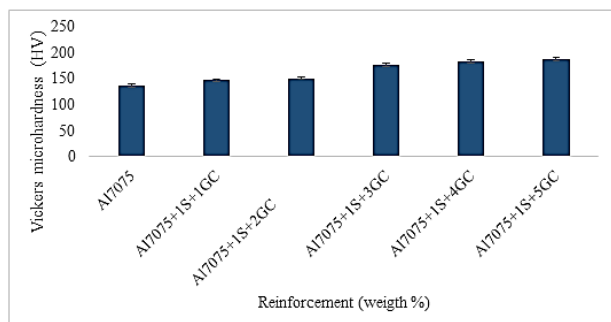


Figure 2: Hardness of Gula Clay at 2wt. % Soot Reinforced Al7075 Composite

3.3 Impact Energy Results

Figure 3 shows the influence of varying amount of Gula clay at 2wt.% of soot on Al7075 Composite.

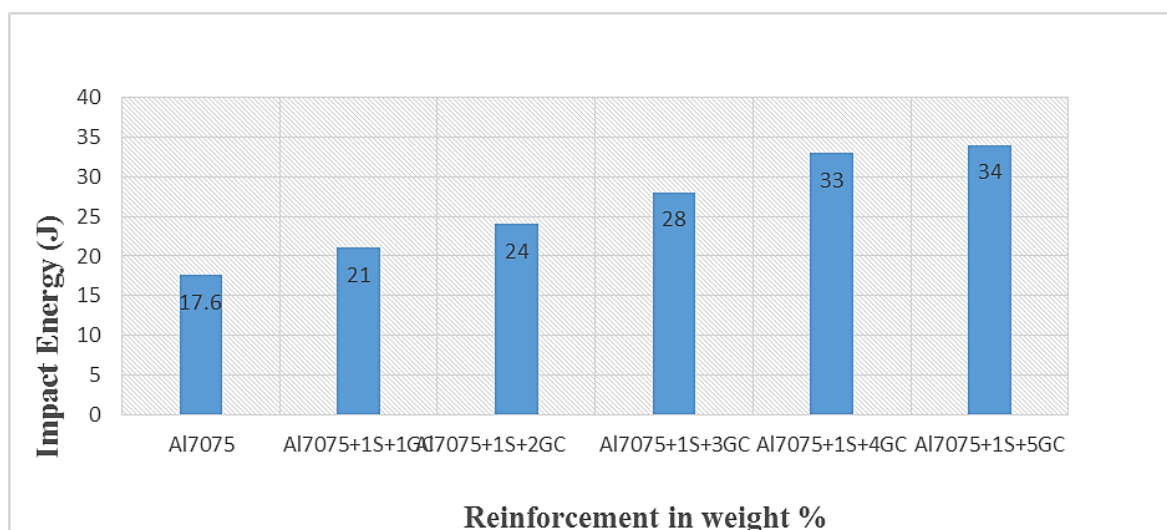


Figure 3: Impact Resistance of Gula Clay at 2wt. % Soot Reinforced Al7075 Composite

3.4 Wear Rate Results

Figure 4 represents the material lost due to wear for each sample. The worn mass generally decreases as the Gula clay content increases from 1wt.% to 5wt.% at constant amount of 2wt.% soot in the Al7075 matrix. The mass loss varies from 0.0259g to 0.005g (81% enhancement), suggesting better wear resistance. The mass loss which is directly related to wear rate reduces with clay content, confirming that clay additions in the range of 1 – 5wt.% at 2wt.% soot lead to greater wear resistance of Al7075. This is due to the fact that clay as a natural alumino-silicate material composed of SiO_2 , Al_2O_3 and Fe_2O_3 when used as a reinforcement in Al7075 matrix composites, it can acts as solid

lubricant and wear barrier, improving load bearing ability and reduce both adhesive and abrasive wear mechanism. Clay particles increase the surface hardness of the Al7075 matrix, reduce material loss during sliding. In addition, fine Gula clay particles distribute the load more evenly, minimizing localized deformation. It forms a tribo – layer on the contact surface, reducing metal to metal contact (Suresh, and Srivastava, 2018).

