SHORT REVIEW: CRASHWORTHINESS CHARACTERISTIC OF NATURAL FIBER COMPOSITE

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Abstract- In recent year, the use of natural fibers in composite plastics is gaining popularity in a variety of areas, and particularly the automotive industry. The application of natural fibers in polymers can provide many advantages compared other technologies and environmentally friendly. Among the automotive industry objectives is currently shifting to "green" technologies are reducing environment pollutions. Natural fibers are low-cost with highly specific properties and low density. Based on these factors, most developing countries begin using natural fibers to produce good quality product with effectively and economically. This review concentrated on types, material properties and the application of natural fiber composite for crashworthiness design.

Keywords- Natural Fiber; Material Properties; Crashworthiness

I. INTRODUCTION

Natural fibers are raw material obtained directly and can be spun into filament, thread or rope. Natural fibers are classified based on their origin, either coming from plants, animals, or minerals. It's increasingly popular in the vehicle and the building industry in recent years due to the high performance in mechanical properties, significant processing advantages, low cost and low density.

Natural fibers are renewable, cheaper, no hazards and reduce environmental pollution by finding new utilization of waste materials. Furthermore, natural fiber reinforced polymer composite form a new class of materials which seem to have good potential in the future as a substitute for scarce wood and wood based materials in structural applications.

The application of natural fiber in vehicle begins in the early 1930's by Henry Ford. He studies a variety of natural materials, including cantaloupe, carrots, corn stalks, cabbages and onions in building an organic car body.

Then, the first prototype car made from hemp fibers produced in the early 1942. Fig. 1 shows Henry Ford performs a durability test on the prototype car made of natural fiber composites.

In the 1950's, Trabant car was the first production vehicle to be built from natural fibers using cotton fiber and still in production up until 1990.

Nowadays, automobile manufacturers such as BMW and Mercedes are beginning to incorporate hemp into car components.

The major car manufacturers now use natural fiber composites in applications such as in Table I

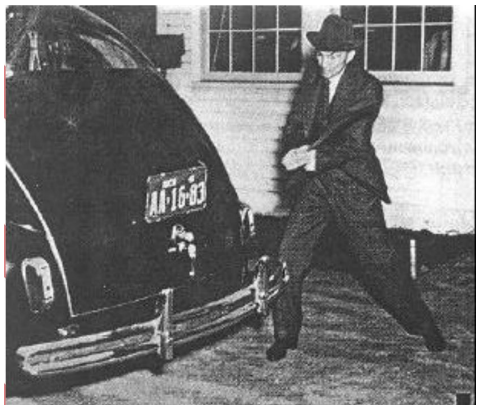


Fig. 1. Durability test on prototype car

Table I. Applications of natural fibers in the automotive industry

Automotive	Model	Applications
AUDI	A2, A3, A4, A6, A8, Roadster, Coupe	Seat backs, side and back door panels, boot lining, hat rack, spare tyre lining
BMW	Model: 3, 5, 7 series	Door panels, headliner panel, boot lining, seat backs, noise insulation panels
CITROEN	C5	Interior door paneling
FIAT	Punto, Brava,Marea, Alfa Romeo 146, 156	-
FORD	Mondeo CD 162, Focus	-
LOTUS	Eco Elise	Body panels, Spoiler, Seats, Interior carpets
PEUGEOT	406	Seat backs, parcel shelf
RENAULT	Clio, Twingo	Rear parcel shelf
ROVER	2000 and others	Insulation, rear storage shelf/panel
SEAT	-	Door panels, seat backs
TOYOTA	Brevis, Harrier, Celsior, Raum	Door panels, seat backs, spare tyre cover
VOLKSWAGEN	Golf, Passat, Bora	Door panel, seat back, boot lid finish panel, boot liner
VOLVO	C70, V70	Seat padding, natural foams, cargo floor tray

Fig. 2 shows the interior and exterior parts from of natural fiber in the vehicle are already in use. Selection of natural fiber for manufacture is influenced by type and the location source of fiber, thus component parts from India and Asia contain jute, ramie and kenaf, parts produced in Europe tend to use flax or hemp fibers, parts from of South America tend to use sisal, curaua and ramie. The components obtained therefore are mostly used to produce non-structural parts such as covers, door panels and roofs of transportation.

