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A Review on Failure Analysis of Date Palm Fibre Reinforced Polymer Composites

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Abstract Date palm fibre (DPF)/polymer composites are being employed extensively in many significant applications recently, including home furnishings, sports equipment, automobile parts, and building insulation systems. The failure analysis of the date palm fibre reinforced polymer composite is the main topic of this review. The failure of the date palm fibre reinforced polymer composite was examined by the researchers in relation to a number of parameters. These variables include the kind of polymer matrix, manufacturing processes, fibre treatment, and composite hybridization with date palm fibre and other fibre. The literature also examined the impact of date palm fiber size on the failure of date palm fibre reinforced polymer composites. Recent research has demonstrated that the chemical treatment of DPF enhances the mechanical characteristics of the polymer/DPF composite and strengthens the link between the polymer and fibre, hence lowering the likelihood of composite failure. Reinforcing polymer matrices with a hybrid of DPF and other fiber improved the composite's mechanical qualities and decreased the chance of failure. DPF may be used to reinforce a wide variety of polymer matrices using various production processes, therefore lowering the likelihood of failure and selecting the optimal polymer composite qualities. As the DPF diameter shrank, the mechanical properties of polymer/DPF composites improved and the likelihood of failure dropped. As the length of the fiber rose to 12 mm, its mechanical properties improved and its likelihood of failure reduced.

Keywords: Date palm fibre; mechanical properties; polymer composite; failure analysis.

1 Introduction

Plants such as seeds, fruits, leaves, bast, core, and bast have a variety of fibers. Certain plant species yield specific forms of fibers, such as the bast fibre, jute core, and leaf fibre from pineapples [1], fruit bundle fibres from oil palm fruits [2], various types of fibres from date palm trees, sugar palm trees [3], coconut trees [4], and so on. The palm family of trees is widely distributed throughout Asia and Africa. Date palms alone provide a significant amount of fiber 42% more than coir, 20% more than hemp, and 10% more than sisal [5]. The date palm fibre is made up of bunches of multicellular fibres, and the cores of the fibres are hollow cavities. The anatomical texture of each palm fibre is polygonal to spherical when viewed in cross-section [6]. Natural fibres have long been employed in engineering applications; examples include the use of wood fibres for reinforcing composites used in clutch disk applications and cotton fibers for insulation foam [7, 8]. By adding natural fibres to reinforcing polymers, materials' thermal and acoustic qualities were improved, their renewability was raised, and their weight was decreased. Natural fibres are superior to synthetic fibres in several ways. Natural fibre reinforced composites were employed by several businesses, including Mercedes Benz, to create door panels [9, 10].

Various natural fibre types, including wood [11, 12], cotton [13], bagasse [14, 15], rice straw [15, 16], rice husk [17, 18], wheat straw [19], flax [20], hemp [21, 22], pineapple leaf [23], coir [24], oil palm [24, 25], date palm [26], doum fruit [27], ramie [28], curaua [29, 30], jowar [31], kenaf [32], bamboo [18, 33], rapeseed waste [34], sisal [35], and jute [36, 37] were among the various polymer matrices that were reinforced by these natural fibre types in numerous studies. Because date palm wastes are widely available and have no practical uses, researchers have been interested in blending them with polymer matrices to create novel polymer composites in recent years [38]. It is well known that date palm fibre has a comparatively high cellulose content, which contributes to the polymer's excellent mechanical qualities. It has been tried to strengthen polymer composites using DPF wastes

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in a variety of polymer matrices, including thermosets [42], polyurethane [43], biodegradable polymers [44, 45], and polyolefins, including PP and PE [39–41]. For instance, when polyethylene was reinforced with 40–75 weight percent of DPF as a coupling agent, the strength of the composite was significantly reduced in comparison to the pure polymer matrix [46].

Therefore, before utilizing natural fibre reinforced polymer composites in the design process for any technical application, they should be assessed based on a wide range of features. This should be carried out while considering the characteristics of the natural fibre as well as the kind of polymer matrix. The researchers propose that these techniques for choosing natural fibre goods be divided into the following categories [47]. as seen in **Fig. 1**.

