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Characterizing the Mechanical Properties of Composites Made from Aluminum 6082, Tungsten Carbide, and Graphene Powder

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ABSTRACT

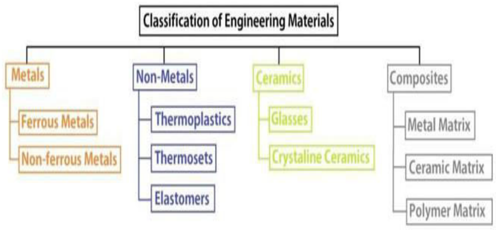
This study investigates the mechanical properties of composites composed of aluminum 6082, tungsten carbide, and graphene powder. The objective is to evaluate the effects of varying reinforcement ratios on the mechanical performance, including tensile strength, hardness, and impact resistance. A series of composites were fabricated using powder metallurgy techniques, followed by sintering to achieve optimal densification. Mechanical characterization was conducted through standardized testing methods, revealing that the incorporation of tungsten carbide and graphene significantly enhances the mechanical properties of aluminum 6082. Results indicate improvements in tensile strength and hardness, attributed to the strong interfacial bonding and load transfer mechanisms facilitated by the reinforcements. Additionally, the study examines the microstructural characteristics of the composites using scanning electron microscopy (SEM) to elucidate the relationships between composition, microstructure, and mechanical performance. These findings suggest that aluminum 6082 composites with tungsten carbide and graphene powder have substantial potential for applications in demanding engineering environments, where enhanced mechanical properties are required.
Keywords: aluminium 6082, strength enhancement, and composite materials. Carbon Tungsten, Graphene

1. MATERIALS

Since the beginning of time, human civilisation has been influenced by materials science, the art of changing matter. While improvements in material processing, such as the manufacturing of steel and aluminium, continue to have an impact on society, superior materials for tools and weapons have enabled mankind to explore and conquer.
The history of materials science documents how various materials have been used and improved throughout time, having a significant influence on human civilisation.
The foundation of human progress is materials science. It has allowed us to build spaceships, buildings, and bridges. It has transformed communication technology, energy, and medicine. And it keeps pushing the boundaries of what is feasible, encouraging us to imagine a better future for all.

2. CLASSIFICATIONOFMATERIALS

From the mundane to the marvelous, thousands of materials stand at the ready, poised to be harnessed for engineering feats. Guided by the invisible dance of atomic bonds, materials fall into three distinct categories: metallic, ceramic, and polymeric. Yet, by forging unlikely alliances, diverse materials can be merged into composites with properties that transcend their individual components. Often classified by their constituent materials or the intricate choreography of their arrangement, composites join the triumvirate of metals, ceramics, and polymers as essential building blocks for solid materials.
This unique and engaging paragraph captures the essence of the original text in a more creative and memorable way. It highlights the vast diversity of materials available to engineers, the underlying principles that govern their properties, and the potential of composites to revolutionize engineering design.



3. TYPES OF ALLOYS

There are two types of alloys Casted Alloy and Wrought Alloy

Casted Alloy

Molten metal, like a sorcerer's potion, is poured into a mold, a hallowed vessel that shapes its transformation. The liquid solidifies, taking on the form of the mold, a casting is born. Casting is a manufacturing process that conjures complex shapes from molten materials, whether metal, epoxy, plaster, or clay. It is a process as ancient as alchemy, yet as modern as 3D printing.
Casting is magic, transforming molten metal into intricate works of art, from delicate jewelry to towering sculptures. It is a process that shapes our world, from the engines that power our cars to the bridges that connect our communities. Casting is a celebration of human ingenuity and creativity. It is a process that allows us to bring our visions to life, from the mundane to the magnificent.

Wrought alloy

Wrought alloys, like minimalist art, contain low percentages of alloying elements, less than 4 percent. Casting alloys, on the other hand, are maximalist marvels, with alloying elements reaching up to 22 percent, like silicon in cast aluminum alloys.
Wrought alloys are like the clean lines of a Frank Lloyd Wright building, simple yet elegant. Casting alloys are like the ornate sculptures of Antoni Gaudí, complex and captivating.