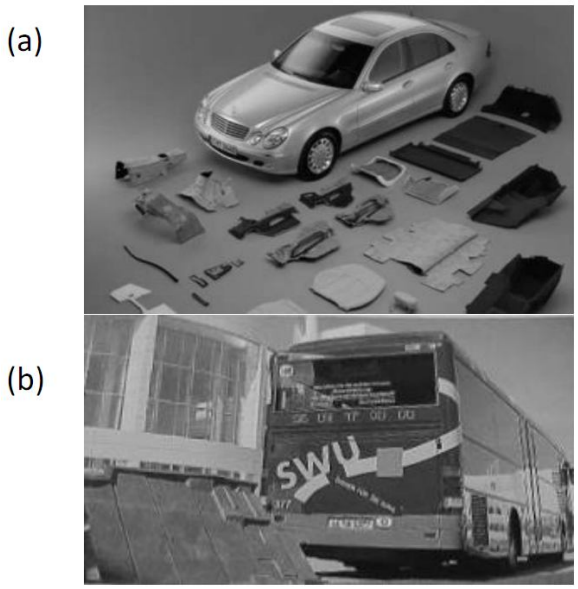
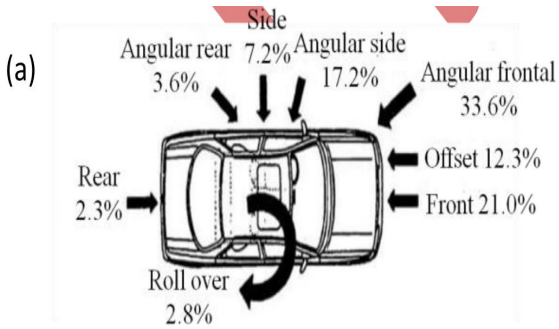


Fig. 2. Applications of natural fibers in the vehicle, (a) Interior part and (b) Exterior part

In vehicle industry, composite structural crashworthiness is part of vehicle has become a significant study in the design of automotive, airplanes, helicopters, spacecraft and locomotives.

Crashworthiness serves as a structure to protect its passenger in a collision, to transform the kinetic energy into the deformation energy, maintain the sufficient survival space and keep the momentum of the crash. Generally, mostly accident's occurrence of the frontal part of vehicle crashes (70%) including direct and offset frontal crashes as shown in Fig. 3(a). One of part used in the frontal crash zones is crash box, generally inserted between the bumper and chassis as shown in Fig. 3(b).



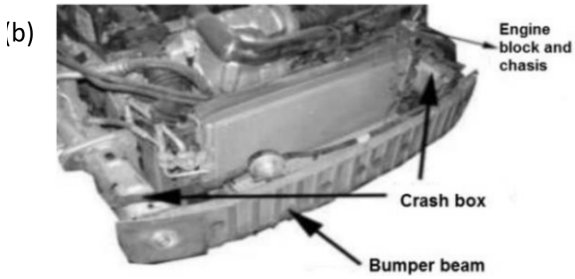


Fig. 3. (a) Types of crash and (b) Crash box position

II. CLASSIFICATION OF NATURAL FIBER COMPOSITES

The classification of natural fiber (Fig. 4) can be separate into three major class groups, namely straw fibers, non-wood bio-fiber and wood fiber. Bast stem, leaf, fruit and seed are obtained from the non-wood bio-fibers. Table II shows the several types of natural fiber in the Malaysia.