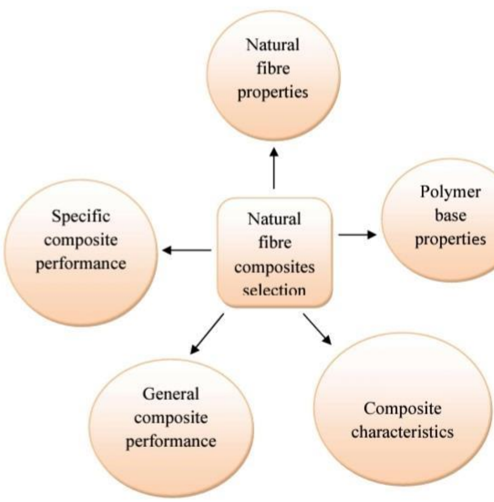

Fig. 1 Schematic diagram of the levels of criteria affecting the selection of the natural fibre composite materials[47]

It is desired to reduce failures by examining the underlying cause and implementing suitable numerator actions later on. Failure analysis is a skill- and practice-intensive process. The success of failure analysis depends on applying fully analytical techniques at a suitable gradation. Aggregate setting information, field visits, understanding the application or failure, specimen collection and preservation, visual monitoring of fracture surfaces, comprehensive inspections, chemical analysis, mechanical properties, and, lastly, studding and analysis of the results to ascertain the cause of failure are among the various analytical methods. Even though each of these procedures is important, the most important one that provides immediate information about the failure's initial cause is visual examination. Brittle, ductile, or fatigue failure modes are indicated by visual monitoring of the fracture surface. In addition to displaying disorder, the fractured sections also show surface faults, voids and porosity, scratches, cracks, and growing stress, all of which might be sources of the crack start [48].

The main objective of this work is studying the failure analyses of date palm fibre reinforced polymer composite because polymer/DPF composite is considered very important composite material and can be used in many engineering applications such as building thermal and acoustic insulations, car parts, home furniture and sport equipments. Knowing the causes of failure can used in reducing the failure of the composite material. It is observed that there are many factors affect on the failure analysis of the polymer/DPF composite. These factors were indicated in this work. These factors include fibre treating, fibres hybridization, manufacturing techniques and various polymer matrices used in composite fabrication. Also the affect of fibre size on failure analysis of DPF reinforced composite was illustrated.

2 Effect of Fibre Treating on Failure of Date Palm Fibre Reinforced Polymer Composites

The date palm fibre's diverse properties when utilized in polymer/DPF composites are demonstrated by the ways in which it is treated. Researchers used illustrations to show how different treatments affected the fibre in date palms. They demonstrated that the largest increase in tensile strength and resistance to heat degradation is achieved by fibres treated with soda. Due to variations in the interfacial adhesion between the fibre and the polymer matrix, this difference will result in a range of composites with different characteristics [49]. The mechanical properties of natural fibres were improved by physical or chemical treatment of the surface of the natural cellulosic fibres [18, 50, 51]. The categorization of treatments performed to natural fibre is shown in **Fig. 2**.

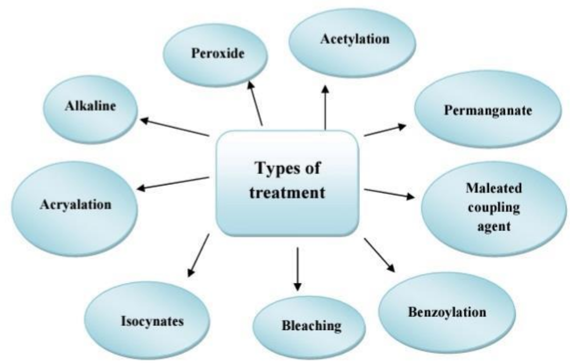

Fig. 2 Classification of treatment applied in Natural fibre

A variety of physical, chemical, and mechanical surface changes have been made to the fibre in an effort to increase the binding ability between the polymer and the fibre. Enhancing the fibres' capacity to bind to the polymer matrix lowers the likelihood of failure. In polymer/DPF composites, date palm fibres, like other natural fibres, are treated to improve the adhesion between the polymer matrix and DPF. Numerous studies have demonstrated that chemical treatment can increase the DPF's effectiveness [26, 42, 49, 52, 53]. The date palm fibre was assessed by Alawar et al. [40] utilizing a variety of alkali treatments, from 0.5% to 5%. The findings showed an improvement in the fibre surface. **Fig. 3** illustrates why treated DPF with chemical treatment is superior to untreated fibre: in treated date palm fibre, the outer layer was cleaned by chemical treatment, resulting in good adhesion and strong bonding between date palm fibre and polymer matrix in the polymer/DPF composites. Untreated fibres have a weak outer layer that reduces the bonding between fibre and polymer matrix.

