Accepted manuscript
doi: 10.1680/jemmr.18.00028

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Emerging Materials Research 2019.8:1-5.

Accepted manuscript
doi: 10.1680/jemmr.18.00028

Submitted: 02 March 2018

Published online in 'accepted manuscript' format: 26 August 2019

Manuscript title: Mechanical Properties of Chemical Treated Woven Banana/Polyvinyl Alcohol Composites

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doi: 10.1680/jemmr.18.00028

Abstract

Present work investigates the effect of chemical treatment on mechanical properties of plain woven banana fabrics (PWBF) reinforced to polyvinyl alcohol (PVA) bio-degradable matrix composite. Woven banana fabrics are chemically treated with different percentages of concentration (0.5, 1, 2, 3 and 4%) for 4 hours at room temperature. The banana fabrics and PVA are used in the ratio of 55% and 45% weight fraction respectively. Composites are prepared using hand-layup method. The samples are tested according to different ASTM standard for tensile, flexural and impact .The results are exhibited that tensile, flexural and impact properties were found to increase with potassium permanganate (KMnO4) treatment. The 1% potassium permanganate treated fabrics shows very good mechanical properties compared to untreated, 0.5, 2, 3 and 4% treated fabrics, 1% treated fabrics gives 68.07% increment in the tensile strength of the composite compared to the untreated fabrics composite. The scanning electron microscopy (SEM) also reveals 1% treated has the better interfacial bonding between fabrics and matrix. This contributes to improvement in the mechanical properties of the composite.

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1. Introduction

Natural fibers become a famous new material because of their high stiffness, high strength, easily available, eco-friendly, low cost, renewable and bio-degradable in nature[1]. There are different types of natural fibers are available today, some examples in use include banana, sisal, jute, bamboo, hemp and oil palm fibers. Generally raw natural fabrics consisting of hemi-cellulose, impurities, dust and other unwanted particles. Due the presence of these constituents, there was no proper bonding between the fabrics to the matrix. That could leads to lower the mechanical strength of composites [2]. Chemical treatment plays a significant role in improving the strength of the fabrics as well as internal adhesion between the fabrics to matrix [3]. Many researchers worked on the alkali treatment of natural fibers with different percentage of concentrations and reported the how the changes in the bonding and strength with various percentages of concentrations [4–8].

D. Bachtiar, et al. worked on alkaline treatment on tensile properties of sugar palm and reported that the treated results higher than the untreated [9]. A.C.H. Barreto, et al, worked in sisal fiber are treated with an alkali solution (5 and 10%) and concluded that the 5% tread fiber got good strength compared to untreated and 10% treated fiber [10]. Min Zhi Rong, et al. worked on different chemical treatments includes alkalization, acetylation, cyanoethylation, silane coupling agent, and heating which shows the how improvement in the surface bonding [11]. Mohammad Asim et al. concluded that the effects of NaOH, silane and NaOH-silane treatments improved the mechanical properties [12]. Jai Inder Preet Singha et al. worked on mechanical properties like tensile strength, flexural strength and impact strength for treated and non-treated natural fiber reinforced and concluded that the treated fiber got good mechanical strength [13]. Muhammad Khusairy et al. concluded that the treated fiber composites have superior properties as compared with untreated fiber composites [14]. Milena Martelli Tosia et al. investigated changes in the chemical composition and structure of soybean straw treated with alkali (5% & 17.5%) [15]. M.J.M. Ridzuan et al. discussed the effect of soaking time during the alkali treatment on the tensile strength of Napier grass fiber and its morphology [16]. R.Yahaya et al. concluded that the treated kenaf improves the mechanical properties of hybrid composites [17]. Ronald Asser et al. concluded that the changes due to chemical treatment were analyzed by Fourier transform infrared and X-ray diffraction methods [18]. Nagamadhu. M, et al. worked on alkali treatment for sisal and jute at different percentages of concentrations 0%, 4% and 6% and concluded that the 4% NaOH shows good strength of hybrid composites [19] [18].

