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Effect of Different Configurations of Reinforcement and Post-Cure Temperature Detailed Survey

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Abstract

Composites with natural fillers have applied many applications, such as interior housekeeping, building and so on but their findings are seldom examined in the mechanical, tribological and dynamic situation. The addition of fillers in GFRP composites enhances the mechanical, thermal and tribological properties due to filler occupied in voids in thermoset resin. There has also been a lot of work done in quantifying the consistency of the operating parameters through statistical analysis and achieving optimal operating conditions. Response surface methodology (RSM), artificial neural networks and Taguchi experimental design are several studies of optimization techniques, from the different techniques Taguchi optimization viable method to interpret the process parameter to find the response. Analysis of variance has shown that the studies are 95% confident and 5% significant. No further production and performance are reported of selectively natural fillers with glass fiber epoxy composites. No work found that the roughness taken as process parameters to influence the response of specific wear rate. The objective of this survey is to critically analyze how reinforcement configurations and post-cure temperatures influence composite performance, particularly regarding mechanical, thermal, tribological, and durability properties.

Keywords: Artificial neural network, GFRP composites, response surface methodology

INTRODUCTION

The proof associated with polymer hybrid composites has been concluded with the help of research articles. The hybrid polymer composites are given importance based on their properties such as High strength to weight ratio, Stiffness, Strength with tailorable properties and High toughness which assure to enhance the conventional engineering materials. It is proved that it has controlled the outstanding progress of composite materials in the past decades. Several features that affect the performance of the hybrid polymeric composite in dynamic conditions is shown in the Cause and Effect diagram in the Figure 1.

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Beginning with the initial construction of the very first airplane, which took place in the latter half of the 19th century, the material systems saw significant transformations and modifications. Fabrics and wood were used in the construction of the first automobiles. Aluminium, in particular, replaced traditional wood as the material of choice for aircraft manufacturing during and after World War I. This was due to the rapid expansion of the aircraft industry. In 1916, the Junkers J4 was the first aircraft to be manufactured in mass quantities using a whole metal structure. In 1933, the Douglas DC-1 was the first aircraft to be exhibited with a wholly stressed-skin, streamlined airframe [1–3].

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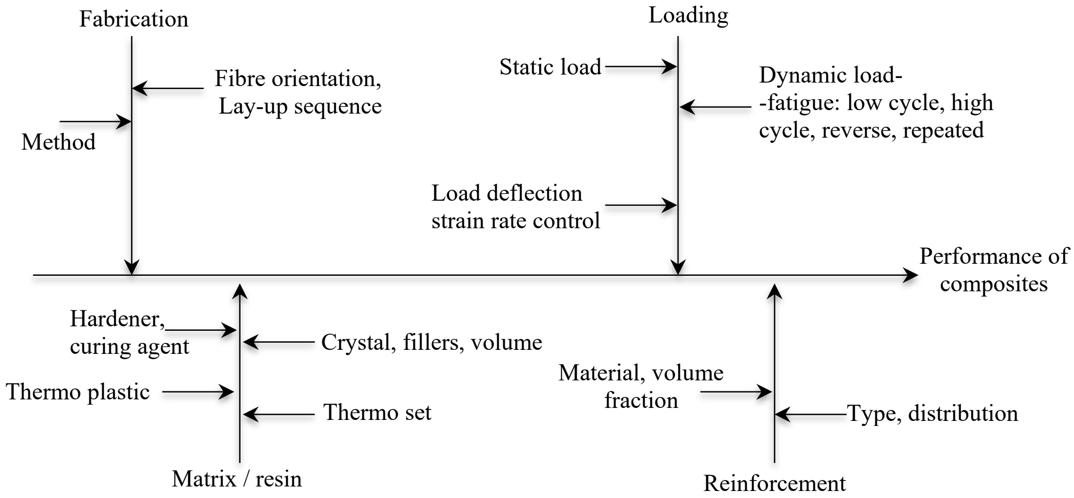

Figure 1. Factors of composite performance.
(Source: Loganathan et al 2017)

Aluminium alloys are used in the production of the vast majority of commercial aircraft in today's world. According to [4], it was anticipated that approximately 78% to 85% of the overall airframes are made of metallic materials in the year 2003. In contrast, fibre reinforced polymer matrix composites are gaining popularity among designers as a result of recent advancements in technology. According to [5], composite materials were first used in various secondary load-bearing components of commercial aircraft, including the Boeing 767 and 757.

Reinforcement configuration directly controls stress transfer and damage resistance, while post-cure temperature affects cross-link density and glass transition behavior. Together, they dictate the structural efficiency and long-term stability of composites in engineering applications. The reviewed studies encompass composites based on thermosets (epoxy, polyester), thermoplastics (PP, PE blends), and bio-based resins (rice husk, conch shell, seashell fillers), demonstrating how reinforcement orientation and cure schedules critically influence performance across matrix classes.

For usage in aircraft applications, advanced composites—often continuous reinforcements made of glass allowing for the development of lighter structures [6]. Emissions are decreased as a result of the lightweight composite structures' substantial fuel consumption reduction. Composite materials were introduced into the general aircraft industry in the 1970s after first being used in military aircraft starting in the 1960s [7]. It wasn't until the 2000s that civil aircraft manufacturers began to use composite materials in key aircraft structures [8]. Leading aircraft manufacturers are rapidly switching from traditional metals to composite laminates in the modern world. This implies that by creating creative designs for the buildings, the full potential of advanced composites can be realised. Both primary and secondary aircraft structural applications are currently being designed using fiber-reinforced polymer matrix composites. Nowadays, a large portion of traditional metals are being replaced by composites in important aircraft structures (the Boeing 787, for instance, is made up of over 50% composites by weight) [9]. The utilisation of composite materials in aircraft design not only lowers emissions and improves fuel efficiency, but it also increases passenger satisfaction. If the fuselage were composed of composite material, the cabin pressure and humidity would be at more pleasant levels. Higher hoop stresses and increased corrosion resistance would be feasible as a result.

