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Evaluation of Mechanical Properties of Bio-degradable Hybrid Particulate Fibre Reinforced Polymer Composite

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Abstract

Recent interest in advancement of biomaterials and their implant applications is well known. In the last five decades, great advances have been made in the field of biomaterials, including ceramics, glasses, polymers, composites, glass-ceramics and metal alloys. A variety of bio implants are currently used in body implantation. In the present study, ISO Polymer and crab shell derived hydroxyapatite (HAp) have been selected to develop composites by hand lay-up method targeted for degradable implant applications. Composite was successfully developed with various fractions of crab shell powder (0%, 5%, 10%, and 15%) & e-glass fiber was composed to prepared hybrid polymer composites. HAp powder reinforced hybrid polymer composites, SEMstudies and mechanical properties (hardness, tensile strength, and impact strength) were determined as per ASTM standards. The higher mechanical properties were obtained at 15% Crabshell powder particulate composite. The introduced CRAB SHELL (HAp) enhances bio mineralization and promotes rapid healing rate in the bio medical implants applications.

Keywords: Carb shell, E-Glass Fibre, ISO polymer, bio medical, implants, hydroxyapatite (HAp), bio-degradable, SEM.

1. INTRODUCTION

Composite materials are materials composed of two or more constituent materials with different physical or chemical properties that, when combined, produce a material with enhanced or unique properties that neither constituent material can achieve alone. The constituent materials may be in the form of fibers, particles, or flakes, and they are usually held together by a matrix material, which can be a polymer, metal, ceramic, or a combination of these materials.

Composite materials are used in a variety of bio medical applications, including bio impantation,dentel and ortho application, due to their high strength, stiffness, durability, and resistance to corrosion and fatigue. Examples of composite materials include fiberglass, E-glass fiber reinforced polymers (EGFRP), and metal matrix composites (MMC).

Biodegradable" refers to a substance or material that can be broken down into its constituent parts by biological processes, typically through the action of microorganisms such as bacteria or fungi. This process of biodegradation typically results in the production of carbon dioxide, water, and other natural substances.

Biodegradable materials are often seen as more environmentally friendly than non-biodegradable materials because they can break down naturally and do not accumulate in the environment.
It's important to properly dispose of biodegradable materials in order to ensure that they are able to break down as intended.
For fabrication of biodegradable material there are few methods they areas follow

- Hand lay-up method
- Roller method
- Spray up method
- Pultrusion method
- Resin transfer moulding method

In this we taken Hand lay-up method
Hand lay-up is the simplest and oldest open molding method for fabricating composites. At first, dry fibers in the form of woven, knitted, stitched, or bond fabrics are manually placed in the mold, and a brush is used to apply the resin matrix on the reinforcing material.

Subsequently, Brush is used to brush the wet composite to ensure an enhanced interaction between the reinforcement and the matrix, to a uniform resin distribution, and to obtain the required thickness.Finally, the laminates are left to cure under standard atmospheric conditions.

2. MATERIALS AND METHODS:

2.1 **E-glass fibre**: E-glass fibre has been in use since 1930, in large-scale industrial applications. E-glass fibres are the most widespread in use, whether in the textile industry or for composite materials**,** and are present in 90 % of reinforcements. This high-quality fibre is distinguished by its resistance to high temperatures and its excellent electrical insulating properties. This fibre is rot-proof, resistant to the most common chemical agents and dimensionally stable, even if substantial variations in humidity and temperature. Mechanical properties are also used to help classify and identify material. The most common properties considered are strength, ductility, hardness, impact resistance.

