Rev. Adv. Mater. Sci. 32 (2012) 106-112

REVIEW ON KENAF FIBER COMPOSITES

M. Thiruchitrambalam[1], A. Alavudeen[2] and N.Venkateshwaran[3]

[1]Department of Mechanical Engineering, Tamilnadu Colllge of Engineering, India
[2]Department of Mechanical Engineering, Arulmigu Kalasalingam College Engineering, India
[3]Rajalakshmi Engineering College,Chennai, India

Received: April 09, 2012

Abstract. Recently the use of natural fiber reinforced polymer composite in the various sectors has increased tremendously. This is due to the environmental problems and health hazard possessed by the synthetic fiber during disposal and manufacturing. The main aim of this paper is to review the work carried out by using kenaf fiber composite. The reinforcement made by using the kenaf fiber shows its potential to replace the glass fiber composite. In addition to the physical and mechanical properties, processing methods and application of kenaf fiber composite is also discussed.

1. INTRODUCTION

Natural fibers are environmental friendly, low cost, easily available and have good specific strength and modulus. Natural fibers are extracted from various parts of the plant (stem, leaf, bark and fruits) and classified accordingly. The most widely used plant fibers are sisal, banana, kenaf, coir, etc., to name the few. Mwaikambo, et al. [1] reviewed the history, properties and application of plant fibers. Review indicate that there is a strong relationship between the fine structure of plant fibres and their mechanical properties

Kenaf, Hibiscus cannabinus L, belong to the family of hibiscus, a biodegradable and environmental friendly crop. Kenaf is mostly suitable for cultivation in tropical and subtropical regions. Hence most of the researches in kenaf fibers are carried out by the researchers in those areas. Chawla [2] has described the conditions required for the cultivation of kenaf fibers and countries of origin of fibers are studied by Manjusri, et al. [3] is listed in Table 1.

Mossello et al. [4] reviewed several empirical studies which highlight the use of kenaf for pulp production (beating, fractionation, and recycled fiber). Mossello et al. [5] reviewed kenaf fiber literatures to evaluate paper and paperboard globally, this will cause the increase demand for fiber.

2. PHYSICAL STRUCTURE AND PROPERTIES OF KENAF FIBER

Kenaf fiber is extracted from bark of the tree. From the bark fibers extracted from the bast and core of the bark. The parts of the kenaf plants [1] are shown in Fig. 1.

The main factors which influence the properties of the fiber, see Table 2, are its chemical composition. Bismark et al. [6] studied the chemical content of various natural fibers which are listed in Table 3. The study shows that the strength of the composite is mainly influenced by the cellulose content of the fiber. Du et al. (2008) [7] reported that kenaf bast fibre has cellulose content as high as 60.8% while Ismawati [8] reported that cellulose content of core fibre is approximately 50.6%.

Chen et al. [9] studied and measured the length of natural fibers such as Kenaf, Ramie and bagasse, which are listed in Table 4. It was found that finesse

Corresponding author: A. Alavudeen, e-mail: ala_parv@yahoo.co.in

Table 1. Fibers and Countries of origin (for more details, see K.M. Manjusri and T.D. Lawrence, 2005. Natural Fibers, Biopolymers, and Bio-composites.CRC Press, Tailor & Francis).

Kenaf	Iraq, Tanzania, Jamaica, South Africa, Cuba and Togo
Banana	Asian Countries
Jute	India, Egypt, Guyana, Jamaica, Ghana, Malaw

of the kenaf fiber is greater than the ramie fiber and lesser than the baggase fiber.

Gita Ramaswamy et al. [10] studied the effect of frost on kenaf fiber quality. He conducted detailed evaluation on fiber processing and chemical composition. Frost-damaged kenaf with fungal growth was decorticated by hand and divided into six sections (26.88 cm:each) from the base to tip of the stem and then retted chemically or bacterially in the laboratory. Fiber characteristics also compared between two process and six locations.

