Composites Part B 81 (2015) 149–157

Contents lists available at ScienceDirect

Composites Part B

journal homepage: www.elsevier.com/locate/compositesb

Development of a biocomposite based on green epoxy polymer and natural cellulose fabric (bark cloth) for automotive instrument panel applications

Samson Rwawiire [a, b, *], Blanka Tomkova [a], Jiri Militky [a], Abdul Jabbar [a], Bandu Madhukar Kale [a]

[a] Technical University of Liberec, Department of Material Engineering, Studentská 2, 461 17 Liberec, Czech Republic
[b] Busitema University, Department of Textile and Ginning Engineering, P.O Box 236, Tororo, Uganda

A R T I C L E I N F O

Article history:
Received 9 March 2015
Received in revised form
15 May 2015
Accepted 29 June 2015
Available online 15 July 2015

Keywords:
A. Fibers
A. Polymer-matrix composites (PMCs)
B. Mechanical properties
D. Mechanical testing

A B S T R A C T

Natural fiber reinforced composites have attracted interest due to their numerous advantages such as biodegradability, dermal non-toxicity and with promising mechanical strength. The desire to mitigate climate change due to greenhouse gas emissions, biodegradable resins are explored as the best forms of polymers for composites apart from their synthetic counterparts which are non-renewable. In this study biodegradable bark cloth reinforced green epoxy composites are developed with view of application to automotive instrument panels. The optimum curing temperature of green epoxy was shown to be 120 °C. The static properties showed a tensile strength of 33 MPa and flexural strength of 207 MPa. The dynamic mechanical properties, frequency sweep showed excellent fiber-matrix bonding of the alkali treated fabric with the green epoxy polymer with glass transition temperature in the range of 160 °C–180 °C. Treatment of the fabric with alkali positively influenced the mechanical properties of the fabric reinforced biocomposites.

1. Introduction

Interest in fiber reinforced composite materials is on a gradual increase due to the fact that the addition of fibers to polymer resins increases the mechanical strength of the resulting materials. Man-made fibers such as carbon and glass whose feedstock is fossil fuels are faced with global concerns with regard to greenhouse gas emissions which are responsible for climate change [1–3]. According to the report on Global Natural Fiber Composites Market 2014–2019: Trends, Forecast and Opportunity Analysis [4], it was shown that by 2016, the natural fiber composites market is expected to be worth US 531.2 million with an expected annual growth rate of 11% for the next five years. Currently, natural fibers account to over 14% share of reinforcement materials; however, the share is projected to rise to 28% by 2020 amounting to about 830,000tonnes of natural fibers [5].

Synthetic fibers whose feedstock is fossil fuel are the leading causes of environmental degradation due to the toxicity of the fumes emitted, demanding energy for production and non-biodegradability whereas natural fibers have advantages such as biodegradability, low cost, non-toxicity, sound absorption properties etc. [6]. Furthermore, the Intergovernmental Panel on Climate Change most recent report recommends cutting of greenhouse gas emissions by 70% and an increase of the use of clean green energy by 2050 respectively. Effective strategies such as utilization of sustainable biodegradable materials instead of synthetic materials can contribute to lowering greenhouse gas emissions thus combating climate change. In reference to European Union guideline 2000/53/EG issued by the European Commission, 95% of the weight of a vehicle have to be recyclable by 2015 [7]. Most plastics and synthetic fibers are faced with disposal concerns due to their resistance to microbial attack; piles of the disposed products which are ignorantly burnt in under-developed countries lead to increase in greenhouse gases and also a health risk to the consumers in the developing countries.

In the quest for a cleaner environment, waste materials can be re-used as reinforcement in engineering composites [8]. This has

* Corresponding author. Technical University of Liberec, Department of Material Engineering, Studentská 2, 461 17 Liberec, Czech Republic. Tel.: +420 776427047; +256 776369920.
E-mail address: rsammy@eng.busitema.ac.ug (S. Rwawiire).

http://dx.doi.org/10.1016/j.compositesb.2015.06.021
1359-8368/

Table 1
Bark cloth composition.

Component	[%]
α-Cellulose	68.69
Hemicellulose	15.07
Lignin	15.24

intensified application of most common plant fibers hemp, kenaf, flax, jute, sisal and abaca as reinforcement of automotive composites for secondary components that don't demand high mechanical strength [9–15].

Uganda is a tropical country endowed with vast resources of natural plant fibers [16]. In order to evaluate the sustainability of plant fibers such as bark cloth for composite applications, it's worth mentioning that it is of utmost importance to utilize non-food crops and regulate quantity of fertilizers or chemicals utilized for growing the crops. The life cycle analysis of fibers has shown that ligno-cellulosic fibers have an edge in terms environmental friendliness [17].

Bark cloth is believed to have originated in South China and the technology of extraction of bark cloth has been confirmed by archaeologists discovering grooved stones in Xiantouling site of Shenzhen similar to grooved hammers used today. It's believed that the extraction of bark cloth in ancient china spread to Taiwan, Philippines, Africa, Central America and Oceania. Bark cloth produced from Polynesia is derived from the bast of mulberry whereas in Uganda the felt is derived from *Ficus natalensis*, *Ficus brachypoda* and *Antiaris toxicaria*. Bark cloth has been in production in Uganda for over six centuries; the technology transfer of bark cloth production from the elderly to the youth has been impeded by rural to urban migration of the youth and influence to modernization. That notwithstanding, in 2005, UNESCO proclaimed bark cloth as a “Masterpiece of the Oral and Intangible Heritage of Humanity”. Bark cloth terracotta in colour, is composed of an array of cellulose microfibers, thermally stable below 200 °C just like other cellulosic fibers. The fabric is used also used in fashion and art, however, its comfort properties are comparable to cotton and it has a warm feeling to touch [16,18]. Rwawiire et al. [19] fabricated bark cloth reinforced petroleum based epoxy composites using vacuum assisted resin transfer moulding using four plies. The effect of ply arrangement on the mechanical properties of bark cloth showed that composites with 90°, 0°, −45°, 45° exhibited the highest strength in comparison to the other three studied.

In this study an exploratory investigation of *F. natalensis* bark cloth as a reinforcement of new and biodegradable epoxy resin is done. Research elsewhere has been done utilizing synthetic thermosetting polymers for natural fiber composites; however, there is limited research work on the utilization of biodegradable epoxy polymer resins.

2. Materials and methods

2.1. Materials

Bark cloth was extracted from *F. natalensis* using a method described by Rwawiire & Tomkova [18]. Table 1 shows the chemical composition of bark cloth. Biodegradable epoxy resin CHS-Epoxy G520 (viscosity = 12.0–14.5 Pa at 25 °C) and hardener Telalit 0600 supplied by Spolchemie, Czech Republic was used in composite sample fabrication. Green epoxy CHS-Epoxy G520 is a low molecular weight basic liquid epoxy resin containing no modifiers, certified by International Environmental Product Declaration Consortium (IEC).

2.1.1. Bark cloth extraction

Fig. 1 shows the detailed process of production of bark cloth. The extraction of the naturally occurring non-woven starts with scraping off the surface layer of the trunk to expose the fresh raw bark using a sharp blade. The blade is held at an angle such that only the surface layer is removed and also avoids damaging the tree

Fig. 1. Extraction of Bark cloth nonwoven natural fabric: (a) Scrapping of tree outer layer. (b) Use of local wedged tool to peel off the bark. (c) Peeling of the bark. (d) Covering of the tree stem for environmental sustainability. (e) Pummelling under the shade. (f) Sun drying of the non-woven fabric.