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Study On Physical and Mechanical Properties of GBF Slag Reinforced Carbon Polymer Composites

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Abstract
This research was done out to enhance the mechanical properties of polymer composites using industrial waste as a potential reinforcement in a carbon fibre polymer composite. Polymer composites possess good mechanical properties and high durability. They also have good frictional and wear performances after reinforcement. Blast furnace slag is one of the industrial wastes in steel industries which consists aluminos, silicates and calcium in different forms. This GBF slag was crushed and milled to 64µm size powder and introduced in carbon fibre polymer matrix. Carbon fibre is significantly stronger than steel in terms of strength to weight ratios. Carbon fibres are around 5–10µm in diameter. These features create the desired composites flexible in many Automobiles structural applications. Composites are fabricated successfully by hand layup technique. Physical and mechanical characterization like SEM, Hardness, tensile and Impact studies done, and results shows that 15% weight of GBF Slag has high strength compared with other composites in Automotive and Aerospace Applications.

Keywords: Carbon Fibre, GBF Slag, polyester Resin, Automotive, Aerospace, Industrial Waste, Polymer Composite.

1. INTRODUCTION

A material which composes of two or more different materials, have chemically distinct phases and is heterogeneous in nature at microscopic scale but is statically homogenous at macroscopic scale is known as a composite material. Compared to the individual materials the composite materials have varied and superior properties. The composite material is made up of a reinforcement which may be continuous or discontinuous but stronger and harder and a matrix that is continuous. The function of the reinforcement is to enhance the properties, increase the load carrying potential and strengthens the matrix. The function of the matrix is to keep the fibres together, protect the fibres from environment, abrasion and evenly distributes the load between the fibres.

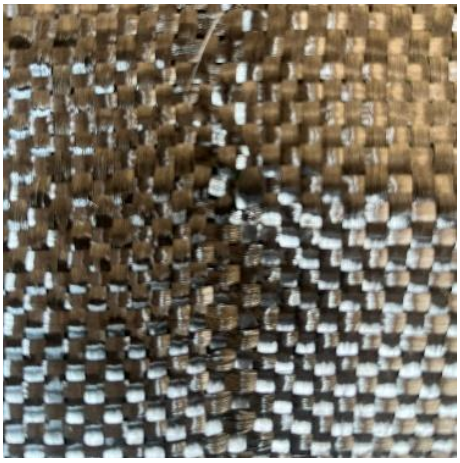
Composites containing more than one different types of reinforcements in a matrix are called hybrid composites. The different types of reinforcements are fibers, particulates, fillers and flakes. These composites exhibit superior mechanical properties than fibre-reinforced plastic composites. Many engineering applications adopts hybrid composite materials because they are lighter in weight, low cost, high strength to weight ratio and the ease of structural development. Automotive industry employs many of these composites in their application for the enhancement of functional requirement. This review outlines the mechanical characteristics of Granulated Blast Furnace (GBF) slag reinforced hybrid composite that can be operated in automobile industry.

The reinforcements used in our composite are particulates and fibres. This study aims to ulilization of the industrial waste for a better cause. Due to the large demand for the materials the amount of slag obtained has also increased throughout the years which should be recycled and hence the particulate reinforcement used in our composite is Granulated Blast Furnace (GBF) slag which is further pulverized into a fine powder of 64µm. Blast furnace slag is defined as the non-metallic product consisting of silicates and alumino-silicates of calcium and other bases that are developed in a blast furnace along with iron during the molten condition. It is one of the major wastes produced by the steel industries. The fibre reinforcement is carbon fibre which is a polymer and is sometimes known as graphite fiber. This is found by THOMAS EDISON once baked cotton threads at high temperatures which then carbonized them into an all-carbon fibre filament. Carbon fibre is made of thin strong crystalline fibres and are thinner than the strand of human hair. Carbon helps in strengthening the material. Along with high strength this fibre also possess high stiffness and tensile strength. They also have good chemical resistance and has recorded low thermal expansion.

