The ability of natural / synthetic fibers compound for ballistic impedance: A review

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Abstrak

This review evaluates on the concept and essential of bio composite and the synthetic composite fabric positioned over the years from the previous studies. The sorts and features of matrix and fibre filler reinforcement materials in composites also are discussed. The main findings in this review show that the centre of composite relies on the natural fiber against synthetic and the roles of interply lamination. Therefore, the contemporary hybrid compound for synthetic fibre and bio composite fibre in a composite shape is anticipated performing higher in the issue of mechanical energy in particular within the application of high impact, besides decreased dependency on artificial fibre. The table and figure previous results are comparing the experimental parameters available inside the literature review. This paper goes over the present advancement structure and development procedures included and related works on upgrading low and high impact energy captivation and upgrading the mechanical tenacity for high impact resistance applications.

Keywords: *Composite fibers, synthetic fibers, reinforcement, mechanical test, high impact test*

1. INTRODUCTION

A substantial composite is made up of two or higher combination numbers creating properties that differ from its components. It can be extremely simple because composites are strong and durable, but very mild in weight and the proportions of strength to weight and volume to weight are much superior compared to the properties of metals and aluminium that plastics, ceramics and polymers cannot achieve themselves [1]. Natural fibres are in trend with their excellent mechanical properties in the automotive, manufacturing and aerospace sectors. Such natural fibres include sisal, flax, coir, cotton, jute, kenaf, and more [2]. Composites consist of different sections, in particular the material and matrix for reinforcement. The strengthening materials are generally solid with a low density, and the matrix is versatile and challenging to ensure that the composite is able to achieve each of its finest features [3]. Natural fibres are used to reinforce the current basic material structure. These provide a complex configuration with a crystalline cellulose amorphous lignin or hemicellulose matrix, which is reinforced by fibril. The key components of it are cellulose (60% - 80%), hemicellulose (5% - 20%), lining and humidity (20%) [4]. The chemically modified natural fibre improves the properties compared to untreated fibres. The chemically managed interface grip between fibre roots and polymer matrix has advanced with natural fibres.

More specific research directed on the intensity of impact and fatigue consistency of natural fibre reinforcement [5]. Currently, natural fibres, including sisal and jute fibres, convert glass and carbon fibres because they are easy to use and durable. The use of synthetic fibres is evolving astonishingly and the reality is that every day, particularly within the automotive industry, the manufacturing sector is advancing. Natural fibre composites were previously intrigued by their biodegradability. Typical strands such as silk, coir, sisal and jute are low-cost, plentiful and reusable, lightweight, low-fat, robust and biodegradable. Natural jute strands might use as a substitute for conventional strengthening in compounds for projects that need strict weight control and external weight reductions [6]. Kevlar 29 has been produced primarily from coal-related materials, and is the most widely used synthetic fibre for soft and hard armour applications. Reduced oil reserves and green fibre growth have enabled scholars towards investigate the possible usage of natural strand for a substitute to man-made fibres. Besides that, combination of natural fibres against man-made fibres can convey the most remarkable attribute that individual fibres are difficult to achieve. This review offers a relative reading of the classification and construction of different varieties of ballistic constituents, as well as the techniques for upgrading shields and distinctive methods employed to facilitate the absorption of ballistic energy.

1.1. Natural plant

Research has recently shown a growing interest in and viability of natural fibers as a reinforcement of the polymer matrix. In order to replace synthetic fibres, natural fibers are proposed for various benefits, such as environmental-friendly, cheap, beautiful, sustainable and strong properties. Natural fibers are extracted and classified accordingly from different plant components (system, leaf and bark) [7]. Supportability is defined as the ability to align execution with natural constraints. The capacity of natural fibers, on the other hand, is enormous and therefore requires a complex reuse. The researchers suggested the petroleum resources and growing focus to green materials to explore the possible use of natural fiber as an alternative to synthetic fibres. The hybridization of natural fiber with synthetic fiber will bring with it the best attribute that is difficult to harvest from the individual fibers. This analysis paper offers a comparative report on the classification and efficiency of different types of ballistic materials, the construction methods of the armor panel and various techniques used to increase the ballistic energy absorption ability. However, research has consistently shown that natural fibers also offer the same mechanical tenacity as the synthetic fibers.

