Nano-Alumina Merging Action on Practical Characteristics of Aluminium Alloy Series Aa7075 Alloy Composite By Semi-Solid Die Cast Process

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Abstract: Reinforcing aluminum alloys with ceramic nanoparticles is an effective way to increase their mechanical and thermal stability for structural applications. This study evaluates the effects of adding nano alumina on the performance of AA7075 alloy composites made using the semi solid die casting technique. When reinforcement levels of 3, 6 and 9 weight percent were added, the composites' tensile strength, hardness and thermal stability were evaluated using mass loss analysis. The results demonstrated that nWhen reinforcement levels of 3, 6 and 9 weight % were added and the composites' tensile strength, hardness and thermal stability were evaluated using mass loss analysis and the results demonstrated that nano alumina significantly enhanced the composites' hardness and tensile properties while also increasing their heat resistance. ano-alumina significantly enhanced the composites' hardness and tensile properties while also increasing their heat resistance. The 6 weight percent alumina reinforced composite offered the finest compromise between strength and thermal stability. These findings validate the potential of AA7075/nano alumina composites for lightweight vehicle structural frame applications.

# Introduction

Due to the exceptional strength-to-weight ratio and machinability the usage of AA7075 is a high strength aluminum alloy that finds extensive use in the automotive and aerospace sectors. Its employment in crucial lightweight constructions under harsh service conditions is, however, restricted by its weak wear resistance and modest thermal stabilityIts hardness resistance to heat degradation and load bearing capability may all be greatly increased by adding ceramic nanoparticles like alumina [1-3].

There has been a lot of research done on the aluminum alloys because AlO₃ particle reinforcements may improve hardness, wear resistance and fracture toughness [4-7]. The function of micro- and nano sized AlO₃ particles in Al7075 MMCs was investigated and showed notable enhancements in mechanical strength and fracture behavior. [1,2]. By creating Al7075 hybrid composites reinforced with nano-AlO₃ and graphene, expanded this study [8-10]. It was shown that the use of cooling agents further influences wear resistance and [11] shown how processing parameters have a significant impact on microstructural development by introducing additive manufacture of Al–Al₂O₃ composites by friction stir deposition.

Alternative processing pathways and reinforcements have been investigated. They investigated the effects of TiCnanotreatment on the fluidity and solidification behavior of Al6063 alloys and used semi solid reciprocating extrusion to refine microstructures in Al₂O₃/7055 composites [12-13], whereas utilized semisolid stir casting with hybrid fillers to improve functional qualities. Similarly using deformation driven metallurgy by [14-16] created functionally graded AA7075–Al₂O₃ composites obtaining a gradient property distribution appropriate for structural uses.

Researchers [17] studied on Mg based hybrid nanocomposites reinforced with AlO₃ and MoS₂, going beyond pure Al alloys and verifying concurrent increases in strength and tribological performance and [18-20] examined structural changes to oxide layers on Al alloys at the review level emphasizing their importance for corrosion resistance. In their investigation of AlO₃ nanoparticle reinforcement in friction stir-welded AA7075–AA6061 joints, [21] discovered increased joint toughness and strength. An overview of Al hybrid nanocomposites was given and emphasized the materials adaptability for both structural and functional uses [22].

The ultrasonic-aided rheo squeeze casting method created that is one recent development in casting and hybridization techniques that produced homogenous dispersion of nanoparticles in Al6061 composites [23-28]. Finally Sundaraselvan [14] evaluated nanoAl₂O₃ reinforced Mg fly ash nanocomposites demonstrating superior mechanical properties which broadens the scope of ceramic nanoparticle reinforcement into magnesium alloy systems.

The semi solid die casting process provides better particle dispersion, reduced porosity and enhanced matrix reinforcement bonding compared to conventional casting methods and the purpose of this study is to assess how different alumina concentrations affect the tensile strength, hardness and thermal stability of AA7075 composites.

# Materials and Methods

## Materials

The aluminum alloy AA7075 which is well identified for its admirable strength to weight ratio and extensive use in automotive and aerospace constructions was select as basis matrix material. As it has exceptional hardness and thermal stability, nano alumina particles which have an average size of 50 nm were selected as the reinforcing phase and the nanoparticles were warmed to 300 °C prior to integration in command to assurance adequate dispersion and avoid moisture induced flaws [29-31].