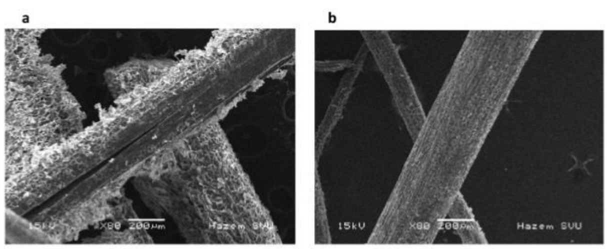

Fig .3 SEM of (a) Untreated date palm fiber and (b) Treated date palm fiber with 5 % NaOH [54]

Many parameters, including fibre extraction from the matrix, fibre breakage, and the degree of adhesion between the fibres and the polymer matrix, are relevant to the failure analysis of natural fiber-reinforced polymer composites [43]. Numerous research have recently examined the impact of chemical treatment on the surface of date palm fibres, as well as how this treatment affects the mechanical characteristics and failure analyses of composites reinforced with date palm fibre. The impact of various treatment procedures on date palm fibre was examined by Alawar et al. [40]. They employed two separate methods of treating hydrochloric acid (HCL) at boiling temperatures: acetic treatment and alkaline treatment (NaOH). They discovered that NaOH works better than HCL for DPF treatment, and the resulting polymer composite had high mechanical qualities and a lower failure rate. DPF was utilized by Alsaeed et al. [26] to reinforce epoxy. They used several doses of NaOH alkaline solution therapy, ranging from 0% to 9%. The outcomes demonstrated that a therapy with a 6% concentration had the best outcomes. Mohammed Y. Abdellah et al. [55] treated the date palm fibre using three separate chemical treatments: alkaline NaOH, HCl, and CH3COOH at three different concentrations of 10%, 20%, and 50% at boiling temperature for one or two hours. The HCl treatment was shown to provide good compatibility with date palm fibres, improve the mechanical characteristics of the epoxy/DPF composite, and lower the likelihood of failure when the treated DPF was used to reinforce epoxy. They showed that applying acidic treatments, such HCL and CH3COOH, to DPF increased the composite's tensile strength and Young's modulus. However, applying NaOH reduced these properties as it destroyed the fibres in the epoxy/DPF material. A comparative analysis of treated and untreated date palm fibre (DPF) and kenaf (KF)-reinforced epoxy hybrid composite was conducted by Syed Waheedullah Ghori et al. [56]. They saw that the treated natural fibre–reinforced hybrid composites improved the composites' tensile strength and Young's modulus while also lowering their failure rate. Additionally, they saw that untreated DPF and KF in hybrid composites displayed fibre pullout, breakage, and poor matrix-fibre bonding, increasing the likelihood that the composites would fail. However, in the case of treated fibres, the interfacial connection between natural fibres and the epoxy matrix was strengthened, and the treated fibres reduced the likelihood of failure in composites.

3 Effect of Hybridization on Failure of Date Palm Fibre Reinforced Polymer Composite

By adding two or more fibres to a single polymer matrix and obtaining the best qualities from each fiber to create the final composite, the hybridization process can improve a variety of polymer composite features, including thermal, physical, and mechanical characteristics [57, 58]. Date palm fibre (DPF) and kenaf were used to strengthen an epoxy composite that was made by Syed Waheedullah Ghori and G. Srinivasa Rao [59]. **Table 1.** shows that they employed 50% epoxy as a matrix and 50% fillers (DPF and kenaf) in varying ratios.