1.2. Synthetic fibres

There is no question that synthetic fibers are prominent in FRP composites, particularly GFRP, but a lot of work has been applied to natural fibers over the past few years in the possibility of replacing synthetic fibres. This is very important as a step towards developing an environmentally friendly solution. As those technological problems of natural fibers seem to be drawbacks to being replacement fibres, the art of improvement embraces the architecture and the method of processing is important. Throughout recent years , natural fibers have been used as a possible substitute for synthetic fibres, such as petroleum products, aramid and glass, due to increased environmental consciousness [8] On the other hand, several writers have claimed that hybridizing natural and high-force synthetic fiber hybridization will enhance natural fiber mechanical properties. The product developer is innovative in the form of hybridising to adapt the material properties, and is one of the best features of composites, according to specifications. Many fiber reinforced studies also point to these materials' environmental benefits [9]. Natural fibers typically have lower mechanical properties as compared to their synthetic or mineral-based counterparts. Such low mechanical properties are a key consideration in the production of high-performance materials. The hybridization of natural fibers with synthetic fibers is one way to increase their mechanical strength. The benefit of the use of hybrids is that the benefits of a single fiber type will outweigh the drawbacks of the other fiber type. The use of both synthetic and environmental effects of natural fibers is a viable compromise between higher material properties of synthetic fibers. Thus, the right composite material design could achieve a balance in cost, performance and sustainability [10]. The physical and mechanical properties of traditional synthetic materials are excellent, although these have significant drawbacks, such as non-renewable, non-recyclable, high power consumption during the manufacturing cycle, risk to health and non-biodegradability. Due to these issues, the composite industry of naturally based composites became involved, when green benefits of natural composites (renewability and biodegradability) became important criteria, not primary motivation for top-end mechanical properties. Everything like low density is known to be suitable for use with lightweight structures, although natural fibres may be used for use as a green replacement. Natural fibers are in most circumstances cheaper than synthetic fibers and cause fewer health problems. The interest in the use of natural fibers to enhance the polymer matrix composite was thus highlighted by the engineering, automotive and consumer sectors. In general, a broad variety of natural fibers are produced primarily from vegetable, animal and mineral fibres [11].

DISCUSSION

Mechanical Properties of Natural Fibre/Synthetic Hybrid Composites

The considerable mechanical properties of natural fibers can be achieved by hybridization with synthetic fibres, based on the high performance requirements. In addition, the material is biodegradable, economical and mechanically outstanding compared to a particular weight. The thermoset polymers including polyester, epoxy and phenolic are the most commonly used binder or resin. However, the use of these natural fibers as reinforcements in polymers is reduced due to certain disadvantages, such as incompatibility between fibers and polymers, the tendency to form aggregates during processing and poor resistance to moisture. Varios treatments and modifications, including bleaching, acetylation and bonding agents use, are used to improve fiber / mature performance.Low Velocity Impact Properties of Natural Fibre Composites [12].

Low Velocity Impact Properties of Natural Fibre/Synthetic Hybrid Composites

The impact loading conditions can be categorised into the following categories by impacting velocity and penetrating mass: (a) low-speed impact and (b) ballistic impact. At a constant speed, quasi-static puncture loading is driven, simulating a penetrator with infinite mass as there is no deceleration during testing. Low-speed impacts can occur in a number of cases, including traffic collisions and debris impacts with low initial heights. Low-velocity impact tests can be conducted in a drop-weight configuration (with a gravity-driven penetrator) or in a hydraulic test device. A variable speed is needed for the drop-weight impact test design, but the hydraulic testing system allows the penetrator to be continuously speeded. In relation to the low velocity effect, the ballistic effect is a highly dynamic phenomenon involving the distribution of the transient stress wave. In some cases, the material affected will collapse until the stress waves represent the material boundary. As the name suggests, ballistic impacts are usually caused by projectiles or bits of explosive ammunition. As a result, the mass is usually much less than the low-speed impact and the impact speed is much greater than the low-speed impact [13].