FIG 2.1: E-glass Fibre

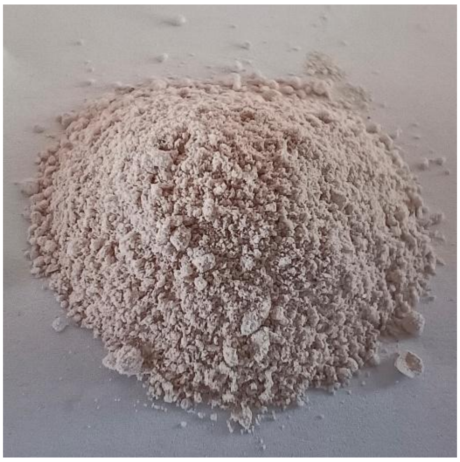


FIG 2.2: Crab shell powder

FIG 2.3: Resin, catlyst, Accelerator

2.2CRAB SHELL: The shellfish processing industry in India generates 8.5 million tons of crab and shrimp waste per year. Crab is one of the sea foods consumed in India as it is a source of protein. But local markets, restaurants and industries are throwing away the shells after they collect the meat. About 80% of the weight of the raw crab material is discarded as waste when it is processed into headless products. The crab waste produced in India accounts for more than 22,561 tons of waste shells. Most of this waste ends up in the oceans. While some of it is used for chitin/chitosan preparation, animal feed making and as fertilizer, much of it remains unused. Crab shells are waste.This helps in waste management. that's why we are chosen this crab shell as a reinforcement material. Hence, the idea of crushing shells and using them as particulates for reinforcement in polymer composites proves useful.

2.3 POLYSTER ISO Resin: Polyester iso Resin is a medium viscosity, medium reactive polyester resin based on Isophthalic acid and superior glycols. It exhibits good mechanical properties together with good chemical resistance compared to general-purpose resins.
ISO resin is often used in applications where high strength and stiffness are required, such as marine components, aerospace parts, automotive panels, and construction materials.
ISO resin can also be modified with fillers, pigments, and other additives to improve its properties, such as fire resistance, electrical conductivity, or dimensional stability.

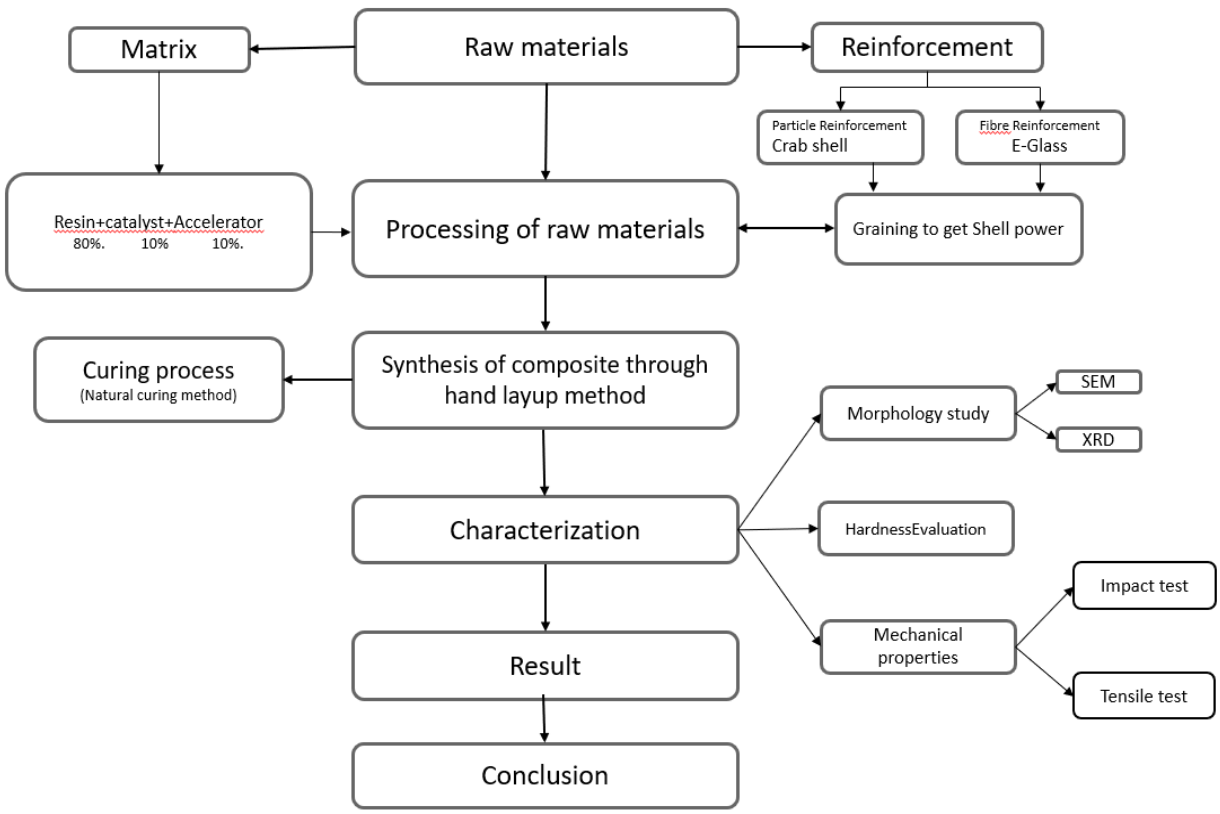
2.4 MEKP CATALYST: MEKP (Methyl Ethyl Ketone Peroxide) is the catalyst added to polyester resins and vinyl ester resins. As the catalyst mixes with the resin, a chemical reaction occurs, creating heat which cures (hardens) the resin. This is called the curing process. MEKP is usually added to the resin in small amounts, typically around 1-2% by weight.

