A Review on Fiber Orientation of Natural Fiber Reinforced Polymer Composite

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Abstract

Nowadays, natural fibers have attracted researches to study and develop new properties of composite for recent technology. As ecological and environmental friendly materials, natural fibers have been widely utilized in manufacturing, automotive and construction industries. Fiber orientation has been found to be one of the important aspects to have excellent mechanical properties in composite. Woven fiber exhibit better tensile and flexure strength compared to longitudinal oriented and random oriented fiber in natural fibers reinforced polymer composite. This paper reviews the reported studies on various fibers orientation in natural fibers reinforced polymer composite. Thus, with this article, researches can design new composites on excellent fiber orientation.

Key Words: natural fiber; orientation; mechanical properties

1.0 INTRODUCTION

Recently, natural fiber composites are becomes a popular choice for application in industry, manufacturing, automotive and construction. In line, the technology improves for natural fibers to deliver enhanced material and product properties. The manufactured products will become more diverse and enter markets that as of yet are unexplored. Today natural fiber reinforced natural fibers are found extensively in automotive sectors. By the time, natural fiber composite materials and associated design methods are sufficiently mature to allow their widespread use, e.g., as construction materials. The development of methods, systems, and standards could see natural fiber composite materials at a distinct advantage over traditional materials.

There are two classifications of fiber orientation namely unidirectional and bidirectional orientation. Fiber orientation in natural fiber composites has been proved as one of the factor that affected the mechanical properties especially flexural and tensile strength. Therefore, this study will focus on various types of fiber orientation and the effects of fiber orientation on mechanical properties of natural fiber reinforced polymer composite.

1.1 Types Of Natural Fiber

Saxena, Pappu, Sharma, Haque, and Wankhede (2011) describes that natural fibers can be categorized according to their origin either from an animal, plant, or mineral source. Animals fibers are hair and silk, plant fibers include seed, leaf, bast, fruit and stalk, while mineral fibers are amosite, crocidolite, trimolite, actinolite, antophyllite and chrysotile (Ntibunka, 2015). Classification of natural fibers is described in Figure 1.