2.3. High Velocity Impact Properties of Natural Fibre/Synthetic Hybrid Composites

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The effect in high-speed collision testing indicates that two or more bodies collide.

Projectile is a term for any object that is being launched. Target is the term for any fixed or mentionable projectile object. There are two types of single-stage firearms, powder and gas weapons. A powder gun uses normal gun powder to propel the projectile, with a maximum speed of approximately 2,0–2,2 km/s. A single stage light gas arm is powered by compressed helium or hydrogen gas [14]. Previous work has investigated the penetration and perforation of Fiber Reinforced Polymer (FRP) composites using flat-faced, hemispheric, conical-tip and truncated-cone-nose projectiles with high velocity effects [15]. In high-speed impacts in both rigid and fabric composites, the shot normally perforates the first few layers of the target on impact. The projectile commonly perforates the first few layers of the target at high-speed results of both rough and soft composites. It works most commonly with sharp fragments, or where the initial pressure of the thread reaches the point of failure. This is called a shear relation. The corresponding layers of tissue or hard target are distributed and absorb energy by membrane action. The array of impact speeds from global to local controlled reaction involves quasi-static low-end loading and high-end hyper-speed impacts [16]. globalised plate deflection at sufficiently high speeds is much less important. The degree to which each of these regimes is observed is the function of attack velocity, target and projectile geometry, and material properties.

Table 1. Reported research on ballistic resistance properties of natural/synthetic fibre hybrid composites

Composites plies	Impact strength (J)	Residual velocity (m/s)	Thickness (mm)	References
4Woven bamboo + 18 woven E-glass	0.368	482.0	18.0	[18]
4Kenaf fibre +15 Aramid	150	230.81	10.08	[12]
1Kenaf fibre (innermost) + 2Aramid	131	339	10.8	[20]
Kenaf foam(sandwiched) + 2 mild steel	120	N/A	45	[21]
12 Coconut sheath + 0.25% GnP + Kevlar 29	180	280	N/A	[22]

Regional energy absorption processes are usually prevalent in low-speed events where there is ample time for the transfer and propagation of projectile energy over a large region of the target. In these situations, the impact event is long enough for the elastic waves generated in the target (flexural and shear) to migrate and reach the boundary of the target. The effect response of single yarns as a specific component of fabrics and laminates has an essential similarities to that of fabric-based targets [17].

The results in Table 1 indicates that the composites construction with the finer filler offers more efficient energy absorbers than the fabric constructed with the coarse yarn, on an equal areal density basis. The studies on impact strength revealed that, with less fiber interlacing, thicker lamination performed significantly better than plain weave fabric composites. In their detailed studies on the failure mechanisms of natural/synthetic composites upon ballistic impact shows that the position of natural fibre as a reinforcement plays important role in determining the optimum impact strength through residual velocities. The initial velocities lost perpendicularly decreased with the ability of the hybrid plies to absorb the impact from the projectiles.

Table 2. Reported research on mechanical properties of natural fibre composites

Properties	Woven Kenaf	Chonta palm wood	Mallow and jute	Coconut sheath	Kevlar 29
Density (g/cm^3)	1.2	1	4.16	1.37–1.50	1.44
Tensile strength (MPa)	101	16.53	N/A	170	3000
Young’s Modulus (MPa)	N/A	798.9	N/A	5.7	600
Elongation (%)	17.3	4.89	N/A	15.5	2.5-3.7
References	[19]	[23]	[24]	[22]	[20]

Table 2 is related to comparison of the properties between natural and synthetic fibers. In the past decades, significant progress has been made in exploiting the intrinsic properties of the macromolecular chain of natural fibers with regard to ultimate synthetic properties. Aramid 29 has better mechanical properties than natural fibers and a low areal density but still the natural fibers offer competence characteristics. The combination of both natural and synthetic fibers can offer economic and biodegradable composites.

