Engineering Science and Technology, an International Journal 19 (2016) 676–683

HOSTED BY

ELSEVIER

Contents lists available at ScienceDirect

Engineering Science and Technology, an International Journal

journal homepage: http://www.elsevier.com/locate/jestch

Full Length Article

Influence of $CaCO_3$, Al_2O_3, and TiO_2 microfillers on physico-mechanical properties of *Luffa cylindrica*/polyester composites

Vinay Kumar Patel *, Anil Dhanola

Department of Mechanical Engineering, Govind Ballabh Pant Engineering College Ghurdauri, Pauri Garhwal 246001, Uttarakhand, India

A R T I C L E I N F O

Article history:
Received 29 July 2015
Received in revised form
6 October 2015
Accepted 30 October 2015
Available online 30 November 2015

Keywords:
Luffa cylindrica
Composites
Polymer composites
Hybrid composites

A B S T R A C T

The development of natural fibre reinforced polymer composites has gained popularity in many applications due to their environment friendly characteristics over the synthetic fibre based polymer composites. This paper describes the fabrication and physical, mechanical, three-body abrasive wear and water absorption behaviour of *Luffa* fibre reinforced polyester composites with and without addition of microfillers of Al_2O_3, $CaCO_3$ and TiO_2. The ranking of the composite materials has been made by using Technique for order preference by similarity to ideal solution (TOPSIS) method with output parameters of their physical, mechanical and abrasive wear and water absorption attributes. The addition of microfillers has enhanced greatly the physical and mechanical properties of *Luffa*-fibre based composites. The addition of microfillers has influenced the physico-mechanical properties of *Luffa*-fibre based polyester composites in descending order of $CaCO_3$, Al_2O_3, and TiO_2.

1. Introduction

Over the past few decades, remarkable interest has been observed in natural fibre as a substitute for glass and ceramic owing to its eco-friendly and renewable nature, low cost, lightweight, high specific mechanical performance, etc. Natural fibres such as kenaf [1], bagasse [2], jute [3–8], ramie, oil palm [9] and hemp [10] have been investigated as reinforcements for the fabrication of fibre-reinforced polymer composites. Natural fibres can be used as alternatives of synthetic fibres, *e.g.* aramid, glass, carbon, etc. [11]. Natural fibre based polymer composites have found application in furniture, packaging, acoustics vibration isolation, impact energy absorption, building, automobile industries, aeronautics, and naval application [12–17]. The fruit of sponge guard (*Luffa cylindrica*) belongs to Cucurbitaceous family [18] and is naturally available in many countries. The young cylindrical Luffa fruit is edible and contains many compounds such as phenolics, lavonoids, triterpenoids and ribosome-inactivating protein. *Luffa* fruit has been effectively utilized for medicinal purposes such as immune-stimulatory and anti-inflammatory agent [19]. *Luffa* sponge is a suitable natural fibre and has been successfully utilized in the process of bio-sorption of heavy metals from waste water. This emerging cash crop has full potential to improve the economy of developing nation. *Luffa cylindrica* is available in mat form naturally [18–21]. The *Luffa* fibres contain 84% holocellulose, 66% cellulose, 17% hemi-cellulose, 15% legnin, 3.2% extractives, and 0.4% ashes [22]. The physical properties of *Luffa* fibre are of density 820 kg/m^3, diameter 25–60 µm, and crystallinity index 59.1 [19,22–24]. Oboh et al. [18] demonstrated the capabilities and applications of *Luffa* fibres in medicine, agriculture, and science and technology. Msahli et al. [25] investigated that flexural strength and adhesion between *Luffa* fibre and polyester matrix was improved by acetylating and cyanoethylating treatments of *Luffa* fibres. Srinivasan et al. [26] investigated that mechanical properties of *Luffa* fibre epoxy composites filled with SiO_2 nanoparticles increased by 2% than unfilled *Luffa* fibre epoxy composites.

