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FABRICATION AND MATERIAL CHARACTERIZATION OF COMPOSITE MATERIAL USING INDUSTRIAL WASTE SCRAPS

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ABSTRACT

A composite material is a combination of two or more different material, it gives superior quality than its constituents. composite materials which is used in wide range of application. There are three types of composites matrix materials like ceramic matrix, metal matrix, polymer matrix. In our project we using metal matrix composite by using this idea we can reduce the costs by using the waste industrial scraps instead of buying a new metal. Nowadays the industrial waste such as scraps (aluminium scraps) are abundant in waste category and today we are widely using aluminium based metal matrix composite for structural, aerospace, marine and automobile applications for its light weight, high strength and low production cost and also aluminium alloys deals with low density and good mechanical properties, better corrosion resistance and wear, low thermal coefficient of expansion as compared to conventional metals and alloys. In our project the industrial waste like aluminium scraps are collected and reused with the combination of micro silica powder and vermiculite (GRADE V). The three compositions amount as (100% Aluminium scraps) , (95% aluminium + 5% Silica) and (95% Aluminium + 5% Vermiculite) .The main aim of our project is to reuse the industrial wastes.

1. INTRODUCTION

Composits material is a macroscopic combination of two or more distinct materials, having a recognizable interface between them. Composites are used not only for their structural properties, but also for electrical, thermal, and environmental applications. Modern composite materials are usually optimized to achieve a particular balance of properties for a given range of applications. Given the vast range of materials that may be considered as composites and the broad range of uses for which composite materials may be designed, it is difficult to agree upon a single, simple, and useful definition. However, as a common practical definition, composite materials may be restricted to emphasize those materials that contain a continuous matrix constituent that binds together and provides form to an array of a stronger, stiffer reinforcement constituent.

The composites are heterogeneous materials, which is an important feature compared for instance to the metal homogeneous plastics. There are many kinds of failure and damage modes in the composite structures. One of them is the interlaminar fracture known as delamination, which is, at the same time one of the most important failure mode. Delamination growth remains a critical failure mode in laminated composite structures. The interlaminar fraction of composite material has been very intensively investigated. The delamination means degradation between adjacent plies of material. The composite materials exhibit superior properties only in the fiber direction; hence the delamination of composite structures results in a significant loss of stiffness and strength. The interlinear crack growth resistance of long fiber-reinforced composites can significantly increase in the presence of fiber bridging, which induces tractions that act over an extended zone in the wake of the crack tip. The resistance to delamination is one of the most important characteristics of laminate and unidirectional composites. One major drawback of composite materials is delamination—separation of a laminate into layers. One major US Company, Kenetech, failed partly because of delamination failure at the trailing edge. The size of the wind turbine blades, without the proper understanding of the material behavior, is likely to produce failure due to delamination.

Many ways have been found to resist delamination, for example weaving the fibers increases the toughness, but introduces micro-buckling modes, which is detrimental to the compressive strength; toughening the resin suppresses delamination but often decreases the modulus, an inherent trade-off in increasing toughness in the resins. Toughened resins are commonly used in aerospace pre impregnated materials, to resist delamination. However, the cost of using prepreg materials in wind turbine manufacture can be high. Hence, low cost composite materials are sought for building wind turbine blades, such as fiberglass, where delamination has not been studied in detail. There are three fundamental ways delamination can happen: opening mode, shearing or sliding mode, and tearing mode. More often than not, delamination occurs under mixed opening and shearing modes, which is the subject of this study. This study is the extension of researches by Darrin Haugen and Robert More head, who studied delamination of the skin-stiffener intersection geometry which is common in composite materials structures like wind turbine blades. This work combines, adds to, and revises their earlier work.

A fiber-reinforced composite (FRC) is a high-performance composite material made up of three components - the fibers as the discontinuous or dispersed phase, the matrix acts as the continuous phase, and the fine interphase region or the interface. The matrix is basically a homogeneous and monolithic material in which a fiber system of a composite is embedded. It is completely continuous. The matrix provides a medium for binding and holding reinforcements together into a solid. It offers protection to the reinforcements from environmental damage, serves to transfer load, and provides finish, texture, colour, durability and functionality.