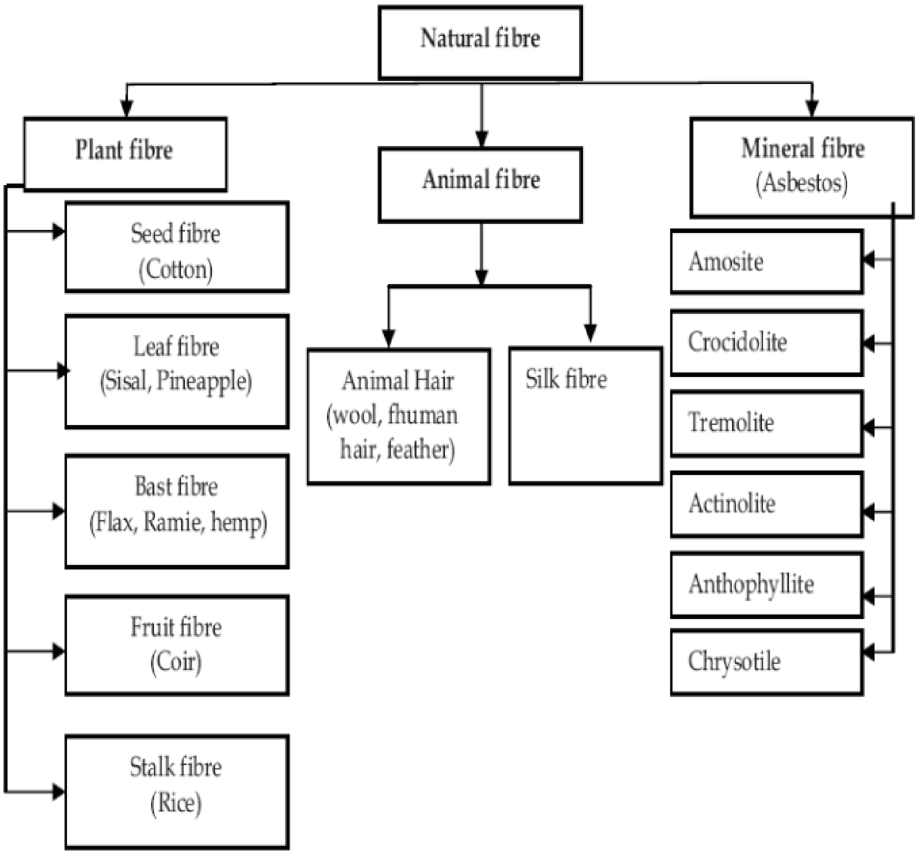

Figure 1: Classification of natural fibers (Saxena *et al.*, 2011; Ntibunka, 2015)

Among those stated natural fibers, plant fibers have been claimed to be the best fibers from all of others to incorporate with polymer due to the presence of cellulose in plants. As the composition of fiber increased, the presence of cellulose will also be increased, therefore mechanical properties of natural fiber reinforced polymer composite will also have been increased as shown in Figure 2 (Ku, Wang, Pattarachaiyakoop, & Trada, 2011). This result has also been proved by Aji, Sapuan, Zainudin, and Abdan (2009); Zaman and Awang (2009); López *et al.* (2012) in their studies.

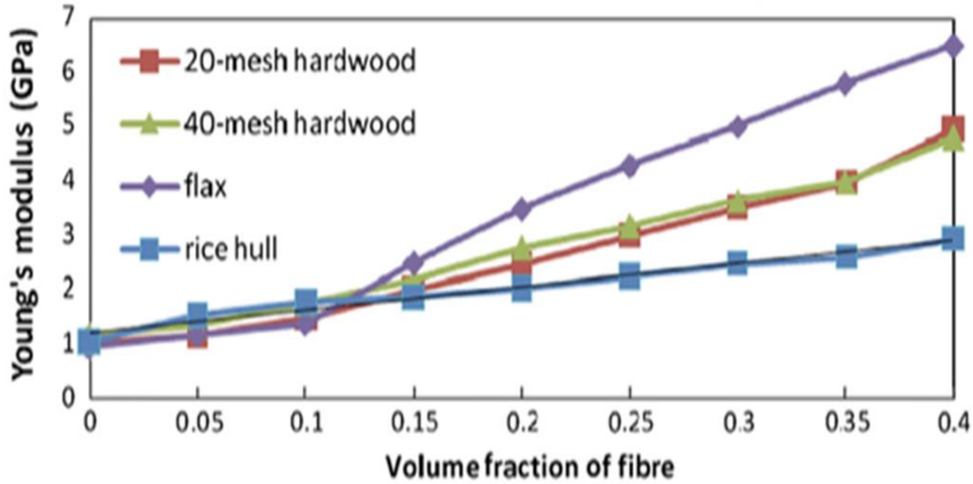

Figure 2: Young's modulus of 20-mesh hardwood, 40-mesh hardwood, flax and rice hull fiber reinforced HDPE composites with fiber loadings of 0–40% vol (Ku *et al.*, 2011).

1.2 Types Of Fiber Orientation On Polymer Composite

Natural fibers have been proved to enhance mechanical properties of the natural fiber reinforced polymer composite. However, the mechanical properties of these materials are dependent on the local orientation of fibers in the parts, which differs with point (Escalante-Solís, Valadez-González, & Herrera-Franco, 2015). Hence, getting reliable measurements of fiber orientation is crucial for estimating the mechanical properties of natural fiber reinforced polymer composite materials (Vélez-García, Wapperom, Kunc, Baird, & Zink-Sharp, 2012). Processing of fiber reinforced polymer composites required the application of specific mechanical properties in order to accomplish in correct types of fiber orientation. (Hensher, 2016)

There are some factors that affecting the processing of natural fiber composite, as well as the properties of the composite products like fiber orientation, fiber content, fiber types and moisture content (Faruk, Bledzki, Fink, & Sain, 2014; Kumar, Prasad, & Patel, 2017). Among all, fiber orientations was found to be the most important factor that affecting the mechanical properties of the composite (Saha *et al.*, 2010; Wang, Zhou, Gui, Ji, & Zhang, 2014). According to Abdalla, Abdel-Moneim, and Nasr (2014), the requisite mechanical properties of fiber reinforced polymer composite can be obtained by controlling the orientation of the fiber during the sample preparation of the composite.

