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Investigation on Mechanical Properties of Al-7075 Alloy Reinforced with Silicon Carbide and Graphite Powder by Stir Casting Process

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Abstract

This research article aims at enhancing the mechanical properties of Al-7075 alloy through the incorporation of silicon carbide and graphite powder using the stir casting process. Diverse weight proportions of reinforcements were employed to fabricate alloy composites, subsequently subject to comprehensive mechanical evaluations encompassing tensile strength, hardness, and impact resistance analyses. The findings elucidate substantial enhancements in mechanical properties following the incorporation of silicon carbide and graphite powder. A thorough microstructural examination utilizing Scanning Electron Microscopy (SEM) highlighted a consistent dispersion of reinforcements within the matrix. These results offer essential insights into the strategic composition optimization for elevated mechanical performance in aluminum-based composites, thus fostering advancements in lightweight, high-strength materials essential for diverse engineering applications.

Keywords: Al-7075 alloy, silicon carbide, graphite powder, stir casting, impact resistance, microstructure analysis, composites

1. Introduction

Composite materials have undergone extensive research and development, classifying into three primary groups: Metal Matrix Composites (MMCs), Polymer Matrix Composites (PMCs), and Ceramic Matrix Composites (CMCs). These categories utilize distinct matrix materials—metal for MMCs, polymer for PMCs, and ceramic for CMCs—each offering unique attributes crucial in material synthesis. The efficiency of composite materials hinges upon a judicious selection of processing methodologies, the choice of matrix and reinforcement constituents, and the strategic amalgamation of these elements [1-3].

The designing metal matrix composite materials centers on joining the desirable qualities inherent in metals and ceramics. Introducing high-strength, high-modulus refractory particles into a pliable metal matrix yields a material possessing mechanical properties bridging the gap between the base alloy and the ceramic reinforcement. Aluminum, being Earth's most abundant metal and the third most prevalent element after oxygen and silicon, stands as the globally dominant non-ferrous metal. Its widespread usage is attributed to its ready availability, commendable strength-to-weight ratio, ease of machining, durability, ductility, and malleability [4].

Aluminum, a lightweight and corrosion-resistant metal, has found extensive use in engineering structures and aerospace manufacturing due to its versatile properties. Its alloys, such as the high-strength 7075 variant, reinforce aircraft structures and marine components, capitalizing on their lightweight nature, high corrosion resistance, and superior strength-to-weight ratio. Furthermore, aluminum's conductivity, ductility, and reflective properties make it indispensable in power transmission lines, architectural applications, and specialized reflective materials. Aluminum's impermeability and recyclability render it ideal for sensitive product packaging. The versatility of aluminum alloys, whether cast or wrought, offers a spectrum of material options suitable for various fabrication techniques, contributing to their widespread use in industries spanning automotive, marine, and construction. These alloys, designed through precise combinations of elements, exhibit tailored mechanical properties vital for specific applications. The designation system for wrought and cast aluminum alloys, adopted by organizations like the Aluminum Association of America, aids in categorizing these alloys based on their compositions and treatments, facilitating their targeted application in engineering practices [5].

Recent studies are focused on enhancing the mechanical properties of aluminum-based composites through various reinforcement materials and fabrication techniques [6]. Several studies delve into the effects of specific reinforcements on aluminum composites, showcasing correlations between reinforcement content and mechanical properties [7]. Notably, the addition of boron carbide to aluminum has demonstrated improved mechanical attributes, including increased hardness and reduced density [8,9]. Additionally, investigations into silicon carbide (Sic) reinforcements have revealed a delicate balance, where increased sic volume fractions correlate with enhanced hardness but may concurrently lead to decreased impact strength beyond certain limits [10,12]. Stir casting, identified as a cost-effective fabrication method for aluminum composites with ceramic particulate reinforcements, remains a focus area for research due to challenges in achieving optimal wetting and homogeneous dispersion of ceramic particles within the matrix [14, 15].

