

Evaluation of Mechanical Properties of Graphite Powder and Bagasse Ash Reinforced Al 7075 Hybrid Metal Matrix Composites

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Abstract:-Metal Matrix Composites (MMC's) consist of either pure metal or an alloy as the matrix material, while the reinforcement generally a ceramic material. Now a days these materials are widely used in space shuttle, commercial airlines, electronic substrates, bicycles, automobiles, etc., Among the MMC's aluminium composites are predominant in use due to their low weight and high strength. The key features of MMC's are specific strength and stiffness, excellent wear resistance, high electrical and thermal conductivity. Hence, it is proposed to form a new class of composite. Al 7075 alloy reinforced with Graphite Powder and Bagasse ash to form MMC using Stir casting. The MMC is obtained for different composition of Graphite powder and Bagasse ash particulates (varying Graphite powder with constant Bagasse ash and varying Bagasse ash with constant Graphite powder percentage). The test specimens are prepared as per ASTM standard size by turning and facing operations to conduct tensile tests, compression tests and hardness tests. The specimens are tested for tensile strength and compression strength as per ASTM standard E8 by using universal testing machine and hardness as per ASTM standard E10 at different loads by using Brinell hardness testing machine. Through the results, it is concluded that the MMC obtained has got better tensile strength, compression strength and hardness properties when compared to Al 7075 alone.

Keywords:-Al7075, Graphite, Bagasse Ash, Ultimate Tensile Strength, Compression strength, hardness.

I. INTRODUCTION

This research is a compilation of the overview of the research work and characteristic aspects of the evaluation of the composite materials fabricated utilizing Aluminium as the matrix phase and Graphite powder and Bagasse ash as the reinforcement phases.

Traditional materials do not always provide the necessary properties under all service conditions. Metal matrix composites (MMC's) are advanced materials resulting from a combination of two or more materials (one of which is metal and the other a non-metal) in which tailored properties are realized. In recent years there has been a considerable interest in the use of metal matrix composites (MMC's) due to their superior properties. Though many desirable mechanical properties are generally obtained with the fibre reinforcement, these composites exhibit an isotropic behaviour and are not easily producible by conventional techniques. MMCs reinforced with Graphite powder and Bagasse ash particulates tend to offer modest enhancement of properties. Among the MMCs the most metal used is aluminium reinforced with Graphite powder and Bagasse ash. Generally, aluminium is light weight, which is fore most requirement application and is less expensive than other light metals such as titanium and magnesium. Moreover, when a reinforcement material is added to Aluminium matrix, the properties will further enhance, thereby making it a prospective material for many light weight applications. Metal-matrix composites are either in use or prototyping for the space shuttle, commercial airliners, electronic substrates, bicycles, automobiles and a variety of other applications. Aluminium matrix composites, a growing number of applications require the matrix properties of super alloys, titanium, copper, magnesium, or iron. Like all composites, aluminium-matrix composites are not a single material but a family of materials whose stiffness, strength, density, thermal and electrical properties can be tailored to the suitable requirement. The matrix alloy, reinforcement material, volume, shape of the reinforcement, the location of the reinforcement, and the fabrication method can all be varied to achieve required properties. Regardless of variations,

however, aluminium composites offer the advantage of low cost over most other MMCs. In addition, they offer an excellent thermal conductivity, high shear strength, abrasion resistance, and high-temperature operation, no flammability, minimal attack by fuels and solvents, and the ability to be formed and treated on conventional equipment. In the present investigation, an Al 7075 alloy was used as the matrix material and Graphite powder, Bagasse ash as additives. The composite was produced using conventional foundry techniques.

II. MATERIALS PROCUREMENT

Aluminium 7075 Alloy

Aluminum alloy 7075 is an aluminum alloy, with zinc as the primary alloying element. It is strong with strength and has good fatigue strength and average machinability. Alloy 7075 is heavily utilized by the aircraft and ordnance industries because of its superior strength.

Figure-1 shows Al-7075 Ingots used in the experiments to prepare samples.



Fig-1: Aluminum 7075 Ingots

Bagasse-Ash

Sugarcane bagasse ash is a byproduct of sugar factories found after burning sugarcane bagasse which itself is found after the extraction of all economical sugar from sugarcane. It is an industrial waste which is used worldwide as fuel in the same sugarcane industry. These sugarcane bagasse ashes (SCBA) have been chemically, physically and miner logically characterized in order to evaluate the possibility of their use as a cement replacing material in concrete industry.