There are two classifications of fiber orientation namely unidirectional and bidirectional orientation. In unidirectional orientation, longitudinal (0°), transverse (90°), and inclined (45°) and random oriented are often the fiber orientation used in natural fiber composites. Meanwhile, in bidirectional, two or more unidirectional fiber taking place in the samples, or it is stacking to each other such as 0°/90°, 0°/45°, 90°/45°, woven, mat and many more. Table 1 describes the classification of fiber orientation.

Table 1: Classification of Fiber Orientation

Unidirectional Orientation	Bidirectional Orientation
longitudinal (0°)	Stacking 0°/90°
transverse (90°)	Stacking 0°/45°
inclined (45°)	Stacking 90°/45°
random oriented	Woven
	Mat

1.3 Fibers with Unidirectional Orientation

Tungjitpornkull and Sombatsompop (2009) describe longitudinal as the fiber that are parallel alignment of the longitudinal axis of the fibers in a single direction. Transverse direction on the other hand is a continuous and oriented fiber which load is applied at 90° angle to the fiber alignment. Fiber orientation direction for unidirectional orientation is shown in Figure 3.

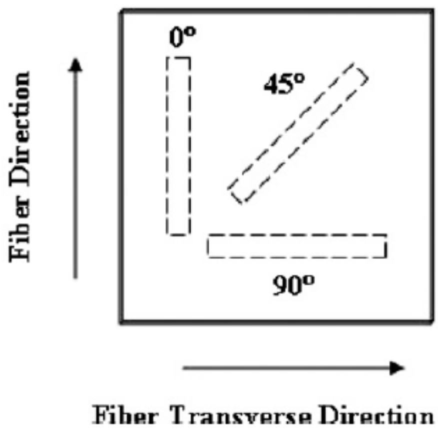

Figure 3: Fiber orientation direction for unidirectional orientation (Tungjitpornkull & Sombatsompop, 2009).

For the tensile test sample preparation, the schematic diagram showing fiber orientation with respect to the load applied are shown in Figure 4.

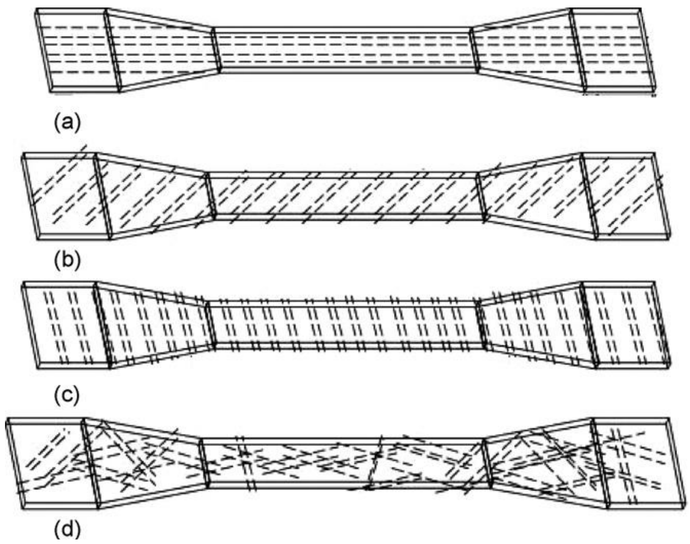

Figure 4: Sample configuration at different fiber orientation angle for tensile test (a) 0° (b) 45°(c) 90° and (d) random (Tungjitpornkull & Sombatsompop, 2009).

2.0 EFFECT OF FIBER ORIENTATION ON MECHANICAL PROPERTIES

Fiber orientations have been found to be one of the factors that affected the mechanical properties of most materials including natural fiber composite (Eik & Herrmann, 2012). Fiber orientation also enables the optimization of the mechanical properties in a specific direction by the designer to draw a composite of part/product (Gay, 2014). Furthermore, for strength analysis in mechanics structure, fiber orientation arrangement is the most convenient starting point to be considered in basic building block (Gibson, 2016).

