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Mechanical Properties of Graphite/Fly Ash Reinforced Epoxy Hybrid Composite

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Abstract: *Light weight structure utilizing novel design and advanced materials is one of the key to improving the fuel efficiency and reducing the environment burden of automotive vehicles. To ensure the low cost of applying fiber-reinforced materials in automotive vehicles, it is proposed to selectively incorporate graphite & fly ash to enhance composites along main loading path. This paper investigates the influence of stacking sequence of the Hybrid composite comprising materials with differing stiffness and strength. Hybrid composite will be manufactured by varying ratio of graphite and fly ash in an epoxy resin.*

1. INTRODUCTION

A composite material [1] can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties. The two constituents are reinforcement and a matrix. The main advantages of composite materials are their high strength and stiffness, combined with low density, when compared with bulk materials, allowing for a weight reduction in the finished part.Today Composites [2] are receiving much attention not only because they are on the cutting edge of active material research field but also because there is a great deal of promise for their potential applications in various industries ranging from aerospace to construction due to their various outstanding properties. Realities of the modern world demand that engineering materials simultaneously possess high stiffness, strength and impact toughness, which is not a trivial task. Typically, stiff and strong materials such as ceramics are brittle, whereas tough materials, for example rubber, are soft and weak. On an Ashby plot this translates into an inverse correlation between strength and toughness. Such problematic behavior, however, is much less pronounced in natural composites like nacre, bone, turtle shell or sponge spicule , where a number of complex reinforcing mechanisms including crack bridging, crack deflection and geometric/structural intricacy provide resistance to fracture propagation and impact toughness .Composites are made up of individual materials referred to as constituent materials. There are two main categories of constituent materials: matrix and reinforcement. At least one portion of each type is required. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart their special mechanical and physical properties to enhance the matrix properties. A synergism produces material properties unavailable from the individual constituent materials, while the wide variety of matrix and strengthening materials allows the designer of the product or structure to choose an optimum combination.Engineered composite materials must be formed to shape. The matrix material can be introduced to the reinforcement before or after the reinforcement material is placed into the mould cavity or onto the mould surface. The matrix material experiences a melting event, after which the part shape is essentially set. Depending upon the nature of the matrix material, this melting event can occur in various ways such as chemical polymerization or solidification.One of the most common and familiar composite is fibre-glass, in which small glass fibre are embedded within a polymeric material (normally an epoxy or polyester). The glass fibre is relatively strong and stiff (but also brittle).

2. LITERATURE REVIEW

Effect of fly ash filler size on mechanical properties of polymer matrix composites

R.Satheesh Raja, K.Manisekar, V.Manikandan (2013) ISSN 2320–4060.

In his work, fly ash has been used as filler material in epoxy polymer to produce particulate reinforced polymer composites. The chemical composition of fly ash and its particle size plays an important role in the enhancement of physical and mechanical properties of polymer matrix composites (PMC). Here four different sizes of fly ash (50 μm, 480 nm, 350 nm, 300 nm) with 10 wt % are impregnated with epoxy resin to process the PMC by using simple mold arrangement. The size reduction is obtained by means of ball milling technique. Scanning electron microscope (SEM) and energy dispersive spectroscopy (EDS) are used to characterize the fly ash. Mechanical properties such as hardness and impact strength are analyzed as per ASTM standards. It was found that size reduction of fly ash particle enhanced the strength of PMC.Fly ash impregnated polymer matrix composite specimens used in this work are manufactured by pouring the mixture contain both fly ash and epoxy resin in the required size of mould. Before that the measured quantity of the fly ash say 10 wt % is put into the epoxy resin and mixed it evenly by using mechanical stirrer. Hardener is added with the mixture for quick setting of composite specimen.The molding box surface was covered with wax plastic sheets along with wax polish, which acts as a releasing agent for easy and quick removal of composite panel. After sometime the specimen is taken out from the mould for mechanical testing.The hardness values indicated that decrease in fly ash filler size increases the hardness. The addition of fly ash filler increases the hardness of composite material due to increase in the resistance strength of polymer to plastic deformation. The composite with 300 nm size fly ash filler yields higher hardness value than other filler sizes due to the better adhesion between the matrix and the filler. In this case, the polymeric matrix phase and the solid filler phase would be pressed together and touch each other more tightly. Thus the interface can transfer pressure more effectively in smaller size fly ash filler than larger one. This might have resulted in an enhancement of hardness.The Charpy impact test was used to evaluate the relative toughness of the test materials which is reported in energy lost per unit of specimen thickness or cross sectional area. High strain rates or impact loads may be expected in many engineering applications of composite materials.It can be observed that the energy absorbed in fracturing the specimens increasing with decreasing fly ash filler size. The impact strength increased in the case of smaller particle size fly ash which confirmed that the void space available in the larger particle size fly ash material. Therefore the stress propagation was greater in the case of a larger fly ash particle size filled composites than that of a smaller fly ash particle size composites.In this work the residue from the thermal power plant is utilized as filler material in the polymer matrix composite materials. Morphological and elemental characterization of fly ash was performed by SEM and EDS. Micron level fly ash particle was converted into Nano level by means of ball milling technique. The composite specimens are prepared by impregnating four different sizes (50 µm, 480 nm, 350 nm, and 300 nm) of fly ash filler materials by using molding process. Mechanical testing such as hardness and impact test was carried out. It is found that the 300 nm size fly ash filler impregnated polymer composite yields better impact energy (14 J) and hardness value (35 Hv) than others. Thus by decreasing the size of fly ash filler leads to increase the interface between the polymeric matrix and the solid fillers.