Kenaf fiber has been successfully reinforced with both thermo plastic and thermoset resins. This indicates the feasibility and a new reinforcing material for polymer matrix composite**.** Yibin Xue et al. [11] compared the experimental and theoretical tensile properties of kenaf fiber bundle. Both experimental and theoretical studies indicate that the tensile strength of the kenaf fiber bundle increases with increasing the strain rate whereas tensile modulus remain unchanged due to change in strain rate. Chen et al. [12] has successfully fabricated the automotive head liner using kenaf/ ramie hybrid composites. Composite is fabricated by carding, needle punching and wet bonding technique. Tajvidi et al. [13] conducted DMA test to analyse the creep behaviour of kenaf–fiber/HDPE composite. Tests were conducted in the frequency range of 0.1 – 10 Hz by varying temperatures. The study revealed that the temperature has more effect on viscoelastic property of the composite than the stress. Zampaloni et al. [14] discussed the problems and solutions of manufacturing kenaf/PP composites. Composite was prepared using kenaf as reinforcement in maleated polypropylene. It shows that the kenaf/polypropylene composite has high modulus/cost and higher specific modulus than sisal, coir, and E-glass, thereby providing an opportunity for replacing existing materials. Wanjun et al. [15] studied the effect of processing method (injection moulding and extrusion) and fiber length on the thermal and mechanical properties of kenaf fiber reinforced composite. The impact strength and heat deflection temperature increases with increase in length indicating the role of fiber bridging effects as predominant factor. Takashi Nishino et al. [16] analyzed the kenaf fiber reinforced poly-lactic acid for its mechanical properties. The study found that kenaf is a suitable candidate for reinforcement in biodegradable polymer composite. Shinji Ochi et al. [17] investigated the mechanical properties of kenaf fiber reinforced in poly lactic acid composite. The study shows that the flexural properties of composite increases with increasing the fiber content. Also, the biodegradable study shows that the 38% of weight reduces in four weeks of compositing. Vineta et al. [18] compared the composite prepa red by injection and compression moulded kenaf/pp. The study shows that the process has no significant effect on the properties of composite. Jamal et al. [19] investigated the tensile properties of wood flour/kenaf–pp composite. The investigation revealed that the addition of long kenaf fiber as reinforcement with wood flour-pp composite has considerably increases the tensile strength and modulus. Symington et al. [20] studied the tensile properties of kenaf fibers for structural application. The study shows that the alkalization will improve the properties of the fiber. Chen et al. [21] fabricated the woven composite made of bagasse, kenaf, ramie as reinforcement with polypropylene (PP) as matrix and determined the mechanical, thermal and wet properties of these composites. The investigation indicated that the thermal properties of these composites depend on the bonding between the fiber and the matrix. This study compared the two types

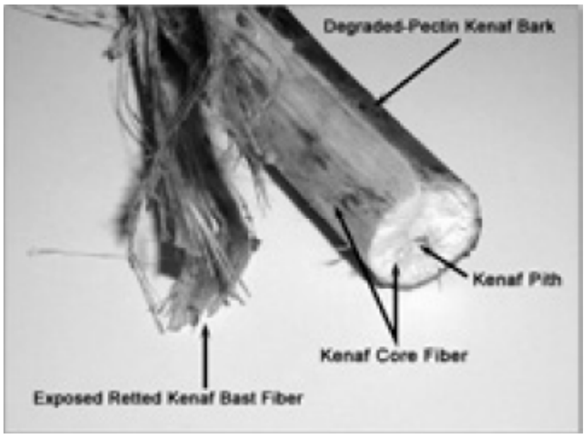

Fig. 1. Kenaf fiber structure.

Table 2. Physical properties of kenaf fibers.