Graphite Powder

Graphite is a form of elemental carbon. Graphite is used in several fields due to its electrical conductivity and chemical properties. Synthetic graphite is a manmade essence contrived by the heavy temperature processing of amorphous carbon materials. The types of amorphous carbon used as precursors to graphite are many and can be consequent from coal, petroleum, or natural and synthetic organic materials. In a few cases graphite can constant be manufactured by the direct precipitation of graphitic carbon (CO) from pyrolysis of a carbonaceous gas such as pyrolytic graphite (acetylene). One important commonality between all graphite precursors is that they must contain carbon.

III. EXPERIMENTAL DETAILS

Composite is picked as matrix material inferable from its wide application in numerous designing divisions including car and aviation areas. Further, this composite displays great quality and formability. Graphite exhibits the properties such as high rigidity, low thickness, low rubbing and wear resistance and high thermal conductivity. The mixture structure of composites utilized as a part of the present study is accounted for in the Table 1. Both Graphite and Al7075 combinations were acquired from M/s Fen expense Metallurgical, Bangalore, India. What's more, bagasse fiery debris is found in mandya sugar stick industrial facility.

The composites are manufactured by following steps:

1. Casting.
2. Machining.
3. Testing.

Casting

The microstructure of any material is a complex function of the casting process, subsequent cooling rates. Therefore, composites fabrication is one the most challenging and difficult task. Stir casting technique of liquid metallurgy was used to prepare Al 7075 and Al 7075 Hybrid composites.

Ingots of AL-7075 amalgam are set in heater and heater is warmed up to 800°C. Refer Fig 4 Ascertained amounts in weight rate are filled in the liquid AL-7075 and mixed utilizing zirconium covered spoon. All around mixture composites are filled in the die, which is as demonstrated in the fig 4.

The melting range of Al 7075 alloy is of 700 – 800°C. A known quantity of Al 7075 ingots were loaded into the Graphite crucible of the furnace for melting. The melt was super-heated to a temperature of 800°C and maintained at that temperature. The molten metal was then degassed using Hexochloro ethane tablets for about 8min.

Machining

Tensile test specimens are arranged according to the ASTM E8 principles utilizing a profoundly refined machine, which is indicated in the Fig 5. Test specimens are of 20mm grasp width, 30mm hold length, 62.5mm gage length and 75 mm length of diminished cross area, inward measurement of 12.5mm and aggregate length 155mm and is indicated in the Fig 6.



Fig 5: Casted composites



Fig 6: Tensile specimen

Compression and Hardness test specimens are prepared according to the ASTM E9 benchmark. The test specimens used are of 20mm breadth and 20mm length as indicated in Fig 7 & 8.



Fig 7: Compression Specimen

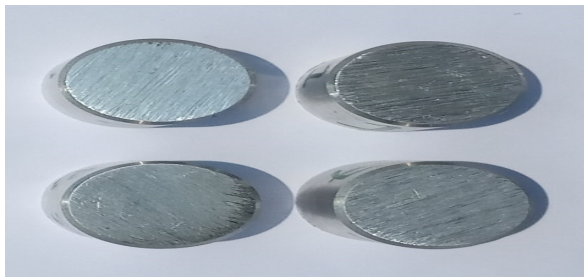


Fig 8: Hardness specimen

Testing

The test specimens are prepared as per ASTM standard size by turning and facing operations to conduct tensile tests, compression tests and hardness tests. The specimens are tested for tensile strength and compression strength as per ASTM standard E8 by using universal testing machine and hardness as per ASTM standard E10 at different loads by using Brinell hardness testing machine. Through the results, it is concluded that the MMC obtained has got better tensile strength, compression strength and hardness properties when compared to Al 7075 alone.

Table 1: Percentage of Reinforcements.

Models	Reinforcements		
	AL 7075 in %	Graphite Powder in %	Bagasse Ash in %
1	97	1	2
2	95	1	4
3	93	1	6

4	95	3	2
5	93	3	4
6	91	3	6
7	93	5	2
8	91	5	4
9	89	5	6

IV. EXPERIMENTAL PROCEDURE

Tension Test

The ASTM E8 method covers the tension testing of metallic materials in any form at room temperature, specifically, the methods of determination of yield strength, yield point, tensile strength, elongation, and reduction of area.

Testing Procedure

1. Measure and record the tensile specimen dimensions of diameter 12.5mm and gauge length 62.5mm were machined from the cast specimens with gauge length of the specimens parallel to the longitudinal axis of the casing necessary to determine the cross-sectional area at its smallest point.
2. Use ink and a scribe or punch to place gage marks on the test specimen gage length of 62.5mm. The distance between the gage marks after the specimen is broken is used to determine the percent elongation at break. To accurately compare elongation values between tests, the gage lengths must be the same.
3. Zero the testing machine without the specimen inserted in the grips. Then install the specimen in the grips and start loading the sample. The speed of testing is generally specified in the rate of straining of the specimen. In addition, the test rate is to remain constant through yield but can then be increased when determining ultimate tensile strength and elongation at break.
4. Run the test until specimen failure or fracture. Remove the broken sample from the machine and the results will be recorded in computerized UTM.