The literature highlights the significance of composite composition optimization for aluminum-based materials, with studies indicating that specific weight fractions of reinforcements, such as SiC, lead to maximum tensile strength, highlighting the trade-off between weight and strength [15]. Furthermore, research explores the microstructural and mechanical behavior of aluminum-silicon carbide particulate composites at varying weight fractions of SiC, revealing trends in hardness evolution and inter-particle interactions affecting composite properties. Simulations assessing the dispersion of SiC particles within different liquid mediums highlight the role of stirring speed and blade design on achieving uniform dispersion, crucial for enhancing composite properties [16]. Additionally, studies have examined the tribological behavior of Al-SiC composites, indicating changes in friction coefficient with the addition of graphite and highlighting the complex interplay of reinforcement materials on composite properties [17,18].

Theliterature provides a comprehensive understanding of the intricate relationships between reinforcement content, fabrication methods, and mechanical properties in aluminum-based composites [19-22]. However, ongoing research continues to explore new avenues to optimize these composites for superior mechanical performance, thereby advancing the realm of lightweight, high-strength materials in engineering applications [23-25].

This investigation aims to analyse the aluminum-based composites by focusing on Al-7075 alloy, renowned for its exceptional mechanical properties. By employing the stir casting technique, this study intricately blends silicon carbide and graphite powder in varying weight percentages to fabricate composite materials. The subsequent mechanical tests encompassing tensile strength, hardness, and impact resistance provide a comprehensive evaluation of these newly synthesized composites.

Furthermore, microstructural analysis is carried out through Scanning Electron Microscopy (SEM), which affords a detailed examination of the dispersion uniformity of the reinforcements within the matrix. These findings collectively elucidate the substantial improvements in mechanical attributes witnessed upon the addition of silicon carbide and graphite powder to the Al-7075 alloy matrix.The significance of this investigation lies in its contribution to the optimization of composite material compositions, thereby paving the way for the development of lightweight yet high-strength materials crucial for diverse engineering applications.

2. Materials

The increasing use of automobiles and the search for alternative fuels have led to the development of lighter, fuel-efficient vehicles. Composite materials offer advantages over steel in automobile manufacturing, making them lighter, safer, and more fuel-efficient. Affordability is a crucial factor in vehicle manufacturing, considering the costs associated with a car's entire life-cycle. Composites are the best choice for developing less dense, low-cost, and highly durable materials. Aluminum alloys have replaced ferrous-based engine components, but their wear resistance is limited. Combining aluminum alloy with materials with good tribological properties can improve wear resistance.

2.1 Material selection

Metal matrix composite materials combine the desirable attributes of metal and ceramics by adding high strength, high modulus refractory particles to a ductile metal matrix. This results in a material with intermediate mechanical properties between the matrix alloy and ceramic reinforcement. Metals have high strength, ductility, and high temperature resistance, but sometimes have low stiffness values. Ceramics are stiff and strong but brittle. Combining materials like aluminum and silicon carbide can produce a MMC with a Young's modulus of 96.6 GPa and yield strength of 510 MPa.

There are several criteria that need to be considered before a right selection of the material can be made, some of these criteria are inter-related. The criteria for the selection of matrix and reinforcement materials are as follows: compatibility, thermal properties, fabrication method, application, cost, properties, and recycling.

2.1.1Compatibility

Chemical stability, wettability, and compatibility of reinforcement with matrix material are crucial for material fabrication and application. Excessive chemical reactions between matrix and ceramic are a major issue in producing most MMC materials. Wetting and bonding are essential, and brittle reactions can negatively impact composite performance. Al2O3 and SiC are excellent ceramic reinforcements for aluminum matrix composites due to their thermal stability during synthesis and application. Table 1 shows examples of interaction with selected reinforcement-matrix systems.

2.1.2 Thermal Properties

Thermal cycling and close tolerances are crucial for applications requiring components to be subjected to thermal cycling or materials cannot expand. Small differences in coefficients of thermal expansion (CTE) when different materials are combined are essential to avoid internal stress and thermal mismatch strain in composites. The reinforcement material's CTE is generally low compared to the matrix alloy, with aluminum having a lower CTE than SiC. The thermal mismatch strain, ε, between reinforcement and matrix is crucial for composites exposed to thermal cycling. This strain is a function of the difference between the CTE of reinforcement and matrix $\Delta\alpha$. Minimizing temperature changes is essential to minimize strain accumulation.