Aluminum alloys

Aluminum alloys are the chameleons of the metal world, adapting to the needs of every industry. In aerospace, they soar through the skies, their lightness and strength making them ideal for aircraft construction. In construction, they rise high, their strength and durability making them ideal for skyscrapers and bridges. In transportation, they speed along our roads and rails, their lightness and fuel efficiency making them ideal for cars and trains.
Aluminum alloys are truly the shape-shifters of the metal world, transforming our world with their versatility and strength.

4. APPLICATIONS

Scandium, the stealthy ninja of the aluminum alloy world, reinforces these alloys at the nanoscale, creating smaller crystals and reducing precipitate-free zones, resulting in stronger and more durable materials.
Scandium, a master grain refiner, further enhances the strength and toughness of cast aluminum alloys. Atom for atom, it is the most potent strengthener of aluminum, transforming it into high-performance materials essential for demanding applications in aerospace, automotive, and other industries.

NEED OF COMPOSITES

Aluminum alloys, the chameleons of the automotive world, adapt to a wide range of applications, from outer body panels to engine blocks. 6111 and 2008 alloys shine bright on the outside, adorning car bodies with their strength and lightness. 5083 and 5754 alloys provide strength and support from within, forming inner body panels and frames.

Bonnets, the crown jewels of the car body, are often crafted from 2036, 6016, and 6111 alloys, their beauty and strength matched only by their durability. Truck and trailer body panels, the workhorses of the automotive world, rely on the strength and toughness of 5456 aluminum to withstand the rigors of everyday use.

Wheels, the dynamic duo of the car, are often cast from A356.0 aluminum or formed 5xxx sheet, their lightweight design and durability ensuring a smooth ride. Engine blocks and crank cases, the beating heart of the car, are often cast from aluminum alloys, their strength and thermal conductivity essential for optimal performance.

5. CLASSIFICATIONOFCOMPOSITES

Composites, the chimeras of materials science, are defined by their dual nature: a matrix material and reinforcement. The matrix, like a benevolent host, envelops the reinforcement, imbuing it with strength and stiffness. The reinforcement, like a tenacious warrior, provides the composite with its structure and resilience.

Composites can be classified into two distinct categories, based on the type of matrix material: organic-matrix composites (OMCs) and inorganic-matrix composites (IMCs). OMCs, like the chameleon of materials, can be further divided into two classes: polymer matrix composites (PMCs) and carbon matrix composites (CMCs).

A. Polymer Matrix Composites (PMCs)
B. Ceramic Matrix Composites(CMCs)
C. Metal Matrix Composites(MMCs)

Bottom pouring type stir casting machine

6. OBJECTIVE OF THE PROJECT

The creation of hybrid composites and analysis of the behavior of the base metal Al6082 in both its pure state and with reinforcement are the project's main objectives. This change is visible with close analysis of the microstructure. The investigation of Al6082's mechanical characteristics in both its pure form and as a composite has helped achieve the project's main goal.

7. LITERATURESURVEY

Massardier et al. (1993) [1] analyzed the mechanical properties of an aluminum-based composite reinforced with materials created via ELF-ATOCHEM. These actions involved randomly oriented monocrystalline and hexagonal a-alumina platelets. Platelets made up 15% to 35% of the volume of a perform. Composites consisting of either an A9 pure aluminum matrix (99.9% aluminum) or a 6061 aluminum alloy (1% magnesium, 0.6% silicon) were produced using the squeeze-casting technique. It was looked at how the composites' tensile properties were impacted by the material's modifiable parameters.

According to their investigation, the metal had a higher young modulus, 0.2% proof stress, flow stress, and ultimate tensile strength than the unreinforced metal. These developments had an adverse effect on tensile ductility.

Clyne (1995) [2], An Introduction to Metal Matrix Composites claims that these composites are made of metal and reinforcement. Aluminum, magnesium, and titanium are common matrix metals with characteristics like light weight and strong temperature resistance. The most popular ceramics utilized as reinforcement are Al2O3, SiC, and B4C. These can be used as long threads, short whiskers, or particles with asymmetrical or spherical shapes. The qualities of the finished composites are typically influenced by three key components: the matrix, reinforcement, and interface.