For usage in aviation applications, composites are commonly designed and produced in sandwich or laminate forms [10]. The bulk of the time, reinforcing fibres are bound using matrix systems made of thermosetting resins like epoxy. These resins are currently being used extensively in the creation of composites because of their comparatively low material and processing costs (Soutis, 2005). New fibre reinforcements [11], new material systems (such resin chemistries) [12], and fabrication

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techniques are becoming more and more popular. The introduction of these innovations aims to attain affordability and cost-effectiveness. From the standpoints of structural cost-efficiency, safety, and affordability, the composites industry faces several significant challenges, guaranteeing manufacturing quality (i.e., flawless and repeatable). In an attempt to address these challenges, academic and industry research centres throughout the world have focused a lot of emphasis on laminated composites research and development.

COMPOSITE MATERIALS: INEFFECTIVE CONDUCT

The design regulations for composite materials are less defined than those for conventional metallic buildings (Soden et al. 2004). Conversely, a robust fiber-matrix interface can produce high stiffness and strength, but it usually shows poor resistance to the spread of cracks. According to research by [13 and 14], the destructive qualities of composites depend on the possible damage modes and their interactions in addition to the material's inherent heterogeneity and anisotropy. The nature of the complicated damage nature is the biggest obstacle to creating a failure criterion that accurately depicts every potential failure mechanism, claim [15]. Additionally, the new production technology often results in a more complex microstructure (e.g., complex reinforcing phases), which causes complicated damage [16]. [17] and [18] state that strain rates and environmental service circumstances have a major impact on the damage nature of composite materials. This is a crucial piece of knowledge to remember. Composite laminates may fail at the structural level (wide component failure), the laminate level (interlaminar delamination), or the lamina level (fibre pull out or fiber-matrix debonding, resin or matrix-cracking, or fibre breaking). Any of these levels may experience failure as a result of mechanical or environmental service conditions. Most of the time, significant subsurface failure in composite laminates is caused by impact loads. This failure is caused by very partially evident surface failure and takes place both intra- and inter-lamina. Consequently, while building and evaluating composite laminates, it is crucial to consider a range of length values[19]. Inter-lamina, intra-lamina, laminate, and entire component scales are some examples of these length levels. According to Spearing et al. (1998), a thorough grasp of the damage processes and the interactions that take place between them at every level is necessary for the creation of strong design standards.

Aeroplane structures must be inspected on a regular basis to guarantee structural integrity, safety, and efficiency [20]. Procedures for these checks have been developed by the other airworthiness agencies and aircraft manufacturers. A number of factors, such as manufacturing flaws, delamination, debonding, and impact damage, affect an aircraft structure's ability to remain airworthy. Mechanical stresses (like impact or indentation), environmental factors (like hydro ageing, hydrothermal ageing, or exposure temperature), or manufacturing defects (like weak bonding or voids) can all cause a product to deteriorate over the course of its service life [21, 22].

Impact-related damage, such as service collisions, fallen tools, or bird attacks, can occasionally pose a major risk to a building's structural stability, claim [23]. Environmental elements that might cause damage include hail, rain erosion, UV radiation, lightning strikes, moisture penetration, and so on. Maintenance inspections are categorised as extensive. The plan for preventative maintenance is determined by the flight hours and battle cycles [24].

Unlike metals, composite laminates are brittle by nature because the matrix structure is brittle due to the brittle fibre reinforcement. In the elastic condition, composite laminates can absorb energy, and they are vulnerable to impact damage due to failure mechanisms [25]. Furthermore, the impacts that composite laminates usually encounter take place in a transverse orientation. This is due to the laminate's comparatively low resistance to damage caused by the lack of fibres that run through its thickness. Richardson and Wisheart (1996) claim that stress wave propagation in high-velocity ballistic impact dominates the laminate reaction. This implies that there is not enough time for the laminate to develop quasi-static failure mechanisms, which eventually leads to localised damage.

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Whether or not low velocity impact damage results in a significant loss of tensile [26]. The impactor has the ability to make this reduction noteworthy. It is challenging to detect subsurface damage using visual inspections because blunt impacts might result in damage that is not apparent from the outside (Kumar & Rai 1993) [27].

Impact pressures can also result in punctures, dents, delamination, and micro-failure, also referred to as matrix-cracking. Delamination starts to appear at the interface that is trapped between a laminate's layers. Interlaminar delamination has the potential to significantly reduce the structural strength which might include matrix cracks, delamination, and fibre breaking. Low-velocity incidents are usually the cause of this kind of damage. However, the chance of a puncture happening is greater than the chance of a dent if the impactor has a small diameter and a high impact energy. A puncture may result in delamination surrounding the puncture, matrix damage, or fibre breaking fibre reinforcements are in charge of regulating the basic material properties. [28] state that this kind of fibre breaking usually occurs only where the impact occurred. The structural integrity and mechanical strength of the components can both be improved by repairing the damaged structural elements[29]. This enhancement can be made at a more affordable price.

INDUSTRY CONCERNS - THE NEED FOR REPAIR

Some industries are concerned about the quick rise in their use in aeroplanes and the fact that aviation regulators like the Federal Aviation Administration (FAA) are aware of this trend. The United States Government Accountability Bureau [30] noted several important aviation safety issues in its most recent report. These problems were divided into four groups: little information about the mechanical response of composite laminates;The substantial increase in demand for composite structures and components worldwide necessitates a pace of technological and expert advancement that keeps pace with this development [31]. To ensure the industry's long-term profitability, this is required. This process is currently proceeding a little slowly. Furthermore, as no design guidelines, manufacturing techniques, or joining methodology have been defined as of yet, Interest in developing innovative and cost-effective production methods has increased in tandem with the growing use of composite laminates in various structural components. Better repair alternatives are needed because this new advancement may result in production flaws and maintenance issues. Even though composite laminate research and development is now underway, the aircraft industry still needs a dependable technique for the repair of primary and secondary components [32].