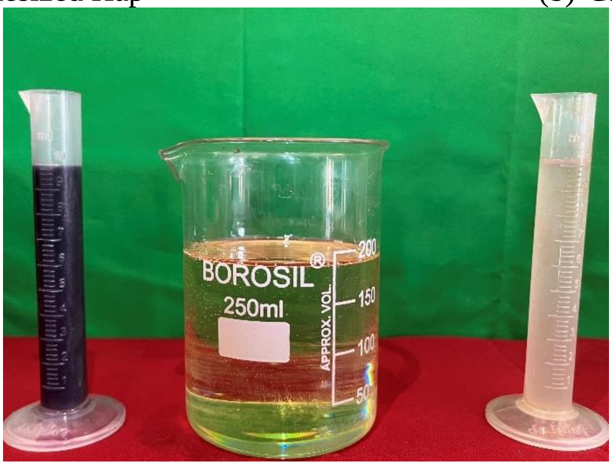
The method incorporated in producing the above composite is Hand-layup technique in which the final composite is acquired by overlapping a fixed number of fibre layers which are drenched in resin. It does not require much technical skills and machinery. This method involves three basic steps resin or gel coating, lay-up, and curing. Curing is the process of hardening the composites that may occur naturally or with an artificial aid.

2. MATERIALS AND METHODS:

(a) Synthesized Hap



(b) Carbon Fibre



(c) Resin, catlyst, Accelerator

FIG 2.1(a,b,c): Materials used for in the fabrication of Composites

2.1 Blast-furnace (BF) slag is defined by the American Society for Testing and Materials as 'the non-metallic product consisting essentially of silicates and alumino-silicates of calcium and other bases that is produced in a molten condition simultaneously with iron in a blast furnace'. This is one of the industrial wastes which comprises of oxides and increases the strength of materials. The lumps of the blast furnace slag are collected and are pulverized into a fine powder. This is again sieved through a mesh for uniform reinforcement. Granulated Blast Furnace Slag is developed when the slag is in molten stage is solidified by quenching it with water rapidly until it attains a glassy state with little or no crystallization occurs.

Oxides	Al2O3	SiO2	Fe2O3	CaO	MgO	TiO2
Wt%	16.94	35.45	1.39	36.45	6.98	1.79

Table 2.1: Chemical Composition of GBF Slag.

2.2 Carbon fibre is an organic polymer characterized by long strings of molecules bounded together by carbon atoms, which is about 5 to 10µm in diameter Carbon fibres are extensively used due to their high stiffness, high tensile strength, high strength to weight ratio, high chemical resistance, high-temperature tolerance, and low thermal expansion. Carbon fibre is made up of a material called precursor. Most of the carbon fibers are made from polyacrylonitrile (PAN) and the only 10% are made from rayon or petroleum pitch.

2.3 Polyester Iso resin is a thermosetting polymer that is commonly used in the production of composites. Its physical and mechanical properties are good, and it is a relatively low-cost resin. Polyester Iso resin is highly resistant to heat, UV radiation, and chemical corrosion, which makes it ideal for outdoor use. It has a low viscosity and can be easily mixed with reinforcement materials and fillers. Polyester Iso resin is simple to process and can be cured at ambient temperature or with heat, depending on the intended application requirements.

2.3.1 MEKP catalyst is a typical initiator employed in the hardening of unsaturated polyester resins. Only a small amount is typically added to the resin system, making up roughly 10% of the entire matrix weight. This transparent and colorless liquid can produce a rapid polymerization response when used with an accelerator.

2.3.2 The Cobalt accelerator is an accelerator commonly utilized in the curing of unsaturated polyester resins. It is often used in trace amounts as part of a resin system and, in conjunction with a peroxide initiator like MEKP, constitutes roughly 10% of the overall matrix weight in composites. The cobalt accelerator plays a vital role in the curing process by enhancing the decomposition of the peroxide initiator, resulting in a faster and more comprehensive response.

To create the desired matrix for embedding the reinforcement, a combination of Polyester Iso resin (80%), MEKP catalyst (10%), and cobalt accelerator (10%) was mixed. Carbon fiber measuring 200mm × 200mm acted as the primary reinforcement, with granulated blast furnace slag powder added as the secondary reinforcement at three varying weight fractions, i.e., 0%, 5%, 10%, and 15% respectively.