Compression Test

Specimens are machined according to ASTM(E9) standards viz, diameter 20mm \pm 0.1mm and length 20mm \pm 1mm and test was conducted on computerized Universal testing machine. Ductility of the specimen is evaluated in term of percentage of elongation, UCS and young's modulus in terms of MPa. The nine specimens of each compositions of cast and heat-treated composites were tested and average results are noted down. The fig 9 & 10 are the photos of compression specimen before the test and after the test respectively.



Fig 9: Compression Specimen before test



Fig 10: Compression Specimen after the test.

Hardness Test

The specimen is placed on the top of the table and raised it with the elevating screw, till the test sample just touched the ball

A load of 250kg is applied on the specimen for a period of 30seconds, during which indenter presses onto the specimen. The steel ball during this period moved to the position of the sample and made indentation.

The diameter of the indentation made in the specimen is recorded by the use of the micrometer microscope. The diameter of indentations is taken and the BHN is calculated.

The fig 11 & 12 are the photos of Hardness specimen before the test and after the test respectively.



Fig 11: Hardness Specimen before test



Fig 12: Hardness Specimen after the test.

V. RESULTS AND DISCUSSIONS

Mechanical properties like Ultimate Tensile strength, Yield strength, Ultimate Compression Strength (UCS) and Hardness are found for the developed composites of different weight % of Graphite powder and Bagasse ash in Al alloy 7075. The present work attempts to understand the influence of reinforcements on the matrix alloy and artificial ageing process on the Al alloy-based Hybrid composites compared to as cast composites.

Figs. 13-15 and Tables 2 shows the effect of Graphite powder and Bagasse ash on the various mechanical properties of all alloy composites viz. Ultimate Tensile strength, Yield strength, Ultimate Compression Strength (UCS) and Hardness respectively. Each value represented is an average of nine measurements. Each value is repeatable in the sense that the individual values did not vary by more than from the mean value.

Ultimate Tensile Strength

The tensile specimens prepared in accordance with ASTM E8 were subjected to homogeneous and uniaxial tensile stresses in a Universal Testing machine.

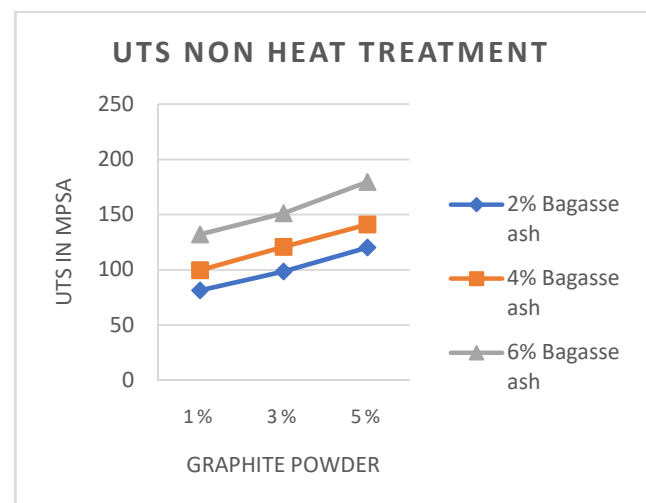


Fig. 13; The effect of Graphite powder and Bagasse ash on the UTS of the Hybrid composites at the non-heat treatment condition.

Effect of Graphite powder and Bagasse ash on UTS

The factors influencing the UTS are complex and inter-related. Several variables, such as distribution of the particles/fiber in the matrix, the mechanical properties of the matrix and the reinforcing particles/fibers and the bonding between the matrix and the reinforcement, are reported to influence the strength of discontinuously reinforced composites strongly. Also, various strengthening mechanism have been proposed to explain the improvement in strength in the case of discontinuously reinforced MMCs. They include the classical composite strengthening through the load transfer between the ductile alloy matrix and the hard and brittle particle reinforcement.

Compression Strength

Compression strength of the hybrid composites specimens and of the base alloy, plotted against the Graphite powder and Bagasse ash.