Kenaf Fiber	Length(mm)	Diameter(μm)	Lumen Diameter(μm)	Cell wall thickness(μm)
Bast	2.32 ± 0.21	21.9 ± 4.6	11.9 ± 3.4	4.2 ± 0.8
Core	0.74	22.2 ± 4.5	13.2 ± 3.6	4.3 ± 0.7

Table 3. Chemical composition, moisture content and microfibrillar angle of plant fibers.

Fibers	Cellulose(%)	Hemi Cellulose(%)	Lignin(wt.%)	Pectin(wt.%)	Moisture content(%)	Waxes(%)	Microfibrillar angle(q)
Kenaf	45-57	21.5	8-13	3-5			
Flax	71	18.6-20.6	2.2	2.3	8-12	1.7	5-10
Hemp	70-74	17.9-22.4	3.7-5.4	0.9	6.2-12	0.8	2-6.2
jute	61-71.5	13.6-20.4	12-13	0.2	12.5-13.7	0.5	8
Ramie	68.6-76.2	13.1-16.7	0.6-0.7	1.9	7.5-17	0.3	7.5

Table 4. Length and tex of fibers.

Fiber	Length(mm)	Finesse(tex)
Kenaf	50.8	9
Ramie	95.3	0.8
Baggase	34.0	58.7

of experimental kenaf/ramie nonwovens with different binders, in terms of mechanical properties, thermal mechanical property, and thermal conductivity.

Sanadi et al. [22] investigated the thermal properties of the kenaf –PP composite using DSC and DMA techniques. The investigation results indicate that the 0.25 volume fraction of kenaf fiber in Polypropylene has improved the thermal stability of the polypropylene matrix. This shows that the addition of fiber has not only improved the thermal stability but also the viscoelastic behavior of the composite also. H.M. Akil [23] overviewed the developments made in the area of kenaf fiber reinforced composites, in terms of their market, manufacturing methods, and overall properties. Thielemans & Wool show that the good adhesion between kenaf fiber and epoxy matrix can be obtain by proper surface treatment. Maddern & Franch [24] (1989) studied the papermaking properties of bleached soda-AQ kenaf bark and core pulp. They found that the bark fibers are long, thin and stiff providing good tear, light scattering and moderate bonding. Ishak et al. [25] used kenaf fiber as reinforcement in bio composite material. The objective was to compare the mechanical properties of short kenaf bast and core fiber reinforced unsaturated polyester composites with varying fiber weight fraction i.e. 0%, 5%, 10%, 20%, 30%, and 40%. The results also showed that the optimum fiber content for achieving highest tensile strength for both bast and core fibre composites were 20 wt.%. Byoung-Ho Lee et al. [26] evaluated kenaf fiber reinforced PLA composite fabricated by carding followed by hot-pressing .Further the fibers are treated with silane coupling agent. The treatment with silane has increased the modulus and swelling capabilities of the composite. The swelling of the composite can be controlled by increasing the concentration of the coupling agent. Bhardwaj et al. (2007) [27] studied the influence on physical and electro-kinetic properties of various cellulosic fibers and found that beating increases the surface charge, specific surface area and specific volume of fibers, but did not change the total fiber charge. Nishino et al. [28] investigated the influence of silane coupling agent (glycidoxypropyl trimethoxysilane) on kenaf fiber-reinforced PLA. The stress on the fibers in the composite under transverse load was monitored in situ and nondestructively using X-ray diffraction

3. INFLUENCE OF CHEMICAL TREATMENT OF KENAF ON THE MECHANICAL PROPERTIES OF THE COMPOSITES

Yuhazri et al. [29] investigated the effect of NaOH on the kenaf fiber reinforced polyester composite. The mechanical properties of the composite increased with increasing the concentration of the alkali. A. M. Mohd Edeerozey, 2007 [30]; H. A. Sharifah, 2004] [31] Study shows that the kenaf fiber can be reinforced with both thermoplastic and thermo set plastic. The increase in the property can be achieved by surface modification of the fiber.