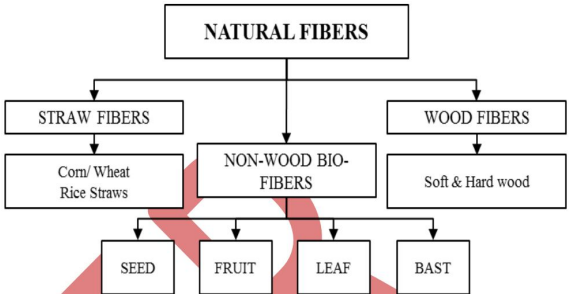


Fig. 4. Classification of natural fibers

Table II. Classification of plant fibers, origin and world annual production

Fiber Type	Botanical Name	Plant Origin	Production (10^3Tonnes)
Banana	Musaceae	Leaf	200
Coir	Cocosnucifera	Fruit	650
Oil palm	Elaeisguineensis	Fruit	-
Pineapple	Ananascomosus	Leaf	-

III. EXTRACTION METHOD OF NATURAL FIBER

Basically, non-wood bio fiber (Fig. 4) are comes from fruit, leaf or bast, normally prepared in bulks or fiber bundle. Meanwhile, seed fiber is a single cell obtained either through the ginning (cotton fiber) or shacking (kapok fiber) process.

Bast fiber refers to 'soft' fiber derived from the stems of various dicotyledonous plants. Meanwhile, leaf fibers, or 'hard' fiber is derived from the leaves or leaf stalks of plants monocotyledons. Fruit fiber obtained from the outer layer of the skin of the fruit through the same methods, such as fiber skin and leaves. Two techniques are used to get the fiber bundle of leafs and bast, which decortication and retting techniques.

Decortication technique is a technique using machine to strip fiber. Meanwhile, retting techniques are defined as chemical or biological treatment techniques for fiber bundles. Retting techniques are divided into three types, namely dew, water and chemical. Dew retting is the process of cutting the stem of the plant and dried in the open air for decomposition. Meanwhile, water retting involves immersion stem into the water. The dew and water techniques known traditional techniques require a long time and have side effects to the environment. Modern retting techniques take a short time and suitable for commercialization at the international level, such as chemical treatment techniques.

This technique is very efficient, clean and able to produce the best fiber surface. Alkali treatment is one of the chemicals that are often used by researchers in obtaining natural fiber. For example, coir fiber (Fig. 5) is obtained from the husk of the fruit of the coconut tree. There are two methods for obtaining the coir fiber, which are traditional and mechanical methods. Both of this method will produce the quality difference of coir fiber.

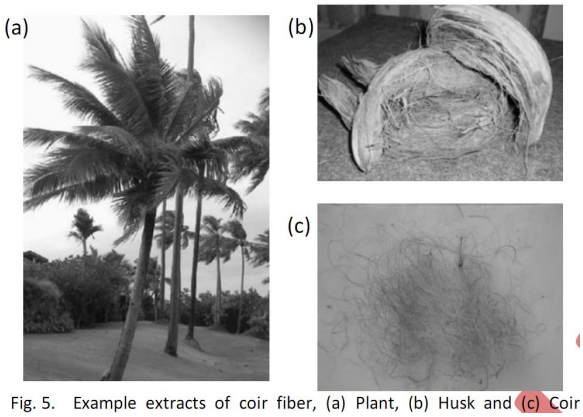


Fig. 5. Example extracts of coir fiber, (a) Plant, (b) Husk and (c) Coir

The traditional fiber methods (Fig. 6a) are complicated, time-consuming process and polluting environment. The husks are processed by various retting techniques for three to six months in ponds of brackish waters or in salt backwaters or lagoons and require 10-12 months to fermentation bacterial processes.

After the retting process, the fibers can be detected and extracted by hand. Finally, the fibers are loosened will cleaned. The fibers, thus obtained are of the highest quality and can be used for spinning and weaving purposes.