Table 3. Reported research on hybrid fabrication of natural/synthetic fibre hybrid composites

Natural fibre	Synthetic fibre	Matrix resin	Fabrication Method	References
Woven bamboo	Woven E - glass	Unsaturated polyester	Hand lay-up	[18]
Kenaf fibre	Aramid	Polyvinyl Butyral	Hot press	[12]
Kenaf fibre	Aramid	Epoxy	Hand lay-up	[20]
Kenaf fibre	Steel plates	Polyurethane foam	Sandwiches	[25]

Chonta palm wood	HDPE	Microparticles filler	Extrusion	[23]
Kenaf fibre	VHDPE	Silane	Non-Woven Matted	[26]
Mallow and jute	-	Epoxy	Lamination	[24]
Coconut sheath	Kevlar	Epoxy and graphene nanoplatelets	Hand Lay - Up And Hot Press	[22]

Table 3 explained by the different manufacturing methods involving composite construction for high impact application. The emphasis on the structural formation of a dry fabric or a dry preform will therefore determine the ability to process methods, the efficiency of the matrix and the composite itself. The manufacturing method such as hand lay-up, compression and closed mould was used in the manufacture of natural composite based composite. Even so, the condition of the twisted continuous thread in the biaxial weave preform requires well-suited matrix material and processing methods for the production of a good composite. This is important as it involves the wetting process, impregnation and penetration between inter-and intra-filament. Because of native properties, the usual problems are the lack of strong interfacial adhesion, low temperature degradation and poor resistance to moisture, which makes it less attractive than synthetic fibre, which has been the only alternative up to now to reinforce polymeric composites due to their superior mechanical characteristics [27].

Table 4. Configurations and properties of bamboo/E-glass/UP composite [18]

Specimens descriptions	Specimens thickness (mm)	Fibre volume fraction (%)	
		Aramid	Kenaf
19 Aramid	8.8	61.94	0
17 Aramid /2 kenaf	10.1	48.42	11.62
16 Aramid /3 kenaf	10.6	43.56	16.69
15 Aramid /4 kenaf	11.1	39.14	21.28
13 Aramid /6 kenaf	12.3	31.29	29.46
11 Aramid /8 kenaf	13.1	24.55	36.44
9 Aramid /10 kenaf	14.3	18.75	42.48
19 Kenaf	17	0	61.96

Table 5. Specifications of the Laminated Hybrid Composites [12]

Types of layer arrangement	Number of layers of each material	Dimension (length*width*height)/mm
Woven bamboo / E-glass	4/18	300*300*18
E-glass /Woven bamboo / E-glass	9/4/9	300*300*18

Table 6. Layering sequence, penetration energy and maximum load of samples in Quasi-static test [20]

Sample	Layering sequence	Energy absorption (J)	Maximum force (N)
A	All Kevlar layers	73.3	9260
B	Kenaf at the outermost layers	90.0	13,275
C	Kenaf at the innermost layers	131.0	17,440
D	Kenaf and Kevlar are at the alternate layers	88.1	16,440
E	All kenaf layers	4.8	790

Table 7. Ballistic testing result using gas gun [20]