A semi solid die casting method was used to create the composite. At around 610 °C the AA7075 alloy was first melted and then ventilated to a semi solid state. After that heated nano alumina particles were added progressively to the semi solid slurry while being mixed for eight minutes at 600 rpm to confirm even dispersion. After that the produced slurry was carefully die cast into steel molds that had been heated beforehand and in order to reduce residual stresses and advance the mechanical qualities of the created composites post casting heat treatment was finally used [32-37].

## Composite Formulations

Four composite formulations were created in order to investigate how the nano-alumina content affected the AA7075 alloys characteristics. Table 1 provides the component information. It was possible to assess the impact of this systematic change in AlO₃ reinforcement (3–9 weight percent) on the density, mechanical properties and surface behavior of the composites based on AA7075 [38-42].

**TABLE 1.** Composite Configurations Table

|  |  |
| --- | --- |
| **Specimen ID** | **Composition** |
| Specimen 1 | AA7075 (Unreinforced) |
| Specimen 2 | AA7075 + 3 wt% Al₂O₃ |
| Specimen 3 | AA7075 + 6 wt% Al₂O₃ |
| Specimen 4 | AA7075 + 9 wt% Al₂O₃ |

Using accepted practices the produced composites were mechanically and thermally characterized:

* Tensile testing: To assess ultimate tensile strength and ductility, standard dog bone specimens are used in accordance with ASTM E8 criteria.
* Hardness Testing: To acquire accurate average results numerous indentations were made throughout each Specimen using a Vickers microhardness tester.
* Thermogravimetric Analysis: To evaluate thermal stability in order to ascertain the temperature at which deterioration begins and the amount of mass retention that remains after a controlled nitrogen atmosphere.

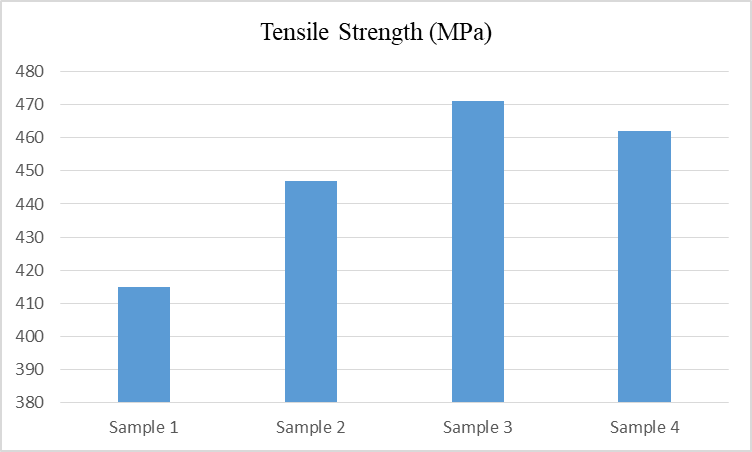
# Results and Discussion

## Tensile Strength

When nano alumina was added the tensile strength of the AA7075/AlO3 composites clearly improved. With reinforcement the base alloy is having 415 MPa gradually climbed to a maximum of 471 MPa at 6 weight percent AlO₃ or a roughly 13% improvement. Grain refinement and efficient load transmission between the matrix and the evenly distributed ceramic particles are responsible for the improvement. A little decrease of 462 MPa was seen at 9 weight % most likely as a result of localized stress concentration and particle clustering which limited further strengthening [43-45].

**TABLE 2**Tensile Strength

|  |  |
| --- | --- |
| Specimen | Tensile Strength (MPa) |
| Specimen 1 | 415 |
| Specimen 2 | 447 |
| Specimen 3 | 471 |
| Specimen 4 | 462 |



**Figure 1.** Tensile Strength

## Hardness

Hardness readings exhibited a consistent rising trend with reinforcing and the HV of the basic alloys increased from 142 to 176 at 9 weight % AlO₃. This significant improvement demonstrates the hardening impact of nano alumina which effectively inhibits dislocation motion and strengthens the matrix by dispersion hardening. In contrast to tensile strength, hardness did not diminish as reinforcement levels increased indicating that clustered alumina particles could still tolerate indentation stresses at 9 weight %.