Industrial waste management is the main problem in the recent world, it is no more spaces to dump the wastes, Aluminium industrial waste recycling is our main scope for this project. The recycled

Aluminium wastes strength can be improved by using the adding ceramic materials will improve its properties. Micro Silica powders and vermiculite powders are added with aluminium scraps with 5% of weight ratios. Material characterization tests are carried out for Aluminium scraps, Aluminium with Si-5% and Aluminium scraps with Vermiculite-5%. Tensile Tests, stress strain, Impact test, and Hardness test are conducted for Aluminium scraps, Aluminium Scraps with 5% Si and Aluminium scraps with Vermiculite-5%.

2. MATERIAL SELECTION

2.1. Aluminum Matrix

In recent years aluminium matrix composites (AMCs) are gaining widespread popularity in several technological sectors owing to their excellent corrosion and wear resistance, higher fatigue life, good high temperature oxidation resistance in addition to being light in weight when compared with conventional alloys[1]. At present AMCs are attractive alternatives for aerospace and automotive applications because of their high stiffness-to-weight characteristics. Currently, focus on development of aluminium, copper, magnesium, titanium based metal matrix composites is carried out to explore their possible applications in several high-tech areas. The various reinforcements that have been tried out to develop AMCs are graphite, silicon carbide, titanium carbide, tungsten, boron, Al_2O_3, fly ash, Zr, Si_3N_4, TiB_2[2].

Addition of Gr particulates facilitates easy machining and results in reduced wear of Al–Gr[3] composites compared to Al alloy. It is reported that the surface finish of the hard reinforced metal matrix composites are inferior when compared with the matrix alloy. Further it is absorbed that during turning, the hard reinforced metal matrix composites resulted in higher flank wear with increased content of the reinforcement. It is reported that composites possessing softer reinforcement

2.2. Silica Powder

Silicon dioxide, also known as silica, is an oxide of silicon with the chemical formula SiO_2[3,4], most commonly found in nature as quartz and in various living organisms. In many parts of the world, silica is the major constituent of sand. Silica is one of the most complex and most abundant families of materials, existing as a compound of several minerals and as synthetic product. Notable examples include fused quartz, fumed silica, silica gel, and aerogels. It is used in structural materials, microelectronics (as an electrical insulator), and as components in the food and pharmaceutical industries.

Inhaling finely divided crystalline silica is toxic and can lead to severe inflammation of the lung tissue, silicosis, bronchitis, lung cancer, and systemic autoimmune diseases, such as lupus and rheumatoid arthritis. Inhalation of amorphous silicon dioxide, in high doses, leads to non-permanent short-term inflammation, where all effects heal.

About 95% of the commercial use of silicon dioxide (sand) occurs in the construction industry, e.g. for the production of concrete (Portland cement concrete).

Silica, in the form of sand is used as the main ingredient in sand casting for the manufacture of metallic components in engineering and other applications. The high melting point of silica enables it to be used in such applications.

Crystalline silica is used in hydraulic fracturing of formations which contain tight oil and shale gas.

2.3. Vermiculite Powder

Vermiculite, a hydrous phyllosilicate mineral, undergoes significant expansion when heated. Exfoliation occurs when the mineral is heated sufficiently,[7,8] and commercial furnaces can routinely produce this effect. Vermiculite forms by the weathering or hydrothermal alteration of biotite or phlogopite. Large commercial vermiculite mines currently exist in Russia, South Africa, China, and Brazil.

Vermiculite is 2:1[9] clay, meaning it has two tetrahedral sheets for every one octahedral sheet. It is a limited-expansion clay with a medium shrink–swell capacity. Vermiculite has a high cation-exchange capacity (CEC) at 100–150 meq/100 g. Vermiculite clays are weathered micas in which the potassium ions between the molecular sheets are replaced by magnesium and iron ions.

Figure 1 Raw materials of the composite material (a) aluminum scrapes (b) Vermiculite Grade v (c) Silica Powder

TABLE I
PROPERTIES OF MATERIALS

Properties	Aluminum	Micro Silica Powder	Vermiculite
Density	2700 Kg/m3	2650 kg/m³	172 Kg/m3
Young's Modulus	70GPa	66.3GPa	11GPa
Poisson's Ratio	0.3	0.15	0.31
Tensile Strength	90 MPa	45 Mpa	---
Melting Point	660.3 °C	1,710 °C	1350°C