No.	Composites Sample	Speed before (m/s)	Speed after (m/s)	Energy abs (Ea)
1	Kevlar (0/100) - 8L	303	210	119.3
2	Kevlar (0/100) - 12L	342	184	207.8
3	Kenaf/Kevlar (30/70) - 8L	305	235	94.5
4	Kenaf/Kevlar (30/70) - 12L	318	204	148.8
5	Kenaf/Kevlar (50/50) - 8L	310	261	69.9
6	Kenaf/Kevlar (50/50) - 12L	317	243	103.6
7	Kenaf/Kevlar (70/30) - 8L	308	281	39.8
8	Kenaf/Kevlar (70/30) - 12L	315	264	73.8
9	Kenaf (100/0) - 8L	300	288	17.6
10	Kenaf (100/0) - 12L	310	285	37.2

As the flexibility is the main concern so the thickness of the composite panel should be as thin as possible without jeopardise the aim of ballistic resistance. Therefore the previous studies shows that mostly the thickness of the panel was less than 20 mm as shown in Table 4 and Table 5.The effect of the layering sequence could have an impact on the trauma injury and failure modes of hybrid composite laminates. It is therefore important to determine the configuration of laminate interplies between hybrid natural fibers and synthetic fibers. structure also defines the energy absorption that represents the capacity of the ballistic resistance composites in real time as shown in Table 6 and Table 7.

The effect characteristics of composites depend on the adhesion between the fiber and the matrix. The impact strength of individually woven composites from natural fiber and hybrid plain is presented in Figure 1. For the same weaving pattern, the impact strength of the composites differs from that of the reinforcement fibers. This assumes that the characteristics and configurations of the individual fiber components are responsible for assessing the impact strength of composites apart from criteria such as interface fiber matrix, design and geometry of composites. However, the influence of inter-laminar delimitation also gives influence strength in addition to interfacial strength with composites reinforced with a weaving pattern. Figure 1 clearly indicates that the hybrid weaving pattern is stronger than pure kenaf woven polyester compounds.

This means that the impact intensity depends mainly on the characteristics of each fiber used for hybridisation in the polymer matrix system and no other parameters.