Material	Matrix wt %	Carbon Fibrewt %	GBF Slag wt %
Base	60	40	0
3% GBF Slag	57	38	5
5% GBF Slag	54.5	35.5	10
7% GBF Slag	55.8	33.2	15

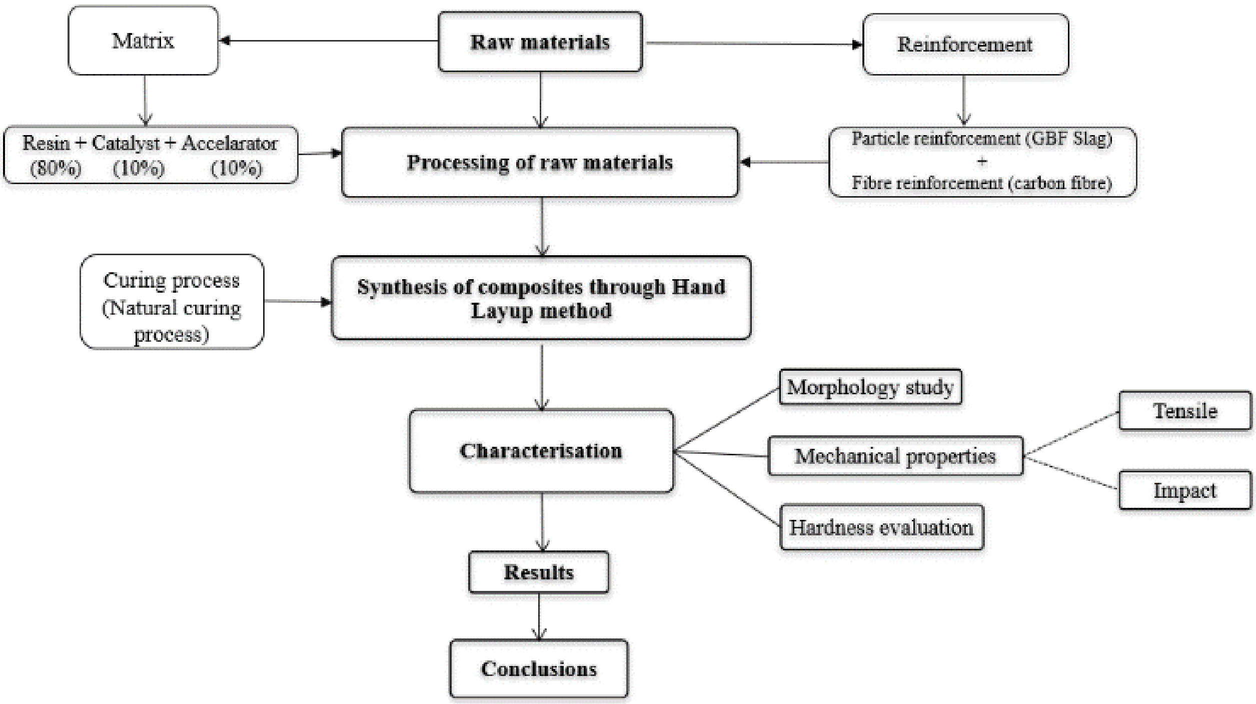
Table 2.2: Chemical Composition of fabricated Composites.

3. EXPERIMENTAL METHODOLOGY

3.1 HAND LAYUP METHOD The fabrication is carried out by hand lay-up technique. The matrix and fibre constituents are in the ratio of 1.5:1 which is as per the reference. Fibre being carbon fibre and the matrix includes iso polyester with MEKP catalyst and Cobalt accelerator. The homogenous mixture of resin is obtained by mixing the iso polyester with the catalyst in the ratio of 10:1 at the room temperature in a beaker with the aid of a glass rod. The agitation of the mixture is done thoroughly in order to minimize the amount of air bubbles that are formed during mixing. the particle reinforcement of this composite is done in three different composition i.e 5%, 10% and 15% to the weight of resin. granulated blast furnace slag which is pulverized and sieved through a mesh to get a fine powder of size 64µm is added to all these mixtures.

The intial step of the process is to lay the plastic sheet on the worktable and apply the predefined matrix mixture to the sheet and lay the carbon fibre. Continue the steps of applying the matrix mixture to carbon fibre by laying all the layers till the composite achieves a thickness of 5mm. the dimension of the fibre is 200x200mm. Now using a roller, the air bubbles are removed in order to avoid porosity within the required composite.

3.2 TESTING AND CHARACTERIZATION: The morphological evaluations are carried out using scanning electron microscope. To determine hardness, specimens are prepared according to ASTM E384 standard and Vickers hardness testing machine was used. The test specimens are prepared as per ASTM D3039 and ASTM A370 standard for tensile testing and Charpy impact testing. The tensile test is done on the universal testing machine (UTM) at a fixed crosshead speed of 0.2 mm/sec and a respective gauge length by loading until the test specimen failed. For analysis and characterization purposes, the tensile strength and toughness of three test specimens were considered for each composite.



