Nano World Journal

https://doi.org/10.17756/nwj.2023-s1-123

Research Article

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Development and Testing of Al6061-TiB_2 Coconut Shell Ash Reinforced Hybrid Composite

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Received: November 24, 2022
Accepted: May 20, 2023
Published: May 22, 2023

Citation: Roy MS, Jawahar P, Rout PK. 2023. Development and Testing of Al6061-TiB_2 Coconut Shell Ash Reinforced Hybrid Composite. *NanoWorld J* 9(S1): S637-S641.

Published by United Scientific Group

Abstract

Enormous research is critically carried out nowadays to find the feasibility of the appropriate composite material, there can be two or more different components in a composite material that have diverse chemical and physical characteristics, but they are still distinguishable at the microscopic level inside the final prepared composite material. Over the last decade intense analysis and developments have been carried out so as to develop hybrid composites including some nature-based reinforcements, which may contribute to sustainability and improved property. Nowadays a trend for light motor electric vehicles is catching much attention, hence research work is focused to find more and more light weight composites which can easily resist wear, have high values of hardness and tensile strength. Here in this current investigation stir casting methodology had been utilized for fabrication purpose and experiments being conducted on Al6061 alloy as matrix material and dried Coconut shell ash (CSA), Titanium diboride (TiB_2) as the reinforcements with varying weight percentages and analyze the developed new hybrid composite through different mechanical testing procedures like hardness, tensile, compression, elongation percentage, hardness, etc. and the microstructure can also be analyzed for future references. The investigation included a suitable combination of reinforcements and working parameter, which was quite different from other research works, like performing solvent extraction method for the coconut shells is itself a different test categorically which makes the coconut shells to be oil and moisture free facilitating towards obtaining better results. It has also been observed that with increasing CSA and TiB_2 percentages, the mechanical properties substantially got improved and using CSA powder is more convenient to impart low density, light weight properties into the new composite.

Keywords

Hybrid composite, Al6061 alloy, Microstructure, Mechanical testing

Introduction

Recently a new kind of particulate reinforced composite, the hybrid type, which is a new generation topic of research trend, is obtained by the use of two or more different kinds of particulates in a single matrix. Stir casting is one of the most widely acknowledged procedures for producing large quantities of particles or discontinuous reinforced composites. Here in this investigation focus is given on dried CSA and TiB_2 as the reinforcements, and different weight percentages are to be analyzed. Composites are categorized according to the matrix and the kind of reinforcement components, which are either particles, whiskers, or fibers. It has much application in industry because of ample number of advantages in pretext of hardness, stiffness, resistance to wear and corrosion over conventional material, also it provides high strength to weight ratio. The technologically sound modern industries adopt more and more advanced and novel materials which have outstanding physical qualities, aesthetics, mechanical, thermal, and wear properties also at the same time readily available at a minimal cost.

The literature survey pinpoints towards the positive trend of using additional variety of reinforcements to the matrix which results superior mechanical and tribological properties of the prepared composites. Also, it had been observed that hybrid composites tend to provide enhanced material properties rather than the single reinforcement composites. Global wide the researchers could find suitable alternatives of naturally available reinforcements, coconut shell among one of them, thus contributing to sustainability on one side and also a low-cost light weight beneficial composite can be manufactured most economically on the other side. During fabrication there are a lot of chances of cluster and pore formation, this can be avoided smartly if proper attention is given and little modifications are added, stir casting can be ultrasonically connected, doing so, were found to be effective in reducing the formation of pores, clusters, and agglomeration, which in turn can contribute to homogenous distribution of reinforcement particulates and ultimately improve the mechanical properties. It was reported that reinforcement addition has a significant role in the solidification of the molten composite and results in grain refinement [1]. Proper reinforcements and suitable fabrication parameters hugely impact the mechanical, wear behavior of the prepared composites, hence effective and exact procedure must be followed for fabricating the composite as it will affect the further analysis of the prepared composite [2].