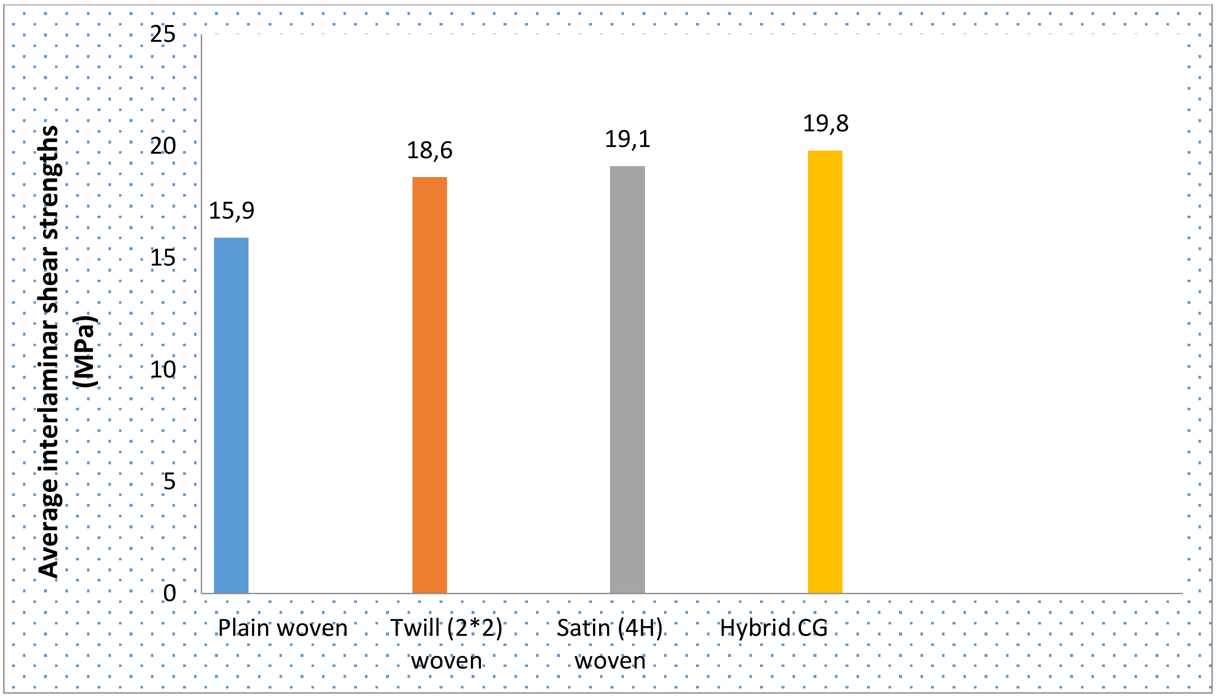

Figure 1. Plot of average interlaminar shear strengths vs. laminate constructions of Kenaf composite [28]

Table 8. Properties of aramid fiber, mallow fiber, jute fiber and epoxy resin [29]

Materials	Density (g/cm3)	Tensile resistance (MPa)	Young's modules (GPa)	Specific resistance (MPa)	Specific modules (GPa)
Aramid	1.4	3000–3150	63–67	2143–2250	45–48
Mallow	1.4	160	17.4	116	13
Jute	1.3–1.4	393–800	13–27	271–615	9.3–21
Epoxy	1.1–1.3	60–80	2–4	46–73	1.5–3.6

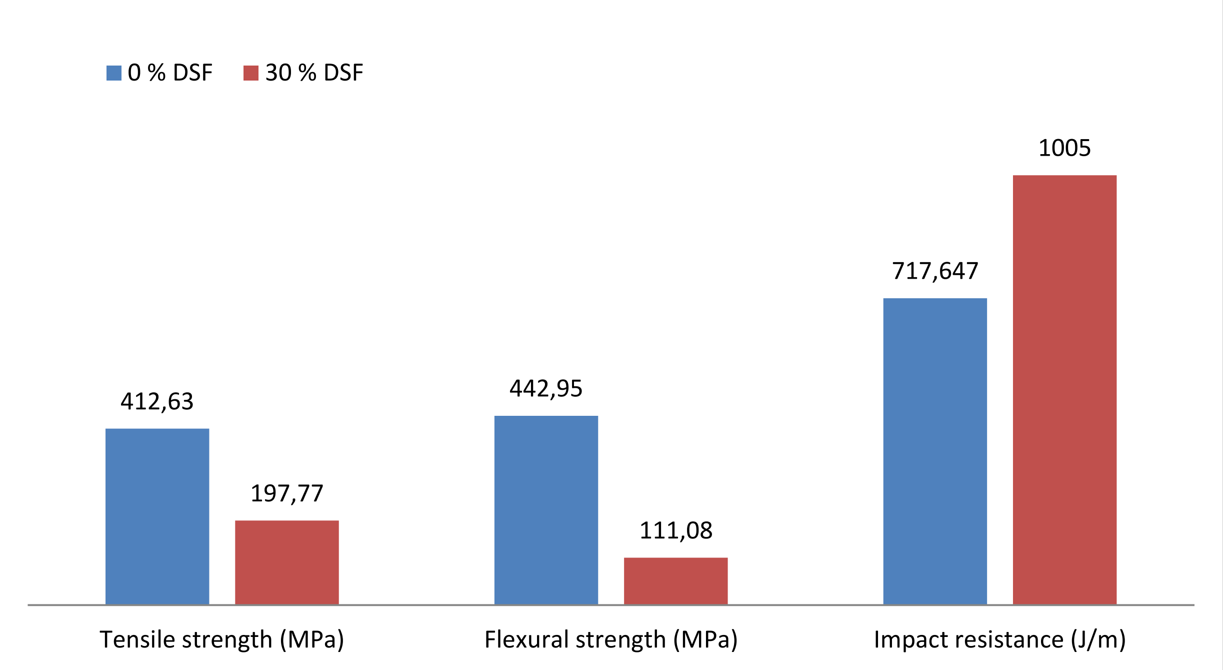

Figure 2. Bar chart of Kevlar Durian Phenolic Skin Hybrid Composites properties specimens [30]