Several years before, Malaiah and Krishna (2013) found that the tensile and flexural strength of 0°/90º fiber orientation is 535% more compared to 45°/45° fiber orientation. This was proved by Senthilkumar *et al.* (2016) in their study on effect of inter-laminar fiber orientation for sisal fiber reinforced polyester composites where fiber of 0/90º orientation had a greatest tensile strength of 46.716MPa compared to 45°/45° orientation around 32MPa. However, Vinod and Sudev (2013) found that flexural strength of 45º fiber orientation (inclined orientated) was much higher than 0/90º orientation (bi-directional). The same trend was found by Retnam, Sivapragash, and Pradeep (2014) where the values of composite with 45°/45° fiber orientation give higher tensile and flexural strength when compared to 0/90º orientation. A studied of analysis of effect of fiber orientation on Young's modulus for unidirectional fiber reinforced composites have found longitudinally aligned fibre composites generally have higher tensile strength compared with transversely directed fibres orientation (Kabir, Wang, Lau, & Cardona, 2012). Recently, research done by Nath and Ziaulhaq (2017), in investigating the mechanical properties of fiber reinforced polyester composite, they revealed that fiber orientation significantly influences the maximum tensile and flexural strength for the composite.

Another studied done by Hossain, Islam, Van Vuure, and Ignaas (2012), regarding on the effect of fiber orientation of jute epoxy laminated composite. The tensile test was done both longitudinal and transverse direction of fibers. From the experimental result, it can be observed that longitudinal tensile strength is higher than transverse direction as depicted in Figure 5.

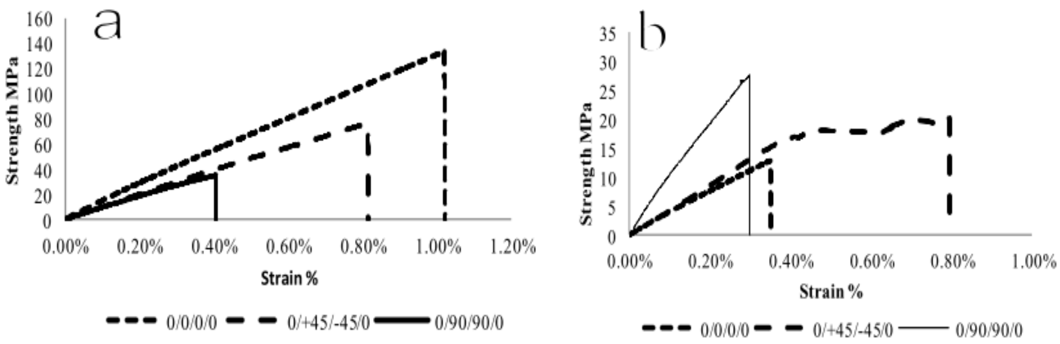

Figure 5: Typical stress strain curve of jute epoxy laminated composite; a) longitudinal and b) transverse (Hossain *et al.*, 2012)

In longitudinal direction, 0°/45° fiber orientation give higher tensile strength when compared to 0/90° orientation. This is because in 0/90°, the load applied is parallel to the fiber orientation which resulted in low tensile strength. However, the results turn around for transverse direction. Here, 0/90° fiber orientation gives better tensile strength when compared to 0°/45° orientation. This is because the load applied is perpendicular to the fiber orientation, thus give higher value of tensile strength as interpreted in Figure 6.