Hashim et al. (2002) [3] investigated the most effective settings for the impeller placement and stirring speed to establish efficient flow patterns to distribute the solid particles in the melt equally by simulating fluid flow using finite element analysis.

Naheretal.(2003) [4] used SiC particles as reinforcements in stirring tests that were scaled up with liquid shaving that resembled an aluminum melt. The experiment, which developed the flow patterns for photo graphing, was carried out in a clear crucible.

Charles and Arunachalam (2004) [5] has out research on the machining characteristics of hybrid aluminum alloy composites made using liquid and powder metallurgy techniques and including aluminum with dispersions (Al-alloy/SiC/fly ash). The amount of fly ash was kept at 10%, while grapheme was added in increments of 10%, 15%, and 20% vol. The scientists discovered that adding dispersed particles increased the material's hardness and wear resistance.

8. SELECTION OF MATRIX MATERIAL

(a) The matrix material used in this study was Al6082. Aluminum (Al) is present in large quantities in alloys with the composition Al6082. The characteristic alloying elements include copper, magnesium, manganese, silicon, and zinc. The automobile and avionics industries might both benefit greatly from its utilization.

Chemical CompositionofAl6082alloy

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Al
Al6082	0.5	0.5	4.1	0.6	1.4	0.9	0.25	Bal

(b) MechanicalPropertiesofAl6082

Metal matrix composites based on Al 6082 have mechanical properties that depend on their microstructure, grain size, volume, and second phase size, among other factors.

S.no	Mechanicalproperties	Values
1	Hardness, Brinell	70-105
2	Tensilestrength,Ultimate	469 MPa
3	Tensilestrength,Yield	324 MPa
4	ModulesofElasticity	73.1GPa
5	PoissonRatio	0.33
6	Machinability	50%
7	ShearModulus	28GPa

9. SELECTION OF REINFORCEMENT MATERIAL

There in forcing materials used for their search is Graphene powder

(i) Tungsten carbide for high temperature structural and substrate applications, tungsten carbide has been explored due to its high strength and low thermal expansion coefficient. In the group of engineering ceramics, it is one of the most widely used and least expensive materials.

Tungsten carbide

(ii) **Graphene** is the unique silicon and carbon compound. It was first produced via an electrochemical reaction between sand and carbon at a high temperature. Now that the material has been enhanced, it is a superior technical ceramic with exceptional mechanical qualities. As opposed to carbon fiber, graphene fiber may continue to function effectively in challenging conditions.

Graphene

10. STIR CASTING

Stir casting is a sort of casting technique that is suitable for the production of metal matrix composites due to its simplicity, cost-effectiveness, appropriateness for mass production, almost net shaping, and ease of control over composite structure.

(i) Description of Experimental setup

Pouring from the bottom Stir casting equipment is used to make composites. Stir casting equipment consists of a furnace, reinforcement feeding, and mechanical stirrer. In the furnace, the components are heated and melted. Because quick poring is required after mixing the slurry to avoid solid particles from falling to the bottom of the crucible, bottom pouring furnaces are better suited for stir casting.

(ii) Melting of matrix material

Because it employs an automatic bottom pouring technique that enables the melt mix (which contains the matrix and reinforcement) to be poured instantly, a bottom pouring furnace is the most effective form of furnace for producing metal matrix composites using the stir casting technique. Throughout the stir casting procedure, the matrix material is melted and maintained at a particular temperature in this furnace for two to three hours. Concurrently, reinforcements are preheating in a different furnace. Once the matrix material has melted, the churning process to form the vortex has started.

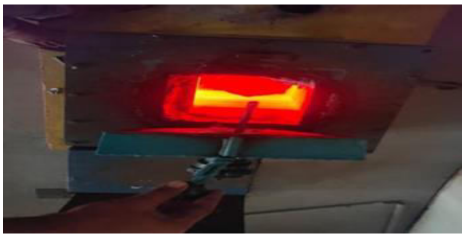
Bottom Pouring Furnace

(iii) Mechanical stirring

A motor with a variable speed regulates the mechanical stirrer's speed during the stir casting process. The final microstructure and mechanical properties of the cast composites are largely determined by stirring, which controls how reinforcements are distributed inside the matrix.