Table 1 Formulation of composites[59]

Hybrid composites	DPF wt % of fibre	Kenaf wt % of fibre
3DPF7K	30	70
1DPF1K	50	50
7DPF3K	70	30

The weight of the epoxy matrix is maintained at 50% with 50% of the fibres separated, as the final tables in three distinct scenarios demonstrate.

They found that every possible fibre ratio improved the tensile properties and decreased the likelihood of failure. The ideal ratio yielded an optimal modulus of 4.61 GPa and an optimal tensile strength of 24.66 MPa, respectively, and was found to be 30% DPF to 70% kenaf. Additionally, they said that a higher kenaf ratio improved the composite's mechanical properties because kenaf has better mechanical properties than date palm fibre alone [60, 61]. For this reason, kenaf was combined with date palm fibre hybrid to reinforce epoxy, improving composite mechanical properties, and lowering the chance of failure.

Mohammed Y. Abdellah et al. [54] produced a hybrid of polyester/DPF and sheep wool as well as polyester/DPF composite. The specimens were put through a fracture toughness test. A compact tension sample is the kind of specimen utilized in fracture toughness testing [62–73]. From 3.45 MPa·$m^{1/2}$ (pure polyester) to 11.55 MPa·$m^{1/2}$ (with 20% date palm fibre loading) and 13.95 MPa·$m^{1/2}$ (with 20% date palm fibre/sheep wool hybrid loading), they found that the fracture toughness had increased. The high adherence between the fibres and polyester increased the energy release rate from 3.99 kJ/m^2 (pure polyester) to 39.82 kJ/m^2 (with 20% date palm fibre loading) and 53 kJ/m^2 (with 20% date palm fibre/sheep wool hybrid loading). They found that in the polymer matrix, adding sheep wool to date palm fibre performed better than date palm fibre alone, and that doing so decreased the composite's failure probability. Mohammed Y. Abdellah et al.'s study [74] examined the effects of polyester reinforced with a hybrid of sheep wool and date palm fibre. Samples were prepared using compression molding and using different fibre contents (0%, 10%, 20% and 30% by weight). The results showed that a blend of reinforced polyester containing 20% DPF and wool worked best. Maximum tensile strength and elastic modulus are 3.69 GPa and 27 MPa respectively, helping to reduce the probability of failure. The ultimate modulus of bending and bending strength were 2507 MPa and 35.4 MPa, respectively. With impact strength of 39.5 kJ/m^2 and a hardness of 64 HB, the likelihood of failure was decreased. Strong adhesion and excellent interfacial bonding between the polyester and date palm/sheep wool fibres were demonstrated by the SEM.

4 Different Polymer Matrices and Manufacturing Techniques Used in Manufacturing DPF Reinforced Polymer Composite

Due to its high qualities, affordability, and lack of other significant uses, date palm fibre has been frequently employed in polymer composite reinforcement in recent decades [38]. Additionally, the high relative amount of cellulose in date palm fibres provides the material with strong mechanical qualities. Date palm remnants' capacity to reinforce several polymer matrices, including epoxy, high density poly ethylene (HDPE), poly lactic acid (PLA), polyester, and poly propylene (PP), has been investigated.

Numerous investigations demonstrated that ethylene terephthalate, polypropylene, epoxy, polyester, and high- and low-density polyethylene (HDPE and LDPE) were among the matrices utilized in the production of polymer/DPF composites. A scanning electron microscope (SEM) image of the polyester/DPF composite upon fracture is shown in Fig. 4. The majority of research showed that adding date palm fibres to polymers enhanced their mechanical, acoustical, and thermal characteristics, including flexural strength, Young's modulus, and tensile strength [49, 52, 53].