lubricant and wear barrier, improving load bearing ability and reduce both adhesive and abrasive wear mechanism. Clay particles increase the surface hardness of the Al7075 matrix, reduce material loss during sliding. In addition, fine Gula clay particles distribute the load more evenly, minimizing localized deformation. It forms a tribo – layer on the contact surface, reducing metal to metal contact (Suresh, and Srivastava, 2018).

3.5 Percentage Elongation Results

Figure 4 showed the Mass Loss of Gula Clay at 2 wt.% Soot Reinforced Al7075 Composite. The ductility (% elongation) tends to decreases gradually as the Gula

clay content in the Al7075 was increased from 1 – 5wt.%. The decrease in percentage elongation is due to the ceramic reinforcement which reduces the overall ductility of the composite, which is a trade-off commonly observed in metal matrix composites (MMCs) (Kumar et al., 2020). However, the decreases

are marginal (3.4%, 4.74%, 6.16%, 8.53% and 10.9% respectively). The result obtained is of similar trends with the work reported on aluminium composites, showing that ductility decreases with increasing reinforcement (Khan, and McNally, 2023).

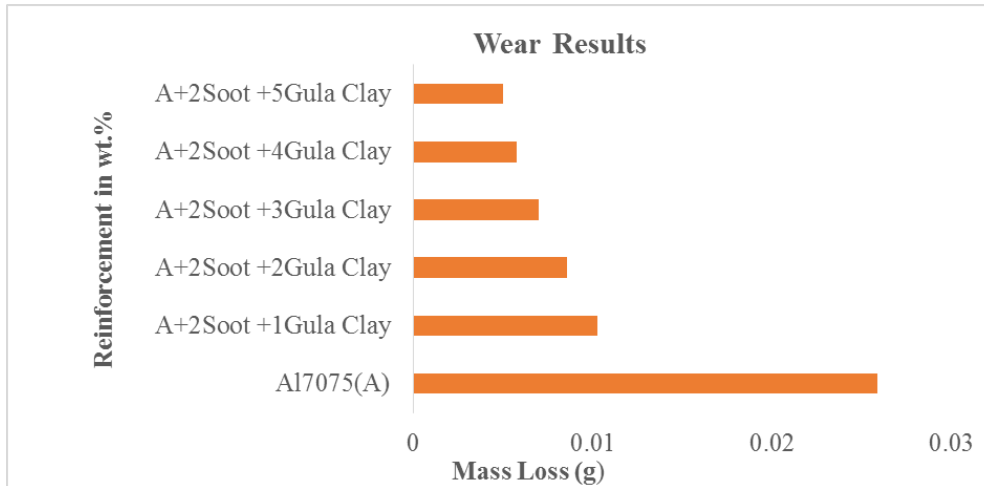


Figure 4: Mass Loss of Gula Clay at Soot Reinforced Al7075 Composite

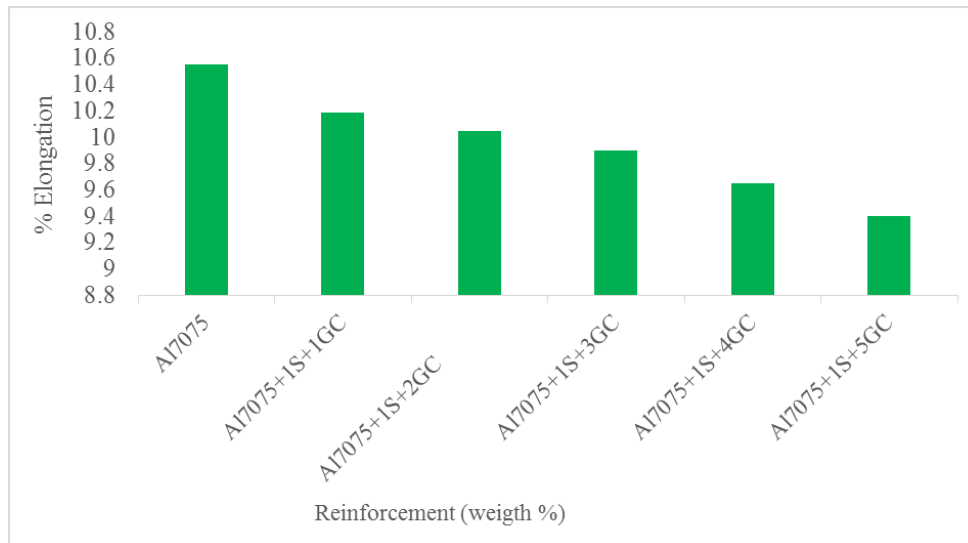


Figure 5: % Elongation of Gula Clay at 2wt. % Soot Reinforced Al7075 Composite

3.6 Tensile Strength Result

Figure 6 illustrates the ultimate tensile strength (UTS) of the material with varying percentages of Gula clay and soot. In the presence of 0 – 5wt. % addition of Gula clay and soot, there is an observable increase in UTS values, which range from 186 MPa to 269 MPa, for the unreinforced Al7075 and Gula clay and soot