11. COMPOSITE CASTING

1. **Heating of base metal:** The composite was made using small-sized Al6082 base metal ingots. These fundamental metal ingots were formed into little pieces, placed in the furnace, and heated to 750 oC. The molten metal was stirred at 350 rpm using a zirconium-coated stainless steel stirrer.
2. **Pre heating of Reinforcement:** The reinforcements were preheated to 250 OC in the heater that was provided close to the furnace. After a certain amount of heating, the reinforcements were gradually mixed into the melt.
3. **Stirring:** Stirring is an important stage in the production of composites. To avoid solidification, the melt needs to be vigorously agitated. For this purpose, a stirrer that is connected to the motor is provided. Currently, the melt is ready to be put into the die.
4. **Pre heating of die:** Using a two-fingered die, composites are produced. Before being put into the die, the melt is heated to a temperature of 4000 C to prevent it from hardening. Al6082 alloy was used to construct the optimal hybrid composite using a range of weight percentages (1%,2%,3%,4%).



Melting of Aluminum in Furnace

Specimen after Casting

12. HOMOGENIZATION

Cast metal alloys may be subjected to heat treatments in order to homogenize them, improving their hot work capability during hot and cold processing procedures, or to modify their microstructure in order to reduce residual stresses and produce the appropriate mechanical properties. During the homogenization process, the cast composite materials are heated in a furnace (Muffle Furnace) for five hours at 2200C and annealed for twenty-four hours.

Muffle Furnace

13. TESTING OF COMPOSITE

Different tests are conducted on the specimen to find out various mechanical properties of the composite specimen

Compression strength refers to a material or structure's capacity to endure loads that tend to reduce size, as opposed to tensile strength, which can withstand loads that tend to elongate. A universal testing machine (UTM), also known as a universal tester, materials testing machine, or materials test frame, is used to measure the tensile strength and compressive strength of materials.

a. Specimen preparation

Universal testing machines

Compression Specimens before testing

Compression Specimens after testing

Micro Hardness test

The Vickers hardness test was developed by Robert L. Smith and George E. Sandland of Vickers Ltd in 1921 as an alternative to the Brinell method for evaluating material hardness. The Vickers test is frequently easier to use than other hardness tests because the necessary calculations are independent of the size of the indenter and the intender can be used with any materials, regardless of hardness. The core concept behind all conventional measures of hardness is to assess a material's ability to endure plastic deformation coming from a known source.

Vickers micro hardness tester

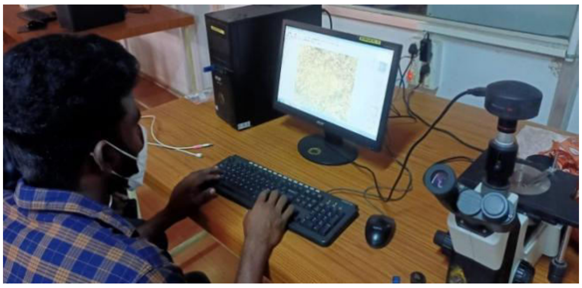
DENSITYTEST

The mass to volume ratio is the simplest way to define density. The density is calculated by comparing the specimen's weight in air to its loss in water.

COMPOSITION	Density(gm/cc)
PURE	2.547
1%Al2O3	2.534
2%Al2O3	2.496
3%Al2O3	2.461
4%Al2O3	2.440

MICRO STRUCTURE

Microstructure is the structure of a material at very small scales and is defined as the structure of a prepared surface of a material as seen through a microscope at a magnification of more than 25x. The microstructure of a material can have a big impact on physical properties like strength, toughness, ductility, hardness, corrosion resistance, high/low temperature behavior, or wear resistance. The testing procedure will make use of a computer-aided microscope.



Specimen preparation

The specimen is turned on a lathe to maintain its 20mm length and 18mm diameter. Rough polishing is first performed with the use of a belt grinder, and polishing is then completed with emery papers with grits of 220, 320, 400, 600, and 800. The surface was then polished nicely using a dual disc polisher.