This work paves a scope for future investigators to obtain the size of filler materials less than 100 nm for better enhancement of mechanical and physical properties of particulate reinforced polymer composites.

Effect of Graphite Filler on Mechanical Behavior of Epoxy Composites by Subita Bhagat, Pardeep Kumar Verma (ISSN 2250-

2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 2, February 2013)

Graphite reinforced epoxy composites with different particulate fractions of graphite were investigated for mechanical properties such as tensile, impact and flexural. The graphite content was varied from 2% to 8% by weight of total matrix in the composites. The results showed that the mechanical properties of the composites mainly depend on dispersion condition of the filler particles, particle size and aggregate structure. The composites showed improved tensile modulus, flexural modulus and impact strength in bending properties with increase filler content as the functional group tends to decrease in composites with increasing filler content as gelation occurs vigorously in the composite.The composite samples were tested for their mechanical strength as:The specimen used in Izod test must be notched according to the ASTM D-256, ISO 179.The reason for notching the specimen is to provide a stress concentration area that promotes a brittle rather than a ductile failure.The samples for tensile testing were prepared according to the ASTM D-638. These samples were cut into a dumb-bell shape with the help of die, operated by hand press.The test sample of specified size 80 mm x 10 mm x 2mm were cut with the help of motor driven blade in machine shop according to ASTM D790.The mechanical properties of composite made of high modulus filler and relatively low modulus polymeric matrix are sensitive to loading rate and temperature. Tensile elongation and tensile modulus measurements are among the most important indications of strength in a material and are the most widely specified properties of plastic materials. Tensile properties are temperature sensitive. The structure and properties of the filler matrix interface play a major role in the mechanical and physical properties of composite materials.It was observed that the tensile modulus increases as the filler concentration increases because of absence of voids in the composite, good mixing of the filler in the matrix and most important is two dimensional structures of graphite particles. The study revealed that as the tensile modulus increases, the ultimate stress and % elongation decreases.It was observed that the elongation at break decreases slowly as filler concentration increases due stiffness increases with filler content. These results proved that graphite flakes have the synergistic effect on improving mechanical properties of epoxy resin. The flexural properties of composites depend critically on the microstructure of the composite and the interfacial bonding between the filler and matrix. In this study flexural strength of the graphite filled polymer composite was measured with respect to filler content.The study reveals that the flexural strength increases from 200 MPa to 285 MPa with the increases of graphite content due to interfacial bonding and additional load-bearing capacity of the matrix, which can be due to good filler matrix adhesion.It was observed that impact strength and toughness decreases with an increase in filler content. The decrease in impact strength is due to decreased availability of epoxy material to bond all the graphite particles in the matrix. It is examined that the impact property of polymeric material are directly related to the over toughness of the material. The impact energy is a measure of toughness .The higher the impact energy of material, the higher the toughness of material vice versa. The study revealed that this type of behavior is common for polymers filled with particulate system. The results showed that the particulate filler initiates a crack formation via stress concentration on the filler surface and slight decrease in energy due to decreased availability of epoxy material to bond all the graphite particles in the matrix.

3. METHODOLOGY

The Hybrid Composite materials used for the present investigation is fabricated by hand layup process.

Epoxy Resins

Epoxy resins are the most commonly used thermoset plastic in polymer matrix composites.

Epoxy resins are a family of thermoset plastic materials which do not give off reaction products when they cure and so have low cure shrinkage. They also have good adhesion to other materials, good chemical and environmental resistance, good chemical properties and good insulating properties. The epoxy resins are generally manufactured by reacting epichlorohydrin with bisphenol. Different resins are formed by varying proportions of the two: as the proportion of epichlorohydrin is reduced the molecular weight of the resin is increased. The general reactive group in epoxies is ECHOCH2.