2.5 COBALT ACCELERATOR: Cobalt accelerator, also known as cobalt octoate or cobalt naphthenate, is a commonly used accelerator in the curing of polyester in composite manufacturing. It is a cobalt-based compound that is added to the resin to increase the rate of curing and reduce the time required for the resin to harden.

3. EXPERIMENTAL METHODOLOGY:

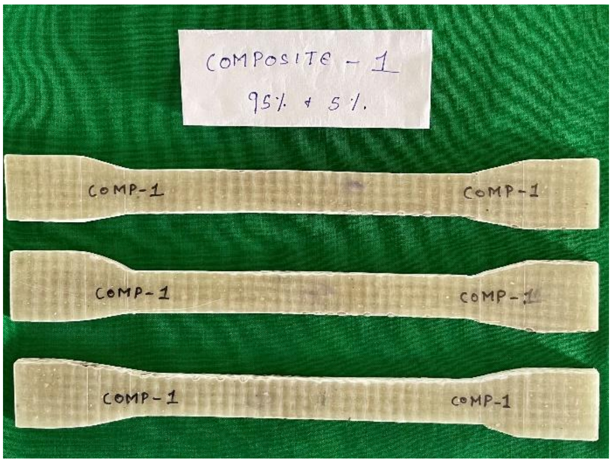
aterial	Matrix wt %	E-GLASS Fibrewt %	CrabShell powder wt %
0% CS	60	40	0
5% CS	57	38	5
10% CS	54	36	10
15% CS	51	34	15

3.1 HAND LAY UP METHOD: The fabrication is done by hand lay-up technique. The matrix and fibre are in the ratio of 1.5:1 which is as per the reference. Fibre being E-Glass fibre and the matrix includes iso polyester with MEKP catalyst and Cobalt accelerator. The mixture of resin is obtained by mixing the iso polyester with the catalyst in the ratio of 10:1. The stirring of the mixture is done thoroughly in order to minimize the air bubbles that are formed during mixing. the particle reinforcement of this composite is done in three different compositions i.e. 5%, 10% and 15% to the weight of resin. Crab shell which is grinding and sieved through a mesh to get a fine powder of size 120μm is added to all these mixtures. The starting step of the process is to take the thin sheet and attached to the work table and then polished with mansion wax to the sheet for easily removal of sheet after curing, and lay up the E-glass fibre to the plastic sheet and apply the matrix and E-glass fibre, so on continue the process up to we get thickness of 4mm.The obtained dimensions of the fibre is 200x200. Now using squeezer,we have to remove air bubbles in order to avoid gaps in the obtained fibre.



FLOW CHART 1: OVERALL FABRICATION & EXPERIMENTAL PROCESS

(a) Base Composite



(b) 5% Crab Shell

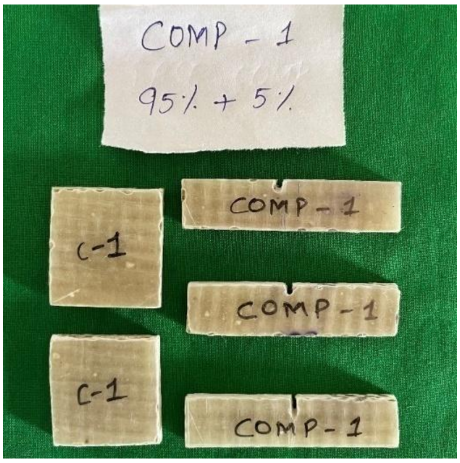
(c) 10% Crab Shell

(d) 15% Crab Shell

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

3.2 TESTING AND CHARATERIZATION: The Morphological examinations are carried out using SEM (Scanning Electon Microscope). To determine tensile and charpy specimens are prepared according to ASTM D638 and ASTM A370 standards the tensile test is done on the UTM (Universal Testing Machine.and Hardness specimens are prepared according to ASTM E384 standards and Rockwell hardness machine was used.The tensile and toughness strengths of three specimens were taken for each composite.