The mechanical fiber method (Fig. 6b) will produce more yarn production within shorter periods. For this method, the coarse long fiber will separated from the short woody parts and the pith. The strong fiber is washed, cleaned, dried, hackled and combed. The quality of the fiber is greatly affected by these procedures.

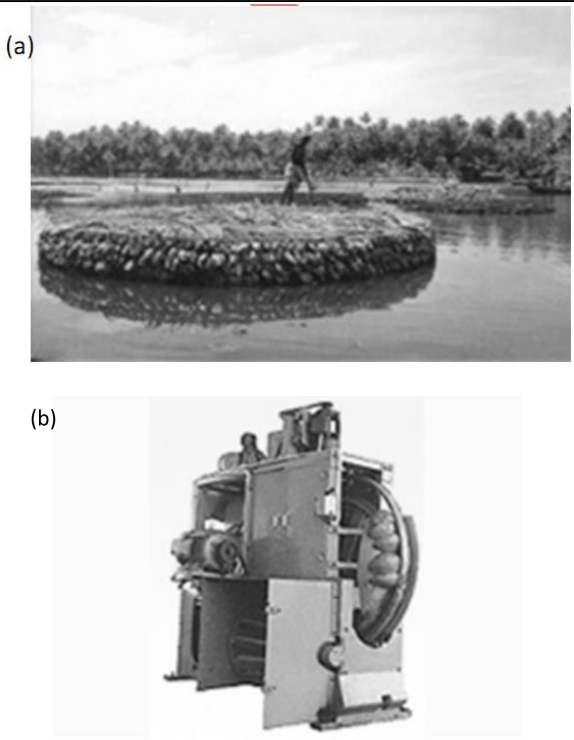


Fig. 6. A method of extracting fiber, (a) Traditional method and (b) Mechanical method [23]

IV. PHYSICAL AND CHEMICAL PROPERTIES OF NATURAL FIBER COMPOSITES

The chemical composition and physical properties of some types of natural fibers are summarized in Table III. The chemical composition obtained in plants such as cellulose, hemicellulose, lignin and pectin. Cellulose is also the reinforcement for lignin, hemicelluloses and pectin. It shows that the chemical composition and physical roperties of plant fibers have an interest in determining the properties of natural fiber composites.

Table III. Physical and chemical properties of natural fibers

	Fiber Type	Banana	Coir	Oil palm	Pineapple
Physical	Diameter (μm)	50-250	16.2-450	8-550	20-80
	Length (mm)	2-3.8	0.9-1.2	0.49-182	-
	Aspect ratio (l/d)	-	64	250	-
	Micro-fibril angle (ϑ)	11-12	39-49	46	6-14
	Density (kg/m^3)	1300-1350	1250	700-1550	1520-1560
	Moisture regain (%)	-	13.00	2.2-9.5	-
Chemical	Cellulose	60-65	46	41.9-65	80-81
	Hemicelluloses	6-19	0.3	-	16-19
	Lignin	5-10	45	19-25	4.6-12
	Pectin	3-5	4	-	2-3
[Ref]		[8, 32, 33]	[8, 21, 33]	[34-37]	[8, 21, 33]

Cellulose is a semi-crystalline polysaccharide and serves as the hydrophilic nature of natural fibers. Hemicellulose is a fully amorphous polysaccharide with a lower molecular weight compared to cellulose. Pectin serves as hold the fiber together, is a polysaccharide like cellulose and hemicelluloses. Lignin is an amorphous polymer and has an effect on water absorption, but unlike hemicelluloses as shown in Fig. 7. Type of cellulose and geometry of the elementary cell influences the mechanical properties of natural fiber.

The cellulose chains are arranged to form bundles, each containing more cellulosic macromolecules linked by hydrogen bonds and through links with amorphous hemicelluloses and lignin which confer stiffness to fiber called micro-fibrils as shown in Fig.8.