Nowadays a trend for light motor electric vehicle is catching much attention, hence research work is focused to find more and more lightweight composites which can easily resist wear, have high values of hardness and tensile strength and corrosion resistant. From the literature study it has been found that the newly prepared composites with reinforcements have shown effectively better properties when compared with the alloy alone. Composites fabricated through stir casting process, requires attention while selection the operational parameters such as the speed with which the stirrer rotates, total stirring time, pattern of stirrer blade, reinforcement particle size, and melting temperature of both matrix and reinforcement particulates, etc. play a vital role on Al6061 composite characteristics [3].The coconut shell ash particles are actually prepared by complete burning of the perfectly dried coconut shells in the open atmosphere kept minimum for a week and then further dried in an oven so as to ensure that not even a small portion of the oil or moisture content is present, solvent extraction process can be followed. The coconut shells after proper drying when burnt in open air ensure complete burning and ash formation without any kind of charcoal particles. The ash so obtained is sieved for different particle sizes. The best part of incorporating CSA as reinforcement particles is that of its low-density property which enables an overall fabrication of a lightweight composite [4]. In other words, the addition of CSA makes a lower-density composite, even if the new composite has a density lower than that of the alloy alone. Ceramics in fact have a wide range of applications and extensive research works have been carried out with SiC, B_4C, TiC, etc. here in this investigation TiB_2 have been chosen for another reinforcement as some literature pinpoints the utilities of successfully using TiB_2 powder into the Aluminum matrix [5].

Materials and Methods

Preparation of coconut shell ash particles

A fully dried in sunlight, coconut shell, is taken and thoroughly cleaned to remove impurities. The outer and inner surfaces must be free from oil and moisture content, solvent extraction procedure is followed to remove oil content perfectly, as the oil content hampers the optimum results and crushed small pieces are burnt to form complete ash.

Tensile, compressive, and hardness test

Tensile specimens having gauge width of 6 mm and thickness of 6 mm extracted from the fabricated composites undergone tensile and compressive tests evaluated through employing a Universal testing machine (UTM), bearing model no. HL-590.20 manufactured by Hydraulic and Engg. Instruments, (HEICO). Both tensile and compression test were performed in UTM. For hardness check, indentation based Rockwell procedure of hardness measurement has been followed to determine hardness values of different composite samples with varying wt.% of reinforcement, bearing model no. MRD-600TS manufactured by HDNS, Kelly Instruments. A steel ball indenter (1/16 inch) is used to create the indentation on the sample, taking a major load of 100 kgf.

Fabricating the hybrid composite

Here in this investigation Al6061 has been taken as matrix material for conducting the experiments, the alloy is first taken in a graphite crucible and heated for a melting

Figure 1: Solvent extraction method.

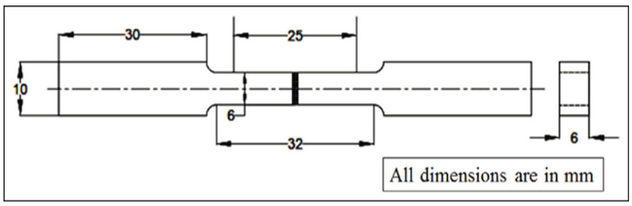

Figure 2: Sample dimensions for tension tensile test.

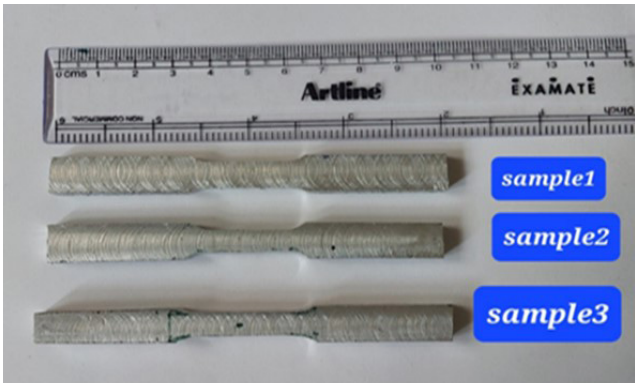

Figure 3: Prepared samples of hybrid composites for tensile test.

Figure 4: Stirring of molten metal.

temperature range of 600 ˚C - 650 ˚C for almost an hour. TiB_2 particulates are allowed for preheating at temperatures 500 ˚C for 1 hour. Optimum preheating must be performed to mitigate the problems related to inhomogeneous distribution and pore and cluster formation which hampers the overall quality of the prepared composite. Muffle furnace temperature was set to approximately 750 ˚C where the alloy gets melted and then slowly cooled for a semi solid state slurry. Stirring is initiated with a constant speed of 350 rpm using a radial drilling machine and the preheated TiB_2 powder and the prepared CSA in the prescribed weight percentages are added manually into the vortex and stirring continues till 10 or 15 minutes for proper homogeneous, gas free casting samples. After completion of the entire stirring procedure now it's time to pour the charge into the moulds that were previously prepared as per our convenient sample shapes and as per the testing criteria and requirement of the current paper. The stir casting methodology involves a superior stirring mechanism, Al6061 matrix selected, placed in the crucible is heated until it melts totally, proper care must be taken as chemical reaction occurs at this stage therefore the crucible must be chemically inert to both matrix and reinforcements. It is suggested to keep inert condition initiating from stirring, mixing till pouring of the prepared charge for a perfect cast composite. Here in this investigation work has been done with the corresponding parameters as prescribed in the table below.