(a) Base Composite



(b) 5% Crab Shell

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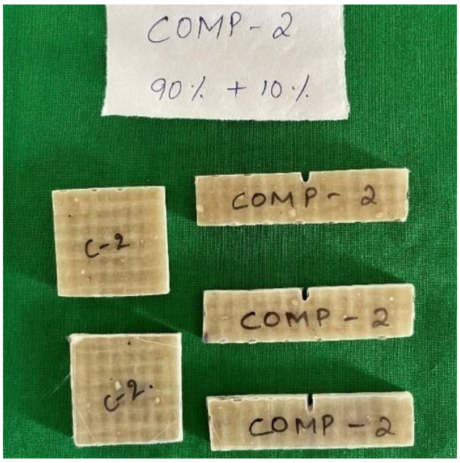
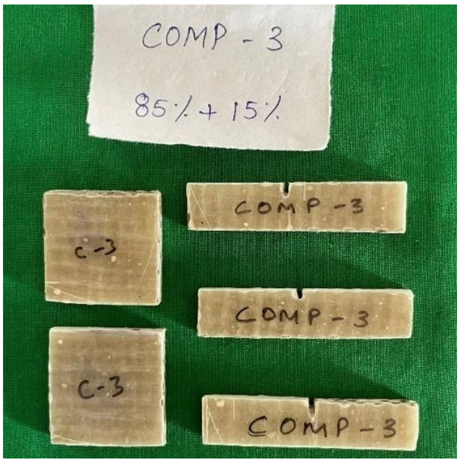


(c) 10% Crab Shell



(d) 15% Crab Shell

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

4. RESULTS:

Material	Hardness (HR_b)	Tensile Strength (Mpa)	Impact Strength (j)	% Rise in Hardness	% Rise in Tensile Strength	% Rise in impact Strength
Base	24	287.2	9.5	0	0	0
5% CS	33.5	323.5	12	39.5	12.3	26.3
10% CS	53	345.8	16	120.8	20.3	68.4
15% CS	58	361.9	18	141.6	25.9	89.5

4.1 Morphology study: The Morphological examinations are carried out using SEM (Scanning Electron Microscope). The SEM analysis of the crab shell powder reinforced composite there is a uniform distribution of the crab shell powder along the fibre matrix and increase in composite strength. This distribution helps to increase in stress from the matrix to the fibre due to the viscous nature between them. It also helps in improving overall Mechanical properties.At last the SEM images of the composite represents that by reinforcing crab shell powder the mechanical properties of the composite have been improved.