reinforced Al7075. This implies that 44.6% improvement in ultimate tensile strength of Al7075.

This consistent increase in tensile strength of the reinforced Al7075 composite indicates that Gula clay within the range of (1 - 5wt.%), at A constant 2wt.% soot plays an important role in determining the mechanical characteristics of the composite, notably is increase in its tensile strength. Incorporating different amounts of Gula clay at constant 2wt.% soot into the Al7075 has a favourable influence on the ultimate

tensile strength of Al7075. The fine and closely packed arrangement of Gula clay and soot particles in the Al7075 are responsible for the increased strength. This arrangement also helps to reinforce the molecular strength in the aluminium lattice for the composites. The strengthening effect of the composites is based on the presence of hard reinforcement particles (fine particulate of Gula clay and ultra – fine soot). In aluminium alloy composite, the ceramic particles (Gula clay and soot) are homogeneously and uniformly distributed, thereby, acted as a block off for

dislocation motion of matrix alloy, the addition of ceramic particles mainly improves the affecting tensile strength of composite by stress transfer from the aluminium matrix (ductile phase) to the reinforced (brittle) particles. This is achieved by Orowan mechanism by which a dislocation bypasses heavy obstacles where a dislocation restricted around a particle. This result is in accordance with the findings of (Murali et al., 2014 and Sambathkumar et al., 2014).