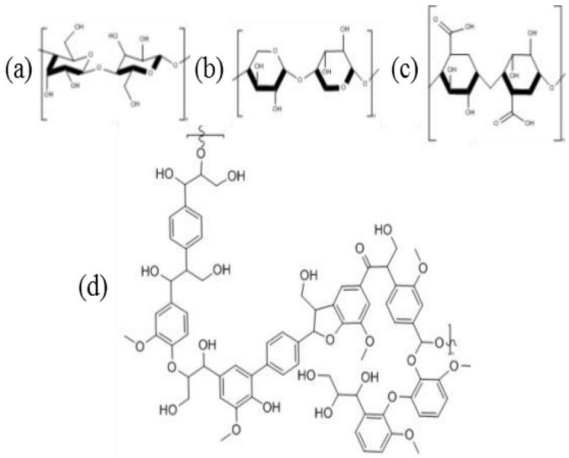


Fig. 7. Overview of structure (a) cellulose, (b) hemicelluloses, (c) pectin and (d) lignin [38]

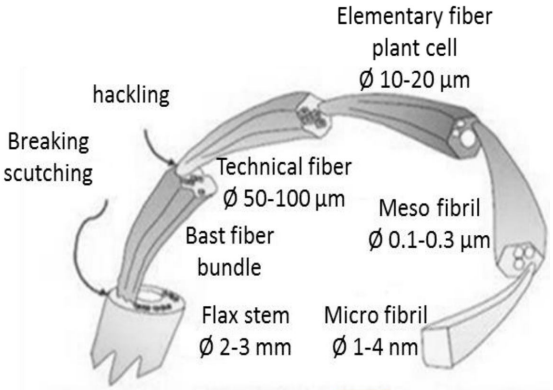


Fig. 8. The structure of natural fiber [8].

V. MECHANICAL PROPERTIES OF NATURAL FIBER COMPOSITES

Mechanical properties are also one of the important properties analyzed to determine the effect of the natural fiber composites. Table IV shows that the mechanical properties of natural fiber composite that has been studied previously and compiled.

Table IV. Mechanical properties of natural fibers

Fiber Type	*Banana*	*Coir*	*Oil palm*	*Pineapple*
Tensile Strength (MPa)	529-914	106-180	71-248	413-1627
Young's Modulus (GPa)	20-24	6	1.7-6.7	60-82
Failure strain (%)	1-3	15-40	11	0-1.6
[Ref]	[8, 40, 41]	[8, 21, 33]	[35, 42]	[8, 21, 43]

The pineapple fiber has the highest tensile strength and Young's modulus compared the other natural fiber. However, the strength of natural fiber depends on field consumption and application. Additional the resin thermoset with natural fiber will increase the strength of material.

VI. RESIN THERMOSET

Thermoset composites are a synthetic polymer used in certain applications such as automobile and aerospace. Thermoset resin is usually obtained in liquid form, and act as a reinforcing agent in fiber. There are several types of thermosetting resins such as polyester and epoxy resin often used in research. Table V shows the mechanical properties of thermoset resins. Epoxy resins are characterized by the presence of more than one epoxide groups per molecule. Epoxy has a wide range of industrial applications, including coatings, electronic and electrical components, electrical insulators, fiber-reinforced plastic materials, and structural adhesives.

Table V. Mechanical properties of thermoset resin

Properties	*Polyester Resin*	*Vinylester Resin*	*Epoxy*
Density (gcm^{-3})	1.2-1.5	1.2-1.4	1.1-1.4
Tensile Strength (MPa)	34-105	73-83	35-130
Young's Modulus (GPa)	2-4.4	3-3.8	2.7-6
Compression Strength (MPa)	90-250	100	100-200

VII. ADVANTAGES AND DISADVANTAGES OF THE NATURAL FIBER AND EPOXY

The advantages and disadvantages of natural fibers and epoxy can be concluded in Table VI and VII.