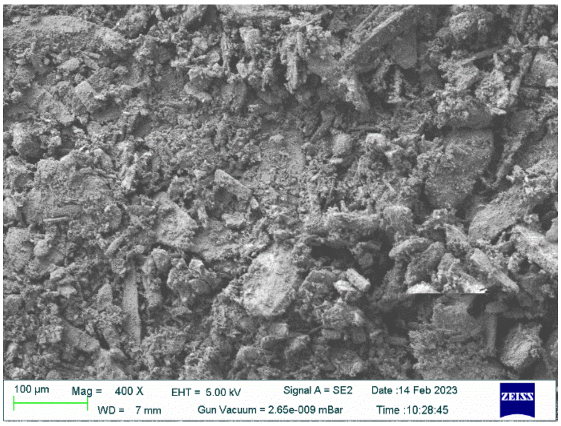


Fig 4.1 400x SEM Micro graph of Crabshell powder

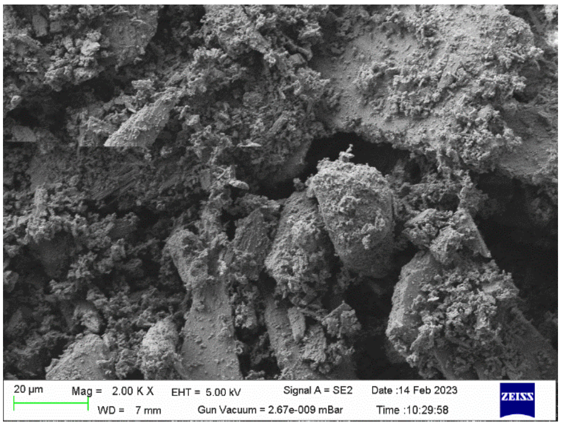


Fig 4.2 2000x SEM Micro graph of Crabshell powder

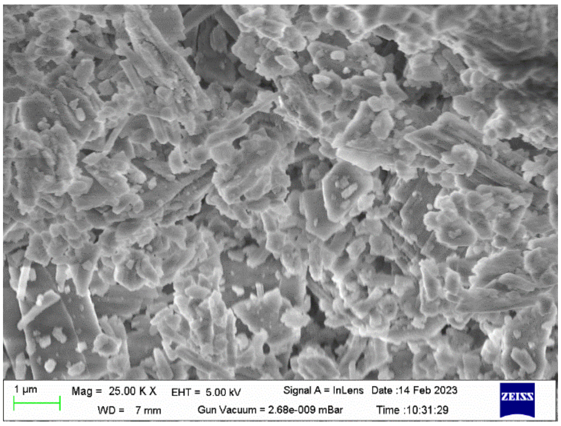


Fig 4.3: 2500x SEM Micro graph of Crabshell powder

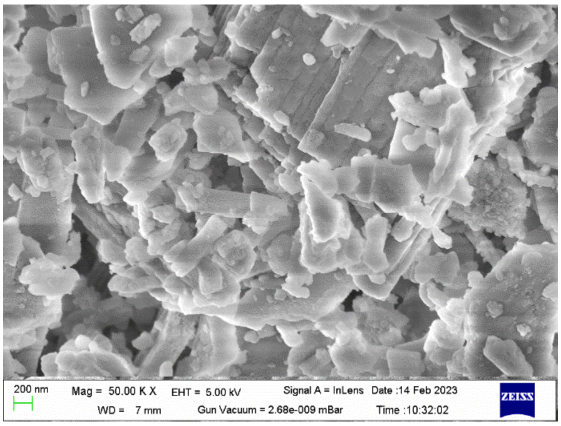


Fig 4.4: 5000x SEM Micro graph of Crabshell powder

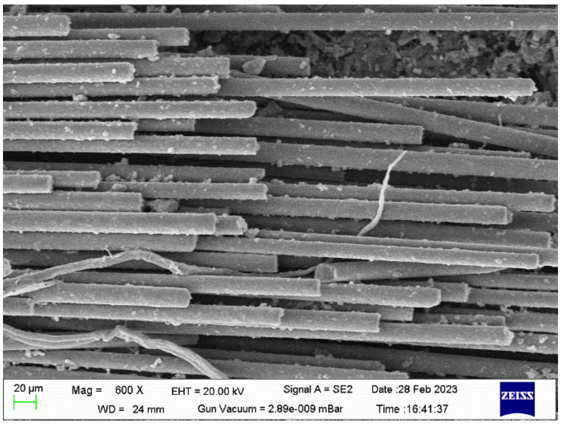


Fig4.5: SEM Micro graph of Base Composite

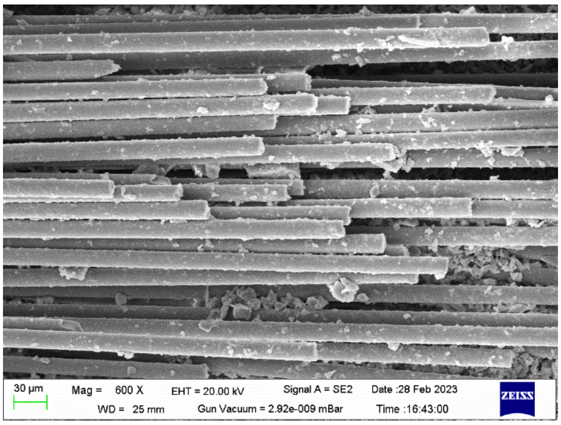


Fig4.6: SEM Micro graph of 5% Crab Shell

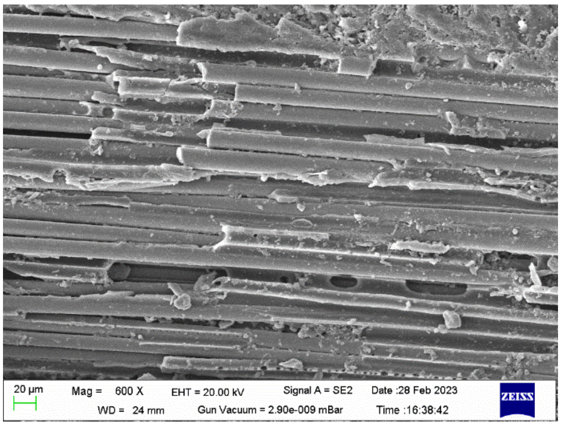


Fig4.7: SEM Micro graph of 10% Crab Shell

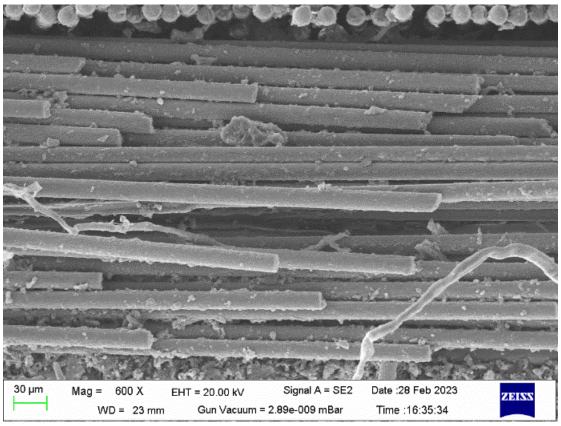


Fig4.8: SEM Micro graph of 15% Crab Shell

(a) Base Composite

(b) 5% Crab Shell

(c) 10% Crab Shell

(d) 15% Crab Shell

FIG 4.9 (a, b, c, d): Tensile sample after experiment.