Table 9. Tensile strength and Young modulus of reinforced HDPE samples for bio composite armours [23]

Bio-composite specimens	Chonta palm wood micro-particles / (wt. %)	Tensile strength /MPa	Strain,Ɛ / %	Young's Modulus /MPa
HDPE 1	0	14.91± 1.77	5.38±1.12	496.8±21.2
Ch10	10	16.16± 1.15	5.45±1.57	724.7±17.4
Ch20	20	16.47± 1.05	6.00±1.36	742.2±13.2
Ch25	30	16.53± 0.27	4.89±1.47	798.9±17.3
Ch30	40	15.19± 0.83	5.13±1.48	730.2±12.1

Often measured was the mechanical performance in terms of tensile, flexural and impact of laminated composites. The main distinguishing features of composite armour systems mean that the mechanical properties of laminated composites may vary. The specification of the product design for the personal body armour was formulated on the basis of the sustainability and performance requirements. The selection criteria are: fibre orientation, cellulose, quality, availability, density, tensile strength and young modulus as shown in Table 8, Table 9 and Figure 2**.** Multiple criteria for consideration will ensure that the results are more meaningful and reliable. This review focuses on soft body armour instead of hard body armour. Soft body armour contains multiple layers of fabric up to 50 layers (weight less than 4.5 kg). Along the way, soft body armour must also withstand the impact of a projectile up to 500 m/s (according to the National Institute of Justice (NIJ) armour standard).

The factors of weight and cost are the main consideration in order to design the body armour ergonomically. Low weight of the body armour on the human body prevents fatigue from the operator and does not affect respiratory conditions, especially when the ambient temperature rises.

3. CONCLUSION

Latest approaches in materials and panel developments for creating a body shield framework have invigorated scholar to study more on this matters. Even so, it is pertinent to say the reasons leading the plan and development of the body shield product. Likewise, the body armour system's flexibility, manufacturing cost and bio sustainability must also be taken into consideration to achieve user-friendly systems. The utilization of natural fibre as strengthening in polymer mixtures was reviewed based on perspective of the condition and the requirements of natural fibres for enhancements in the polymer composite based. This also provides a means for economic development in rural areas, owing with the use of natural materials in different industrial applications and manufacture activities. This list complies with the Malaysian government concern on the diversification of local woodland-based product besides of craft and furniture industries. The resultant of this review suggests that the properties of reinforced polyester hybrid natural fibres with synthetic fibres embedded with polymers may be improved. But only some investigations carried out on the potential of woven natural reinforcement hybrid with synthetic fibres. There are obvious strength enhancements between the yarns of fibres in the frame of various weaving patterns. The bonding structure upon intraply between fibre yarns and the interply between laminar is still under studied by the previous researches.

The literature revealed regarding only few data offered on the investigation process to ascertain the properties of especially lamination on woven natural fibres with synthetic composite. Intent of an effective hybrid with the betterment of stacking series will have optimal weight and cost reduction applications in the ballistic resistance. This leads to upgrades over the mechanical characteristic of woven natural fibres with man-made fibre strengthened compounds by consuming Quasi-static experiment techniques thus validating the results through finite element simulation and statistical analysis. The advancements of kinetic, strain, and friction energy constituents, proportion to composite mass and angle of obliquity, need further studied for the improved ballistic fortification of common weaving style compared to other weaving pattern. This analysis shows that structural architecture and composite lamination for the entire projectile protection of inter-ply approaches are still not explored. Exploration of effect disruption and high-strength flexibility fibre structure has turn them into favourable constituents not only for army services, but domestic protecting uses, such as personal armour outfit, head covering, and auto parts. Equally for the bio sustainability, long term effect makes the composite biodegradable and practically used for.

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