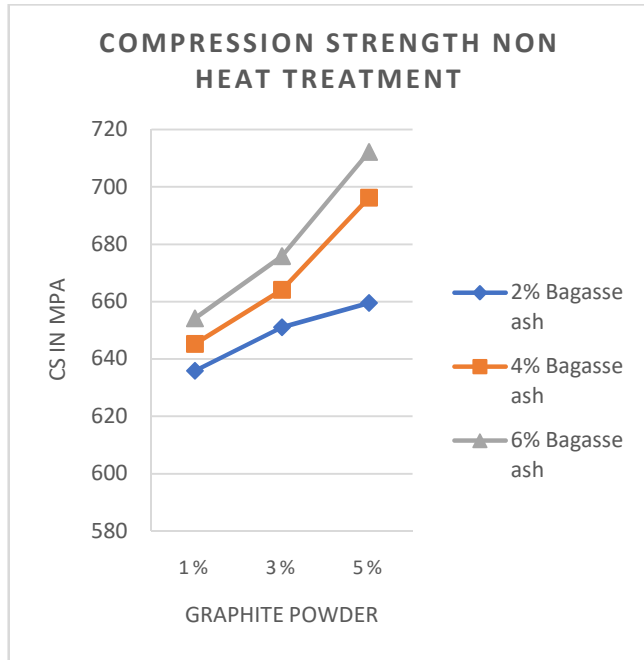


Fig. 14; The effect of Graphite powder and Bagasse ash on the Compression strength of the Hybrid composites at as cast condition.

Effect of heat treatment on Compression strength

Fig. 14 revealed that the heat treatment of composites has increased their compressive strength this may be due to reinforcement of microstructure that acted as barrier to dislocation of grains.

In the present investigation heat treatment and addition of Graphite powder and Bagasse ash reinforcements were found to increase compression strength. As more graphite powder and Bagasse ash particulate were added, decrease in the inter-fibre distance between hard Graphite powder caused an increase in dislocation pile-up. Moreover, improvement in compression may be due to the matrix strengthening that might have occurred following a reduction in composites grain size and the generation of a high dislocation density in the matrix as a result of difference in coefficient of thermal expansion between matrix and reinforcements. The heat treatment has increased the compressive strength by significant amounts.

Hardness

Hardness measurements were made on different sections of the as cast and heat-treated material as per ASTM E10 standards and the results are plotted in Fig.8.41 & 8.42 Brinell hardness tests were carried out on samples of both cast alloy and heat treatment composites, by applying 250 kg for a period of 15 seconds.

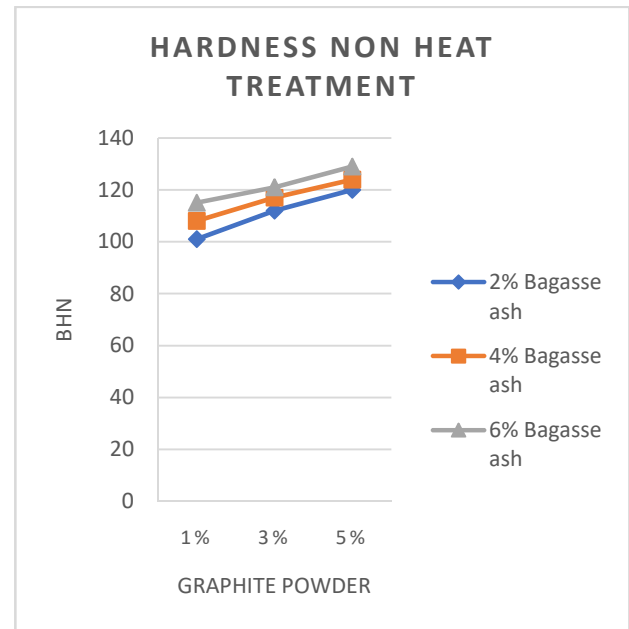


Fig. 15; The effect of Graphite powder and Bagasse ash on the Brinell Hardness of the Hybrid composites at as cast condition.

Effect of Graphite powder and Bagasse ash on Hardness

The hardness of the aluminum alloys is increased with the addition of Bagasse ash and Graphite powder reinforcements. Table 2 show the increase in the hardness is due to the addition of graphite powder particles and Bagasse ash, which can be attributed to the fact that the Graphite powder and Bagasse ash possess higher hardness and its presence in the matrix improves the hardness of the composite.