4.2 Tensile test: The test has done for all the composites.From the results the different comosites with differe nt weights having different strengths in which the 15% wt has a more tensile strength (361.91Mpa) and has a more strength as compare to base composite.the bar chart is also plotted,and the tensile stength is increased as the % of crab shell powder is increased.

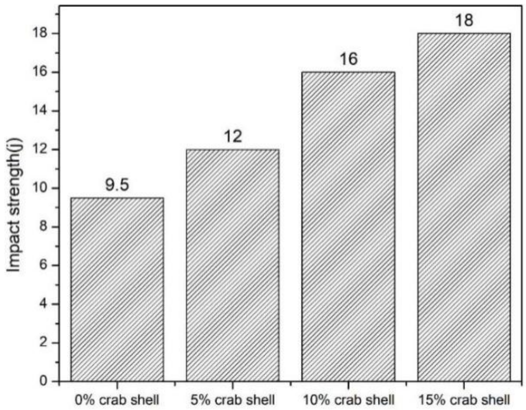
4.3 Impact test:The charpy test is done for 3 samples of each composites.Comparing of all the composites the base composite of 0% crab shell has a value of(9.5N/mm²). The composite of 15% crab shell has a highest value of (18N/mm²). Hence, the15% crab shell composite has higher impact strength when comparative to other composites.

(a) Base Composite

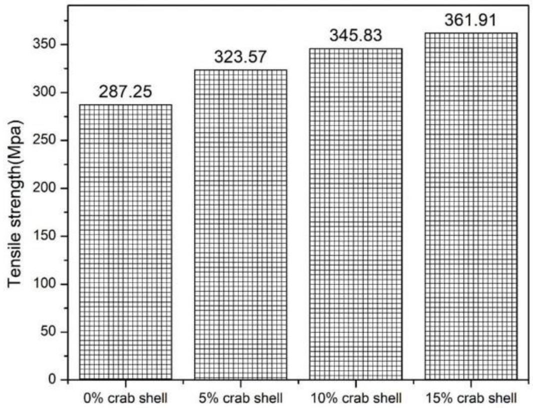
(b) 5% Crab Shell

(c) 10% Crab Shell

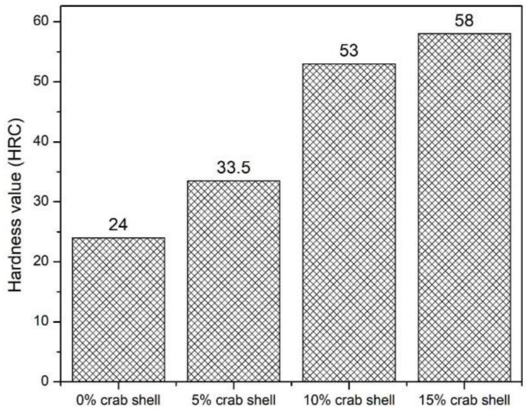
(d) 15% Crab Shell



(a) Impact Strength



(b) Tensile Strength



(c) Hardness values

FIG4.10(a,b,c): Comparison studies of Impact, tensile Strength and Hardness.