However, thermal mismatch strain is generated during cooling from high temperatures during materials processing. For example, the coefficient of thermal expansion of aluminum alloy and silicon carbide particle is 24 x 10-6/°C and 4 x 10-6/°C, respectively.

This strain accumulation due to thermal mismatch is a critical consideration in the design and performance of composite materials. When subjected to temperature variations, especially during processing and subsequent use in varying thermal environments, the differential thermal expansion rates between the reinforcement and matrix materials can induce internal stresses. These stresses, caused by the mismatch in thermal expansion coefficients, have the potential to lead to microstructural changes, crack initiation, or even failure in the composite structure.

Table 1: *Interaction with selected reinforcement-matrix systems*

System	**Interaction**	**Approx. temperature of significant interaction (°C)**
C – Al	Formation of Al_4C_3	550
B – Al	Formation of borides	500
SiC – Al	No significant reaction below melting point	Melting point, 660
SiC – Ni	Formation of nickel silicides	800
Al_2O_3 - Al	No significant reaction below melting point	Melting point, 660

2.1.3 Fabrication Method

Powder metallurgy (PM) is the most common fabrication technique for discontinuous reinforced MMC materials, as it minimizes interaction between the matrix and reinforcement, improving mechanical properties. PM can also be used for composites that cannot be prepared through liquid metallurgy, such as SiC whiskers that dissolve in molten Ti-alloy matrix. However, liquid metal processing can cause reactions between ceramic particles and the molten alloy matrix. Stir casting methods may not be suitable for using reinforcement materials like fiber or filament due to the breaking action required for dispersing reinforcement material in the molten matrix.

2.1.4 Application

If the composite is to be used in a structural application, the module, strength and density will be important, which requires high module, low-density reinforcement. In this case particle shape may also be a factor, since angular particles can act as local stress raisers, thus potentially reducing ductility. If the composite is to be used in a thermal structural management application, the CTE and thermal conductivity are important. The CTE is generally important because it influences the long-term strength of the composite. Repeated application in many thermal cycles from ambient to approximately 200° C will cause internal stress to be regenerated at each cycle, and it is possible that excessive plastic strain could be developed which is greater than the allowable creep strain.

2.1.5 Cost

Recent developments in MMC fabrication aim to use cheaper and simpler techniques, such as liquid state processing, casting methods, powder metallurgy methods, and in-situ processing. However, the powder metallurgy route is difficult to automate, making it not the ideal solution for economical aluminum matrix composite production. Casting methods are the most economical and widely used, but they can be limited in size and shape, making machining difficult. Alternative reinforcement phase morphologies, such as discontinuous reinforcement phase and powder metallurgy and casting techniques, are being investigated to reduce the cost of MMCs while maintaining their attractive properties.

Table 2:*Various cost systems based on processing method and reinforcement type*

Processing Method	Cost	Reinforcement Type
Diffusion Bonding	High	Mono Filaments
Powder Metallurgy	↑	Whiskers
Spray Methods		Fiber
Liquid State Processes	Low	Particle

2.1.6 Properties

Low density MMCs can be created by using low density alloys like aluminum and magnesium as the matrix material. Nickel and titanium-based alloys can be used for optimal strength-density ratio and thermal stability. Metallic matrices have higher CTEs than most available reinforcement materials.

A discontinuous reinforcement phase in a metal matrix increases fatigue life, influenced by composite constituents, reinforcement phase size, and matrix interface. Aluminum alloy has lower hardness values than steel or cast iron, making it unsuitable for extensive abrasion applications. Wear resistance increases with reinforcement, but the combination of properties is crucial. Aluminum matrix composites may not always be justified due to high specific properties, such as low weight and weight saving.

2.1.7 Recycling

The production cost of aluminum is expensive compared to other commercial materials such as steel, but if aluminum is recycled, great savings in energy consumption can be gained. The energy consumed when aluminum is recycled is only about 5% of that used in primary production. It is important to choose matrix and reinforcement with the consideration that detrimental inter-metallic may be formed that will make recycling difficult. The formation of certain intermediate phases will decrease the possibilities of recycling. This problem is possible to avoid by carefully selecting reinforcements having compatibility with the matrix.

