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Analytical Examination of Mechanical Characteristics of an Al-based Composite Reinforced with Waste Materials

Ashish Kumar Srivastava and Rajendra Prasad Verma***

ABSTRACT

In today's technologically evolved world, when governments and industries compete aggressively with one another, decreasing output or imposing constraints on industry will not alleviate the pollution problem. Waste created by industry may be recycled as an effective alternative strategy in this area. Utilising these wastes could aid in the resolution of some environmental problems. Recycling these wastes is the simplest way to get rid of them; however, adequate handling of these wastes is currently required. More advanced hybrid materials are required for several new technological developments. A functionally graded material (FGM) prototype has been developed by researchers, who have also recommended other material combinations that might be utilised in the prototype and tested its mechanical properties against industry requirements. It is possible to increase the hardness and tensile strength of materials by employing waste materials such as SiC and Alumina (Al2O3), which are both high in calcium carbonate. This paper includes the testing of the effect of waste materials like carbonized alumina and SIC on the physical quantities of Al-based metal composites. Along with this, the factors affecting the hardness are also analyzed like after effects of heat treatment.

Keywords: *Silicon Carbide (SiC), Functionally Graded Material, Carbonized Alumina, Hardness, Ball-milling, Microstructure.*

1.0 Introduction

Pollution is a major challenge for all countries. Industries are mostly to blame for disrupting the natural order of pollution cycles. Industries create wastes such as Silicon carbide (SiC)s and Alumina (Al_2O_3) that may be harmful to the environment and cause illnesses if they are left untreated or let to decompose. The easiest strategy to get rid of these wastes is to recycle them; proper treatment of these wastes is needed now. Improved hybrid materials are needed for a number of new technical advancements, including military, aerospace, and automotive, all of which have advanced science and technology at their disposal [1-3]. Scientists and experts are particularly concerned about pollution, which is spreading at an alarming pace throughout the world [4-6]. Many scientists throughout the world have been inspired by the problem of pollution to look for a way to decrease pollution without sacrificing present lifestyles. In the air, water, and even on land, industrial waste is a major source of pollution [7-9].

**Corresponding author; Assistant Professor, Department of Mechanical Engineering, United University, Prayagraj, Uttar Pradesh, India (E-mail: ashishsay342@gmail.com)*
*** Department of Mechanical Engineering, United University, Prayagraj, Uttar Pradesh, India*

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This is an urgent matter, and reducing output or imposing limitations on industry would not solve the pollution problem in today's technologically advanced world where governments and industries compete fiercely with one another [10-11]. Waste created by industry may be recycled as an effective alternative strategy in this area [12-14]. Many nations, even emerging ones like India, are constantly working to achieve this goal by encouraging researchers and scientists to use an increasing number of recycled materials [15-17]. Recycling garbage has a number of advantages, including reduced pollution, conservation of finite natural resources that are renewing rapidly, and, of course, lower capital expenditures [18-19]. The use of these wastes might help alleviate certain environmental issues. Researchers have created a functionally graded material (FGM) prototype and tested its mechanical qualities against industry standards, as well as suggesting additional material combinations that may be used in the prototype [20].

Elastic speed is related to the aspect ratio of the graded index. Prior to any processing or grading, it is necessary to specify sigmoid functionally graded material in order to optimise the disc output. 9 percent chrome steels were tested for sensitivity and stability using dissolution and temperature [22-23]. During the tempering and normalizing processes of P91B steel, the heat affected zone was studied. Many scientists have experimented with the creation of green composites using industrial waste derived from agricultural waste. Improvement of base material mechanical characteristics and reduction of pollutants are main goals in this programmed [24]. Several processes, including thermodynamics, kinetics, adsorption, and diffusion, have been employed to remove phosphorus from aluminium using modified Silicon carbide (SiC) [25]. It is possible to increase the hardness and tensile strength of materials by employing waste materials such as SiC and Alumina (Al_2O_3), which are both high in calcium carbonate. SiC has just recently been applied to the base metal, and it is a typical phenomena that the egg shell is undervalued. So the uniqueness of studying and increasing the base metal's mechanical characteristics is amply supported by this work.

Subsection 2.1 provides a quick overview of the SiC attributes. Another first for this research is the use of Alumina (Al_2O_3), an agro-based waste material, in the basic material.