COMPOSITE LAMINATE REPAIRS

Armstrong et al. state that the primary objective of any laminated composite restoration process is to maximise the remaining strength and stiffness of a damaged structure while also regaining as much of its original structural and operational performance as feasible. Mechanical fasteners and adhesively bonded fixes have been extensively employed to enhance the mechanical qualities of damaged laminates [33].

Comparison of Adhesively Bonded External Patch Repairs and Mechanical Fastener Repairs

There are several advantages to an adhesively bonded exterior patch repair over a typical mechanical fastener repair. Low stress concentration, high strain to failure, good fatigue response, robust corrosion resistance, and light weight are some of these advantages. Furthermore, compared to traditional mechanical fastener replacement methods, patch repairs have attracted a lot of attention [34]. This is due to the fact that patch repairs are compatible with bonding damaged laminates with complex geometries, have a longer service life, a cheaper machining cost, a residual strength and stiffness to weight ratio, a reduced maintenance cost, and require less time. Furthermore, the patch repair can provide the basic structural needs required for thin composite laminate repair [35]. Patch fixes' high specific mechanical qualities and low stress concentration make them potentially useful in the aerospace industry. When patch repairs are designed and executed appropriately or optimally, they can yield the highest level of efficiency. Additionally, an outside patch repair bonded with adhesive

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technology can prevent the main fracture in the parent laminate from re-initiation and progressing. Most of the mechanical damage problems that existed in aeroplane structures have been adequately resolved with the use of this restoration procedure. This is demonstrated by the increasing interest that the scientific community is gradually showing in adhesively bonded patch repairs.

Comparing External Patch Repairs with Adhesively Bonded Scarves

According to the two adhesively bonded repair methods most frequently used in composite laminates are the scarf repair and the adhesively bonded patch repair. The surrounding area, patch repair is very simple. However, scarf restoration is especially challenging to perform on curved surfaces because it requires accurate machining. As a result, patch repair is frequently the method of choice for fixing a curved surface. Because it is so difficult to perform, the adhesively bonded scarf repair is usually avoided. This is because the time-consuming machining process needed for optimum scarfing, the costly equipment needed, and the specialised labour needed are all factors. This type of restoration is usually applied when a flush aerodynamic surface is needed, and it is especially useful for repairing damaged laminates that are thicker than three millimetres. According to research, repairing a scarf requires having the right tools to remove the damaged portion from the parent laminate, determine the ideal taper angle, and combine the filled materials.

For the past 20 years or so, it has been demonstrated that using scarf repair to reinforce composite laminates works well. According to, scarf restoration can raise the residual strength of laminates that have been repaired to a level that is similar to that of normally intact laminates. This is accomplished by carefully choosing the scarf angle in accordance with the laminate's structural specifications. However, the technique of employing a scarf to repair a broken structure has been reported to have a number of problems. In conclusion, even though scarf repair produces exceptional results, this approach is very difficult, time-consuming, and requires the use of costly equipment to complete the repair.

Adhesively bonded external patches are increasingly being used in composite restorations because these repair techniques may successfully incorporate intricate components that are challenging to build and disassemble for replacement. It is far easier and takes less time to fix an exterior patch using adhesive bonding than it is to mend a scarf using the same technique. The patch repair technique has garnered in the last 10 years as a means of fixing damaged composite laminate systems. The increased success of this repair technique can be attributed to a number of factors, including improved particular mechanical qualities, low stress concentration, increased design flexibility, low operational cost, reduced time consumption, and the need for basic equipment to accomplish the repair operation. Numerous works of literature have proven the advantages of using external patches that are bonded with adhesive to repair damaged composite laminates. Additionally, when operational constraints like the repair environment, available time, and equipment facilities are important considerations, the patch repair technique is usually selected. Any thickness of laminate, including thin laminates, can be repaired using the patch repair method.

In contrast, patch repairs are usually seen as a short-term solution for large load-bearing structures. On the other hand, it can offer a long-term fix for thin composite structures and secondary loads. The main driver behind the growth and widespread use of adhesively bonded patch repair is the development of structurally sound and economically feasible design parameters that can tolerate a variety of real-world loading situations.

GFRP POLYMER WITH NATURAL FILLERS COMPOSITES

Dhawan et al. examined the effect of the different fillers which are Wheat husk filler, Rice husk filler, and Coconut coir filler, and also with GFRP-epoxy and GFRP-polyester with all natural fillers. When compared, GFRP with epoxy shows higher tensile strength and the natural fillers like coconut fillers have maximum strength. on the whole, it is proved that epoxy based composites have better

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properties in tensile hardness and specific gravity and that GFRP with polyester have better properties of impact strength and water absorption.

Gokulkumar et al. have reported on the mechanical properties of different natural fibers in combination with GFRP and tea dust fillers. Ramie fiber with GFRP and Tea dust have superior properties compared to the other ones. It is observed that Uni-direction orientation fiber based composites have resilient cellulosic microfiber and GFRP based composites may be applied in various engineering applications like under floor protection, automobile inner body etc.

Reis. have assessed the GFRP composites in environmental conditions (Distilled water, Alkaline solutions and Acid solutions) with respect to time, temperature and concentration of solutions. The study has revealed that while increasing the temperature and time, the impact tensile strength decreases, and also compared to acid solutions, alkaline solution have more influence as its leads to the lower value than acid solutions.

INDUSTRIAL SOLID WASTE PARTICLES RECOVERY

Currently, both the government and corporations are diligently addressing the issue of wasted industrial solid waste and promoting more ecologically sustainable manufacturing practices. Furthermore, it promotes the recovery and reutilization of industrial solid waste by firms for multifunctional operations. Due to recent technological breakthroughs, it is highly practical today. Industrial cutting kerf particles represent a substantial and increasing category of solid waste that is unavoidable due to the rapid advancement of the industrial sector. The current research findings indicate that the study concentrated on the utilisation of waste particles derived from silicon and diamond kerf as potential fillers in epoxy polymer composites.