2.2 Selection of matrix

Aluminum is a lightweight, ductile, and malleable metal with excellent corrosion resistance due to passivation. Its lower density compared to steel makes it suitable for castings. Aluminum alloys, made from elements like silicon, copper, magnesium, zinc, and Boron, have good casting and corrosion resistance properties. They are now being used to replace ferrous alloys in automobile components. However, aluminum alloys have limited hardness and wear resistance compared to ferrous alloys. To improve these properties, suitable reinforcement is mixed. Aluminum 7075 alloy was used as a metal matrix composite, with magnesium used as a wetting agent. The chemical composition and mechanical properties
are provided in Table 3&4.

Table 3: *Various cost systems based on processing method and reinforcement type*

Mechanical Property	Numerical Value
Density (x1000 kg/m^3)	2.818 (at 27°C)
Poisson’s Ratio	0.33
Tensile Strength (MPa)	202
Yield Strength (MPa)	150
Hardness (HB500)	60
Fatigue Strength (MPa)	160

Fig 1: Aluminum 7075 Alloy Ingots

Aluminium alloys have such remarkable properties, usage of aluminum is limited to some components because, compared to ferrous alloys aluminum alloys possess less hardness and wear resistance which can be improved by mixing suitable reinforcement.

2.3 Selection of Reinforcements

Aluminium alloys have poor wear resistance compared to ferrous alloys, making it crucial to increase their hardness and wear properties. Ceramics are a top choice for reinforcement, offering superior qualities compared to ferrous alloys. Chemical stability and corrosion resistance are also important. Research has shown that materials like B4C, graphite, granite, garnet, silicon carbide, Boron nitride, and titanium carbide can improve aluminum alloys' hardness and wear properties. The focus is on developing a hybrid composite reinforced with SiC and graphite particles.

2.4 Silicon carbide(SiC)

Silicon carbide (SiC), also known as carborundum, is a semiconductor containing silicon and carbon. It is produced as synthetic SiC powder since 1893 for abrasive purposes. It is used in applications like car brakes, car clutches, and bulletproof vests. Electronic applications like LEDs and early radios were first demonstrated around 1907. SiC is used in semiconductor electronics devices operating at high temperatures or voltages. Large single crystals of SiC can be grown using the Lely method and cut into synthetic moissanite gems. In the 1980s and 1990s, SiC was studied for high-temperature gas turbine components, but none resulted in production due to its low impact resistance and fracture toughness. It is also used in composite armor and ceramic plates in bulletproof vests. In 2015, a new strong and plastic alloy was created using silicon carbide nano-particles in molten magnesium.

Table 4: *Mechanical properties of Silicon carbide*

Mechanical property	Value
Density (gm/cc)	3.1
Elastic modulus (GPa)	550
Poisson’s ratio	0.14
Hardness (Kg/mm^2)	2800
Flexural strength (MPa)	550
Compressive strength (MPa)	3900

2.5 Graphite

Graphite, also known as plumbago, is a hexagonal carbon crystalline form that is stable under standard conditions. It is used in pencils, lubricants, electronic products, paints, and coatings. Its high conductivity makes it useful in metals like steel. Graphite and molybdenum disulfide are the main dry lubricants, offering lubrication at higher temperatures than liquid and oil-based lubricants. They are often used in applications like locks or dry lubricated bearings.

Fig 2: Graphite powder

Table 5: *Mechanical properties of Graphite*

Mechanical property	**Value**
Bulk density (g/cc)	1.3 - 1.95
Porosity	0.7 % - 53%
Modulus of elasticity (GPa)	8 – 15
Compressive strength (MPa)	20 – 200

3. Fabrication Method

Advanced processes for producing metal matrix composites with discontinuous particulate reinforcement include stir casting, which produces a vortex in the crucible using mechanical stirring. This method is suitable and cost-effective for larger components with a homogeneous mixture of metal-ceramic particulates. Liquid metallurgy techniques are used for most automobile components.

3.1. Stir-casting process

Stir casting is a process used to create metal matrix composites (MMCs) by creating a melt of the chosen matrix material, introducing a reinforcing material, and solidifying the melt to achieve the desired distribution of particles. The particle distribution in composites depends on process parameters, and solidification must occur before settling. Continuous stirring with a motor-driven agitator is crucial to prevent particle settling, as denser particles will naturally sink to the bottom of the melt. Stirrers are typically used in the stir-casting process to ensure proper particle distribution.