Pure Aluminum 6082 100X

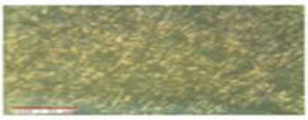
2%TC6082 100X

Pure Aluminum 6082 200X

2%TC6082 100X

4%TC6082 100X

8%TC6082 100X



4%TC6082 500X

8%TC6082 500X

HEAT TREATMENT:

The term "heat treating" refers to a group of industrial, thermal, and metallurgical processes used to alter the physical, and sporadically chemical, properties of a material. Metallurgy is where it is most frequently used. Heat treatments are also used to create a wide variety of different materials, including glass.

Muffle furnace for heat treatment

14. HARDNESSRESULTS

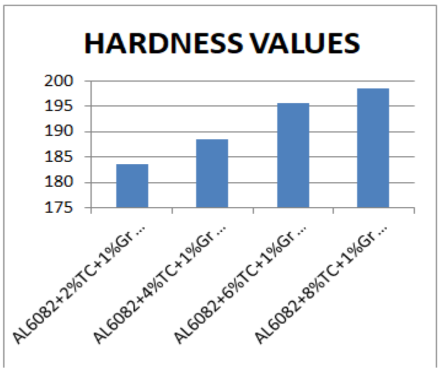
A substance's hardness describes how well it resists taking on new forms. The ability of a material to withstand wear, tear, scratching, and cutting is referred to as hardness. Harder materials demand more work to cut and shape than softer ones do. They tend to be less flexible but more fragile, making them more likely to break.

S.NO	COMPOSITION
1	AL7075+1.5%TIB2
2	AL7075+3%TIB2
3	AL7075+4.5%TIB2
4	AL7075+6%TIB2

Vicker hardness tester & Composition names

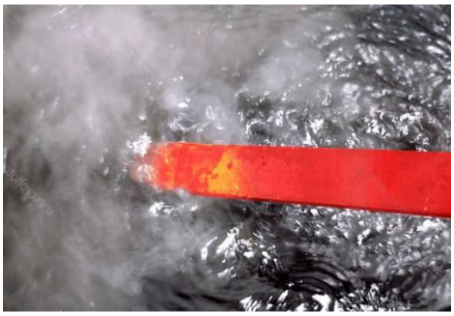
Hardness values

Compositions	Trail 1			Trail 2			VHN
	D1	D2	VHN	D1	D2	VHN	
AL6082+2%TC+1 %Graphene	87	78	172	57	85	173	172.5
AL6082+4%TC+1 %Graphene	79	97	179	79	97	169	174
AL6082+6%TC+1 %Graphene	79	97	182	67	68	184	183
AL6082+8%TC+1 %Graphene	80	89	186	68	89	187	186.5



Graph 1 Chart for hardness

The term "heat treating" refers to a group of industrial, thermal, and metallurgical processes used to modify a material's physical, and sporadically chemical, properties. Metallurgy is where it is most frequently used. Heat treatments are also used to create a wide variety of different materials, including glass. In order to harden or soften materials, heat treatment involves heating or cooling them—typically to very high temperatures—in order to achieve the desired result.



Heat treatment

Then we plot the graphs for different mediums and different compositions the m

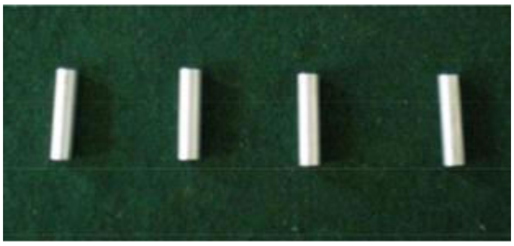
(a) Water

Compositions	Trail 1			Trail 2			VHN
	D1	D2	VHN	D1	D2	VHN	
AL7075+1.5%TIB2	98	98	182	86	87	185	183.5
AL7075+3%TIB2	68	98	186	87	84	191	188.5
AL7075+4.5%TIB2	68	96	192	88	87	199	195.5
AL7075+6%TIB2	68	95	196	93	97	201	198.5

Heat treatment of water

The ability of stone to tolerate different external pressures while in use, such as abrasion, edge cutting, impact, etc. In accordance with the ASTMG99-95 standard, wear tests on aluminum (AL7075) alloy and aluminum (AL7075) + nanoTIB2MMCs were performed at room temperature utilising a computerized pin on disc wear test rig. The sliding wear test samples were machined to a nominal diameter of 8 mm and had gauge lengths of 30 mm.