Reinforcing materials Alumina and SiC were used in this investigation to create aluminum-based composite materials. Mismatched densities lead to worse mechanical properties in carbonised SiC powder. It took us 75 hours to grind together carbonised SiC particles and Alumina (Al_2O_3)in a ball mill. In the construction of an aluminium metal matrix composite (AMMC), waste elements such as zeolite, fly ash, and coconut shell were discovered to be very uncommon. SiC or Alumina (Al_2O_3) have been used as reinforcement in the development of AMMC. In the current investigation, SiC or Alumina (Al_2O_3), and 1% Cr were used as primary and secondary reinforcing agents, respectively.

2.0 Reinforcement Composition

2.1 Silicon carbide (SiC)

Industrial waste in the form of a hard shell egg. Calcium carbonate accounts for the bulk of its composition (SiO2). The SiC contains a calcium ion. Protein and a wide variety of minerals make up the remainder. The majority of SiO2 has been incorporated into SiC. It's accessible in around 90% of the cases in SiC. Table 1 provides a breakdown of the chemical make-up. The commercial usage of SiC is a waste product since it is readily accessible. Polyamide is recommended to correctly influence electricity because of the SiC's high compressive strength. A rudimentary form of silicon carbide is produced by combining silica (SiO2) and carbon (C) in an electric resistance furnace at temperatures in the vicinity of 2,500 degrees Celsius. When it comes to the production of SiC crude, Washington

Mills utilises not one, but two distinct manufacturing processes: the time-honored Acheson technique, and the massive furnace technology.

2.2 Alumina (Al_2O_3)

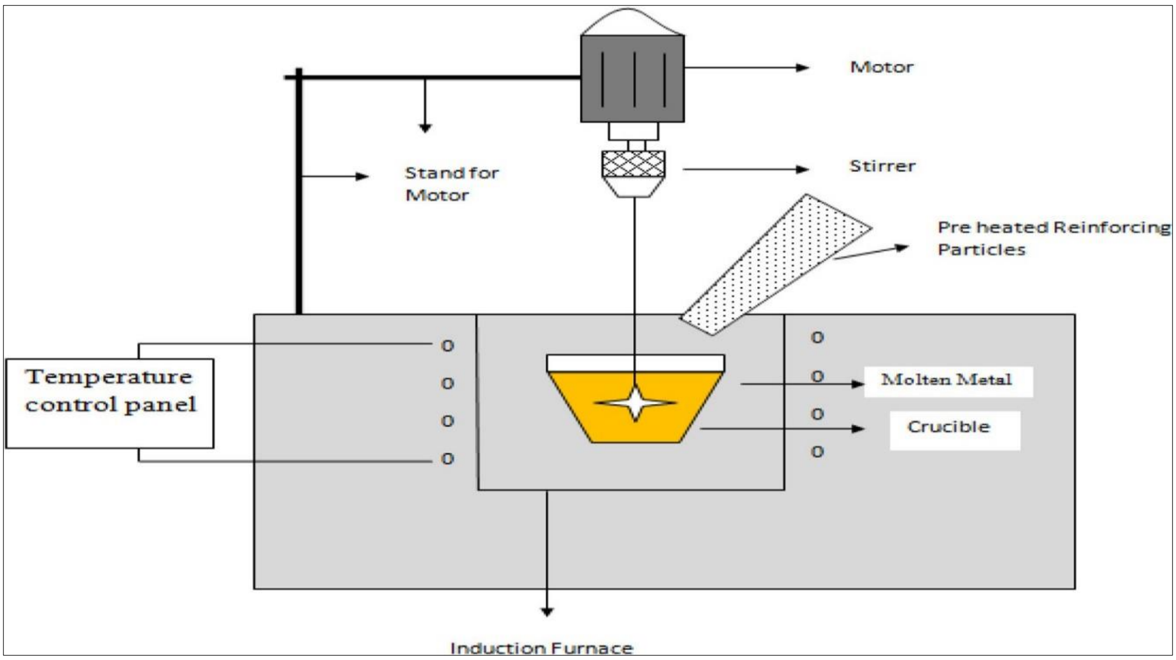
Alumina, commonly known as aluminium oxide, is a white or almost colourless crystalline substance that is used as a starting material in the smelting of aluminium metal. alumina is created synthetically and goes by the chemical formula Al_2O_3, which stands for aluminium oxide.