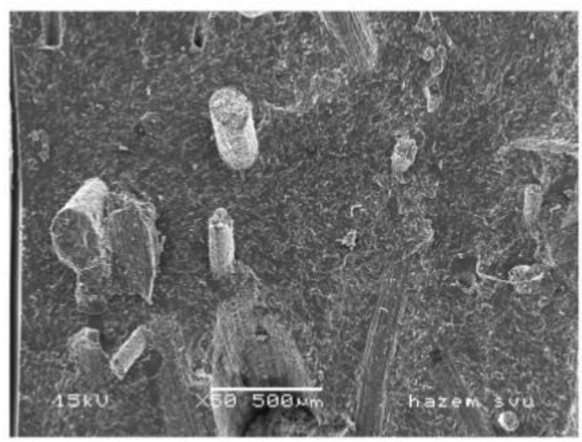

Fig .4 SEM micrograph of fracture surface of date palm fibre/polyester composite[54]

4.1 Date palm fibre (DPF) reinforced epoxy composite

One of the most important polymer matrices that effectively contribute to the advancement of the polymer composites sector is epoxy resin. Epoxy was employed by the researchers in a variety of production processes and reinforcing stages [75]. Epoxy was treated with hardener to create solid forms, which were then employed in various applications. Low cure retraction and excellent adherence are two characteristics of epoxy resin [76]. There are several drawbacks to using conventional resins, including high viscosities, lengthy curing times, and moisture absorption. The polymer sector has access to a wide variety of resins and co-reagents. Excellent mechanical qualities of epoxy resins include minimal creep, chemical resistance, high strength, and fire retardancy. Their suitable electrical properties enable their employment in several industries, including the construction, aerospace, and automotive sectors [77, 78].

Numerous researchers produced epoxy/DPF composites to enhance the characteristics of the epoxy matrix and employed DPF to strengthen epoxy. Samah M. Hussein [79] manufactured the samples by hand-layup technique and reinforced epoxy with DPF. The weight percentages of fiber content were 5%, 10%, 15%, and 20%. She noticed that adding more DPF resulted in an increase in the hardness, impact strength, and Young's modulus values. Regarding tensile strength, it was found that 5% and 10% DPF enhanced the tensile strength, while 15% and 20% DPF lowered it. This was because the date palm fibre and epoxy did not adhere well to one other, which increased the likelihood of failure. Malek Ali [80] investigated the epoxy/DPF composite's characteristics. He produced and evaluated DPF-reinforced epoxy in various DPF ratios (5, 10, 15, and 20 wt%). Because the date palm fibre structure contains a high percentage of lignin (20–28 wt%), it has good adhesion and stronger interfacial bonding between DPF and the epoxy matrix, which reduces the likelihood of failure. He observed that creep impact and tensile were enhanced by increasing the date palm fibre ratio in the epoxy matrix. He observed that when date palm fibre is increased to 15 weight percent, the hardness increases. The hardness of the date palm fibre reinforced epoxy composites with 20 weight percent DPF was decreased due to porosity, poor adhesion, low interfacial bonding, and disappearance of epoxy between date palm fibres. This led to unsatisfactory mechanical test results and an increased risk of failure. He noticed that the epoxy/DPF composite's highest impact strength and lowest failure probability was reached at 20 weight percent DPF. Basheer A. Alshammari et al. [81] created epoxy/DPF composites with a 50% weight fibre content by hand lay-up method. The date palm leaf sheath, date palm fruit cluster stalk, date palm leaf stalk, and date palm tree stem were the four kinds DPF fillers they employed. They found that adding date palm fruit bunch stalk improved the strength of the flexural (32.11–110.16 MPa), impact (45.71–99.45 J/m), and tensile (20.60–40.12 MPa). Due to their improved mechanical characteristics and superior performance over other types of composites, the epoxy/date palm fruit bunch stalk composites showed comparatively lower fibre pull-out and void content in the broken surface morphologies findings.

4.2 Date palm fibre (DPF) reinforced High Density Polyethylene (HDPE) composite

To improve the qualities of the HDPE matrix, several researchers created HDPE/DPF composites and employed DPF to strengthen HDPE. Using a co-rotating twin screw extruder, VenitalityaAugustia et al. [82] produced HPDE/DPF composites in five different DPF weights (5, 10, 20, and 30 wt%). They noticed that all of the composites' tensile strengths were greater than those of pure HDPE and that they had all improved. However, the greatest increase was attained at the 5% DPF content, where it was around 19.23 MPa (138% higher than that of pure HDPE), which decreased the likelihood that failure would occur. They also noted that, while the flexural strength showed outstanding results at 5% DPF, at 10% DPF content, the flexural strength was comparable to the flexural strength of pure HDPE, and at 20% and 30% DPF, the flexural strength declined.

