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Experimental Analysis of Mechanical Properties of Aluminium 7075 Using Al_2O_3 Reinforcement

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ABSTRACT

This project focuses on the Experimental Analysis of Mechanical Properties of Aluminium 7075 by incorporating Al_2O_3 (Aluminium Oxide) reinforcement particles. Aluminium 7075 is widely favoured in aerospace and automotive sectors for its high strength-to-weight ratio; however, its relatively low wear resistance and hardness limit its use in high-friction environments. To address these limitations, metal matrix composites (MMCs) were fabricated using the stir casting process, with reinforcement levels varying from 2 wt.% to 10 wt.%. The mechanical performance of the samples was evaluated through wear testing, as well as Charpy and Izod impact tests. Results indicated that the addition of Al_2O_3 significantly enhanced the wear resistance of the alloy due to the hard ceramic phase resisting surface abrasion. Conversely, impact strength showed a slight decline as reinforcement increased, reflecting a transition toward more brittle behaviour. Microstructural analysis confirmed a fairly uniform distribution of particles at moderate reinforcement levels. The study concluded that an optimum reinforcement level of 6 wt.% Al_2O_3 provides the most effective balance between enhanced wear resistance and maintained impact toughness. These findings suggest that the developed composite is a viable candidate for high-strength, wear-resistant structural applications.

Keywords: Aluminium 7075, Al_2O_3, Metal Matrix Composite (MMC), Stir Casting, Wear Resistance, Impact Strength, Experimentation.

1. INTRODUCTION

In modern engineering applications, materials with superior mechanical properties, high strength-to-weight ratio, and excellent corrosion resistance are in great demand. Among lightweight materials, aluminium and its alloys are the most widely used due to their outstanding combination of low density, good formability, and adequate mechanical strength. Aluminium alloys are increasingly replacing traditional materials such as steel in the aerospace, automotive, and marine sectors to achieve weight reduction and improved fuel efficiency without compromising structural integrity. Among various aluminium alloys, Aluminium 7075 has gained particular attention because of its exceptional strength and favourable mechanical characteristics. It belongs to the 7xxx series of aluminium alloys, in which zinc is the primary alloying element, along with smaller amounts of magnesium, copper, and chromium. This alloy exhibits a very high strength-to-weight ratio, good fatigue resistance, and excellent machinability, making it suitable for critical components such as aircraft fittings, gears, shafts, and high- stress structural parts. The combination of low

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density and high tensile strength makes Aluminium 7075 one of the strongest commercially available aluminium alloys.

Despite its superior mechanical properties, Aluminium 7075 still faces limitations in certain engineering applications. Its wear resistance, hardness, and performance at elevated temperatures are relatively low when compared to other structural materials. These drawbacks restrict its use in environments that involve high friction, abrasion, or thermal stresses. To overcome these shortcomings and extend the application range of Aluminium 7075, researchers have focused on the development of metal matrix composites (MMCs) - materials that combine a ductile metal matrix with hard ceramic reinforcements.

Metal matrix composites have emerged as an important class of advanced engineering materials because they exhibit a unique combination of properties that cannot be achieved by conventional alloys. By incorporating hard ceramic particles into the metal matrix, it is possible to enhance the stiffness, hardness, wear resistance, and strength of the base metal while maintaining its lightweight nature. Among various ceramic reinforcements, aluminium oxide (Al_2O_3) has been extensively used due to its excellent hardness, high melting point, good thermal stability, and chemical compatibility with aluminium matrices.

The incorporation of Al_2O_3 particles into the Aluminium 7075 matrix leads to the formation of a composite material with improved mechanical and tribological characteristics. The uniform dispersion of Al_2O_3 particles within the matrix acts as a barrier to dislocation motion, which strengthens the material through a mechanism known as dispersion strengthening. The hard ceramic particles also improve wear resistance by reducing surface deformation and material removal under frictional contact. Furthermore, Al_2O_3 has a relatively low density compared to other ceramic materials, which helps maintain the lightweight advantage of the aluminium matrix.

Several processing techniques have been employed to fabricate Aluminium 7075–Al_2O_3 composites, including stir casting, powder metallurgy, squeeze casting, and friction stir processing. Among these, stir casting is widely preferred for its simplicity, cost-effectiveness, and ability to produce near-net-shape components. However, achieving a uniform distribution of reinforcement particles remains a major challenge due to particle agglomeration and poor wettability between the ceramic and metal phases. Therefore, careful control of processing parameters such as stirring speed, temperature, and reinforcement percentage is essential to obtain composites with superior mechanical properties.