(a) Base Composite

(b) 5% GBF Slag

(c) 10% GBF Slag

(d) 15% GBF Slag

FIG 3.1: (a, b, c, d) tensile test samples of the respective composite materials.

(a) Base Composite

(b) 5% GBF Slag

(c) 10% GBF Slag

(d) 15% GBF Slag

FIG 3.2: (a, b, c, d) Hardness & Impact samples of the respective composite materials.

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4. RESULTS:

4.1 Morphology Study: The SEM analysis of the GBF slag reinforced composite reveal that there is a uniform particle distribution along the fibre Matrix and hence the strength of the composite increases. This uniform distribution of particles also leads to an effective transfer of stress from the matrix to the fibre due to the adhesive nature between them. It also enhances a more uniform and homogeneous microstructure and improving overall Mechanical properties. Finally, the SEM images of the composite represents that by reinforcing GBF slag particles the mechanical performance characteristics of the composite have been comparatively improved.

4.2 Physical Properties: Leco Vickers hardness tester machine is used to measure the hardness of all the fabricated composite i.e base, 5% GBF slab, 10% GBF slag and 15% GBF slag. This test is performed under a load of 3kgs with a time duration of 15 seconds, for each composite and average value of 6 readings were taken. The comparative statement of hardness and %rise in hardness of all the fabricated composite is shown in the figure. Hence from the results we can conclude that the hardness value of the 15%wt reinforced composite show superior hardness (118.2 VHN) then the base composite (81.8 VHN) So it is proved that due to particulate reinforcement the hardness increases with proportionate to the %weight of the particulate increases.

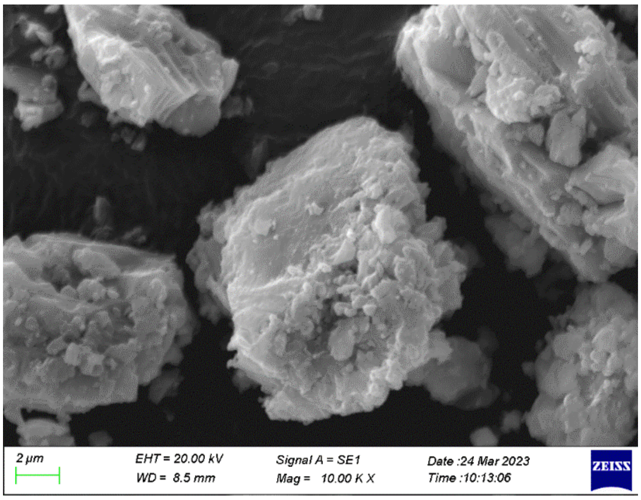

Fig 4.1 SEM Micro graph of Eggshell powder

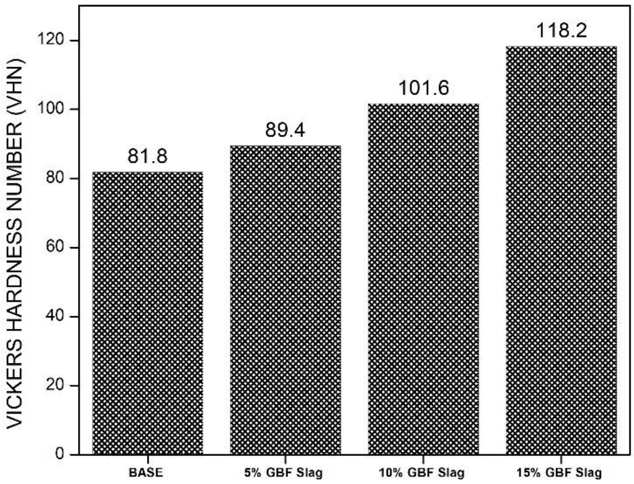

Fig 4.2 comparison of Hardness of the composites.