3. FABRICATION PROCESS

3.1. Ball milling

Ball milling process where a powder mixture placed in the ball mill is subjected to high-energy collision from the balls. This process was developed by Benjamin and his co-workers at the International Nickel Company in the late of 1960. It was found that this method, termed mechanical alloying, could successfully produce fine, uniform dispersions of oxide particles (Al_2O_3, Y_2O_3, ThO_2) in nickel-base superalloys that could not be made by more conventional powder metallurgy methods. Besides materials synthesis, high-energy ball milling is a way of modifying the conditions in which chemical reactions usually take place either by changing the reactivity of as-milled solids (mechanical activation increasing reaction rates, lowering reaction temperature of the ground powders)or by inducing chemical reactions during milling (mechanochemistry). It is, furthermore, a way of inducing phase transformations in starting powders whose particles have all the same chemical composition: amorphization or polymorphic transformations of compounds, disordering of ordered alloys, etc.

The alloying process can be carried out using different apparatus, namely, attritor, planetary mill or a horizontal ball mill. However, the principles of these operations are same for all the techniques. Since the powders are cold welded and fractured during mechanical alloying, it is critical to establish a balance between the two processes in order to alloy successfully. Planetary ball mill is a most frequently used system for mechanical alloying since only a very small amount of powder is required. Therefore, the system is particularly suitable for research purpose in the laboratory. The ball mill system consists of one turn disc (turn table) and two or four bowls. The turn disc rotates in one direction while the bowls rotate in the opposite direction. The centrifugal forces, created by the rotation of the bowl around its own axis together with the rotation of the turn disc, are applied to the powder mixture and milling balls in the bowl. The powder mixture is fractured and cold welded under high energy impact.

The rotation directions of the bowl and turn disc are opposite, the centrifugal forces are alternately synchronized. Thus friction resulted from the hardened milling balls and the powder mixture being ground alternately rolling on the inner wall of the bowl and striking the opposite wall. The impact energy of the milling balls in the normal direction attains a value of up to 40 times higher than that due to gravitational acceleration. Hence, the planetary ball mill can be used for high-speed milling.

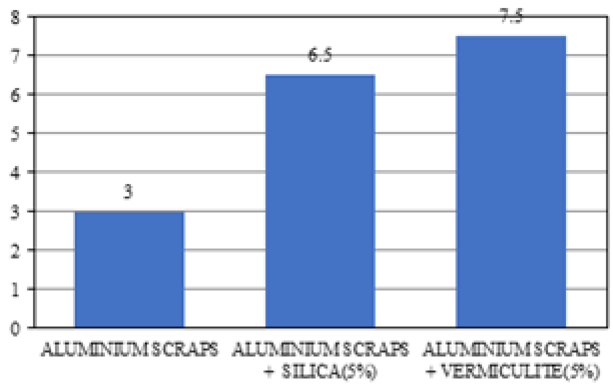

Figure 2 Impact test result

3.2. Stir Casting process

In a stir casting process, the reinforcing phases are distributed into molten matrix by mechanical stirring. Stir casting of metal matrix composites was initiated in 1968, when S. Ray introduced alumina particles into aluminum melt by stirring molten aluminum alloys containing the ceramic powders. Mechanical stirring in the furnace is a key element of this process. The resultant molten alloy, with ceramic particles, can then be used for die casting, permanent mold casting, or sand casting. Stir casting is suitable for manufacturing composites with up to 30% volume fractions of reinforcement.

The cast composites are sometimes further extruded to reduce porosity, refine the microstructure, and homogenize the distribution of the reinforcement. A major concern associated with the stir casting process is the segregation of reinforcing particles which is caused by the surfacing or settling of the reinforcement particles during the melting and casting processes. The final distribution of the particles in the solid depends on material properties and process parameters such as the wetting condition of the particles with the melt, strength of mixing, relative density, and rate of solidification .The distribution of the particles in the molten matrix depends on the geometry of the mechanical stirrer, stirring parameters, placement of the mechanical stirrer in the melt, melting temperature, and the characteristics of the particles added.

An interesting recent development in stir casting is a two-step mixing process. In this process, the matrix material is heated to above its liquids temperature so that the metal is totally melted. The melt is then cooled down to a temperature between the liquids and solidus points and kept in a semi-solid state. At this stage, the preheated particles are added and mixed. The slurry is again heated to a fully liquid state and mixed thoroughly. This two-step mixing process has been used in the fabrication of aluminum. Among all the well-established metal matrix composite fabrication methods, stir casting is the most economical. For that reason, stir casting is currently the most popular commercial method of producing aluminum based composites.