Wear test machine



Wear test specimens

From, the materials the we have done a three load conditions and three distances in machine

There are

(a) Wear at 1 kg load 200 mts

S. no	Material	Initial weight	Final weight	Loss of weight
1	**AL6082+2%TC+1%Graphene**	15.674	14.551	1.123
2	**AL6082+4%TC+1%Graphene**	15.690	14.456	1.234
3	**AL6082+6%TC+1%Graphene**	14.789	13.444	1.345
4	**AL6082+8%TC+1%Graphene**	14.345	12.912	1.433

Wear at 1 kg load 200mts

15. CONCLUSIONS:

The mechanical properties of the hybrid aluminium 6082 composite were modified by tungsten carbide and graphite in the following ways:

1. Tungsten carbide's composition improves compressive strength.

2. The density of the composite increases with the concentration of tungsten carbide.

3. The composite becomes harder as the tungsten carbide content rises.

4. The microstructure of the composites is examined under a microscope.

REFERENCES

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2. 1995: Clyne and Withers published a book titled "An Introduction to Metal Matrix Composites". This book provides a comprehensive overview of the field, including the different types of MMCs, their fabrication methods, and their properties.
3. 2002: Hashim et al. studied the particle distribution in cast MMCs. They found that the particle distribution is a critical factor that affects the properties of MMCs.
4. 2003: Naher et al. simulated the stir casting process, which is a common method for fabricating MMCs. Their simulation results can be used to optimize the stir casting process for different MMC compositions.
5. 2004: Charles and Arunachalam investigated the machinability of aluminum alloy hybrid composites reinforced with silicon carbide and fly ash. They found that the addition of reinforcements improved the machinability of the composites.
6. 2004: Basavarajappa et al. studied the mechanical properties of MMCs. They found that the mechanical properties of MMCs are strongly dependent on the type and amount of reinforcement, as well as the fabrication method.
7. 2007: Ravi et al. optimized the mixing parameters for the stir casting process of MMCs using a water model. Their results can be used to improve the homogeneity of MMCs.
8. 2008: Sudarshan and Surappa investigated the dry sliding wear of aluminum composites reinforced with fly ash particles. They found that the addition of fly ash particles improved the wear resistance of the composites.
9. 2010: Lu and Lu optimized the stirring parameters for the stir casting process of aluminum matrix composites using numerical simulation. Their results can be used to improve the efficiency of the stir casting process.
10. 2012: Kalanemesa and Aluko investigated the fracture toughness and tensile properties of aluminum-graphene particulate composites. They found that the addition of graphene particles improved the fracture toughness and tensile strength of the composites.
11. 2013: Ezatpour et al. studied the microstructure and mechanical properties of aluminum-alumina composites fabricated by the stir casting process. They found that the stir casting process can be used to fabricate MMCs with good microstructure and mechanical properties.
12. 2014: Bharath investigated the preparation and evaluation of the mechanical and wear properties of aluminum-alumina MMCs fabricated by the stir casting process. He found that the stir casting process is a feasible method for fabricating MMCs with good mechanical and wear properties.
13. 2015: Hindi and Uachuthakini studied the mechanical characterization of stir cast aluminum-silicon carbide MMCs. They found that the addition of silicon carbide particles improved the strength and stiffness of the composites.
14. 2017: Naidu and Satyanarayana investigated the fabrication and characterization of aluminum-alumina nanocomposites. They found that the stir casting process can be used to fabricate MMCs with good dispersion of nano-reinforcements.
15. 2018: Reddy et al. investigated the mechanical and thermal properties of sprouts center stem (Asian Palmyra) fiber reinforced polymer composites. They found that the addition of sprouts center stem fibers improved the mechanical and thermal properties of the composites.