4.4 Hardness test: The Hardness test is done on the Rockwell hardness test of all composites of 5% crab shell,10% crab shell and 15% crab shell powder.and the harsness values of composites are given in below table.The value of the composite 3 that is 15% crab shell powder (58 HR) is higher than the base composite (14.5 HR). So, hence proved that the hardness is increased when the reinforcement particle is increased to 15% wt.

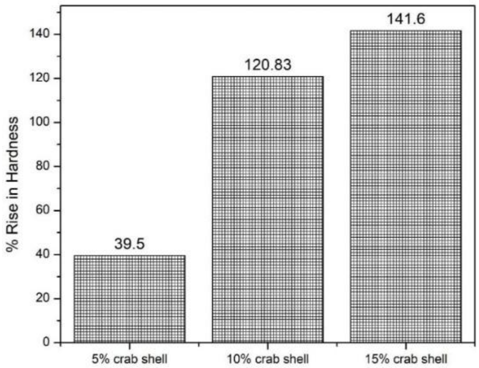


Fig 4.11Comparison of % of the rise in Hardness

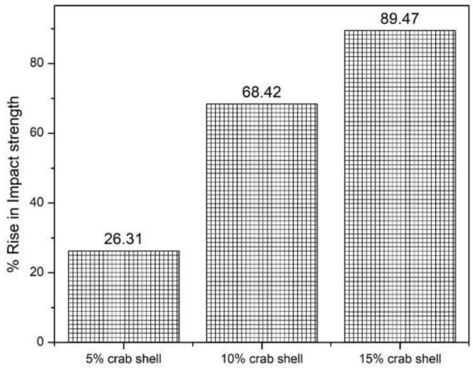


Fig 4.12Comparison of % of the rise in Impact Strength

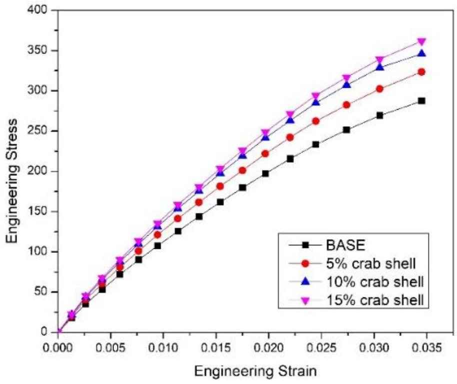


Fig 4.13Comparison of Stress – Strain Curve

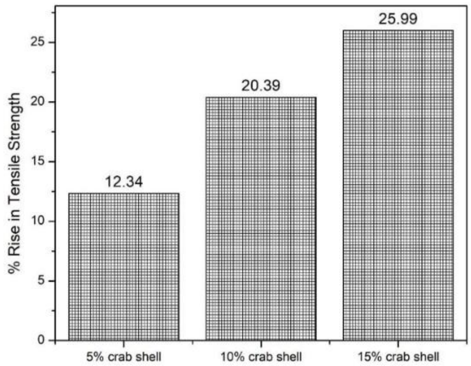


Fig 4.14Comparison of % of the rise in Tensile Strength

5. CONCLUSION:

The present work deals with the physical & Mechanical Properties of CRAB SHELL particulate &E-Glassfibre reinforced polyester Composite. Physical and mechanical properties of Polyester- reinforced E-GLASSfibre composites with and without CRAB SHELL powder were evaluated. The SEM images revealed that the CRAB SHELL 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 Bio medical implantation like dental ortho Applications.

- The CRAB SHELL powder particulates introduced in E-glassfibre polyester matrix improved properties such as maximum tensile, impact & Hardness values of 361.9Mpa, 18j &58RHC respectively.
- The study found that increase in the weight percentage of CRAB SHELL (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 25.9, 89.5&141.6 a maximum percentage rise in tensile, impact & Hardness respectively for 15 wt% of CRAB SHELL composite.
- Overall, this research work suggests 15% CRAB SHELL hybrid composite have promising mechanical properties, which are more likely suitable for a wide range of BIO-MEDICAL like dental and ortho applications.

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BIOGRAPHIES

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