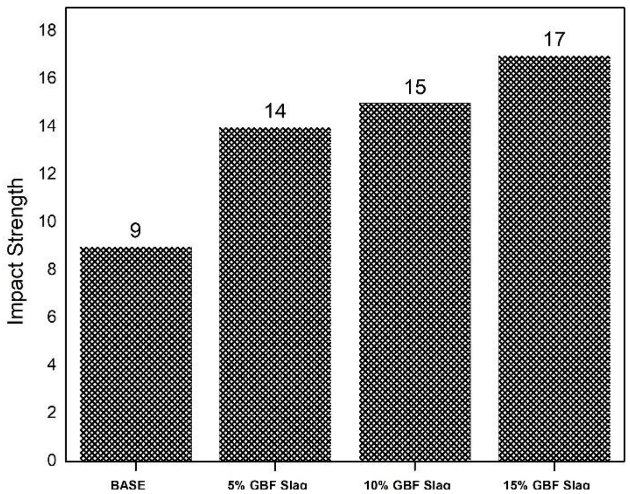

Fig 4.3 comparison of Impact Strength of the composites

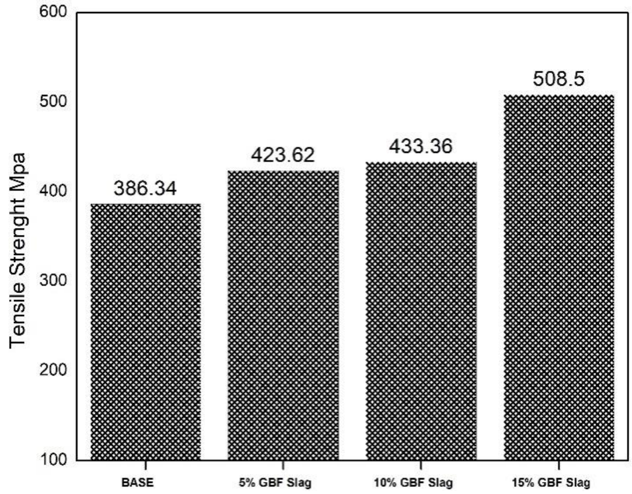

Fig 4.4 comparison of tensile Strength of the composites

4.3 Tensile Studies: The tensile test has been carried out to all the fabricated composites. From the results it can be concluded that different weight percentage composite shows different tensile strengths in which the 15% weight reinforced composite shows the maximum tensile strength(598.5Mpa) and has the highest rise in tensile strength compared to the base composite. The stress strain curve is also plotted, and the tensile strength has increased due to the reinforcement of GBF slag.

4.4 Toughness Study: The impact test has been conducted for 3 test samples of each composite. The impact strength results of the GBF slag reinforced composite is shown in the figure. Comparing all the composite the base composite with 0% GBF reinforcement noted the lowest impact strength(9N/mm^2). The composite with 15% GBF slag reinforced noted the highest impact strength (17 N/mm^2). Due to the presence of oxides in the GBF slab helps in improvement of the impact strength of the composite and hence it is confirmed that the 15%wt GBF slag reinforced composite have higher impact strength when compared with the other composites.