Reinforcement particles are ground into fine powder using a ball mill The development of a hybrid metal matrix composite material that incorporates two or more reinforcing particles is always a difficult task. During the stirring process, a lack of consistency in the density of reinforcing particles caused a number of issues. In some cases, the reinforcement particles were floating, while in other cases, the reinforcement particles had settled to the ground. Fortunately, the ball-milling process may alleviate some of these problems. A single entity powder was obtained from the ball-milling of carbonised SiC powder and Alumina in this work. Up to 75 hours of ball milling were used.

2.3 Development of composite material

As can be seen in Figure 1, the AMMC development procedure is based on the stir casting technique. Table 3 displays the parameters for the stir casting process. In this case, it was AA 3105 that was used as the matrix material. Ball-milled carbonised SiC particles and Alumina were synthesised as a single entity at 220°C before being combined into the matrix material. There was a muffle furnace used to melt down the AA3105. When the matrix reached 690°C, reinforcement particles were added. Using the universal testing machine's mushy zone and a squeezing pressure of 60 MPa, the porosity and uneven distribution of reinforcing particles were reduced. Even yet, a little quantity of Cr particles (1 Wt. percent) was included into all composite materials. A new composite material having a composition that combines.

Figure 1: Stir Casting Set up



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The percentage of reinforcing weight stated in Table 2. Twenty-five samples of the composite were tested for mechanical properties such as toughness, ductility, and hardness, with varying ratios of SiC and Alumina.

2.4 Fabrication the specimen and testing

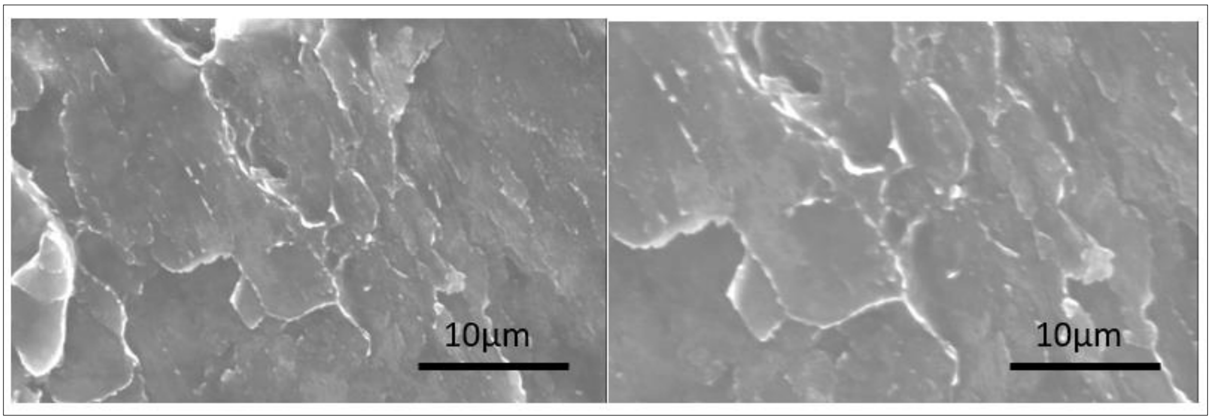
Each of freshly produced composites was tested for microstructure, tensile strength, and hardness (measured in millimetres, not decimal points). According to ASTM A370, tensile strength of 10x10x55mm3 with a 45° V notch in the middle of 2mm depth. We used room temperature materials for the tensile samples. ASTM B557 was used to collect the tensile samples (test methods for tension testing wrought and cast aluminium and magnesium-alloy products). I built my gauge to 36mm length and 6mm diameter to generate my test sample. Composite samples are tested tensile using a computerized universal testing system. It was used to conduct hardness testing on composite materials. An optical microscope was used to create a microstructure picture. Test Method-ASM-9–2009 detected the metallographic characteristics of composite materials.