4.3 Date palm fibre (DPF) reinforced Polylactic Acid (PLA) composite

Numerous researchers produced PLA/DPF composites and reinforced PLA with DPF to evaluate the PLA matrix's characteristics. Using the melt-mixing and compression molding techniques, Said Awad et al. [83] investigated the impact of incorporating DPF into PLA on the mechanical characteristics of PLA/DPF composite. They found that the PLA/DPF composite's flexural strength, tensile strength, and impact strength all reduced as the DPF concentration increased. **Table 2** illustrates the different polymer matrices reinforced with DPF and manufacturing techniques used in composites fabrication.

Table 2 Different polymer matrices reinforced with DPF and manufacturing techniques used in composites fabrication

composites	Polymer matrix	Manufacturing technique
Polyester/DPF	Polyester	Compression moulding
PLA/DPF	PLA	Compression moulding
Polyester/DPF	Polyester	Hand lay-up
Epoxy/DPF	Epoxy	Hand lay-up
PP/DPF	PP	Injection moulding
HDPE/DPF	HDPE	Injection moulding

4.4 Date palm fibre (DPF) reinforced polyester composite

In order to investigate the characteristics of polyester/DPF composite, several researchers produced polyester/DPF composite and reinforced polyester with DPF. Petiole date palm fibres with lengths ranging from 2 to 3 mm and volume fractions of 10, 20, 30, and 40% were utilized by Dr. Sihama I. Salih et al. [84] to create polyester/DPF composites using a manual lay-up approach. Using various compression loads (0, 2, 4, and 6 MPa), she investigated the impact of pre-deformation for petiole date palm fibre on the mechanical characteristics of the composites that were created. She found that for petiole date palm fibre-reinforced polyester with a volume fraction of 40%, in which the petiole date palm fibre was pre-deformed under a compressive stress of 6 MPa, the tensile strength and hardness reached the optimal value (133 MPa)) and (106). Mohammed Y. Abdellah et al. [54] used the compression molding process to produce polyester/DPF with four distinct mass contents of DPF: 0%, 10%, 20%, and 30%. Because of the high adhesion between polyester and DPF, they found that adding 10% and 20% DPF contents to polyester increased the tensile strength of the polyester/DPF composite. The tensile strength increased from 17 to 18.4 MPa and the modulus of elasticity increased from 2.98 to 3.19 GPa when the DPF content was 10%. When the DPF content was 20%, the tensile strength increased to 19.2 MPa, the elastic modulus increased to 3.35 GPa, and the likelihood of failure decreased. However, with 30% DPF concentration, the tensile strength dropped to 15.8 MPa because of the polyester matrix's poor interfacial bonding and weak adhesion to the DPF. Additionally, the modulus of elasticity was reduced to 2.83 GPa because to the weak adhesion between the polyester and DPF, increasing the likelihood of failure. They also demonstrated how polyester is a brittle material, with a comparatively low fracture toughness of 3.45 $MPa\cdot m^{1/2}$. The fracture toughness increased to 7.98 and 11.55 $MPa\cdot m^{1/2}$, respectively, when it was reinforced with DPF at mass fractions of 10% and 20%. This was because the DPF and polyester bonded strongly. The resultant composites' ability to endure high breaking forces was enhanced by the tight connection between the matrix and DPF. However, the fracture toughness decreased to 6.84 $MPa\cdot m^{1/2}$ with a 30% DPF concentration because of the poor interfacial bonding and weak adhesion between polyester and DPF. Low fracture toughness was the result of the link between the fibre and polyester decreasing at a DPF content of more than 20%.As shown in **Table 3.** various studies on date palm material reinforced polymer composites are indicated.