From the literature survey, it was recommended that there was no work carried out on the permanganate treatment for natural fibers and totally it is a new class of work, the present work discussed on potassium permanganate treatment of plain woven banana fabrics with various percentages of concentrations and their mechanical characterization and morphology using SEM.

2. Materials and methods

Plain woven banana fabric of 400 gsm are collected from jolly enterprise kolkata and polyvinyl alcohol (PVA) purchased from local dealers pragathi industries, bangalore is used for preparing the composite specimens, resin and hardener mixed with 2:1 ratio. The plain woven banana fabric was immersed in $KMnO_4$ solution with different percentages of concentration 0.5, 1, 2, 3 and 4% for 4 hours, fabrics are thoroughly washed after treatment with regular water and natural curing for 2-3 days. The banana fabrics and PVA are used in the ratio of 55% and 45% weight fraction respectively. Composites are prepared using hand-layup method[20]. The size of the mould used for preparing composite laminates are 250 X 200 X 4mm^3 rectangular mild steel, initially top and bottom plates are cleaned with smoother, so that easy removal of any unwanted /dust particles from both the plates, realizing agent applied to top and bottom plate which helps in easy removal of composite laminates from the mould, fabrics are cut as per the mould dimensions, layers of untreated and treated fabrics were used for preparing the composite laminates as per weight fraction, a polyethylene sheet was laid on the clean and dry mould before preparation of composite laminates, the resin and hardener were mixed together, then fabric layer placed inside the mould, then a mixture of resin and hardener poured slowly into the mould, same procedure followed till thickness reaches 4mm, once the thickness is reached it is covered with top plate and bottom and top plate had an arrangement of nut and bolt assembly for compressing is as shown in Figure 1(a). Pressure is applied by tightening the nuts and is left for curing up to 24 hours. Cured sapmles are removed after 24 hours and cut to required dimension are shown in Figure 1(b).

3. Mechanical strength

Tensile testing specimen was prepared as per ASTM D-638M to measure the tensile strength of untreated and treated fabrics; the size of the specimen is 160 X 12.5 X 4 mm3, test specimen placed in the testing machine and gradual load applied till the specimen fractures. The elongation of the specimen during the test was reported and three samples are tested with a 5mm/min crosshead speed and 100mm gauge length, average values were taken and sample testing with fixture is shown in Figure2(a). Flexural testing specimens was made as per the ASTM D-790M to measure the bending strength of untreated and treated fabrics. The size of the specimen is 127 X 12.7 X 4 mm3, three samples are tested with a 5 mm/min crosshead speed and 70 mm span length, tensile and flexural strength were measured by Venus universal testing machine (model UTV-40 PC-M), sample testing with fixture is shown in Figure 2(b). Impact testing specimens were prepared as per the ASTM D-256M to measure the impact strength of untreated and treated fabrics. The size of the specimens is 94 X 12.7 X 4 mm3, impact test carried out using venus impact testing machine (model VI-300) sample testing with fixture is shwon in Figure2(c). Interfacial properties, such as fabrics-matrix interaction, fracture behavior and fabrics pullout of samples after mechanical test were observed using TESCAN Vega 3-LMU scanning electron microscope at BMS College Bangalore.

4. Results and disunion

This chapter highlighted the mechanical strength of untreated and KMnO4 treated fabrics, the results of tensile, flexural and impact strength are discussed and reported in Figures 3(a), (b) and (c).The effect of different percentages of concentration on tensile strength was carried out in a universal testing machine as per ASTM standards. The tensile strength of untreated, 0.5, 1, 2, 3, and 4% treated fabrics are 73.30, 111.2, 123.20, 119.20, 113.0 and 106.2MPa respectively as shown in Figure 3(a). The tensile strength of 0.5% treated fabric composite increased by 51.70% compared to the untreated fabric composite, 10.79% increased compared to 0.5% treated fabric composite, 3.24% decreased compared to 1% treated fabric composite. From the experimental