Mehdi Jonoobi et al. [32] characterized the kenaf *(Hibiscus cannabinus)* nano fibers by environmental scanning electron microscopy (ESEM) and transmission electron microscopy (TEM), which were isolated from unbleached and bleached pulp by a combination of chemical and mechanical treatments. Moreover, thermogravimetric analysis (TGA) indicated that both pulp types as well as the nanofibers displayed a superior thermal stability as compared to the raw kenaf. Fourier transform infrared (FTIR) spectroscopy demonstrated that the content of lignin and hemi cellulose decreased during the pulping process and lignin was almost removed during bleaching. Alavudeen et al. [33] studied the effect of NaOH and sodium lauryl sulphate treatment on mechanical properties of randomly mixed hybrid fiber composites for varying fiber percentage weight (wt.%). Result indicate that both the treatment improve the mechanical properties of the composites, but on comparing them it shows that the SLS treatement has better mechanical properties than NaOH. Tajvidi et al.[34] investigated the effect of MA modification on viscoelastic properties of kenaf fiber-reinforced PP composites. An increase in storage and loss moduli and a decrease in the mechanical loss factor were observed for all treated composites, indicating more elastic behavior of the composites when compared with the pure PP. Aziz et al. [35] investigated the effect of modified polyester resins in alkali-treated kenaf fiber composites. Four types of polyester resins were used in this study. Rajeev et al. [36] has compared the tensile properties of silane treated kenaf fiber treated with sisal fiber. It was found that the composites based on the modified matrix have, in general, superior mechanical properties to those containing the unmodified matrix. Maya Jacob et al. [37] used zein as a coupling agent in this experimental study and it was found that chemically modified kenaf fibers were found to possess improved mechanical and visco- elastic properties.

4. WOVEN KENAF FIBER COMPOSITE

Woven composites are known to be complex systems, which have additional features such as, interlace spacing or gap, interlace point and unit cell. There are very few reports on woven fabric composites reported so far. The popularity of woven composites is increasing due to simple processing and acceptable mechanical properties. Woven fabric composites provide more balanced properties in the fabric plane than unidirectional lamina. The weaving of the fiber provides an interlocking that increases strength better than can be achieved by fiber matrix adhesion. Not much work was carried out using woven kenaf as reinforcement in composite.

Bel-Berger et al.[38] evaluated the effects of retting on yarn quality and fabric and also investigated chemical and enzyme treatments for improving the softness and hand of the fabrics produced. Thiruchitrambalam et al. [39] studied the effect of NaOH and SLS treatment on Banana/kenaf woven composite. It was found that the composites made using SLS (Sodium lauryl sulphate) treated fibers has higher strength then the composites made using alkali treated fiber. Alavudeen et al. [40] reviewed woven natural fiber composites and their developments. Thiruchitrambalam et al. [41] fabricated clutch plate using hybrid woven fabric reinforced with polyester composite. The objectives of this investigation are to assess the potential for manufacturing a high quality clutch plate via hand lay-up technique. Lai et al. [42] used woven betel palm and kenaf fibers as a reinforcing phase in unsaturated polyester .Authors evaluated the morphology, physical properties, and mechanical properties of the natural fibers. Kenaf fibers exhibit higher tensile properties than betel palm fibers due to the higher amount of cellulose content. Authors found that untreated woven kenaf composites exhibit comparable flexural strength with those of untreated woven betel palm composites. However, untreated kenaf composites exhibit superior flexural modulus to those of betel palm composites. In general, mechanical properties of the woven composites made from alkali-treated fibers were superior to the untreated fibers. Xu Jianying et al. [43] fabricated the kenaf composite panels were made using a one-step steam-injection pressing method and a two-step pressing method (the particleboard is steam pressed first, followed by overlaying).