Curing of Epoxy Resins

Epoxy resins are cured by means of a curing agent, often referred as catalysts, hardeners or activators. Often amines are used as curing agents. In amine curing agents, each hydrogen on an amine nitrogen is reactive and can open one epoxide ring to form a covalent bond.

Experimentation

Commercially available ARALDITE AW 106 along with Hardner HV 953 IN was used as matrix material in fabrication of different specimen. For processing the mix ratio (by weight) of ARALDITE (100 parts) and hardner (25 parts) are used as specified.

Raw Material Used

Fly ash:- Class F

Epoxy resin:- Araldite- AW- 106

Hardener :- HV-953 IN

Graphite

Fabrication of Material

The fabrication of the Hybrid composite was done at room temperature. The required

Ingredients of resin, hardener, fly ash and graphite were mixed thoroughly in beaker as shown and the mixture so made was transferred to mould cavity of the mould.

Dough preparation

The required mixture of resin & hardner were made by mixing them in (10:2.5) parts in a beaker by stirring the mixture in a beaker by a rod taking into care that no air should be entrapped inside the solution.

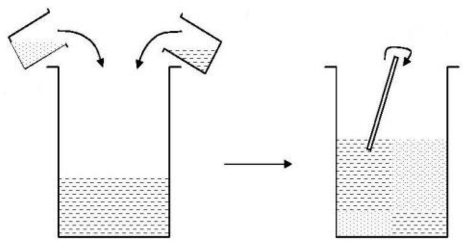

FIG. 3.1 Dough Preparation

FIG. 3.2 Graphite Powder FIG. 3.3 Fly ash

FIG. 3.4 Epoxy resin

Casting of slabs

The dough prepared was transferred to mould cavity by care that the mould cavity should be thoroughly filled. Leveling was done to uniformly fill the cavity.

Curing

Curing was done at room temperature for approx. 24 hrs. After curing the mould was opened slab taken out of the mould.

FIG. 5.5 Specimen

Sample Preparation

Three different composition specimens were made of 180X40X20(mm) & then samples were taken each for Hardness & Impact test.

Material composition

Following nomenclature shown in Table is used for identification of different compositions.

Material Designation	% of graphite by weight	% of fly ash by weight	% of epoxy resin by weight
A	30	10	60
B	20	20	60
C	10	30	60

APPLICATIONS

1. In Aerospace- Approximately 50% component of the airspace is made from composites. The primary benefits that hybrid composite components are reduced weight and assembly simplification. The large scale use of hybrid composites in current program of development of helicopters, military fighter aircraft, small and big civil transport aircraft, satellites, launch vehicles and missiles. Various components of aircraft are fabricated by composites, e.g. rudder, spoilers, airbrakes, elevators, LG doors, engine cowlings, keel beam, rear bulkhead, wing ribs, main wings, turbine engine fan blades, propellers, Interior components etc.

2. In Automotive – Hybrid Composites are being considered to make low weight, safer and more fuel-efficient vehicles. A Hybrid composite is composed of a high strength fiber (carbon or glass) in a matrix material (epoxy polymer) that when combined provides magnify properties compared with the individual materials by themselves. Many components like steering wheel, dashboard, seat, roof, hatch, mats, energy absorber, instrument cluster, interior and exterior panel, leaf spring, wheels, engine cover etc. fabricated by composite materials.

3. In Medical- A Hybrid composite is a nonviable material used in a medical device and intended to interact with biological system. Over the centuries, advancement in synthetic materials, surgical technique and sterilization methods have permitted the use of composite material in many ways. Medical practice today utilizes a large number of devices and implants.

4. Hybrid Composites in the form of sutures, bone and joint replacements, vascular grafts, heart valves, intraocular lenses, dental implants, pacemakers, biosensors, artificial hearts etc. widely used to replace and/or restore the function of disturbed or degenerated tissues or organs, to improve function, to assist in healing, to correct abnormalities and thus improve the quality of life of the patients.

5. In Electrical field- Hybrid Composite materials have strength, high modulus; electronic composites emphasize high thermal conductivity, low thermal expansion, low dielectric constant and high/low electrical conductivity depending on the particular electronic applications. Electronics hybrid composites can use expensive fillers, such as silver particles, which serve to provide high electrical conductivity. The application of composites in electronics include interconnections, printed circuit boards, interlayer dielectrics, die attach, lids, thermal interface materials, electrical contacts, connectors, heat sinks, housings etc

6.In Sports- Hybrid Composite materials are used in sports equipment because they offer ease of transport, resistance, low weight, low maintenance and durability. Initially, natural materials, like wood, were used due to its good shock absorption, but these materials had some drawbacks. The anisotropic nature resulted in low resistance and the variation in properties and high moisture absorption allocate various deformations. The hybrid composite material has characteristics of fatigue resistance break resistance, superior thermo stability, friction resistance, abrasion resistance and vibration attenuation, and it has light weight, high strength and high design freedom, and can be processed and shaped easily, so it is widely used in sports equipment. There are various goods made of hybrid composite materials, including the planning boats, sailing boats, sailboards tennis rackets, badminton rackets, softball bats, ice hockey sticks, bows and arrows etc.