Table 2: Tensile strength, Compression strength and Hardness of hybrid composites

Composition no	Tensile strength in N/mm ²	Compression Strength in N/mm ²	Brinell Hardness
A1G2B	81.25	635.87	101
A1G4B	99.82	645.15	108
A1G6B	132.08	654.09	115
A3G2B	98.35	651.04	112
A3G4B	120.65	664.04	117
A3G6B	151.24	675.79	121
A5G2B	120.06	659.49	120
A5G4B	140.93	696.14	124
A5G6B	179.52	712.18	129

VI. CONCLUSIONS

The recently developed hybrid composites have been considered as candidate materials for applications in severe environments confronting modern technologies. Among various composites, MMCs are great practical interest. MMCs feature compositional variations from ceramic at one surface

to metal at the other leads to the unique advantages of a smooth transition in thermal stress across the thickness and minimized stress concentration at the interface of dissimilar materials. As a result, such composites are rapidly finding applications in aggressive environments with steep temperature gradients such as turbine components and rockets nozzles.

The summary of the effect of particulates and fibres on the Mechanical properties of Aluminum 7075 hybrid composites like Ultimate Tensile Strength, Yield strength, Young's modulus, ductility, Compression strength etc. are as follows.

- New MMCs can be synthesized both by liquid metallurgy technique successfully with enhanced properties using low cost Graphite Powder and Bagasse ash particulate reinforcement. Stir and permanent mold castings can be obtained with microscopically uniform distribution of particles.
- There have been notable improvements in the essential material properties with the increase in the reinforcement compositions, the properties like Ultimate Tensile strength, Yield strength, Young's modulus and Compression strength have increased significantly with the addition of Graphite powder and Bagasse ash particulate content up to 1%, beyond that we observe that there is not much change in the properties.
- The addition of the reinforcements has resulted in a steady increase in the hardness. The addition of graphite powder and Bagasse ash, could have caused the increase as composites are generally hard.
- The heat treatment on the hybrid composites has got very good effect on all the mechanical properties, because it has further improved the properties with appreciable amount.

REFERENCES

- [1]. Zhao, M. "Friction and wear properties of TiB₂/P/Al composite", Composites Part A, 200611
- [2]. Srivatsan, T.S, Meslet Al-Hajri, M Petraroli, B Hotton, and P.C Lam. "Influence of silicon carbide particulate reinforcement on quasi static and cyclic fatigue fracture behavior of 6061 aluminum alloy composites", Materials Science and Engineering A, 2002. Publication.
- [3]. Baradeswaran, A. and A. Elaya Perumal (2014). "Wear and Mechanical Characteristics of Al 7075/Graphite Composites." Composites Part B: Engineering, Vol.56, pp.472-476.
- [4]. Baradeswaran, A. and A. Elaya Perumal (2014). "Study on Mechanical and Wear Properties of Al 7075/Al₂O₃/Graphite Hybrid Composites." Composites Part B: Engineering, Vol.56, pp.464471.
- [5]. Ravinder Kumar and Suresh Dhiman (2013). "A Study of Sliding Wear Behaviors of Al-7075 Alloy and Al-7075 Hybrid Composite by Response Surface Methodology Analysis." Materials & Design, Vol.50, pp.351-359.
- [6]. Ramesh, C.S., R. Keshavamurthy, and J. Madhusudhan. "Fatigue Behavior of Ni-P Coated Si₃N₄ Reinforced Al6061 Composites", Procedia Materials Science, 2014.
- [7]. C. S. Ramesh. "Sand Abrasive Wear Behavior of Hot Forged Al 6061-TiO₂ Composites", Journal of Materials Engineering and Performance, 12/23/2010 Publication
- [8]. Chinnakurli Suryanarayana, Ramesh, Umam Khan Attallah, Kumar Saheb, Apoorva Kumar, and Manoj Kumar Rajput. "Slurry Erosive Wear Behavior of Forged Al6061-CeO₂-TiO₂ Hybrid Composites", Volume 2A Advanced Manufacturing, 2013. Publication wear behaviour of hot extruded Al6061-SiC_p (Ni-P coated) composites", Wear, 20110729 Publication
- [9]. Bhagat, R.B. "Elevated-temperature mechanical properties of silicon-carbide whisker-reinforced aluminum matrix composites", Materials Science & Engineering Publication
- [10]. N. Altinkok. "Use of Artificial Neural Network for Prediction of Mechanical Properties of - Al₂O₃ Particulate-reinforced Al-Si10Mg Alloy Composites Prepared by using Stir Casting Process", Journal of Composite Materials, 07/12/2005
- [11]. Chen, Fei, Zongning Chen, Feng Mao, Tongmin Wang, and Zhiqiang Cao. "TiB₂ reinforced aluminum based in situ composites fabricated by stir casting", Materials Science and Engineering A, 2015. Publication
- [12]. Sukumaran, K. "Studies on squeeze casting of Al 2124 alloy and 2124-10% SiC_p metal matrix composite", Materials Science & Engineering A, 20080825 Publication