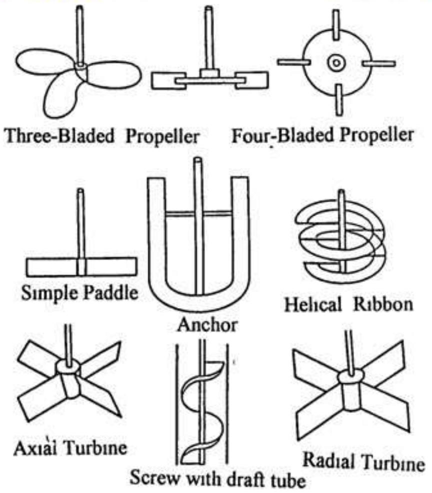

Fig 3: Types of Stirrer blades

The use of mechanical stirrers for dispersion in composite slurry has become popular due to its ability to mix non-wettable ceramic phases into a melt, creating a homogeneous suspension. The uniformity of particle dispersion is controlled by particle movement in agitated vessels. The vortex method is the most common, as stirring a melt naturally forms a vortex. Ceramic particles are introduced through the side of the vortex, which is created at different agitation speeds. Particles can be continuously stirred for 45 minutes or 15 minutes. Some foundries use a slowly rotating propeller for continuousstirring.

3.2 Selectionof optimal composition

Research on Al-SiC/Graphite MMCs has been limited, with studies focusing on 15% w/w silicon carbide in the Al matrix. The current study suggests a 2%-5% w/w silic and 2%-4% w/w graphite composition for better results. Comparing these with similar ceramic particulates like granite and alumina may yield better results. A hybrid composite will be prepared, combining aluminum, graphite, and silicon carbide. Silicon carbide can be limited to 15% w/w, and if the trend continues, the work can be extended to a 25% w/w boron carbide composition.

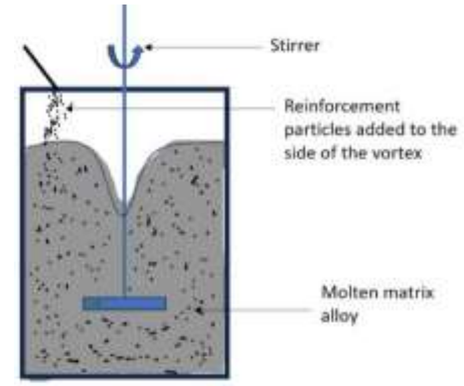

Fig 4: Schematic diagram of producing MMC slurry using a vortex method.

The study investigate the tensile strength behavior of Al-SiC/Graphite metal matrix composite (MMC) made from aluminum alloy grade 7075 with varying percentage compositions of SiC and Graphite particles using stir casting technique. The experiment targeted to predict the mechanical properties of MMCs by analyzing the effect of percentage composition variation.

4. Experimental Work

4.1 Construction of stir casting furnace

The present work requires a custom-made conventional stir casting furnace with 3 blade graphite stirrers, as stir casting is not a conventional casting method. The furnace is cheaper and best suited for varying process parameters electric furnace, crucible, temperature controller, stirring equipment.

A furnace is made from a sheet metal drum, lined with refractory ceramic material and sealed with glass wool. It can produce heat up to 1350^0C and is protected by 20mm ceramic material.A furnace is made from a sheet metal drum, lined with refractory ceramic material and sealed with glass wool. It can produce heat up to 1350^0C and is protected by 20mm ceramic material.

Fig 5: Furnace setup

Electric furnaces are heat-producing equipment that use electric power to produce various heat products, including central heating plants, steel making and smelting, industrial heat-treating furnaces, electrically heated kilns, induction furnaces, and modern muffle furnaces. Aluminum making in electric arc furnace (EAF) has become an important process in recent years, with mini steel plants producing different grades of finished products from scrap and other metallic charge materials. EAF steelmaking contributes significantly to the global total production of steel, accounting for 40 to 45% of total world steel production. However, EAF consumes a lot of electric energy. Crucibles are containers that can withstand high temperatures and are used for metal, glass, and pigment production, as well as modern laboratory processes. They are typically made of high temperature-resistant materials like porcelain, alumina, or an inert metal. Large porcelain crucibles are commonly used for gravimetric chemical analysis.