**TABLE 3.** Hardness

|  |  |
| --- | --- |
| Specimen | Hardness (HV) |
| Specimen 1 | 142 |
| Specimen 2 | 158 |
| Specimen 3 | 171 |
| Specimen 4 | 176 |

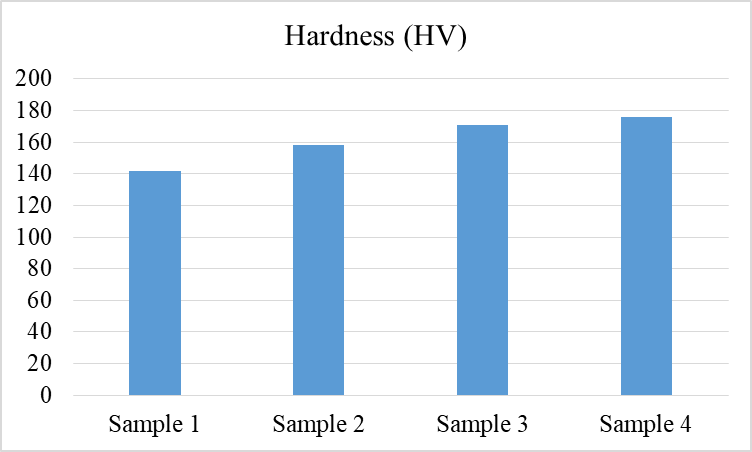


Figure 2. Hardness

## Thermal Mass Loss

Thermogravimetric analysis indicated that the use of nano alumina improved the thermal stability of the composite. At 500°C, the unreinforced AA7075 alloy lost 7.2% of its mass but the 9% reinforced Specimen lost 5.3% of its mass over time and this gradual improvement shows how alumina particles act as a barrier and slows down oxidation and heat deterioration of the matrix. Because of this alumina greatly enhances the mechanical characteristics of composites and performance at high temperatures [46-51].

**TABLE 4.** Thermal Stability

|  |  |
| --- | --- |
| Specimen | Mass Loss at 500 °C (%) |
| Specimen 1 | 7.2 |
| Specimen 2 | 6.1 |
| Specimen 3 | 5.6 |
| Specimen 4 | 5.3 |

# Applications in Automotive Structures

Materials for car structural frames need to be able to handle wear, dynamic loads, and temperature changes without adding too much weight. Traditional steel frames are strong but they are also heavier and Lightweight alloys like AA7075 work better when they are reinforced with nanoceramics.

The created AA7075/nano alumina composites significantly improved tensile strength, hardness

, and thermal stability. This was especially true at 6 weight % nano-alumina where the reinforcement offered the best combination of properties and the best composition of materials makes it perfect for:

* Lightweight structural frameworks that maintain rigidity and making the vehicle lighter overall.
* Parts that don't break in a crash: stronger and more energy absorbing parts make passengers safer.

Because load bearing panels and chassis components wear down more slowly and remain stable at high temperatures, they last longer in harsh environments. Suspension and control arm systems must be able to withstand cyclic loads without getting tired or losing their form.

By making automobiles lighter, stronger and better and these composites aid the automotive industry in its transition to design modifications centered on safety, electrification and fuel economy.

# Conclusion

The inclusion of nano alumina using the semi-solid die casting process significantly enhanced the mechanical and thermal performance of AA7075 alloy and the results indicate that:

* Tensile strength and hardness rose gradually with reinforcement and the ideal strength-to-ductility ratio was reached at 6 weight percent alumina.
* 9 weight % alumina produced the highest hardness. Because of the aggregation and clustering of nanoparticles this was followed by a little reduction in strength.
* The enhanced thermal stability of composites allowed for dependable performance at high service temperatures and cyclic loads.

The optimized AA7075 with 6% weight percentage nano alumina composite shows promise as a lightweight, very durable and thermally stable automotive structural frame material that will aid in the creation of next generation car designs that need sustainability and performance.

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