Recovery of Silicon Kerf Particles

Solar energy is employed in several applications, with solar cells acknowledged as a crucial element in electrical power generation. Silicon-based solar cells are often favoured due to their minimal emission and great purity. assert that solar cells constitute 94% of total output and are widely employed in the photovoltaic (PV) sector. Silicon constitutes around 90 percent of the total materials utilised in the photovoltaic (PV) industry, indicating a significant dependence on silicon. The production of crystalline silicon involves that the fabrication of silicon wafers constitutes approximately sixty percent of the overall manufacturing costs. assert that the fixed diamond saw cutting method is a prevalent technique for slicing silicon ingots into wafers.

The waste from the slurry not only exacerbates environmental degradation but also substantially elevates manufacturing costs due to the disposal of silicon slurry. The process of recycling wasted silicon slurry into silicon ingots incurs substantial costs. An alternative is to use this silicon cutting waste particle as a filler in a polymer composite, an approach that is both economical and environmentally sustainable. Si particles are an exemplary option for reinforcement or filler since they exhibit all necessary properties. indicate that the demand for composite materials is rising across all sectors of industry. This is due to the ease of fabrication, rapid installation, low density, excellent corrosion resistance, and cost-effectiveness of composite materials. The valuable silicon particles can thus be harvested and repurposed to enhance the ecologically sustainable manufacturing process. To investigate the feasibility of recovering silicon particles, several separation and purification procedures are employed by both industries and researchers. indicate that separation and purification procedures often encompass a range of methods, including physical, chemical, magnetic, and metallurgical techniques. A review of the recovery of silicon particles utilising various approaches is provided below Figure 2.

The cutting of crystalline silicon ingots facilitates the extraction and recovery of silicon particles. Carbothermic reduction serves as a preparation for silicon kerf particles to remove any impurities present in the initial stage.

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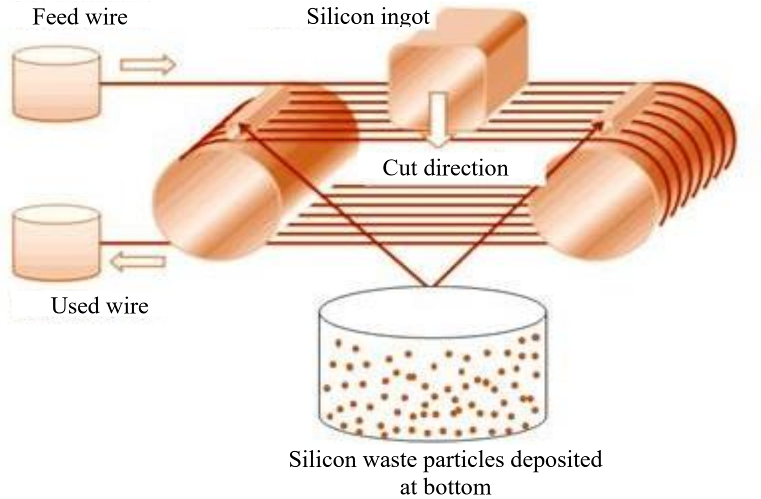

Figure 2. Schematic representation of silicon waste particles collection.

Additional processing for directed solidification can be conducted in a vacuum induction furnace. state that the purification procedure is executed by integrating the density differential and thermal conductivity of various particles. It is subsequently filtered via a gravity-coupled electric field.

Recovery of Diamond Kerf Particles

Grinding and sawing are secondary machining procedures essential for companies to produce products with adequate dimensional accuracy. The processing of luxury diamonds in the gem industry requires the execution of certain final finishing techniques to enhance its appeal and value. Slurry or fine particles are generated due to the unavoidable disposal of waste during the finishing procedures. This dumping has markedly increased over the past few years. assert that retaining and repurposing waste diamond slurry and particles is highly advantageous for sustainable manufacturing, as well as for environmental and economic benefits.

Composites of Fiber-Reinforced Polymers

Investigated how epoxy polymer composites were affected by glass fibre reinforcement that was positioned randomly. The tensile and flexural strengths increased by 14.5% and 123.65%, respectively, according to the experimental and numerical analysis of mechanical characteristics. At up to 20 weight percent glass fibre reinforcement, effective load transfers between the fibre and matrix were credited with the increase in mechanical strength. They suggested that adding glass fibre up to 50 weight percent to the epoxy composite without filler particles was beneficial. The epoxy composite delaminated as a result of the addition of glass fibre.

Composites of Particle-Reinforced Polymers

The testing findings showed that increasing the amount of boron filler in the mixture volume raised the levels of water absorption. According to their findings, the strength of boron particles enhanced the compressive strength of reinforcing materials by as much as 50%. The increase in filler volume percentage indicates that insufficient load transfer between the matrix and the particle reinforcement is the cause of the decrease in flexural strength. did a study to examine the effects of hybrid inorganic filler materials on epoxy polymer composites. Furthermore, they noted that the mechanical properties of impact, flexural, and ultimate tensile strengths were enhanced with the incorporation of filler material up to 20 weight percent, which subsequently decreased.

Hybrid Polymer Composites

Due of their exceptional strength and durability, composites including hard components are widely employed across numerous applications. Examples of these applications include the polishing of stones and the digging of petroleum wells. Conversely, the refinement of marbles and stones does not

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necessitate the employment of very abrasive metallic compounds. Conversely, polymer matrix composites can provide and meet the functional requirements. Epoxy composites containing hard diamond particles exhibit exceptional resistance to polishing wear and are appropriate for the application. Robust ceramic materials with elevated thermal conductivity are employed to enhance the thermal characteristics of the materials, rendering them suitable for various applications. The enhanced mechanical, thermal, and dielectric properties of metal oxide-filled polymer composites render them suitable for the packaging and miniaturisation of integrated circuit (IC) chips and other electronic devices. Metal oxide is included into polymer composites.