Previous studies have demonstrated that the addition of Al_2O_3 significantly enhances the hardness and tensile strength of Aluminium 7075 up to an optimal reinforcement level, typically between 5–10% by weight. Beyond this range, excessive particle clustering and porosity can lead to a reduction in ductility and impact strength. Therefore, optimization of reinforcement parameters — including particle size, weight fraction, and dispersion method plays a crucial role in achieving the desired balance between strength and toughness.

Objective

The main aim of this project is to develop and evaluate Aluminium 7075–Al_2O_3 metal matrix composites with enhanced mechanical properties. The specific objectives are as follows:

1. To fabricate Aluminium 7075 matrix composites reinforced with varying weight percentages of aluminium oxide (Al_2O_3) using the stir casting process.
2. To analyze the mechanical properties of the fabricated composites, including: Wear resistance, Impact Strength.
3. To determine the influence of Al_2O_3 content on the overall mechanical performance of the composite material.

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4. To identify the optimum composition and processing parameters of Al_2O_3 reinforcement for achieving the best balance between strength, hardness, and ductility.

2. METHODOLOGY

The methodology adopted in this study involves systematic steps for the fabrication, testing, and evaluation of Aluminium 7075–Al_2O_3 metal matrix composites.

1. Selection of Material
2. Weighing and Preheating of Al7075 & Al_2O_3
3. Stir Casting Process
4. Casting into Mould
5. Specimen Preparation (ASTM Standards) 6.Mechanical Testing (Wear, Impact)

2.1 Selection of Materials

Aluminium 7075 is selected as the base matrix material due to its high strength-to-weight ratio, good fatigue resistance, and wide industrial applications. Aluminium oxide (Al_2O_3) is chosen as the reinforcement material owing to its high hardness, excellent wear resistance, and thermal stability, making it suitable for improving the mechanical properties of the composite.

2.2 Weighing and Preheating of Materials

The required quantities of Aluminium 7075 alloy and Al_2O_3 particles are calculated based on selected weight percentages (e.g., 2%, 4%, 6%, etc.). Both the matrix and reinforcement materials are preheated to appropriate temperatures:

1. To remove moisture content.
2. To enhance wettability between matrix and reinforcement
3. To reduce thermal gradients during mixing

2.3 Stir Casting Process

The stir casting technique is employed for composite fabrication due to its simplicity and cost-effectiveness. The procedure includes:

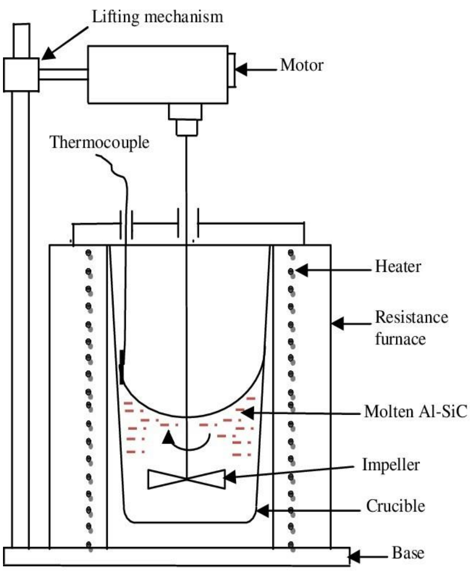

Fig.3.3a Stir Casting Process

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1. Melting Aluminium 7075 in a crucible furnace at a temperature of approximately 700–750°C
2. Preheating Al_2O_3 particles to improve bonding 3.Introducing the reinforcement particles into the molten metal 4.Continuous mechanical stirring at controlled speed (e.g., 300–600 rpm) to ensure uniform dispersion
3. Maintaining proper stirring time to minimize particle agglomeration

2.4 Casting into Mould

The uniformly mixed molten composite is poured into preheated metallic moulds. Controlled solidification conditions are maintained to:

1. Reduce porosity
2. Improve grain structure
3. Achieve better surface finish

2.5 Specimen Preparation

The casted composites are removed from the moulds and machined into standard test specimens as per ASTM standards:

1. Impact test specimens
2. Wear test samples

Proper surface finishing and polishing are carried out before testing.