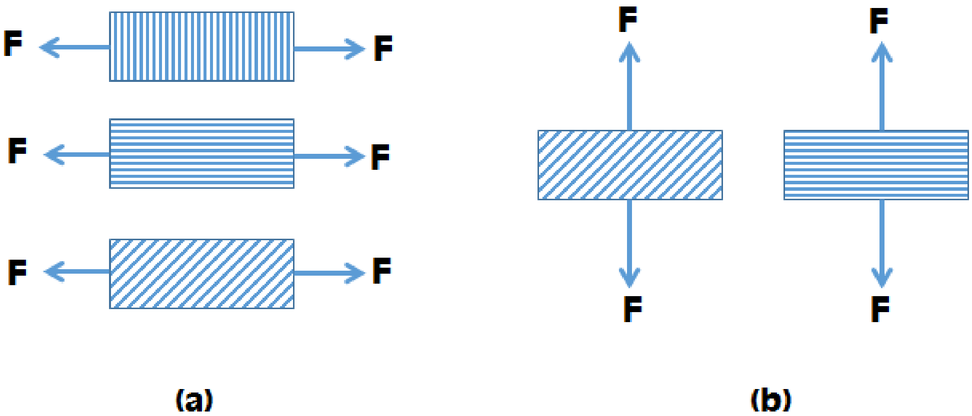

Figure 6: (a) Longitudinal tensile test (b) transverse tensile test

In the study of tensile properties of hybrid-natural fiber composites, the tensile strength of the hybrid composite in transverse direction higher than longitudinal direction which is 31.56 MPa (Venkateshwaran, Elayaperumal, & Sathiya, 2012). Another study on mechanical properties of woven fabric by Alavudeen, Rajini, Karthikeyan, Thiruchitrambalam, and Venkateshwaren (2015), proved that the hybrid plain woven with random orientation has the highest tensile and flexural strength compared to orientations. However, there are another studied for natural fiber reinforced biodegradable polymer composites which found that the value of flexural strength for random orientation is in the middle between longitudinal and transverse orientation as depicted in Figure 7.

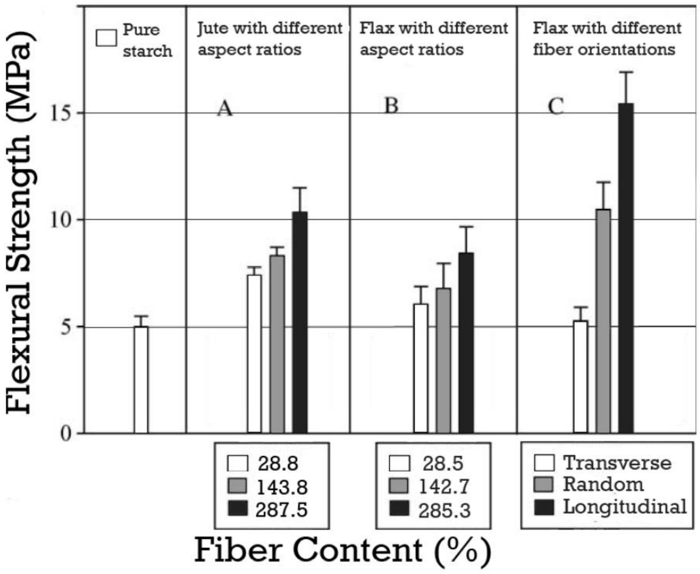

Figure 7: Starch-based composite foams reinforced with flax fibers of different fiber orientations (Sahari & Sapuan, 2011)

Alam, Habib, Irfan, Iqbal, and Khalid (2010) investigated that the maximum value of tensile strength of 90° fiber orientation is higher compared to 45° fiber orientation. Yahaya, Sapuan, Jawaid, Leman, and Zainudin (2015) studied the effect of kenaf fiber volume and orientation on tensile and flexural properties of kenaf/Kevlar hybrid composites investigated the results of unidirectional at 0/90° orientation have highest tensile compared to woven and mat fiber orientation.

However in the next study, Yahaya, Sapuan, Jawaid, Leman, and Zainudin (2016) have found that tensile strength of kenaf-aramid hybrid composite of unidirectional at $0/90^{o}$ orientation in intermediate with values of 115.36MPa compared with the woven sample had been higher of tensile strength of 145.8MPa. The same trend goes to flexural strength where woven sample give the highest value compared to mat and unidirectional samples. The results are plotted in Figure 8. Furthermore in another studied by khan et.al, also have found the tensile and flexural strength of woven fabric composites are higher than those of unidirectional and randomly oriented composites (Khan, Terano, Gafur, & Alam, 2016; Maslinda, Majid, Ridzuan, Afendi, & Gibson, 2017).