Suresha and colleagues conducted a study in 2007 to investigate the effects of graphite particles ranging from 50 to 60 µm in an epoxy–glass fibre composite. To attain enhanced tensile strength, the supplementary reinforcement particles incorporated into the composites constituted up to 7.5 weight percent of graphite particles. The tensile strength increased because to the exceptional fiber-matrix interaction and effective load transmission in the applied direction by both the fibre and filler material. The researchers observed that the epoxy-glass fibre composite packed with graphite particles exhibited reduced elongation, enhanced tensile strength, and increased surface hardness. The composite's overall dimensional stability was maintained. examined the influence of diverse natural particles, such as rice husk ash, carrot powder, and sawdust reinforcement. The integration of natural particles as reinforcement in the epoxy–glass fibre composites led to an elevation in void content. Furthermore, they found that the proportion of water absorption increased linearly with the augmentation of reinforcement volume %. Consequently, it was essential to augment the quantity of synthetic or reclaimed metal or ceramic particle reinforcement in hybrid polymer composites to reduce their water absorption.

In their 2018 study, Mahesh Babu and Venkateswara Rao examine the influence of supplementary filler on glass fibre reinforced epoxy composites. The hybrid composite containing basalt powders exhibited enhancements in mechanical strength of 7.5%, 2.5%, and 2.5% respectively. The mean particle diameter of the basalt powders was 75 µm. The enhanced interaction between the fibre and the matrix was identified as the cause of the increased tensile strength, whereas the decline in tensile strength observed after 7.5 weight percent of filler material was ascribed to excessive contact among the fibres or particles. The initial enhancement in impact strength was attained due to the uniformity in fibre dimensions and the enhanced homogeneity. The rupture of the fibre, which transpired when it was extricated due to an external force, was an additional element that diminished the impact strength. The incorporation of nano diamond thread, the researchers concluded, improved mechanical strength. The material's mechanical strength was increased as a result of the diamond particles' interfacial interaction and mechanical interlocking with the PMMA matrix. This consequently enables mechanical interlocking and weight transfer capabilities.

NATURAL FILLERS

Elamvazhudi et al. (2018) provided the details of conch fillers with epoxy resin in different volume of fraction. There was a significant increase in impact, tensile and hardness. The dispersed conch fillers formed a linkage in epoxy resin, which influenced in hardness and toughness.

Alberet al. (2006) investigated the properties of three types conch are Strombusgigas, giant clam (Tridacnagigas) and red abalone (Haliotis rufescens) of sea shells. It has been reported that sea shells are composed of $CaCO_3$ crystals interleaved with layers of viscoelastic proteins, having dense, tailored structures that yield excellent mechanical properties. Mechanical tests have been carried out on these shells for a comparison of strength with respect to the microstructural architecture and sample orientation. The conch has compression strength in the range of 166–218 MPa. The appreciable compressive strength observed in the conch is attributed to the microstructural architecture in the form of 2-D laminates, enhancing the fracture toughness and enabling higher stresses to develop before fracture. The crack propagation from the outer layer is blunted by the

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organic–inorganic interface before traveling through second order lamellae presenting a zig-zag pattern during failure. This mode of failure increases the toughness by bifurcating and delocalizing the cracks in the brittle phase. Schematic drawing of the cross-lamellar structure Sea Shell shown in Figure 3.

Mustata et al. explained the effect of diglyceryl ether of bisphenol A/p-aminobenzoic acid systems with calcium carbonate as filler which is derived from natural conch of Rapanathomasiana shell. The Glass transition temperature (Tg) was found to have increased while adding percentage of $CaCO_3$ fillers, as conch fillers increased contact area.

Yang et al investigated the behavioral structure and mechanical characteristics in Saxidomu spurpuratus bivalve shells which have calcium carbonate (aragonite). The cross-lamellar structure is present in the inner layer and middle layer of the shell. The outer to Inner layer has blocky‟ regions due to that porosity will avoid. The hardness is less in outer layer when compared to the inner and middle layers. The compression strength is much lower compared to others shells like Haliotisrufescens, Strombusgigas (conch) shells, Araguala river clam etc. modified.

The effect of surface treatment of Egg Shell powder (EG) and $CaCO_3$ on cure reaction of epoxy was studied et al. Unlike modified $CaCO_3$, functionalised EG hindered the cure reaction of epoxy with anhydride. In case of pristine fillers, the higher specific surface area of ES particle resulting from its porous structure enabled ES to receive more terpolymer entities by utilizing more carboxyl groups. On the other hand, functionalization of ES provided less amount of residual carboxyl group in ES particles to reach epoxy leading to a reduction in the number of effective contacts between epoxy and anhydride, compared to the treated $CaCO_3$ particles. Further, a contradicting result are obtained in terms of lesser activation energy in pristine ES than $CaCO_3$.

OPTIMIZATION OF GFRP COMPOSITES

Biswas et al. (2009) provided the report on the solid particle erosion of epoxy with addition of glass fiber and red mud. They have taken six optimization control factors used for erosion (velocity of impact 43, 54, 65 m/s, filler content = 0,10, 20%, erodent temperature = 40^o, 50^o, and 60^{o}C, impingement angle = 40^o, 50^o, and 60^o, stand-off distance=65 mm,75mm,85mm, abrasive size filler 300,400,500μm). They used L27 orthogonal array and three levels of Taguchi‟s factorial experiment and also used fixed factors are Erodent (Silica sand), Erodent feed rate (10.0 ± 1.0(g/min)), Nozzle diameter (3 mm), and Length of nozzle (80mm). The optimization of erosion characteristics lower is better one. The micro harness, density increased addition of red mud fillers. Inter laminar shear strength and flexural strength will decrease and increase addition of percent of redmud fillers it's may lead due to the voids in matrix.