2.6 Mechanical Testing

The fabricated specimens are subjected to various tests to evaluate their performance:

Wear Test: To determine wear resistance under different loads and sliding conditions

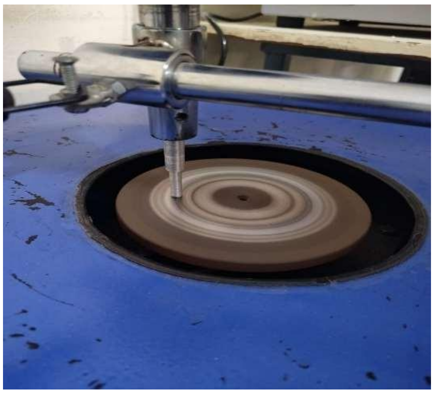

Fig 3.6a Wear Test

Impact Test: To evaluate toughness and energy absorption capacity

Fig 3.6b Impact Test

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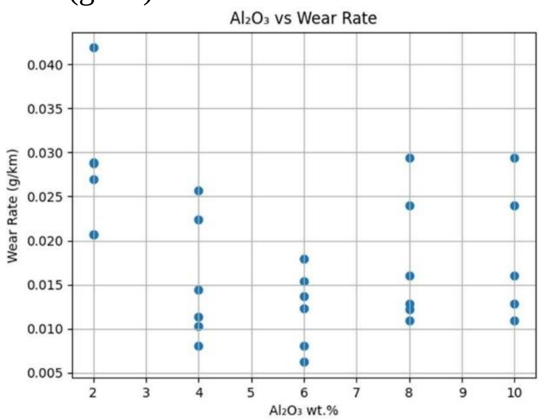
3. RESULT

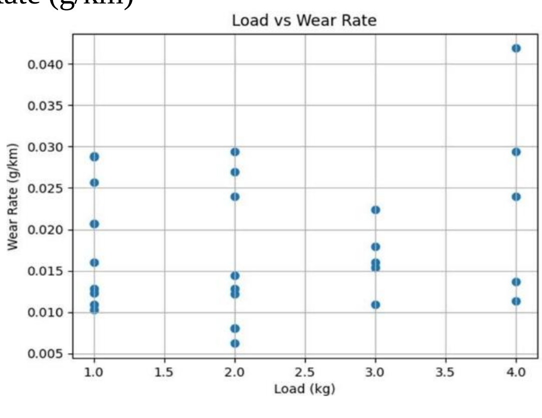
Aluminium 7075–Al_2O_3 composites were successfully fabricated using the stir casting process with fairly uniform particle distribution. Wear resistance improved with increasing Al_2O_3 content up to 6 wt.% due to the high hardness of ceramic particles. However, Charpy and Izod impact strengths showed a slight decrease with higher reinforcement, attributed to reduced ductility and increased brittleness.
An optimum reinforcement of 6 wt.% Al_2O_3 was identified, providing a balanced combination of wear resistance and impact strength. Overall, the addition of Al_2O_3 enhanced the mechanical performance of Aluminium 7075, making it suitable for high- strength and wear-resistant applications.

1. Al_2O_3 wt.% vs Wear Rate (g/km)



The graph shows that wear rate generally decreases with the increase in Al_2O_3 content up to a certain level, due to improved hardness and wear resistance of the composite. However, beyond the optimum percentage, wear rate slightly increases, which may be due to particle agglomeration and poor bonding. Thus, an optimum Al_2O_3 wt.% exists for achieving minimum wear.

2. Load (kg) vs Wear Rate (g/km)



The graph indicates that wear rate increases with increasing applied load, as higher load leads to greater friction and material removal. At lower loads, the wear rate is relatively low due to less contact stress. Hence, load is a significant factor influencing the wear behaviour of the composite.

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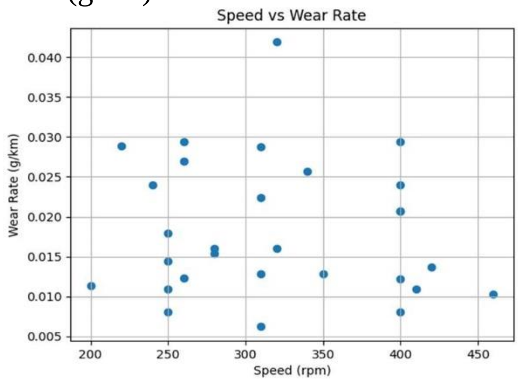
3. Speed (rpm) vs Wear Rate (g/km)



The graph shows a variation in wear rate with sliding distance, where wear initially increases due to surface contact and material removal. As sliding continues, a stable layer may form, reducing the rate of wear slightly. Thus, wear behavior depends on both initial surface conditions and prolonged interaction
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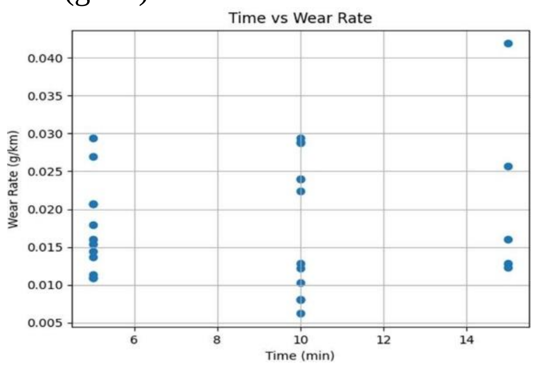
4. Time (min) vs Wear Rate (g/km)



The graph shows that the wear rate of the material generally increases with time. There is some variation at each time interval, but overall, longer exposure leads to higher wear, indicating progressive material degradation over time.