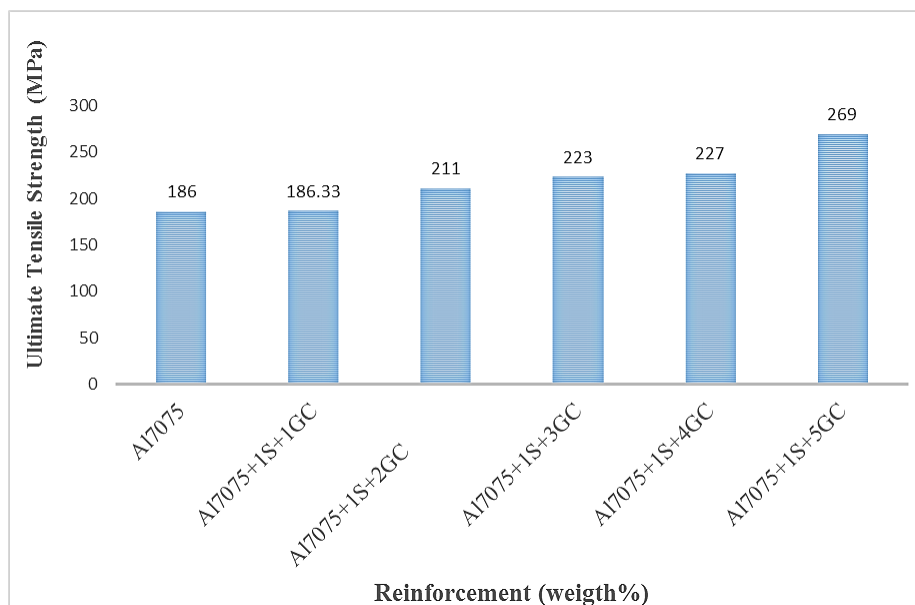


Figure 6: Ultimate Tensile Strength of Gula Clay at 2wt. % Soot Reinforced Al7075 Composite

4 Conclusion

Based on the experimental results, it can be concluded that:

1. Al7075 was successfully reinforced with 1 – 5 wt.% of Gula clay and 2wt.% soot through stir – sand casting technique.
2. Optical micrographs of the produced samples consist of Zn – Al rich (primary and secondary soft phases) matrix with uniformly distributed (hard phase) fine particulate of Gula clay and ultra-fine soot.
3. The hardness property of Al7075 was improved by 37.5%.
4. The impact strength of Al7075 was increased by 48% at the maximum weight of 5wt.% Gula clay and 2wt.% soot.
5. Wear resistance of Al7075 was enhanced by 81%

6. There was a marginal reduction in ductility of Al7075 by 3.4 to 10.9%.
7. The tensile strength of Al7075 was improved by 44.6%.
8. The interplay of soot and Gula clay enhanced the microstructural and mechanical properties of Al7075 alloy for ballistic protection material application.

References

- Agboola, O., Fayomi, O. S. I., and Popoola, A. P. I. (2020). Processing and Characterization of Clay-Reinforced Aluminium Composites for Structural Applications. *Journal of King Saud University - Engineering Sciences*, 32(3), pp.189–196.
- Angadi S., Pidaparthi, M., Bhavanasi S., Kumar, S., and Navdeep, S., (2024). Investigating the Mechanical Properties of Al7075 Metal Matrix