Table VI. Advantages and disadvantages of natural fiber

Advantages	Disadvantages
Low specific weight of fibers	Low impact strength properties
The production requires little energy, and CO_2 is used	Variation in quality, depending on unpredictable influences such as weather
Producible with low investment at low cost	Moisture absorption, which causes swelling of the fibers
Eco-Friendly processing, no wear of tooling, no skin problems	Restricted maximum processing temperature
Thermal recycling is possible, where glass causes problems in combustion furnaces	Lower durability, fiber treatments can improve this considerably
Good thermal and acoustic insulating properties	Poor fire resistance

Table VII. Advantages and disadvantages of epoxy

Advantages	Limitations
Low densities	Low transverse strength
Good corrosion resistance	Low operational temperature limits
Low thermal conductivities	
Low electrical conductivities	
Translucence	
Aesthetic color effects	

VIII. APPLICATION NATURAL FIBER IN CRASHWORTHINESS

Composite structure crashworthiness design generally divided into three areas: front, middle and rear energy absorption areas. Example of the automobile body (Fig. 9a), the front energy absorption area is mainly made up of front bumper beams, bumper beam buffer block, engine hood front end and crash box. Meanwhile, Fig. 9(b) shows the crash force transmission routes during occurs frontal crash. The front area consists of bumper beam and crash box, which is the major force transmission route in the course of the crash. The bumper beam and the crash box split the energy produced in the crash leftward and rightward and absorb the energy initially, and then transfer to other components. Statistic of road accident 2012 in Malaysia shows that 24,439 casualties and damages caused by road accidents occur caused by user's vehicle.

The road accident increased 60% from years 2003-2012. Meanwhile, the casualties and damages decrease 46% from years 2003-2012. In the future study, natural fiber epoxy will used serves as an absorption energy tool. The main focus of natural fiber is the vehicle. The objectives of the study are determined the material properties and specific energy absorption of natural fiber for crashworthiness design.

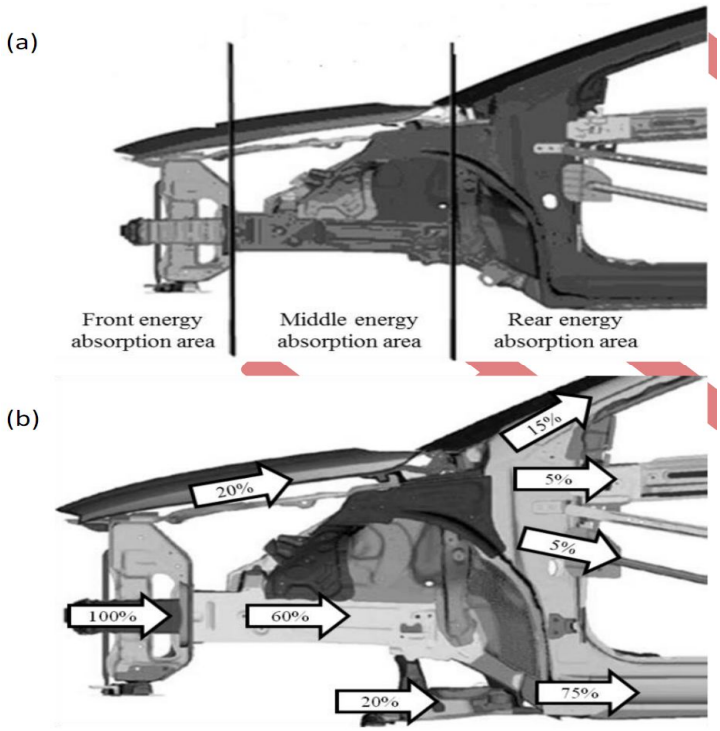


Fig. 9. (a) Division of crash energy absorption areas and (b) Crash force transmission

CONCLUSIONS

The short review on crashworthiness characteristic of natural fiber composite revealed the natural fibers have the advantages. Additional the epoxy serves to increase the material properties of natural fiber. Natural fiber-epoxy will used in crashworthiness design serves as an absorption energy tool.

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