5. DEVELOPMENTS FOR FUTURE

Kenaf fiber reinforced composite has a good potential for usage as reinforcement in composite. The most interesting development of kenaf fiber reinforced composite is utilizing its availability and readiness to be used with various manufacturing processes that have never been associated with other natural fibers before, such as pultrusion and potentially, filament winding. Based on this brief review, the application of kenaf fiber reinforced composite as an alternative composite material, especially in building and construction, is highly plausible with both lightweight and low cost as its main driving forces.

REFERENCES

[1] L. Y. Mwaikambo // *African Journal of Science and Technology (AJST) Science and Engineering Series* **7** (2006) 120.

[2] K.K. Chawla, *Fibrous material* (Cambridge University press, 1998).

[3] K. M. Manjusri and T.D. Lawrence, *Natural Fibers, Biopolymers, and Bio-composites* (CRC Press, Tailor & Francis, 2005).

[4] A.A. Mossello, Jalaluddin Harun, Paridah Md Tahir, Hossein Resalati, Rushdan Ibrahim, Seyed Rashid, Fallah Shamsi and Ainun Zuriyati Mohmamed // *Modern Applied Science* **4** (2010) 21.

[5] A.A. Mossello, J. Harun, S.R.F. Shamsi, H. Resalati, P.M. Tahir, R. Ibrahim and A.Z. Mohmamed // *Agric. J.* **5** (2010) 131.

[6] A. Bismarck, S. Mishra and T. Lampke, In: *Natural fibers, biopolymers and biocomposites*, ed. by A.K. Mohanty, M. Mishra and L.T. Drzal (Boca Raton (FL), CRC Press; 2005).

[7] Y. Du, J. Zhang and Y. Xue // *Forest Product Journal* 22(4) (2008) 506.

[8] P. Ismawati, *Carboxymethylation of Cellulose from Kenaf (Hibiscus cannabinus L.) Core for Hydrogel Production* (Master Thesis, Universiti Putra, Malaysia, 2006).

[9] O. Chiparus, Chen Sun, I. Negulescu, D.V. Parikh and T. A. Calamari // *Journal of Industrial Textiles* **35** (2005) 47.