3.0 Results and discussion

3.1 Microstructure of composite

Composite material microscopic structure is shown in Figure 2. Reinforcement particles of Alumina and SiC were combined with the previously prepared single entity of Alumina and SiC. The Alumina and SiC reinforcing particles will not be disseminated evenly if they are not ball milled due to their varying densities. Using a ball mill, it is simpler to distribute these milled reinforced particles throughout the composite.

Figure 2: Microstructure of the AMMC Composite



3.2 Tensile strength of composite

When Alumina and SiC was used as the only additive in AA, the tensile strength remained unaffected. A significant improvement in tensile strength may be achieved by adding carbonated SiC powder into the mixture. It was also found that the Alumina and SiC powders melted together increased tensile strength. The tensile strength, on the other hand, was not adequately improved because of disproportionate density of reinforcing particles. Figure 3 shows tensile strength of a dogbone specimen manufactured in accordance with the ASTM standard. The tensile strength of reinforcing particles filled with ball milling steadily improves with an increase in combined number of reinforcing particles. Optimal tensile strength for reinforced composite ball milling was found to be 181.85 MPa.

Figure 3: Dog-bone shape of AMMC

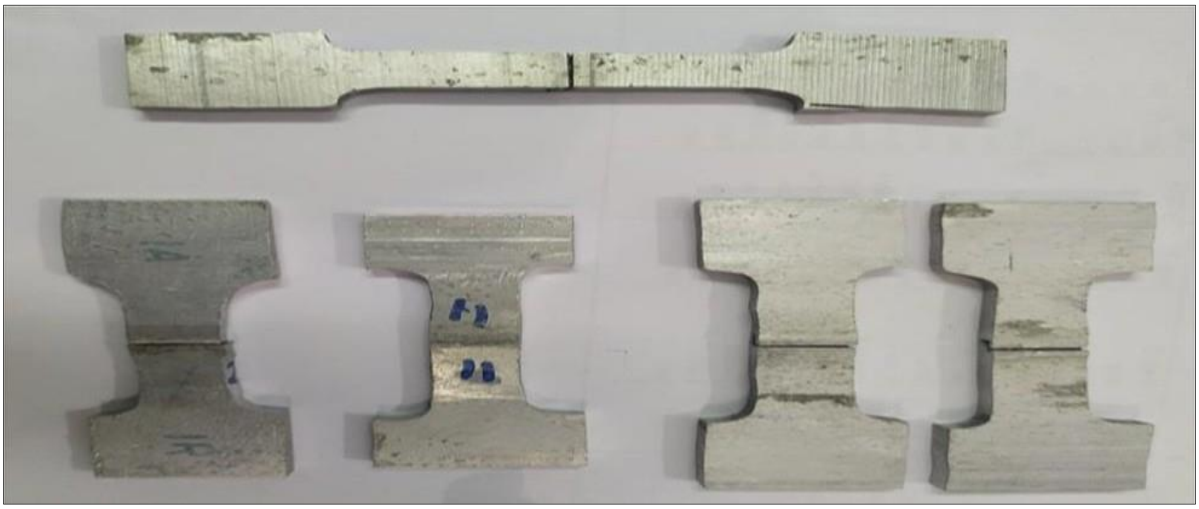


Figure 4: Tensile Strength of Al-composite Prepared

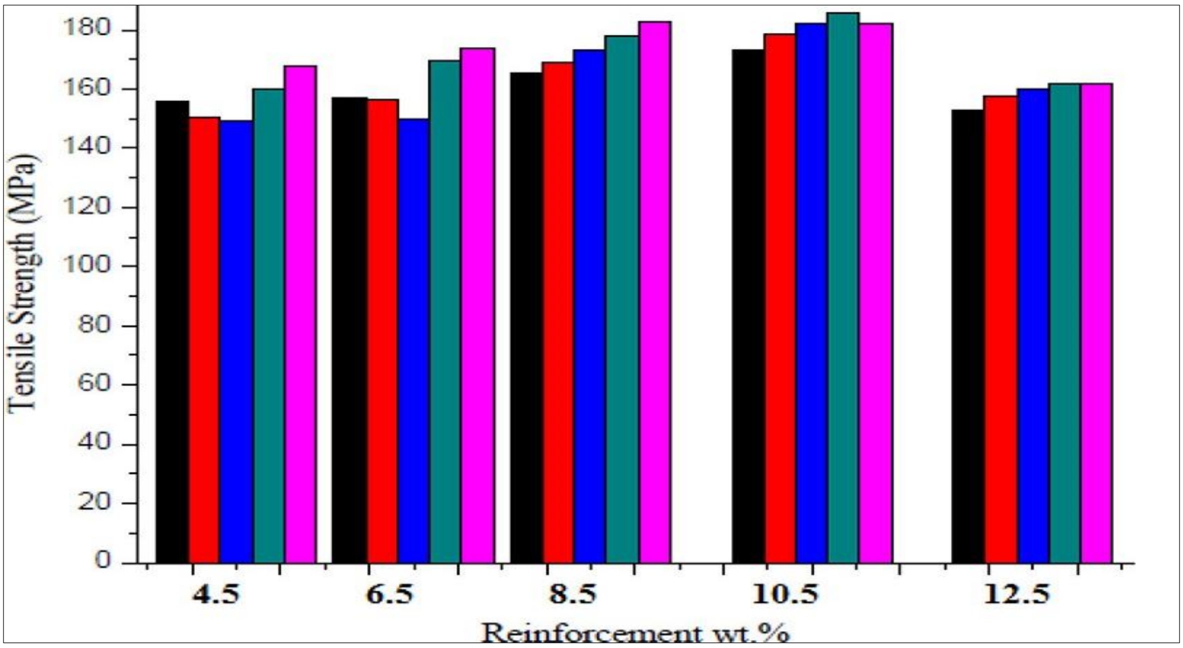


Table 1: Different Types of Ball Mills

Variables	Attritors	Vibratory ball mills	Planetary ball mills	Roller mills
Shock frequency (Hz)	>900	10–230	5.5–110	0–2.8
Kinetic energy (10^{23}J/hit)	<15	150	0.5–860	0–180
Ball velocity (m/s) Ball weight powder ratio	4.6–5.3 <0.004	≤4.2 0.005-0.28	0.26–12.24 0–1.663	<8 0–0.2