4. CONCLUSION

The present project successfully demonstrated the fabrication and characterization of Aluminium 7075 metal matrix composites reinforced with aluminium oxide (Al_2O_3) particles using the stir casting process. The primary objective was to enhance the mechanical and wear properties of Aluminium 7075 by optimizing the percentage of Al_2O_3 reinforcement.

From this study, it can be concluded that reinforcing Aluminium 7075 with Al_2O_3 particles is an effective method to enhance its mechanical and wear properties. The developed composite material has strong potential for use in aerospace, automotive, and structural applications where lightweight and wear-resistant materials are required.

5. REFERENCES

1. Investigation on Mechanical Properties of Aluminium 7075 – Boron Carbide - Coconut Shell Fly Ash Reinforced Hybrid Metal Matrix Composites - Balasubramani

ISSN: 2945-4565 VOL 05, ISSUE 02, 2026

Subramaniam, Balaji Natarajan, B.Kaliyaperumal, Samson Jerold Samuel Chelladurai

2. Reinforcement and Hot Workability of Aluminium Alloy 7075 Particulate Composites: A Review – Q. M. Azpen, B. T. H. T. Baharudin, S. Shamsuddin, F. Mustapha
3. Evaluation of Mechanical Properties of Aluminium Alloy 7075 Reinforced with Short Coated Carbon Metal Matrix Composites – Jaimon D. Quadros, N. L. Vaishak, Suhas
4. Mechanical and Wear Behaviour of AA7075 Aluminium Matrix Composites Reinforced by Al_2O_3 Nanoparticles – Huda A. Al Salihi, Adil Akram Mahmood, Hussain J. Alalkawi
5. Mechanical Behaviour of Aluminium 7075 Reinforced with Silicon Carbide Particulates – K. Umanath, S. T. Selvamani, K. Palanikumar
6. Fabrication and Mechanical Properties of AA7075–Al_2O_3 Metal Matrix Composites by Stir Casting – P. Senthilkumar, R. Rajesh
7. Study on Wear Behaviour of AA7075 Hybrid Composites Reinforced with B_4C and Graphite – M. Ravichandran, A. Naveen Sait
8. Mechanical and Tribological Properties of Aluminium 7075 Reinforced with Fly Ash Particles – S. Basavarajappa, G. Chandramohan
9. Effect of Reinforcement on Mechanical Properties of AA7075 Metal Matrix Composites - V. C. Uvaraja, N. Natarajan
10. Processing and Characterization of AA7075 Based Metal Matrix Composites Reinforced with Ceramic Particles – A. Baradeswaran, A. Elayaperumal.
11. Godase, M. V., Mulani, A., Ghodak, M. R., Birajadar, M. G., Takale, M. S., & Kolte, M. A MapReduce and Kalman Filter based Secure IIoT Environment in Hadoop. Sanshodhak, Volume 19, June 2024.
12. Mulani, A. O., & Mane, P. B. (2017). Watermarking and cryptography based image authentication on reconfigurable platform. Bulletin of Electrical Engineering and Informatics, 6(2), 181-187.
13. Gadade, B., Mulani, A. O., & Harale, A. D. IoT Based Smart School Bus and Student Tracking System. Sanshodhak, Volume 19, June 2024.
14. Dhanawade, A., Mulani, A. O., & Pise, A. C. IOT based Smart farming using Agri BOT. Sanshodhak, Volume 20, June 2024.
15. Mulani, A., & Mane, P. B. (2016). DWT based robust invisible watermarking. Scholars' Press.
16. R. G. Ghodke, G. B. Birajdar, A.O. Mulani, G.N. Shinde, R.B. Pawar, Design and Development of an Efficient and Cost-Effective surveillance Quadcopter using Arduino, Sanshodhak, Volume 20, June 2024.
17. R. G. Ghodke, G. B. Birajdar, A.O. Mulani, G.N. Shinde, R.B. Pawar, Design and Development of Wireless Controlled ROBOT using Bluetooth Technology, Sanshodhak, Volume 20, June 2024.