[10] Gita N. Ramaswamy, Bambang Soeharto, Catherine R. Boyd and Brian S. Baldwin // *Industrial Crops and Products* **19** (1999) 189.
[11] Yibin Xue, Yicheng Du, Steve Elder, Kunpeng Wang and Jilei Zhang // *Composites Part B* **40** (2009) 189.
[12] Yan Chen, Liangfeng Sun, Ovidiu Chiparus, Ioan Negulescu, Val Yachmenev and Mary Warnoc // *Journal of Polymers and the Environment* **13** (2005) DOI: 10.1007/s10924-005-2942-z.
[13] Mehdi Tajvidi, Robert H. Falk and John C. Hermanson // *J. Appl. Polym. Sci.* **97** (2005) 1995.
[14] M. Zampaloni, F. Pourboghrat, S.A. Yankovich, B.N. Rodgers, J.Moore, L.T. Drzal, A.K. Mohanty and M. Misra // *Composites Part A* **38** (2007) 1569.
[15] Wanjun Liu, Lawrence T. Drzal, Amar K. Mohanty and Manjusri Misra // *Composites Part B* **38** (2007) 352.
[16] Takashi Nishino, Koichi Hirao, Masaru Kotera, Katsuhiko Nakamae and Hiroshi Inagaki // *Composites Science and Technology* **63** (2003) 1281.
[17] Shinji Ochi // *Mechanics of Materials* **40** (2008) 446.
[18] Vineta Srebrenkoska, Gordana Bogoeva Gaceva and Dimko Dimesk // *Macedonian Journal of Chemistry and Chemical Engineering* **28** (2009) 99.
[19] Jamal Mirbagheri, Mehdi Tajvidi, John C. Hermanson and Ismaeil Ghasemi // *Journal of Applied Polymer Science* **105** (2007) 3054.
[20] Mark C. Symington, W.M. Banks, Opukuro David West and R.A. Pethrick // *Journal of Composite Materials* **43** (2009) 1083.
[21] Yan Chen, Liangfeng Sun, Ovidiu Chiparus, Ioan Negulescu, Val Yachmenev and Mary Warnock // *Journal of Polymers and the Environment* **13** (2005) 107.
[22] Daan Feng, F. Caulfield and R. Sanadi // *Polym. Compos.* **22** (2001) 506.
[23] H.M. Akil, M.F. Omar, A.A.M. Mazuki, S. Safiee, Z.A.M. Ishak and A. Abu Bakar // *Materials and Design* **32** (2011) 4107.
[24] K.N. Maddern and J. French // *Appita Journal* **42** (1989) 433.
[25] M.R. Ishak, Z. Leman, S.M. Sapuan, A.M.M. Edeerozey and I.S. Othman, *Mechanical properties of kenaf bast and core fibre reinforced unsaturated polyester composites* (IOP Publishing Ltd., 2010).
[26] Byoung-Ho Lee, Hee-Soo Kim, Sena Lee, Hyun-Joong Kim and John R. Dorgan // *Composites Science and Technology* **69** (2009) 2573.
[27] N.K. Bhardwaj, V. Hoang and K.L. Nguyen // *Bioresource technology* **98** (2007) 1647.
[28] T. Nishino, K. Hirao and M. Kotera // *Compos. A* **37** (2006) 2269.
[29] Mohd Yuhazri, P.T. Phongsakorn, Haeryip Sihombing, A.R. Jeefferie, Puvanasvaran Perumal, A.M. Kamarul and Kannan Rassiah // *International Journal of Engineering & Technology* **11** (2011) 127.
[30] A.M. Mohd Edeerozey, M.A. Harizan, A.B. Azhar and M.I. Zainal Ariffin // *Materials Letters* **61** (2007) 2023-2025.
[31] H. A. Sharifah and P. A. Martin // *Composites Science and Technology* **64** (2004) 1219.
[32] Mehdi Jonoobi; Jalaludin Harun; Manju Mishra and Kristina Oksman // *Bioresources* **4** (2009) 626.
[33] A. Alavudeen, M. Thiruchitrambalam, N. Venkateshwaran, A. Elayaperumal and A. Athijayamani // *Hybrid Composites* **7** (2011) 172.
[34] M. Tajvidi, R.H. Falk and J.C. Hermanson // *J. Appl.Polym. Sci*. **101** (2006) 4341.
[35] S.H. Aziz, M.P. Ansell, S.J. Clarke and S.R. Panteny // *Comf CXpos. Sci. Technol.* **65** (2005) 525.
[36] Rajeev Karnani, Mohan Krishnan and Ramani Narayan // *Polymer Engineering and Science* **37** (1997) 476.
[37] Maya Jacob John, Cornelia Bellmann and Rajesh D. Anandjiwala // Carbohydrate Polymers **82** (2010) 549.
[38] P. Bel-Berger, T. Von Hoven, G.N. Ramaswamy, L. Kimmel and E. Boylston // *The Journal of Cotton Science* **3** (1999) 60.
[39] M. Thiruchirambalam, A. Alavudeen, A.Athijayamani, N. Venkateshwaran and A. Elayaperumal // *Mater. Phys. Mech.* **8** (2009) 165.
[40] A. Alavudeen, M. Thiruchitrambalam, N. Venkateshwaran and A.Athijayamani // *Rev. Adv. Mater. Sci.* **27** (2011) 146.
[41] A. Alavudeen, M. Thiruchitrambalam and A. Athijayamani // *Material Research Innovations*, DOI 10.1179/143307511X13018917925676, 2011.
[42] W.L. Lai, M. Mariatti and Jani S. Mohamad // *Polymer-Plastics Technology and Engineering* **47** (2008) 1193.
[43] Xu Jianying, Widyorini Ragil and Kawai Shuichi // J. Wood Sci. **51** (2005) 415.