3.3. Machining

Machining is used to introduce features that cannot be produced during the casting process. This is due to the very small tolerances of the design dimensions. In these instances, a 'machining allowance' is incorporated at the design stage so that the casting can eventually be machined back to the exact dimensions.

Machining takes place once any fettling or heat treatment has been completed but before any finishing processes, such as anodising or painting. Machining is carried out by computer numerical control (CNC). Specialist computers are programmed to guide the machining tools and shape the component accordingly.

Table 2

PROPERTIES OF MATERIALS

Properties	Aluminum	Micro Silica Powder	
Composition 1	1000 grams	---	---
Composition 2	950 grams	50 grams	---
Composition 3	950 grams	---	50 grams

Figure 2 Specimens for testing

4. MECHANICAL TESTING

4.1. Impact Test

Izod impact testing is an ASTM standard method of determining the impact resistance of materials. A pivoting arm is raised to a specific height (constant potential energy) and then released. The arm swings down hitting the sample, breaking the specimen.

Table 3

IMPACT TEST RESULTS

Specimen	Impact Value (J)
Aluminium scraps	3
Aluminium scraps + silica (5%)	6.5
Aluminium scraps + vermiculite (5%)	7.5

4.2. Tensile Test

Tensile testing, is also known as tension testing, is a fundamental materials science test in which a sample is subjected to a controlled tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area. From these measurements the following properties can also be determined: Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics. Uniaxial tensile testing is the most commonly used for obtaining the mechanical characteristics of isotropic materials. For anisotropic materials, such as composite materials and textiles, biaxial tensile testing is required.

4.3. Hardness Test

The Rockwell scale is a hardness scale based on indentation hardness of a material. The Rockwell test measuring the depth of penetration of an indenter under a large load (major load) compared to the penetration made by a preload (minor load).[1] There are different scales, denoted by a single letter, that use different loads or indenters. The result is a dimensionless number noted as HRA, HRB, HRC, etc., where the last letter is the respective Rockwell scale (see below). When testing metals, indentation hardness correlates linearly with tensile strength

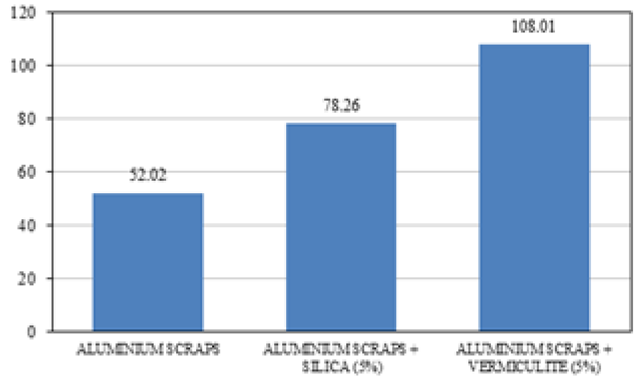

Figure 3 Tensile test result

Table 4

TENSILE TEST RESULTS

Specimen	Vermiculite
Aluminium scraps	52.02
Aluminium scraps + silica (5%)	78.26
Aluminium scraps + vermiculite (5%)	108.1

Table 5

HARDNESS TEST RESULTS

Specimen	Rockwell Hardness (HRB)
Aluminium scraps	42.4
Aluminium scraps + silica (5%)	43.6
Aluminium scraps + vermiculite (5%)	44.8

5. CONCLUSION

In the present work, an experimental investigation is carried out on the topic of fabrication and material characterization of composite material using industrial waste scraps for the waste management purpose. The various specimens were prepared with the different composition such as Aluminium scraps, Aluminium scraps + silica and Aluminium scraps + vermiculite. The graphs were plotted for the results obtained from mechanical tests like, Tensile test, Yield test, Impact test, Hardness test, Elongation test, Scanning Electron Microscope test, From the result tables and graphs we can able to conclude that (95%Aluminium scraps +5% vermiculite) possess good mechanical properties than other composition.(95% Aluminium scraps +5% vermiculite) > (95%Aluminium + 5% silica) > (100% Aluminium scraps) .So we can conclude that (95%Aluminium scraps +5% vermiculite) is having better mechanical properties in all aspects when compare to the (95% aluminium scraps + 5% silica) and (100 % aluminium scraps).Please include a brief summary of the possible clinical implications of your work in the conclusion section. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. Consider elaborating on the translational importance of the work or suggest applications and extensions.

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