Figure 5: Melting of Al6061.

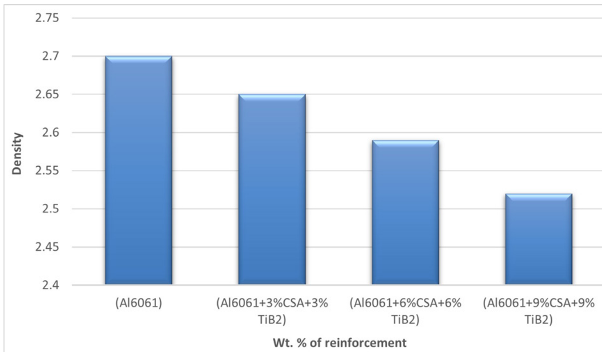

Figure 6: Density vs weight percentage of reinforcement.

Results and Discussion

The samples of the prepared hybrid composites namely (Al6061+3%CSA+3%TiB_2), (Al6061+6%CSA+6%TiB_2), (Al6061+9%CSA+9%TiB_2) and the base alloy Al6061 undergone different mechanical testing procedures to evaluate their exact behaviour: Apart from these testing the density check of the newly fabricated composite is also a vital considerable criterion.

1. Tensile test
2. Compression test
3. Hardness-Rockwell
4. Elongation %

Density

Apart from the mechanical testing procedures the prepared fabricated hybrid composite samples along with the base alloy underwent density check, mathematically calculated using Archimedes principle. It is quite evident from the fact that CSA having light density properties, when included as reinforcements in different weight percentages to the composite, imparts in developing lightweight hybrid composites, as the reinforcement percentages goes on increasing, the overall density of the prepared hybrid composite shows a decreasing trend. The graph below shows the effects of CSA and TiB_2 as reinforcements in different wt.% in pretext of density.

Test results of tensile, compressive strength, elongation %, and hardness

In this investigation, the crucial machine utilized for conducting the mechanical test is the UTM. The CSA and

Table 1: Working parameters selected.

Sl. No.	Name of Sample	Particle size (μm) of reinforcement	Weight percentage		Stirring speed
1	Al6061	Nil	0%TiB$_2$	0%CSA	350
2	Al6061+3%CSA+3%TiB$_2$	38 - 60	3%CSA	3%TiB$_2$	350
3	Al6061+6%CSA+6%TiB$_2$	38 - 60	6%CSA	6%TiB$_2$	350
4	Al6061+9%CSA+9%TiB$_2$	38 - 60	9%CSA	9%TiB$_2$	350

Table 2: Mechanical testing values and density check.

Sl. No.	Name of Sample	Elongation %	Tensile strength N/mm^2	Compressive strength N/mm^2	Density g/cm^3	Hardness HR
1	Al6061	7.1	115	350	2.7	30
2	Al6061+3%CSA+3%TiB$_2$	6.7	158	470	2.65	47
3	Al6061+6%CSA+6%TiB$_2$	5.3	174	485	2.59	59
4	Al6061+9%CSA+9%TiB$_2$	3.7	171	450	2.52	62

TiB$_2$ particles as reinforcement in different weight percentages superiorly impart greater tensile strength in comparison to the Al6061 alloy alone. Observations predicted gives a strong indication of the fact that increase in reinforcement % substantially improves the tensile strength when compared with the base alloy, 6% and 9% reinforcement have narrow difference of tensile strength values. The compressive strength shows an increasing trend with increase in reinforcement addition, but with 9 wt.% of reinforcement suddenly starts showing a declining trend, because of cluster formation and non-homogeneous distribution of reinforcement particulates in the matrix material with increase of reinforcement quantity. Hardness dominantly shows an increasing trend, with reinforcement addition, but 6 and 9 wt.% reveals almost similar or very close proximity values, the graphs below indicate the same.