TOPSIS method is a powerful Multiple-Attribute Decision Making technique for selecting the best alternatives from number of possible alternatives. According to this the best alternative would be the one that is closest to the positive ideal solution and farthest from the negative ideal (hypothetically worst) solution. The main aim of TOPSIS is to select the top ranked alternative and compare it with all ranks in this set of simulations. TOPSIS method has been standardized as a multi-criteria decision making tool in a much wider horizon of applications such as Supply Chain Management and Logistics, Design, Engineering and Manufacturing Systems, Business and Marketing Management, Health, Safety and Environment Management, Human Resources Management, Energy Management, Chemical Engineering, Water Resources Management and others as nicely reviewed by analysing 266 scholary papers from 2000 to 2012 [27]. In Design, Engineering and Manufacturing Systems, TOPSIS provided the best possible solution to seventy-two different applications in materials, manufacturing, machatronics, robotics, automobiles, aviation, energy and power, engineering design. Etc. [27]. TOPSIS

* Corresponding author. Tel.: +91 9807822530; fax: +911368228062.
E-mail address: vinaykrpatel@gmail.com (V.K. Patel).
Peer review under responsibility of Karabuk University.

http://dx.doi.org/10.1016/j.jestch.2015.10.005

has been explored as a useful tool in the selection of subsystems for a composite product development in order of preference for a given application [28,29]. For composites, the TOPSIS method can be effectively applied for determining the ranking based on the relative importance/weightage of one or more physical/chemical/mechanical properties according to the service requirements or products' qualities. In this work all the composite materials have been compared using TOPSIS method and ranking has been done accordingly. The decision matrix, normalization matrix, weight normalized matrix, ideal positive and ideal negative solution, separation measure, relative closeness value and ranking are tabulated in Tables 4, 5, 6, 7, 8 and 9 respectively.

The incorporation of filler into polymer has proved to be an alternative for the improvement of the performance of the resultant composites. Hybridization of fibres with fillers has been used to enhance the properties of composites. A judicious selection of matrix and the reinforcing phase can lead to a composite with a combination of strength and modulus comparable to or even better than those of conventional metallic materials. The improved performance of polymers and their composites in industrial and structural applications by the addition of particulate filler materials has shown a great promise and so has lately been a subject of considerable interest. Specific fillers (additives) are added to enhance and modify the quality of composites. Mechanical properties are reckoned as the most important of all the physical and chemical properties in majority of applications [30]. The plastics/polymers should be able to sustain high tensile loading, impact loading, fatigue loading, etc. and offer high resistance to wear, abrasion, etc. in order to achieve a widespread applicability as well as economical and lightweight alternatives of ferrous and non-ferrous materials. Tensile strength is one of the most widely measured mechanical properties of composites utilized in structural applications. Fibre reinforcement enabled a good combination of properties to polymer composites finding wide usefulness in structural and automotive's components applications [31]. The car manufacturers fabricated non-structural components using hemp and flax fibres owing to their higher specific strength and lower cost compared to conventional reinforcements [32]. The natural fibres are eco-friendly; most economically sustainable resources are available abundantly in nature and are exploited selectively and wisely in the development of high performance polymer composites. Therefore, it has been the prime motives of many materialists and researchers to develop polymeric composites with high mechanical properties by suitable selection of fibres and their chemical modifications, resin compounds and hybrid fillers in a most economical way. In recent years, studies have been made about the fabrication and physical/chemical/mechanical characterization of plain and chemically treated *luffa* fibres based polymer composites. Demir et al. treated *Luffa* fibres by three different coupling agents namely (3-aminopropyl)-triethoxysilane (AS), 3-(trimethoxysilyl)-1-propanethiol (MS), and maleic anhydride grafted polypropylene (MAPP) and demonstrated better mechanical properties with MS-treated *Luffa* fibre based polypropylene composites owing to better adhesion between matrix and fibres [33]. Recently, the effect of chemical (2% NaOH/1–3% Methacrylamide) treatments of *Luffa cylindrica* on physico-mechanical properties of polyester composites were investigated [34]. In a novel value addition to *Luffa cylindrica*/Polyester composites, an attempt has been made to identify one or more selective micro-additives for developing high performance polymer composites with enhanced physico-mechanical properties. In the present work, the effect of different micro-additives such as Al_2O_3, $CaCO_3$ and TiO_2 has been investigated on the physico-mechanical, three body abrasive wear and water absorption behaviour of *Luffa* fibre reinforced polyester composites. Finally, the ranking of as fabricated polymer composites has been made by TOPSIS method on the basis of their physical, mechanical and abrasive wear and water absorption attributes.