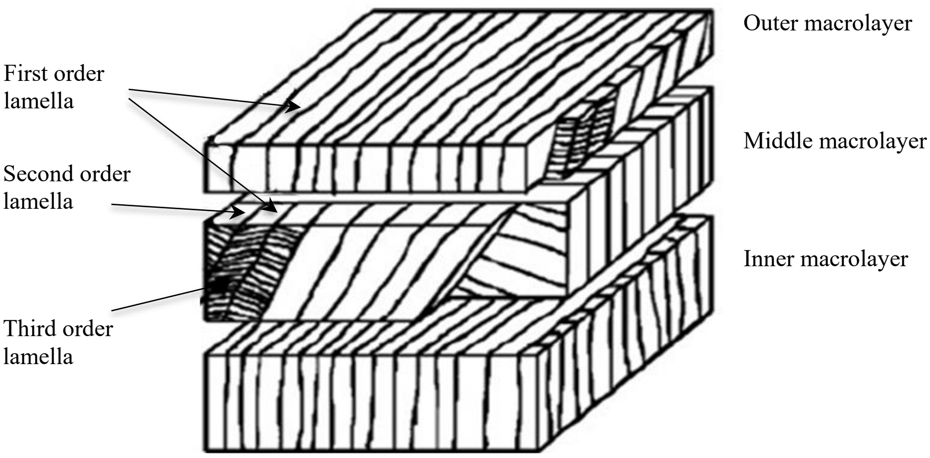

Figure 3. Schematic drawing of the cross-lamellar structure Sea shell.

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The optimization significance 5% of level of confidence. The Anova table shows that p values are very small and highly significant. the erodent size omitted will not influence in control factors. Mousavi et al. (2019) have analysed the two-optimization tool are Taguchi method and artificial neural network for the CFRP with glass and Kevlar composites. He said that Taguchi is the best method to optimise and Taguchi will minimize the more experiments. Artificial neural networks are prediction models and computational algorithms, predictions are learning steps for control parameters. Artificial neural networks and Taguchi have been shown to have closely tackled results but, considering the low Taguchi values relative to RMSE, mean absolute percentage error (MAPE)from the Analysis of Variance (ANOVA). table, process parameters have minimal F-value that does not affect the response parameters.

Abdulmajeed et al. (2011) took up of the subject of GFRP with two percentages (5 and 10 % wt.) While the addition with GFRP filler volume fractions enhances elasticity, capacity and toughness modules. It was statistically insignificant to get the P value of less than 0.05. The GFRP volume fraction raises by more than 10% wt, but there is no change to mechanical properties. The osteopathic manipulation, head and neck and dental implantation are used for Fiber reinforced composites.

Ayaz et al. (2016) have studied mechanical properties of polypropylene/linear low-density polyethylene/nano-titanium dioxide/styrene- ethylene-butylene-styrene (PP/LLDPE/TiO_2/ SEBS) nano-composites by using grey relational analysis (GRA) of S/N ratio. The process optimization of Taguchi (L9 orthogonal array) was used for the optimization between three different levels and three variables. The Taguchi method optimizes to reduce defaults using one of the parameters are the-nominal-the-best (NB), the- smaller-the-better (SB), and the larger-the-better (LB). The best optimisation tool for control parameters has been demonstrated by GRA (Taguchi method).

The research study of Ji et al. (2015) studied the effect of Clino cardium californiense shell indentation toughness and microstructures by a fractal method. Clino cardium californiense shell having three layers of hierarchical structure, the following layers having structure of inner layer (cross-lamellar structure), middle layer (cross-lamellar structure), and outer layer (prismatic structure). The aragonite sheets formed arranged in middle layer in form of complex structure. The indentation toughness is high at inner layer due to aragonite structure. The presence structure layers offer indentation toughness attributed to the fine microstructure and complex arrangement of aragonite sheet. Thus, this form of structured layer could be adopted for increasing the toughness of the component and the same is proposed in this work.

The investigation made by Haozeet et al. (2013) on hierarchical assembly and mechanical properties of conch shell constitutes an important counterpart for functional materials. It has been observed that, the basic building blocks in conch shell are third ordered lamellae with aragonite nanoparticles exhibiting ductility. The reason behind the ductility is because of crack interlocks via crack deflection along the interfaces in three dimension revealing conch shells mechanical robustness offering additional guidelines for bio-inspired materials.

Sara et al. (2013) observed the Compressive Strength and hardness of the different shell are Eastern Oyster, Crassostrea virginica, and the Asian Oyster, Crassostrea ariakensis. They compared with ages of shell is 1, 4, 6, and 9 for compressive strength and hardness it reveals that four year old shells have more compressive strength (1.47 + or -0.16 Gpa). There is no any significant role play by ages in hardness.

Oladele et al. (2019) found a decrease in wear coefficient in epoxy with Calcium carbonate, this is due to the strong interface with fillers and matrix. Bio-Degradation (90 Days) of buried and normal samples are similar ultimate tensile strength at 20% wt of Calcium carbonate with epoxy. Charred palm kernel shell fillers having 91.07% Crystallinity index (CI), its leads to improve the adhesion

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bonding with $CaCO_3$ with Epoxy. The results emphases that while addition of $CaCO_3$ with epoxy have better mechanical properties. When Calcium Carbonate mixed to polypropylene (PP), it increases the rigidity and toughness of the polypropylene composites. Oladele concluded that $CaCO_3$ with epoxy is gives better improvements in increase the crystallinity, tensile, glass transition temperature, toughness, and biodegradability.