A temperature controller is a device that regulates temperature by comparing the actual temperature to the desired control temperature. It is a crucial component of a temperature control system, requiring careful analysis to ensure accurate temperature control without extensive operator involvement. The controller's output is connected to a heating element.

Fig 6: Temperature controller

Non-homogeneous particle distribution is a major issue in casting metal matrix composites (MMCs) due to varying density, melting point, and boiling point of materials. Light materials like aluminum, copper, and magnesium have less density, making particle mixing difficult. A 200 rpm high torque reversible motor is used, connected to a potentiometer, and grinded to produce a vortex, which is then tested by stirring molten metal in a crucible.

A 10-liter capacity clay graphite crucible is bought for this purpose and is preheated to red hot condition (650^0C) to relieve from internal stress. A stand is prepared for mounting of stirrer assembly above the furnace. To avoid vibrations in the stirrer, motor is mounted on springs which damp the vibrations. A ceramic cap is used to prevent motor from exposing to direct heat from the furnace. The stand is made as such that some small adjustments can be made to Centre the stirrer to the crucible.

Techno grade solutions Pvt Ltd assists in the casting process, using aluminium 7075 alloy ingots from a local company, silicon carbide and graphite powders from Metorex powder metallurgy, and a graphite blade from a Chennai metal powders shop.

4.2 Sample preparation

Fig 7: Stirring equipment

A standard test bar is prepared using sand casting in a college foundry to produce a cylindrical rod with a conical shape. The test cavity requires 580 to 600 grams of molten metal. The metal is melted in a furnace, and a stirrer is mounted on top. The molten metal is transferred to the cavity using a M.S ladle. The metal is maintained at 850-900^0C temperature. Raw aluminum is taken in and melted at 665^0C. Silicon carbide and graphite are preheated in an LPG gas burner. After the temperature settles above 900^0C, metal treatment is performed by adding overall to the molten metal. A stirrer is inserted and rotated to create a vortex, with the speed controlled using a potentiometer. Reinforcements are added slowly to the vortex.

Fig 8: Stir casting process

The stir casting process involves pouring molten metal into a mold cavity, allowing it to cure for two minutes, and then using the remaining metal for test samples. This process is repeated for samples of 3 and 2 % Silicon carbide and 2 % Graphite, which are then grouped and marked for heat treatment.The process involves pouring molten metal into a mold cavity, allowing it to cure for two minutes, and then using the remaining metal for test samples. This process is repeated for samples of 3 and 2 % Silicon carbide and 2 % Graphite, which are then grouped and marked for heat treatment.

The samples underwent a comprehensive heat treatment process, including 12 hours of solution heat at 520-530^{0}C, quenching in hot water, and 8 hours of precipitation at 170oC. Following this, the samples were turned to the required dimensions, subjected to a hardness test, and tensile test using a Universal testing machine.After completion of Heat treatment process each sample is separately tested for various mechanical properties such as tensile strength, hardness and for study of microstructure.

Fig 9: Sample piece after solidification

4.3 Tensile test

Tensile testing is a crucial material science and engineering test that measures ultimate tensile strength, breaking strength, maximum elongation, and reduction in area. It also determines properties like Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics. Uniaxial tensile testing is commonly used for isotropic materials, while some use biaxial testing.

Tensile testing serves various purposes, including selecting materials for applications, predicting performance, assessing product development, demonstrating patent utility, providing standard data for scientific, engineering, and quality assurance functions, facilitating technical communication, comparing options, and providing evidence in legal proceedings. It also serves as a basis for technical communication.

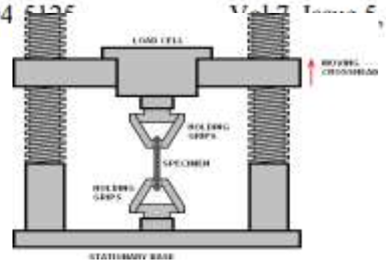

Fig 10: Tensile test process

Tensile specimens are standardized samples with two large shoulders and a gauge section between them. They can be manufactured in various ways to match different grips in a testing machine. Each system has advantages and disadvantages, such as serrated grips being easy and cheap, pinned grips ensuring good alignment, and threaded shoulders and grips ensuring good alignment. In large castings and forgings, extra material is added to remove from the casting for test specimens, which may not be an exact representation of the whole work-piece due to grain structure differences. In smaller work-pieces or critical parts of the casting, a work-piece may be sacrificed to create test specimens. For machined bar stock work-pieces, test specimens can be made from the same piece.