7. In Chemical Industry- Advantages of hybrid composites of fire resistance properties, lightweight, mold ability, and resistance to chemicals has made the material used in the chemical industry. Hybrid Composites are extensively used in industrial gratings, scrubbers, ducting, piping, exhaust stacks, pumps & blowers, structural supports, storage tanks, columns, reactors etc. for alkaline & acidic environments. Some applications are drive shaft, fan blades, ducts, stacks, underground storage tanks, casings, composite vessels etc. Internationally, Hybrid composites applications in chemical industry are a relatively small segment in relation to the total usage of composites.

4. RESULTS

Specimens are as per the proportions shown in fig.7.1 by keeping epoxy resin quantity constant in all the three specimens A, B & C. Each specimen weight apprx 195gm and dimensions are 185X40X20 mm.

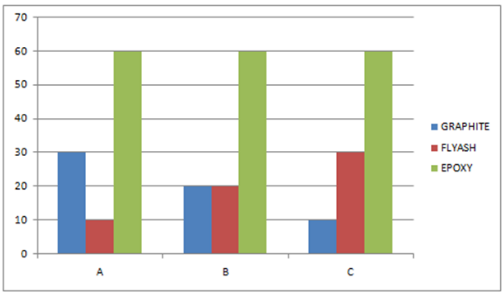

FIG.7.1 Weight percentage variation of specimen

Charpy impact tests are performed on each specimen for three trials as per ASTM D-256 on 30J capacity KRISTAL ELMEC equipment. Each specimen is machined as per the standard dimensions need and a V notch is made on three test pieces of each specimen A,B & C. The results obtained are shown in fig.7.2. For each specimen the impact result obtained is same.

Specimen	Observed values (J)
A	2,2,2
B	2,2,2
C	2,2,2

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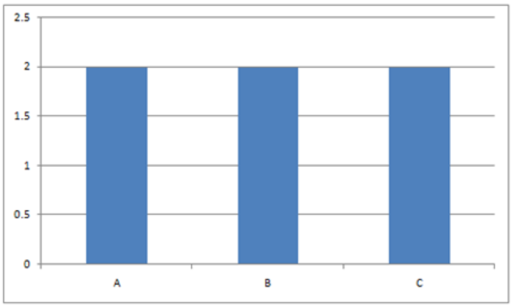

FIG.7.2 Charpy Impact test for Joules Vs Specimen

Shore Hardness test is also performed as per the standard ASTM D-2240 on SHR-GOLD equipment and the standard block is 50 SHORE D. The three specimens are taken each for three trial test pieces and the hardness test id done using intender D. The results obtained varied on comparing to each other. The specimen A with more graphite percentage showed greater hardness compared to other two specimens B & C, which is shown in fig.7.3.

Specimen	Shore 'D' hardness
A	54,55,54
B	53,52,53
C	54,54,53

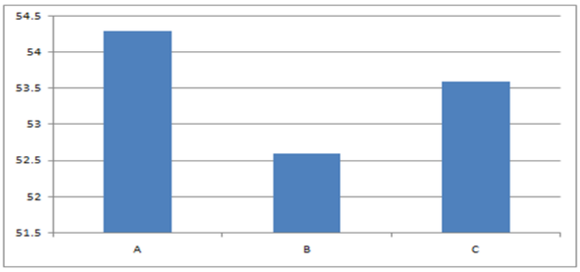

FIG.7.3 Shore hardness test, Avg. Hardness Vs specimen

5. CONCLUSION

The Hybrid composite made with reinforcing both graphite & fly ash together by varying and also with equal proportions in epoxy resin did not have much variation in toughness & hardness as shown above in results. But among the compared results, with more quantity of graphite as filler the greater toughness of material is attained. Hence, the hybrid composite with lesser fly ash and higher graphite proportions make better composite.In comparison to the work of R.Satheesh Raja, K.Manisekar, V.Manikandan, The composite specimens prepared of fly ash filler materials by using molding process yields impact energy (14 J) and hardness value (35 Hv) . whereas in my work I have gotThe material made further by testing in certain aspects can be of great use in market in various fields.

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