Hong et al. (2015) have studied the compressive behaviour and relevant fracture mechanisms of Veinedrapa whelk shells with four kinds of oriented specimens. In this shell, both the inner and middle layers show a crossed-lamellar structure, while the outer layer exhibits a homogeneous structure. The compression experiments and Weibull analysis show that the compressive behaviour of this shell shows an obviously anisotropic characteristic. The compressive behaviour of this shell is greatly influenced by both macro and micro-architectures. The interfaces of different-level lamellae in the adjacent macro layers (i.e., inner and middle layers) will exert effects on the mechanical behaviour in a coordinated fashion. The present research findings are expected to provide beneficial references for the design of strong and tough biomimetic materials with an appropriately oriented and hierarchical microstructure extending over several distinct length scales.

Murtuza Ali Syed et al. (2012) The influence of bio particle (turmeric spent) in the load carrying and wear of polypropylene composite has been studied by Murtuza et al. The Tensile modulus of composites increased from 1041 to 1771 MPa with the increase in filler addition from 0 to 40 wt. %. Flexural strength and flexural modulus of composites were improved after incorporation of TS into PP matrix. Except higher loading, the fillers in the PP composites are intact and offering higher wear resistance. This exhibits the load threshold of the natural filler considered in the study.

The comparative research effect of the mechanical properties and structure of several sea shells (Strombus gigas, Tridacna gigas, Haliotis rufescens) is observed Albert et al. (2006). Because of viscoelastic proteins, high density and tailored structures, the sea shells provide excellent mechanical properties. Albert et al stated that bio composites act like calcium carbonate. As compared with other sea shells, the compressive strength (233– 540 MPa) and flexure toughness of Haliotis rufescens has higher properties. Figure 4 shows the inside the sea shells three lamella in three regions. Three shells optimised the brick-and-mortar scheme hierarchically inbuilt. The applications of sea shells are body Armor. Detailed discussions on thermal, mechanical and water absorption studies of echinoid spike particles with kenaf fibre and bio-resin mixture with epoxy were conducted Arun Prakash et al. (2019).

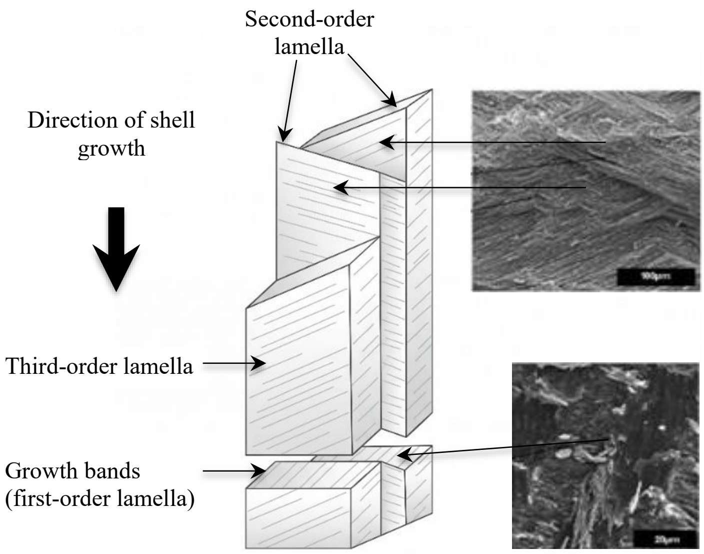

Figure 4. Strombus gigas shell outer region graphic illustration and SEM image.

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This is due to the high load absorbance and load disruption of sea urchin. Inter laminar shear strength decreased by the addition of spike patches. ($CaCo_3$). The wear rate and friction coefficient of specific are almost 22% and 58% respectively. the water absorption properties having a low contact angle because of hydrophobic nature due to the $CaCo_3$.

GFRP POLYMER COMPOSITES

As the orientation of the fibres increases, the flexural modulus diminishes, leading to reduced resistance, decreased stiffness, and an altered damage transmission mechanism. The symmetric ply 0/0/0/0 has a high flexural modulus as it mitigates matrix crazing, dependency, and other analogous phenomena. The loading frequency is the primary factor influencing the flexural modulus. The frequency exerts a more significant influence on the flexural modulus than the loading cycle. Furthermore, the short-term matrix toughening is seen in the asymmetric ply configuration 0/45/0/-45.

Investigations have been undertaken to examine the significance of GFRP composites influenced by jute and flax. Publication by Ramnath et al. in 2014. Both surfaces can achieve their desired surface finishes and hardness levels with GFRP. In comparison to mono fibre composites, hybrid composites have superior tensile properties, hardness, and interlaminar delamination resistance. On the other hand, when compared to hybrid composites, nanofiber composites have superior elongation, impact resistance, and ultimate shear strength.

They also looked at the fracture density at critical stress and the thickness of the lamina that cracked. It has been noted that interface decohesion is present in fibre laminate composites orientated 90 degrees and 0 degrees. Moreover, the transverse ply strength indicates that the initiation of cracks is independent of the laminate thickness.

Devendra et al. (2013) utilised fly ash, aluminium oxide (Al_2O_3), magnesium hydroxide ($Mg(OH)_2$), and haematite powder as fillers to examine their impacts on epoxy and glass fibre reinforced polymer (GFRP). They concluded that the combination of epoxy with GFRP and 10% magnesium hydroxide ($Mg\ (OH)_2$) enhanced both tensile strength and hardness compared to other combinations. The robust interfacial adhesion, superior stress alleviation, and prevention of agglomeration among polymers, fibres, and fillers account for this outcome. Other designations may forfeit their properties due to the existence of greater voids (Hand Layup Fabrications), fillers that fail to inhibit crack propagation, and a diminished volume percentage of GFRP.