Table 3 Reported studies on date palm material reinforced polymer composites

Date palm fibres	Polymer Matrix	References
Date palm sheath fibres	Commercial chitosan	[85]
Alkali treated DPF	Polyurethane	[43]
Alkali treated date palm leaf fibres	Recycled poly (ethylene-terephthalate	[43]
Date palm sheath fibres	Polycaprolactone	[45]
Date palm petiole wood	Parenchyma (matrix).	[86]
Hybridized date palm leaf/Glass fibres	Epoxy	[87]
Date palm wastes	Linear-low density polyethylene matrix	[88]
Hybridized date palm and flax fibres	Thermoplastic starch	[44]
Date palm stem fibres	Epoxy	[60]
Date palm leaflets	Expanded polystyrene	[89]
Date palm wood flour (rachis, leaflet and leaf)	Polyethylene	[46]

5 Effect of date palm fibre size on failure of date palm fibre reinforced polymer composites

5.1 Effect of the date palm fibre diameter on failure of the polymer/DPF composite

It was investigated how various DPF diameters treated with 6% NaOH solution affected the strength of epoxy/DPF composites. It was shown that when the treated DPF diameter shrunk, the mechanical qualities increased, and the likelihood of a failure decreased. The mechanical properties of date palm fibre with a diameter of 200 μm to 400 μm are respectively 120% and 13% greater than those of date palm fibre with a diameter of 600 μm to 800 μm. When comparing date palm fibre diameters between 200 μm and 400 μm, 400 μm and 600 μm, and 600 μm and 800 μm, the elongation strain of untreated DPF reinforced epoxy is greater by 65%, 77%, and 15%, respectively [52].

5.2 Effect of the date palm fibre length on failure o the polymer/DPF composite

It was determined how the length of the natural fibres (date palm and coir) affected the composite's mechanical qualities [90]. After gathering and treating the DPF and coir fibre with 5% NaOH, they were cleaned and allowed to air dry. Chopped into different lengths of 3, 6, 9, 12, and 15 mm, coir fibers and DPF were combined in a 1 to 1 ratio. Epoxy resin was utilized as the matrix in the hand lay-up approach employed to create the composite specimens. As the length of the fiber rose to 12 mm, the results showed that the tensile strength improved as well. When compared to unreinforced specimens, it was shown that the tensile strength of the fibres with a length of 3 mm increased by 3.94%, reducing the likelihood that failure would occur. The tensile strength was increased by 24.87% by the fibers with a length of 12 mm. Tensile modulus findings showed a similar shift; for the unreinforced specimens, the modulus result was 3.5 GPa, but for the reinforced specimens with 12 mm fibre length, it increased to 3.9 GPa because of an increase in the effective contact area between the matrix and fibres. Additionally, it was noted that the tensile modulus and strength decreased as the fibre's length approached 15 mm. Similar patterns were also seen in the flexural strength values. For the unreinforced specimens, the flexural strength was 27.7 MPa before improving to 81.75 MPa with the usage of 12 mm fibre lengths. The flexural strength dropped to 48.2 MPa when the fibre length reached 15 mm. The impact strength values rose as the fibre length grew, in contrast to the flexural and tensile values. Impact strength values improved to 6.41 kJ/m^2 for the reinforced specimens with a 15 mm fibre length from 2.09 kJ/m^2 for the unreinforced specimens. The influence of DPF length on the flexural characteristics of polyester composite was investigated in Al-Kaabi and Al-Khanbashi[91]. The lengths of DPF used were 0.5, 1, 2, and 3 cm after treatments using 5% NaOH solution, and bleaching with dioxin solution. Polyester matrix reinforced with raw DPF with various lengths and with DPF treated with various treatments were tested for impact and flexural properties. Results indicated that raw date palm fibre reinforced polyester with 2 cm fibre length gives the best flexural strength among all used fibre lengths. Results also indicated that the composite reinforced with DPF treated with 5% NaOH gave the best flexural strength value of 70 MPa. The researcher also showed that composite manufactured from polyester resin with 2 cm DPF treated with 5% NaOH gave the best flexural strength result with content of 9%DPF by weight. The impact strength increased and gave the best impact strength of 12 kJ/m^2 when the weight content of DPF was 9% and the length of the fibre was 2 cm and the DPF were alkali treated, which reduced the opportunity of failure occurring.

6 Applications of date palm fibre reinforced polymer composites

Rapid industrialization led to a demand for improved materials with respect to stiffness, strength, and density as well as cost and environmental friendliness. Because of their excellent qualities and versatility, composite materials are regarded as extremely significant materials [92–95]. One material offers the matrix phase, and another material presents the additives in the form of fibres or particles. Composite materials are made up of two or more distinct materials. The use of natural or synthetic fibres in the creation of composite materials has shown significant benefits in a number of industries, including the fabrication of mechanical components, aerospace, marine, construction, automotive, and biomedical [96–99].