Conclusion

The newly developed hybrid composite with two different varieties of reinforcements was fabricated successfully through stir casting methodology. The investigation provided interesting facts about the fabricated hybrid composite of different wt.%, we can say that coconut shells as a bio-waste can successfully be utilized in preparing hybrid composites which imparts low density, but high in mechanical properties, reducing the overall weight of the material, making it a good choice for lightweight automotive applications. The lowest density measured was found to be 2.54 gm/cm^3, Rockwell hardness value augmented to 62 for sample with 9 wt.% of reinforcement. As we go on increasing the reinforcement particles, we deserve to obtain a high-quality hybrid composite with improved mechanical properties, but tensile and compressive strength was found to achieve its maximum values of 174 N/mm^2 and 485 N/mm^2 with 6 wt.% of reinforcement.

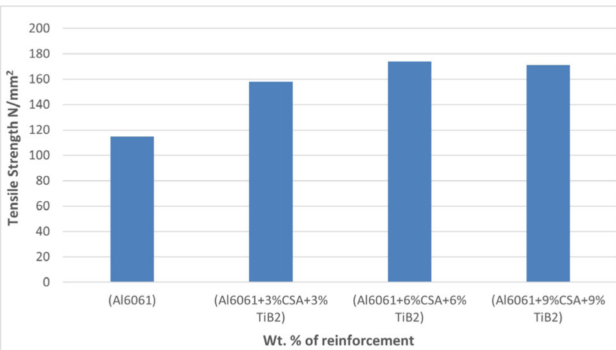

Figure 7: Tensile strength vs weight percentage of reinforcement.

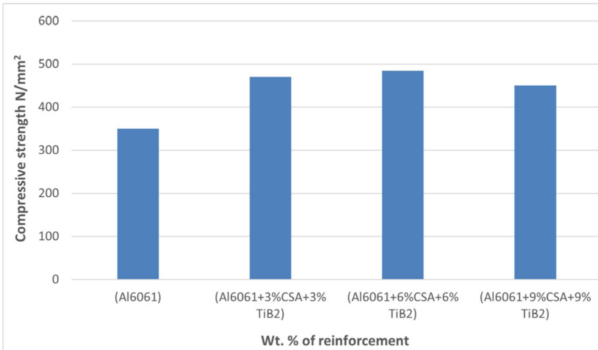

Figure 8: Compressive strength vs weight percentage of reinforcement.

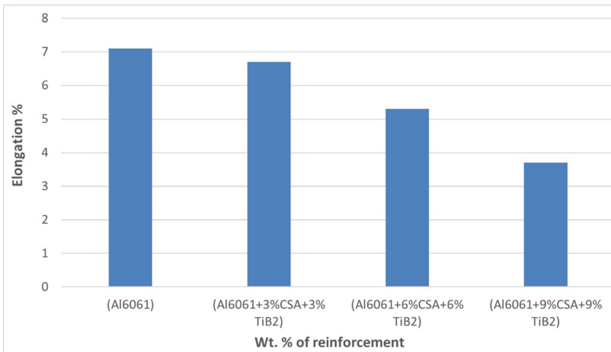

Figure 9: Elongation % vs weight percentage of reinforcement.

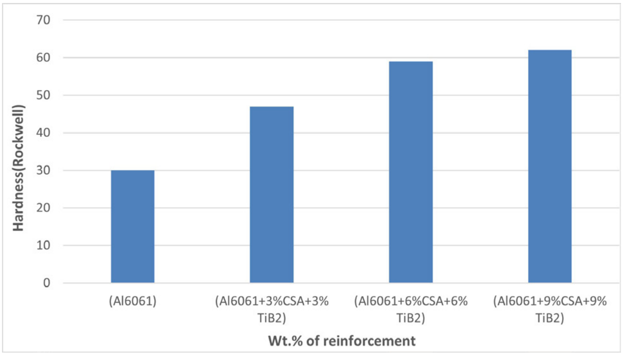

Figure 10: Hardness vs weight percentage of reinforcement.

Acknowledgments

The authors would like to extend their heartfelt gratitude to the technical staff of Production, Mechanical and Civil department of NIT Agartala, also like to express thanks to CIPET Agartala and the staffs of SOM Laboratory and research scholars who extended their support. I would like to express my gratitude to Materials Science Engineering. Dept., Tripura University for providing me this opportunity.

Conflict of Interest

The authors declare no conflict of interests that are relevant to the content of this article.

Credit Author Statement

Moutoshi Singha Roy: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Data validation, Visualization, Writing - original draft preparation; P. Jawahar: Resources, Writing - review and editing, Supervision; Prasanta Kumar Rout: Data validation, Project administration. All the authors read and approve the manuscript.

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