A review has been performed on the hybrid polymer fibre composites created by Gupta et al. (2016). Gupta discussed the application of fiber-reinforced composite materials across several sectors, including aerospace, automotive, and construction industries. Thermoset polymers, or matrixes, surpass thermoplastic composites in their capacity to retain stiffness, enhance physical properties and toughness, and resist corrosion and chemical reactions. Composites fabricated using epoxy-based polymers exhibit numerous beneficial features, such as enhanced tensile strength, modulus, and compressive strength. Epoxy exhibits a glass transition temperature exceeding 130-300 degrees Celsius when compared to phenolics, polyesters, and vinyl esters. The hand lay-up technique is an effective method for achieving an aesthetically pleasing surface finish. Moreover, it has been found that E-glass fibre has remarkable thermal expansion and tensile strength.

Various amounts of bagasse were incorporated into GFRP composites developed by Tewari et al. (2012). Research indicates that augmenting the proportion of fillers enhances both the modulus of elasticity and the impact strength of the material. As the proportion of fillers increases, the material's density concurrently diminishes. Moreover, as the proportion of fillers increases, the tensile strength, flexural strength, and hardness of the material generally diminish, although the elongation percentages typically rise. This arises due to the low compatibility factor and voids present between GFRP and bagasse.

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In contrast to adding microsilica particles to the glass fiber-reinforced epoxy mixture, adding surface-functionalized nanosilica at a weight percentage of 2% improved the polymer composite's tensile and flexural characteristics. A potential reason for this enhancement is that nanosilica was more uniformly dispersed within the polymer matrix. The enhancement of dispersion quality due to the surface modification PDDA resulted in improved mechanical properties. The clusters generated due to particle concentration beyond two weight percentages resulted in a decline in mechanical and thermal characteristics.

Dhawa et al. (2013) examined glass fibre reinforced with natural fillers in their investigation. Composite materials, commonly referred to as fiber-reinforced plastics (FRP), have supplanted conventional engineering materials. The FRP has created numerous opportunities in the automotive sector and other industries. This study utilised GFRP with natural fillers and two polymer composites (rice husk, wheat husk, and coconut coir) to examine the material's mechanical qualities.

OPTIMIZATION OF GFRP COMPOSITES

In 2009, A study by Biswas and colleagues clarified the solid particle erosion of epoxy that happens when glass fibre and red mud are added to the mixture. They have employed six distinct optimisation control factors for erosion, which include the following: The impact velocity is 43, 54, or 65 meters per second; the filler content is 0%, 10%, or 20%; the erodent temperature is 40, 50, or 60 degrees Celsius; the impingement angle is 30, 60, or 90 degrees; the stand-off distance is 65, 75, or 85 millimetres; and the abrasive particle size is 300, 400, or 500 micrometres. The researchers employed an L27 orthogonal array and three phases of Taguchi's factorial experiment. A more effective method for optimising erosion characteristics is available at a reduced cost. The incorporation of red mud fillers significantly increased the micro hardness density. The presence of voids in the matrix will diminish interlaminar shear strength and flexural strength, whereas the incorporation of red mud fillers will result in an increased percentage of these fillers. The significance of optimisation is assessed at a confidence level of 5%. The ANOVA table indicates that the p-values are exceedingly low and possess substantial significance. The omission of the erodent's size will not affect the control factors.

Mousavi et al. (2019) analysed two optimisation strategies for carbon fibre reinforced plastic (CFRP) with glass and Kevlar composites: the Taguchi methodology and artificial neural networks. He asserted that the Taguchi method is the most efficacious means of optimisation and that the Taguchi approach will diminish the number of experiments required. Predictions serve as learning phases for control parameters, while artificial neural networks function as models and computational algorithms that generate predictions. The table indicates that the F-value for the process parameters is relatively low, resulting in minimal influence on the response parameters.

RESEARCH GAP

The literature review findings are used as a source of basic understanding for this research work. In comparison, there was no thorough work done to evaluate the effectiveness of natural fillers (conch fillers) with GFRP on the mechanical properties, dynamic mechanical analysis (DMA) and abrasion-corrosion based application response.

Thus, even though they have dynamic properties, the hybrid composite has micro applications and could be used for several engineering applications. The need for hybrid polymer composite therefore has enormous demand and focuses on the advancement of science.

Extensive research was conducted on glass fibre with epoxy-based hybrid polymer composites using conservative fillers, only a limited study was recorded on glass fibre with epoxy polymer composites filled with natural bio-waste such as rice husk, coconut shell and rice straw despite their availability.

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In the literature study revealed, E-Glass fibre and epoxy composites with Bio waste filler composites with different weight percentages for assessing and comparing their density, tensile, flexural, effect, interlaminar sharpness, fatigue, water absorption, wear and dynamic properties under different test conditions were done only few works. No work has found surface roughness to influence the response of a specific wear rate as a process parameter.

SCOPE OF THE STUDY

The scope of the current research on E-glass fibre, conch shell particulate matter-reinforced epoxy resin hybrid composites was explained in answers to the following questions.

1. Fabrication of composites minimises the energy spent on designing, finishing which enhances the affordable productivity of composite structure.
2. This study concerns the reaction characteristics of composite laminates in terms of tensile strength, flexural strength, durability and wearing through experimental investigation under different percentages of conch's fillers.
3. The use of natural material in component making minimises the disposal problem and increases the recyclability.
4. The Micro - Macro characteristic response of the biodegradable composite deploys its application in specific area such as auto mobile, electrical, wear application etc.

FINDINGS OF STUDY

The specific findings of this thesis shall be

1. The study of characteristic behaviour of synthetic fibre reinforced polymer composite (GFRP) with and without dispersion of conch - shell particle.
1. Analysis of Macro and Micro Characterization of E-glass fibre reinforced epoxy composite with conch- shell particle dispersion by conducting Tensile, Flexural, Impact, ILSS, TGA, Fatigue tests, wear test, water absorption, SEM, XRD, DMA and Modal Analysis.
2. Evaluating the effect of wear test parameters and their levels on specific wear rate performance, interaction, development of regression equation, and optimization of influencing factor levels by ANOVA.

Declaration of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this manuscript.

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