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results it was found that the 1% KMnO4 treated fabric composite got better tensile strength as compared to untreated, 0.5 2, 3 and 4% treated fabrics. For 1% treated fabric composite the tensile strength are 123.20MPa which is 68.07% more than that of untreated fabrics composite [7]. Upon increasing the treatment above 1% decrement in the strength noticed, this could be due to the fiber damage caused by permanganate treatment which leads to improper bonding between the fabrics to matrix. Hence 1% treatment is the superior permanganate treatment that provides the best internal bonding between fabrics to the matrix.

The flexural test carried out in a universal testing machine under 3-point bending mode. Figure 3(b) shows that the experimental results of flexural strength of untreated and treated fabric composite and which also shows that the flexural strength of treated fabric composite are more than the untreated fabric composite. 1% treated fabric composite has better flexural strength as compared to untreated, 0.5, 2, 3 and 4% treated fabric composite. For 1% treated fabric composite the flexural strength is 95.10MPa which is 21.92% more than that of untreated fabric composite. So by comparing with untreated fabric composite there was gradual improvement in the flexural strength up to 1%, as percentages of concentration increases the strength of the fabric composite reduces caused by permanganate treatment, due to this there was no proper bonding between fabrics to matrix which could leads to decrease the flexural strength of fabrics.

Impact strength can be measured the energy required to break the composite laminate when sudden load was applied, the impact strength of treated and untreated composite laminates is represented in Figure 3(c), the impact strength of untreated, 0.5, 1, 2, 3 and 4% are 0.6, 0.8, 1.0,

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0.8, 0.6 and 0.4J/m2 respectively. The impact strength of 0.5% treated fabric increased by 33.33% compared to untreated fabric composite, 25.0% increased compared to 0.5% treated fabric composite, 20% decreased compared to 1% treated fabric composite. Experimental results reveals that the 1% treated fabric composite got better impact strength as compared to untreated, 0.5, 2, 3 and 4% fabrics composite.

4.1 Fractography study

In order to analyze the nature of fracture behavior, internal bonding of composite laminates after mechanical test a micrograph study was necessary. Figure 4(a) shows the SEM of untreated composite laminate, generally fabrics are available in raw materials. Raw fabrics consisting of hemi-cellulose, impurities, dust and other unwanted particles, due the presence of these constituents, there was no proper bonding between the fabrics to the matrix. Which is clearly observed from the figure that could leads to lower the mechanical strength to overcome this, chemical treatment plays a significant role in improving the strength of the fabrics as well as internal adhesion between the fabrics to matrix.

Figure 4(b) shows the SEM of 0.5% treated composite laminate, there was small amount of impurities, hemi-cellulose and other dust/unwanted particles removed as compared with untreated laminates which was observed in the figure, due to this small amount of improvement in the bonding between fabrics to matrix, it was observed that there was less amount of unwanted particles which leads changes in the strength as compared to untreated fabrics. Figure 4(c) shows the SEM of 1% treated composite laminates. From this figure it could be noticed that almost all the unwanted particles were removed from the fabric and the formation of smooth surfaces takes

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place, which leads to enhancing the strength of the composite[19]. Figure 4(d) shows the SEM of 2% treated composite laminate; there was a loose bonding between the fiber bundles and matrix and also fiber damage occurs, which could leads to decrement in the strength. Figure 4(e) and 4(f) shows the SEM of 3% and 4% treated composite, as treatment percentage increases the strength of fabrics decreases, this may be due to peeling or burning of fabric surfaces.