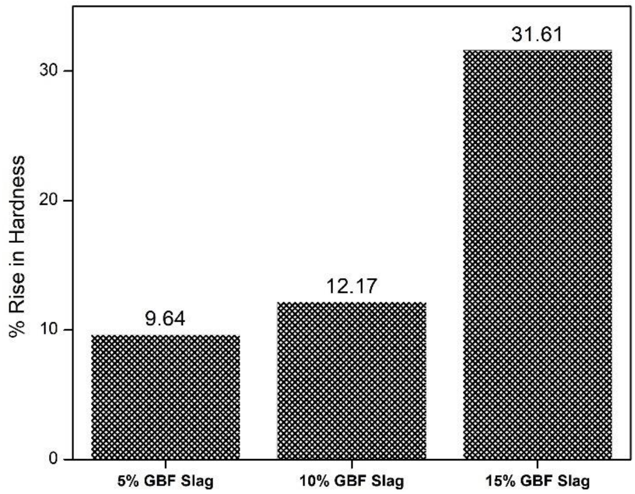

Fig 4.5 Comparison of % of the rise in Hardness

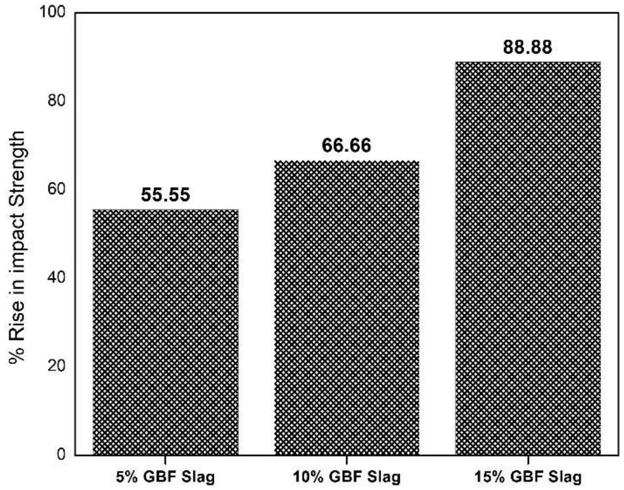

Fig 4.6 Comparison of % of the rise in Impact Strength

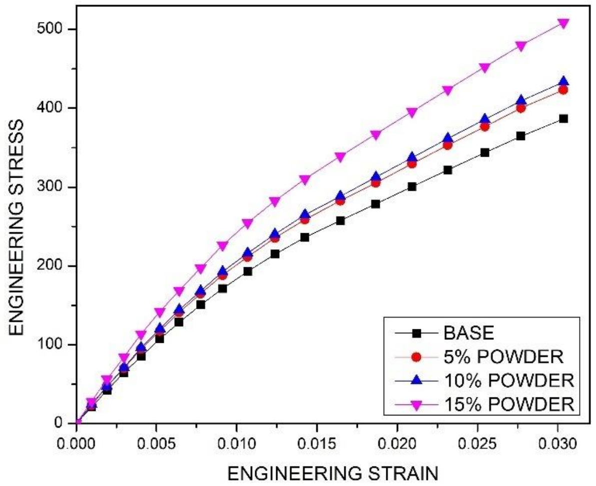

Fig 4.7 Comparison of Stress – Strain Curve

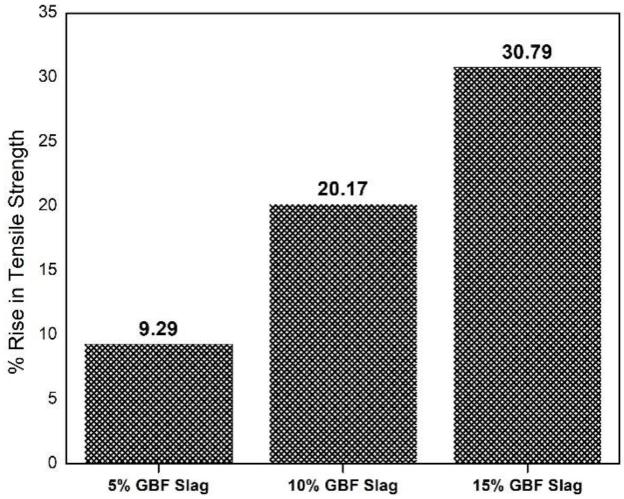

Fig 4.8 Comparison of % of the rise in Tensile Strength

5. CONCLUSION:

The present work deals with the physical & Mechanical Properties of GBF particulate & Carbon fibre reinforced polyester Composite. Physical and mechanical properties of Polyester- reinforced Carbon fibre composites with and without GBF powder were evaluated. The SEM images revealed that the GBF Slag particulates are distributed uniformly throughout the polyester polymer matrix. The physical and mechanical properties of the composites understudy shows to the following conclusions.The utilization of Industrial waste as a potential reinforcement is an innovative approach, that can offer a cost-effective and sustainable solution in Automotive and Aerospace Applications.

- The GBF Slag particulates introduced in carbon fibre polyester matrix improved properties such as maximum tensile, impact & Hardness values of 508.3Mpa, 17j & 118VHN respectively.
- The study found that increase in the weight percentage of GBF Slag (up to 15%) was effective in enhancing the mechanical properties of the composites.
- The hand lay-up method was used to develop the composites, and the resulting materials shows 30.79, 88.88 & 31.61 a maximum percentage rise in tensile, impact & Hardness respectively for 15 wt% of GBF Slag composite.
- Overall, this research work suggests 15% GBF Slag hybrid composite have promising mechanical properties, which are more likely suitable for a wide range of automotive and aerospace applications.

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BIOGRAPHIES

Project guide, assistant professor, 8 years of Research + teaching experience & 4 years of industrial experience. Sir was invited as field training instructor to CQEA(EFS) Indian Navy. Under his guidance more than 100+ students qualified and secured top ranks in competitive exams like GATE, ECET & PGECET and they got placed in reputed universities and IIT's. He is one the former students of Prof. B S Murthy Research Group.

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