Numerous natural fibre types, including flax, jute, coir, hemp, sisal, and date palm fibre, have been used in the production of car components and other industrial applications because of their strong mechanical qualities, which lower the likelihood that these parts would break. For instance, Daimler AG was able to improve the mechanical properties of the Mercedes-Benz E-class door panels. The use of epoxy resin bonded with natural fibre material was the reason for this improvement in door panels. Additionally, it was possible to reduce the weight of the door panels by 20% while also improving passenger safety in the event of an accident [100]. When evaluating attributes like cost, tensile strength, and availability, natural fibres like flax, date palm fibre, sisal, and hemp are superior than synthetic fibers like E-glass for usage in reinforcing polymer composites in various applications. When comparing natural and synthetic fibres, E-glass fibres are always utilized as the standard since they are crucial to the production of polymer composites that are reinforced and utilized in a variety of industrial applications [100, 101].

Petroleum-based polymers (PBP) and polymer matrices have been important in improving various parts and configurations for several industrial uses. Unlike their predecessors, which were derived from nature, synthetic polymers have been around since the advent of Bakelite at the beginning of the 20th century [102]. The exceptional qualities of polymers have led to a rapid expansion in their manufacture during the last seven decades. In addition to having many other desirable qualities like being light weight and strong, polymers may also be rigid or flexible, transparent or colored, conductors or insulators, and resistant to deterioration. They can also be strengthened by adding natural fibres, such the fibres from date palms, to further enhance their qualities. Applications for date palm fibre reinforced polymer include packaging, automotive, construction, and other industrial fields.

Numerous polymer matrices with desirable properties, such as polyester, epoxy resin, and polypropylene (PP), can be reinforced with DPF and employed in a variety of applications. Chemical resistance makes polypropylene (PP) useful in the automotive, packaging, and construction industries [97, 103-108]. High strength epoxy resin is used in the automotive, aerospace, and marine industries [104, 109–111]. Polyester may be utilized in structural applications because it is strong, water- and chemical-resistant, and resilient [112] and [113]. The head impact criteria (HIC) was used to gauge the level of safety considerations, and the results showed that composite constructions with natural fibre reinforcements make sense for making car body parts [114–118].

Numerous studies looked at the use of polymer/DPF composites in automobile components. Thermoplastics and thermosetting materials both utilize these fibres as functional fillers [52, 119, 120]. Researchers [119] provided evidence of the significance of employing DPF in the production of polymer composites for industrial use in the automobile industry. Because of their excellent wear resistance, mechanical, and electrical properties, fibre-reinforced polymer composites have been used in the aerospace industry to create good, low-density, highly durable materials for the aircraft structure industry [121–123]. Also a study by Mohammed Y. Abdellah [124] illustrated that fibre reinforced polymer composites can be used in aerospace industry.

7 Conclusions

Date palm fibre (DPF) reinforced polymer composites have potential applications in home furnishings, automobile components, aircraft, sports equipment, and affordable building insulation solutions. There are many factors can improved the polymer/DPF composites and reduce the failure chance of the composites such as using treated DPF because treated fibres can enhance the mechanical characteristics of DPF-reinforced polymer composites by lowering the likelihood of failure through strong fibre-matrix adhesion. Other factors can improve polymer/DPF properties such as reinforcing polymer composites with a hybridization system between DPF and other fibre this decrease the likelihood of failure. Selecting an optimal polymer matrix and manufacturing process can also improve mechanical qualities and decrease failure rates. Various polymer matrices and manufacturing techniques can be used in polymer/DPF composite fabrication are epoxy, high density polyethylene (HDPE), poly lactic acid (PLA), polyester, and poly propylene (PP). Additionally as the DPF diameter shrank, the mechanical characteristics of the polymer/DPF composites can be improved and the likelihood of failure dropped. As the fibre length rose to 12 mm, the mechanical characteristics of the polymer/DPF composites can be improved and the likelihood of failure reduced.

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