5. Conclusion

The chemical treated plain woven banana fabrics with polyvinyl alcohol are successfully fabricated using hand lay-up technique. Chemical treatment plays a major role in improving the strength and bonding between the fabrics to matrix. Tensile, flexural and impact properties were evaluated as per the ASTM standard, from the results it was concluded that the 1% potassium permanganate (KMnO4) treated composite laminates found better mechanical strength. Tensile strength of 1% treated composite has increased by 68.07%, flexural strength increased by 21.92% and impact strength increased by 66.66% as compared to untreated composite laminates. Increasing the potassium permanganate concentration up to 1% there was proper removal of unwanted and other dust particles which leads to increase the strength of the fabric composite. The percentages of concentration increased above 1%, fiber surface damaged, which may leads to decreasing the mechanical strength of the composites. The nature of fracture behavior, internal bonding and surface modification was observed by scanning electron microscope (SEM) and which also truly support the above phenomenon of increment up to 1% treatment their after decrement in the mechanical properties.

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Accepted manuscript
doi: 10.1680/jemmr.18.00028

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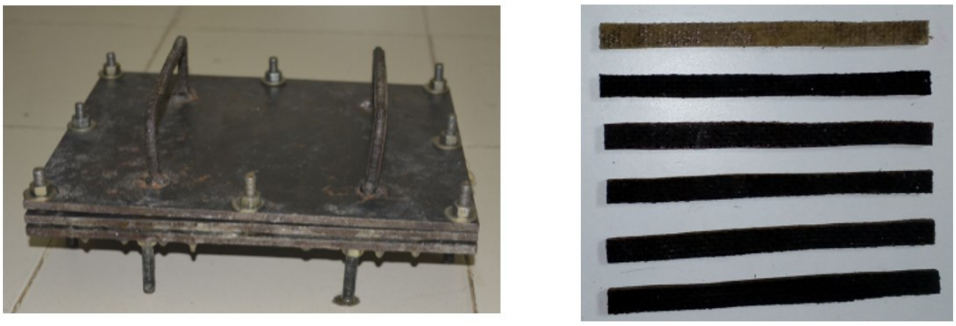
Figure 1. (a) Mold for sample preparation. (b) Prepared Samples after cutting



(a) (b)

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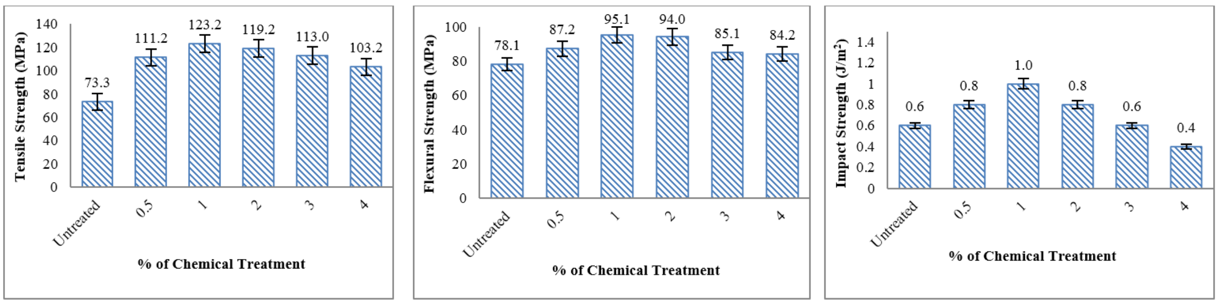
doi: 10.1680/jemmr.18.00028

Figure 2. (a) Fixture with tensile specimen. (b) Fixture with Flexural specimen. (c) Fixture with Impact specimen

(a) (b) (c)

doi: 10.1680/jemmr.18.00028

Figure 3. (a) Tensile strength of composite. (b) Flexural strength of composite. (c) Impact strength of composite



(a) (b) (c)

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doi: 10.1680/jemmr.18.00028

Figure 4. (a) SEM for untreated fabric. (b) SEM for 0.5% treated fabric. (c) SEM for 1% treated fabric. (d) SEM for 2% treated fabric. (e) SEM for 3% treated fabric. (f) SEM for 4% treated fabric