- Composite with Improved Performance through the Incorporation of Fe₃O₄ and RHS. MATEC Web of conferences, 392, pp. 01025
- Balos, S., Rajnovic, D., and Sidjanin, L., (2021). Enhancing the Mechanical Properties of Aluminium Alloys for Ballistic Applications using Natural Reinforcements. *Materials and Design*, 210, pp.110045.
- Baradeswaran, A., Elaya Perumal, A., (2013). Influence of B₄C on the Tribological and Mechanical Properties of Al 7075–B₄C Composites. *Composites Part B: Engineering*, 54(0), pp.146-152
- Bilinski, P., and Syduzzaman, M., (2022). *Lightweight Materials for Ballistic Applications: A review of Aluminium Alloys and Composites. *Journal of Defense*
- Davis, J. R. (1999). *Heat Treatment of Aluminium Alloys: Principles and Practices*. ASM International.
- Fatile B. O. Adewuyi, B.O., and Owoyemi H. T., (2017). Synthesis and Characterization of ZA – 27 alloy matrix Composites Reinforced with Zinc Oxide Nanoparticles *Journal of Engineering Science and Technology*, 20, Pp.1147 – 1154.
- Ikubanni, P. P., Oki, M., and Adeleke, A. A., (2022). Pulverization and Sieving of Natural Clay for Reinforcement in Aluminium Composites. *Materials Today: Proceedings*, 38, pp.1234 - 1240.
- Jiejun, W., Chenggong, L., Dianbin, W., and Manchang, G., (2003). Damping and Sound Absorption Properties of Particle Reinforced Al Matrix Composite Foams. *Composites Science and Technology* 63(3), pp. 569-574.
- Khan, M. A., & McNally, T., (2023). Sustainable Materials for Defence Applications: A Review of Natural Reinforcements in Metal Matrix Composites. *Sustainable Materials and Technologies*, 35, pp.00512.
- Kumar. R., Senthilkumar, T., and Prakash, S., (2020). Effect of Carbon Soot Reinforcement on Mechanical and Tribological Properties of Al7075 Matrix Composites. *Materials Today: Proceedings*, 27, pp.2420 – 2426.
- Lumley, R. N., Polmear, I. J., and Morton, A. J., (2009). Heat Treatment of Aluminium Alloys for Aerospace Applications. *Materials Science and Engineering: A*, 500(1–2), pp.20–28.
- Mishra, R. S., Ma, Z. Y., and Charit, I., (2020). Heat Treatment of Aluminium Alloys for Enhanced Mechanical Properties. *Progress in Materials Science*, 110, pp.100634.
- Mukhopadhyay, P., and Karmakar, S. (2019). Iron Content and its Effect on the Mechanical Properties of aluminium alloys. *Journal of Alloys and Compounds*, 780, pp.123–130.
- Murali, M., Sambathkumar, M., and Saravanan, M. S., (2014). Micro Structural and Mechanical Properties of AA 7075/TiO₂ InSitu Composites. *Universal Journal of Materials Science*, 2(3), Pp.49-53.
- Previtali, B., Pocci, D., Taccardo, C., (2008). Application of traditional investment casting process to aluminium matrix composites. *Composites Part A: Applied Science and Manufacturing*, 39(10), pp.1606-1617
- Rao, R. N., Das, S., and Mondal, D. P., (2021). Effect of Ceramic Reinforcements on the Yield Strength of Aluminium Composites. *Materials Science and Engineering: A*, 800, pp.140345.
- Ravikumar, K., Senthilkumar, T., and Babu S. P., (2018). Microstructure and Mechanical Characterization of Al7075 Hybrid Composites Reinforced with Carbon – based particles. *Journal of Alloys and Compounds*, 735, pp.2215 – 2223.
- Singh, R., Kumar, A., and Sharma, V., (2020). Effect of Soot Reinforcement on the Mechanical Properties of Aluminium Composites. *Journal of Materials Science*, 55(14), pp.5678–5690.
- Su, Y. H. F., Chen, Y. C., Tsao, C. Y. A., (2004). Workability of Spray-Formed 7075 Al Alloy Reinforced with SiCp at Elevated Temperatures. *Materials Science and Engineering: A* 364(1–2), pp.296-304.
- Suresh S., Kumar, M. S., and Jayavel. R., (2017). Tribological Behaviour of Al7075 – Clay Hybrid Composites Prepared by Stir Casting. *Materials Today Proceedings*, 4(2), pp.2574 – 2580..
- Suresh, S., and Srivastava, V. C., (2018). Wear and Friction Behaviour of Al7075 - Clay Particulate Composites, *Materials Today. Proceedings*, 5(2), pp.7721 – 7727
- Takahashi, K., Kitade, S., and Morita, H., (2002). Development of High Speed Composite Flywheel Rotors for Energy Storage Systems.

- Advanced Composite Materials, 11(1), pp. 40-49.
- Vintila, R., Charest, A., Drew, R., and Brochu, M., (2011). Synthesis and Consolidation via Spark Plasma Sintering of Nanostructured Al-5356/B4C Composite. *Materials Science and Engineering: A* 528(13), pp. 4395-4407.
- Wu, C., Fang, P., Luo, G., Chen, F., Shen, Q., Zhang, L., and Lavernia, E. J., (2014). Effect of Plasma Activated Sintering Parameters on Microstructure and Mechanical Properties of Al-7075/B4C Composites. *Journal of Alloys and Compounds* 615, pp.276-282.
- Zhang, Y., Zhao, X., Zhang, and Li, X., (2019). *Effect of reinforcement distribution on the hardness of aluminium composites. *Journal of Alloys and Compounds*, 740, pp.123–130