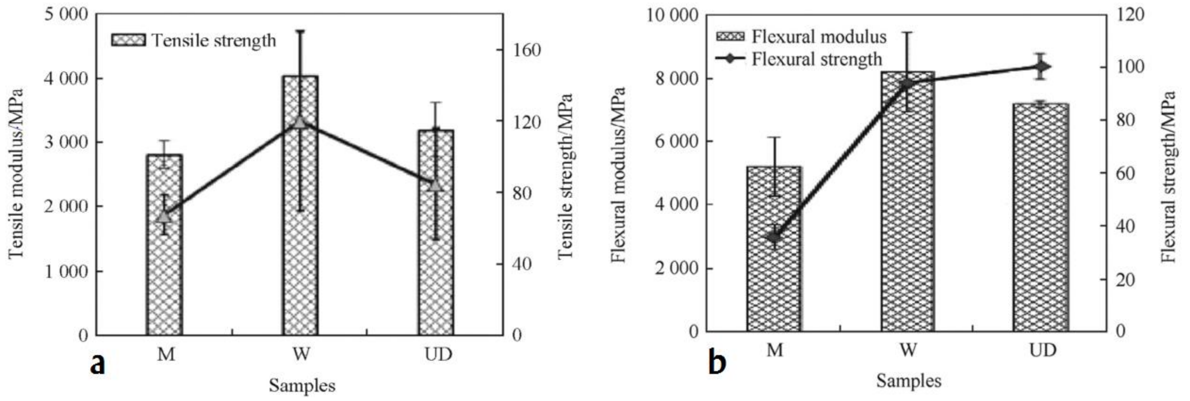

Figure 8: Mechanical properties of hybrid composites (a) tensile (b) flexural (Yahaya *et al.*, 2016)

Ramnath *et al.* (2014) studied of the mechanical properties of intra-layer abaca–jute–glass have found the superior mechanical properties of the composites were obtained when the orientation of the fibers was at 45^{o}.In studied by Pannu, Singh, and Dhawan (2015) for the sisal jute, bamboo of natural fiber, it was found that higher of strength were recorded at 0/90° fiber orientation. The results of the experiment by Sathishkumar, Navaneethakrishnan, Shankar, and Rajasekar (2013) have found the mechanical properties of the longitudinally oriented fiber reinforced polyester composites are higher than the randomly oriented short fiber composites. Furthermore in studied by Yong, Ching, Chuah, and Liou (2015) of Polyester/kenaf composite with kenaf fiber have found anisotropic arrangement (unidirectional orientation) achieved the highest tensile and flexural properties shown in Figure 9.

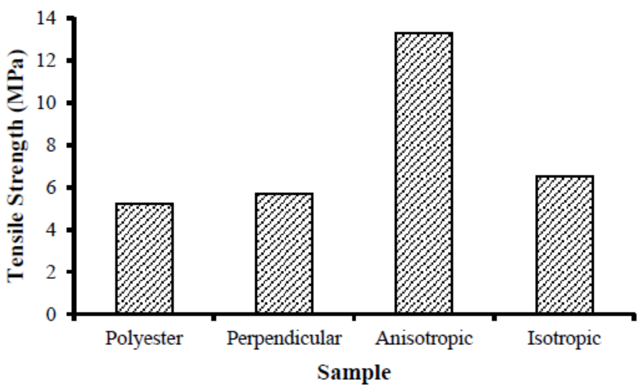

Figure 9: Effect of fiber orientation on tensile strength of polyester/kenaf composite (Yong *et al.*, 2015)

3.0 CONCLUSION

The mechanical properties of Natural Fiber Reinforced Polymer can be affected by fiber orientation in the composites. Among all orientations, inclined 45° has the highest value for both tensile strength and flexural strength. For tensile test, longitudinal direction gives better result rather than in transverse direction. Moreover, the flexural strength of inclined 45° gives higher value compared to its tensile strength. Thus, it can be concluded that inclined 45° is the best for researches to design new composites on excellent fiber orientation.

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