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Table 2: AMMC Composition

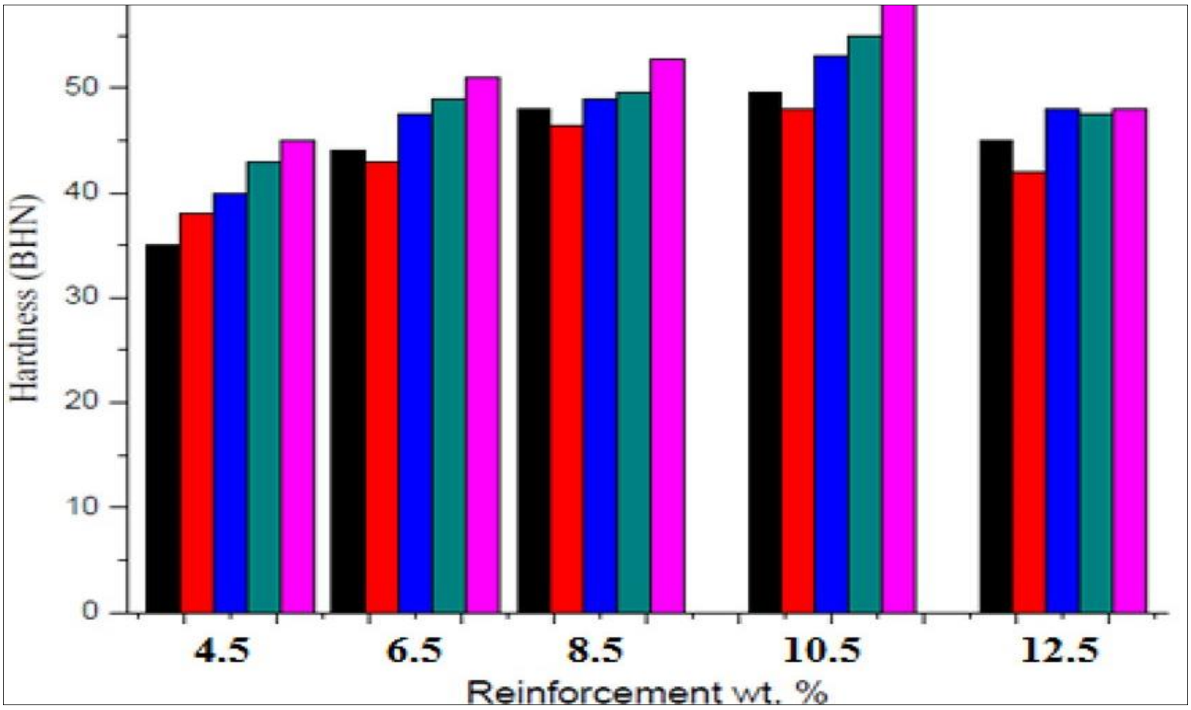
S. No.	Reinforcement (Wt.%)			AA3105/SiC/Al2O3 composition with	AA3105/ SiC/Al2O3 composition without
		AA3105/SiC/1% Cr	AA3105/Al2O3/1% Cr	ball milled/1% Cr	ball milled/1% Cr
1	4.75	Al/3.75% SiC /1% Cr	Al/3.75% Al2O3/1% Cr	Al/1.875% SiC /	Al/1.875% SiC /1.875%
				1.875% Al2O3/1% Cr	Al2O3/1% Cr
2	6.75	Al/5.75% SiC /1% Cr	Al/5.75% Al2O3/1% Cr	Al/2.875% SiC /	Al/2.875% SiC /2.875%
				2.875% Al2O3/1% Cr	Al2O31% Cr
3	8.75	Al/7.75% SiC /1% Cr	Al/7.75% Al2O3/1% Cr	Al/3.875% SiC /	Al/3.875% SiC /3.875%
				3.875% Al2O3/1% Cr	Al2O3/1% Cr
4	10.75	Al/9.75% SiC /1% Cr	Al/9.75% Al2O3/1% Cr	Al/4.875% SiC /	Al/4.875% SiC /4.875%
				4.875% Al2O3/1% Cr	Al2O3/1% Cr
5	12.75	Al/11.75% SiC /1% Cr	Al/11.75% Al2O3/1% Cr	Al/5.875% SiC /	Al/5.875% SiC / 5.875%
				5.875% Al2O3/1% Cr	Al2O3/1% Cr

An excellent heat treatment product is made up of Alumina powder, carbonated SiC powder, and 1% Cr. Ball-milled reinforced composite has an increased tensile strength of 22.41 percent above the tensile strength of AA3105 after reinforcement, which is about 150 MPa. Al-composite produced using SiC and Alumina has a tensile strength shown in Figure 4.

3.3 Analysis of hardness

Carbonized Alumina and SiC powders have increased the toughness of Al-based metal matrix composites. The hardness of the reinforcing particles was not affected by the ball-milling process. SiC powder and improved Alumina particles in a particular entity have been shown to improve the performance of ball combinations. As seen in Figure 5, this is the case. Aluminium alloy with 4.75 percent Alumina and SiC reinforcements, and 1% Cr had 48.5 BHN hardness before heat treatment.

Figure 5: Hardness Analysis of Al-composite Prepared



There is a substantial increase in hardness after heat treatment. Al/4.75 percent carbonated SiC powder/4.75 percent Alumina/1 percent Cr composite was found to have a hardness of 56 BHN after heat treatment. Carbonised SiC particles may be used as reinforcement to increase the hardness of an aluminium composite material. Ball-milled enhanced composite has a hardness 45.2 percent greater than the base metal's hardness, which is around 45 BHN before reinforcement.

4.0 Conclusions

The impact of waste materials such as SIC and carbonised alumina on the physical properties of Al-based metal composites is tested in this paper. In addition, the variables influencing the hardness are examined, such as the consequences of heat treatment. The Alumina is blended with the standard aluminium in a stir casting method for AMMC of SiC and Industrial-residues. Specimen's mechanical properties are enhanced by the process of making it. An increase in the effectiveness of Alumina in reducing pollution from industrial and agricultural waste. Modification of Al-based composite material with these reinforced wastes would alleviate these environmental issues. Ball-milling a combination of component particles for up to 75 hours produces a single entity. A homogeneous distribution of SiC and Alumina reinforcement particles was found in the Al-based MMC (Al3105) after they were ball-milled.

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