Tensile test methods/specifications

- ASTMA370
- ASTMB557
- ASTMD638
- ASTME8
- ASTME21
- EN10002-1
- ISO527-1
- ISO6892-1

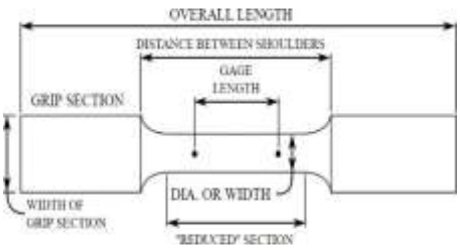

Fig 11: Test specimen details

Materials andequipment

- Tensilespecimens
- Micrometer or Vernier calipers
- Universal testing machine
- Stereoscope

The process involves measuring and recording specimen dimensions for engineering stress and strain calculations, fitting them onto a universal testing machine, and calculating Young's modulus, yield strength, ultimate tensile strength, fracture strain, % elongation, and % area of reduction. The specimens are then analyzed using a stereoscope, and the results are discussed and conclusions provided. The process ensures accurate and reliable measurements of the specimens.

4.4 Hardness test

The Brinell hardness test involves indenting test material with a 10mm diameter ball under a load of 3000 kg, typically applied for 10-15 seconds for iron and steel, and 30 seconds for other metals. The indentation diameter is measured using a low-powered microscope, and the Brinell harness number is calculated by dividing the load applied by the indentation's surface area.

Specimen	Weight % Of Al - 7075	Weight %of SiC	Weight % of Graphite	Yield strength (MPa)	Ultimate tensile strength (MPa)	Young's modulus (GPa)
Base alloy	100	0	0	150	202	103.5
A	95	3	2	201	235	122.4
B	93	5		236	254	133.7

The Brinell hardness number table simplifies the determination of Brinell hardness by calculating the diameter of the impression. A well-structured number indicates test conditions, such as "75 HB 10/500/30" for a 10mm diameter hardened steel with a 500-kilogram load applied for 30 seconds. For extremely hard metals, a tungsten carbide ball is used. The Brinell ball makes the deepest and widest indentation, averaging hardness over a wider amount of material, accounting for multiple grain structures and irregularities in uniformity.

The Rockwell hardness test involves indenting test material with a diamond cone or hardened steel ball under a preliminary minor load, usually 10 kg. An indicating device responds to changes in penetration depth. An additional major load increases penetration, and when equilibrium is reached, the additional major load is removed, allowing partial recovery and reducing penetration depth.

The Rockwell hardness method is used to measure the hardness of various materials, including cemented carbides, thin steel, and shallow case-hardened steel. It has advantages like direct Rockwell hardness number readout and rapid testing time. However, it has disadvantages like arbitrary non-related scales and possible effects from the specimen support anvil. The experimental procedure involves polishing the surface of specimens, fitting them in a sample holder, performing Brinell, Rockwell, and Rockwell superficial hardness tests, measuring dimensions, taking the mean of readings, and presenting a conclusion.

Table 6: *Properties of base alloy, specimen A and specimen B*

Fig 12: Tested samples of specimen A

Fig 13: Tested samples of specimen B

5. Results and discussion

After heat treatment of all samples, each sample was separately tested for the density, hardness and tensile strength and the average values were analyzed by comparing with the zero sample. The results in various tests were discussed below.

The result shows without reinforcement and with reinforcement has been presented for yield strength, young's modulus and ultimate tensile strength. The results of experimentation, it clearly shows as reinforcement by weight percentage increases yield strength, young's modulus and ultimate tensile strength also increases in mechanical properties.

The tensile test results showed that specimen A and B's mechanical properties increased with the base alloy Al-7075 material. The yield strength increased from 150 to 201 MPa, with 34% of it from the base alloy, and from 201 to 236 MPa, with 57.3% from the base alloy. Additionally, the ultimate tensile strength and young's modulus values increased by 17% and 25.7%,respectively.