2. Experimental details

2.1. Materials

Luffa fruits (shown in Fig. 1a) were collected locally from the hilly terrain of Pauri-Garhwal, India and further treated with water for 24 hours in order to remove wax, lignin and oil from the external surface of Luffa fibres and then dried at room temperature. After drying under Sun-bath for a few days, a fibrous mat was cut from the outer core of *Luffa* fruit-shell which was further placed between two flat wooden plates and straightened to uniform thickness by applying uniform compressive load with mechanical Bench Vice for a few hours. Finally a fibrous mat of dimension (290 mm × 200 mm) was cut as shown in Fig. 1b. Al_2O_3, $CaCO_3$ and TiO_2 were taken as micro particulate fillers and unsaturated pure polyester was taken as a matrix material. Micro particulate fillers (Al_2O_3, $CaCO_3$ and TiO_2) were procured from Kalindi Medicure Pvt. Ltd, Dehradun India and Intelligent Materials Pvt Ltd, Chandigarh, India. Unsaturated Polyester (Isophthalic) resin was obtained from Amtech Esters Pvt. Ltd. New Delhi, India. The chemical structure of isophthalic polyester resin is shown in Fig. 1c [35].

2.2. Composite fabrication

Fabrication of composite was done by a conventional method called hand lay-up method. Hand lay-up method has been a widely explored technique of fabricating natural fibre based composites owing to its simplicity, cost effectiveness and flexibility, which is economically suitable to developing countries and less financially supported Universities and Colleges. A nice review on characterization of natural fibre and composites has been made by Satishkumar et al. where lots of natural fibre based composites were prepared by hand lay-up method [36]. A wooden mould of dimension $300 \times 210 \times 20$ mm^3 was used. Al_2O_3, $CaCO_3$ and TiO_2 microfillers were mixed carefully and mechanically stirred in a plastic jar according to composition of composites with polyester resin, hardener and accelerator in the ratio of 100:1.5:1.5 by weight [37,38]. For quick and easy removal of composites, a mould release sheet was put over

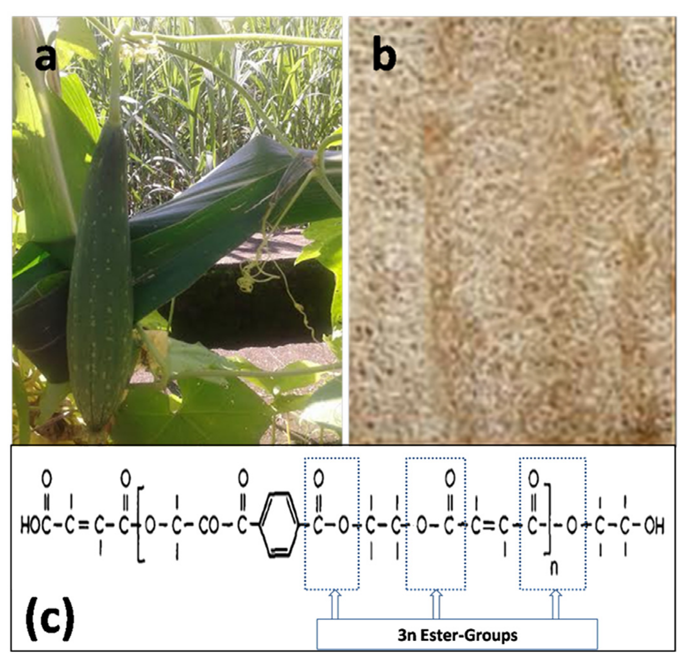

Fig. 1. The image of (a) *Luffa cylindrica* Fruit, (b) rectangular portion of *Luffa* fibre, (c) chemical structure of isophthalic polyester resin.