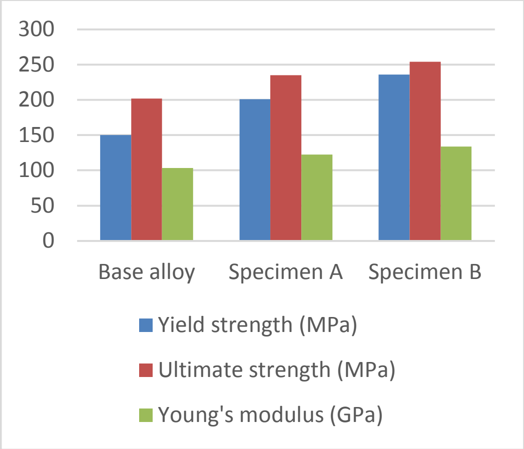

Fig 14: Tensile test values

The study found that SiC, which is superior to aluminum and graphite in hardness, significantly increases the hardness of composites. The increase in hardness from Base alloy to Specimen A was 4.55 BHN, while from Specimen A to Specimen B was only 3.8 BHN. This suggests that the incorporation of SiC in aluminum enhances the composite's hardness, but further increase in SiC results in a slight increase due to the domination of aluminum alloy. since the composition of SiC is only 5% of weight and Graphite is 2% of weight.

Further addition of graphite may give a considerable increase in hardness at some point but may affect interfacial strength and uniform distribution of reinforcement and the other mechanical properties like density, tensilestrength.

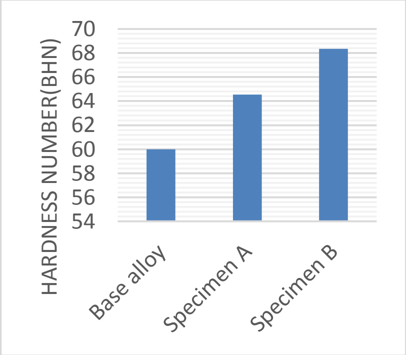

Fig 15: Hardness test values

The hardness test revealed that specimen A and B's mechanical properties increased with the addition of 3% SiC and 5% graphite to the base alloy Al-7075 material, resulting in a 7.58% and 13.91% increase in hardness respectively. Density of each sample was measured based on Archimedes principle in a calibrated glass jar. In table 6.3, it can be noticed that the density of composite is increased because of the increase of SiCcomposition.

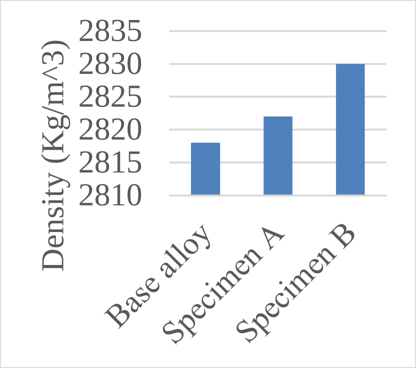

Fig 16: Density test values

From the above results of density test, we found that the mechanical properties of specimen A and specimen B had been increased with reference to base alloy Al-7075 material. The density for the prepared composite materials was increased from 2818 to 2822 kg/m^3 by 0.14% for specimen A and to 2830 kg/m^3 by 0.42% for specimen B in reference with the base alloy.

Conclusion

The investigation into Aluminum 7075 alloy reinforced with silicon carbide and graphite powder via stir casting highlights the marked enhancements in mechanical properties, the substantial increase of tensile strength and hardness, validating the efficiency of SiC as a reinforcing agent. The results revealed that adding SiC increases the composite's mechanical properties. Al-7075 with 2% graphite and 5% SiC is the most suitable for regular casting. The composite material's tensile strength and hardness increased by 17% and 25.7% for 3% and 5% SiC, respectively, with 2% graphite. The density increased by 0.14% and 0.42% for 3% and 5% SiC, respectively, with 2% graphite. The study suggests that with changes in process parameters, such as preheating temperature and the use of modifiers like strontium, hold significant potential for developing composites maintaining the same aluminum density while achieving over 50% increased hardnessand significant gains in tensile strength and modulus of elasticity.

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