Wear 322-323 (2015) 10–16

Contents lists available at ScienceDirect

Wear

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

Interaction of a non-aqueous solvent system on bamboo, cotton, polyester and their blends: the effect on abrasive wear resistance

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ARTICLE INFO

Article history:
Received 4 June 2014
Received in revised form
20 October 2014
Accepted 22 October 2014
Available online 31 October 2014

Keywords:
Trichloroacetic acid-Methylene chloride modification
Polymer modification
Bamboo
Organic cotton
Polyester
Abrasive wear resistance

ABSTRACT

This article investigates the use of Trichloroacetic acid-Methylene chloride (TCAMC) solvent system with a view to study the abrasive wear resistance of bamboo, cotton, organic cotton, polyester (PES), cotton/bamboo and polyester/cotton blended woven fabrics. The fabrics were treated with different concentrations of 1%, 5% and 10% of TCAMC for 5, 30 and 60 mins at room temperature. Martindale Abrasion Tester was employed to test the abrasive wear resistance of fabrics. The weight loss of fabrics was checked after every 1000 abrasive cycles. The results suggest that the bamboo fabric, without TCAMC treatment, possesses an abrasive wear resistance that is comparable to that of organic cotton fabric. However, cotton/bamboo blend fabric was found to have enhanced abrasion wear resistance than that of 100% bamboo fabric. The results also indicate that the TCAMC treatment enhanced the abrasion wear resistance of 100% bamboo and 100% organic cotton fabrics. The treatment does not influence the wear resistance of 100% cotton and its blends. The abrasive wear resistance of untreated polyester (PES) fabric was tested and compared with cellulosics and it was found that PES possessed higher abrasive wear resistance. However, the abrasive wear resistance of TCAMC treated PES decreased considerably.

1. Introduction

The interest in sustainable and organic natural fibres has increased significantly in the recent years. Among natural fibres, bamboo fibre is considered as more environment friendly because of its quick degradability. Bamboo fibres are lignocellulosic and they are very soft, have higher dye take-up, antimicrobial, require no pesticide during planting and are classed as organic. Bamboo fibres are used in various applications such as textile garments, textile reinforced composites [1–4].They can be blended with a range of synthetic fibres such as polypropylene, polyamide, polyester and polyolefin. Blended yarns and reinforced composites containing bamboo fibres possess enhanced thermo mechanical characteristics, impact resistance, flexural modulus, oxygen permeation, chemical and moisture properties [5]. Although bamboo is an emerging natural fibre, cotton is still dominated for a variety of applications. However, cotton is not considered to be fully environment friendly fibre as it is highly susceptible to infestation. It is reported [6–8] that more than 10% of pesticides (including herbicides, insecticides and defoliants) are used on cotton crops. Organic cotton is fully environmental friendly because it does not involve genetic modification of the seeds or pesticides and chemical fertilisers. Production of organic cotton has superior advantages for the environment but is more expensive than normal cotton due to the increase in production cost and lower efficiency. Due to the economic and efficiency reasons, organic cotton production currently is around 1% of all the normal cotton crops in the world [9–10].

The abrasion and tensile strength of textile fibres depend mainly on molecular structure (crystalline and amorphous regions) and arrangement of molecular chains in fibres. The properties of fibres can be improved either by changing their genetic character or by suitable chemical modification to reorganise fibre structure. Since changing fibre genetics is a time-consuming long-term process, the surface modification by using suitable chemicals is mostly preferred [11]. In addition, the mechanical properties of cotton can also be affected by convolutions, spiral angles, structural reversals, strength of inter-fibrillar bonds and inherent strains. The presence of weak links in cotton fibre, which depends on the growth of cotton, also affects the tensile properties.. It is known that increase in moisture content of cellulosic fibres increases the tensile strength and elongation. Moisture allows the residual stresses present in cotton to relax and hence the increase in tensile property [12]. Among various properties, abrasive wear resistance is considered to be

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http://dx.doi.org/10.1016/j.wear.2014.10.006
0043-1648/

crucial during weaving and for determining the durability of fabrics, apparels and garments. It should be mentioned that cellulose and cellulosic blends influence the abrasive wear resistance. For instance, the abrasive wear resistance of bamboo fibres and their blends with cotton are inferior to that of viscose and their blends with cotton although these fibres are cellulosics [13–16].

It is known that the functional properties of wearable textiles depend on fibre types, polymer molecular structure and fabric structures. It is possible to alter the properties of polymeric materials by solvent-polymer-modification process. One approach that has been explored to a considerable extent is the structural modification of regular polymeric fibres making use of highly interacting solvents. It has been demonstrated that the interacting power of Trichloroacetic acid-methylene chloride (TCAMC) solvent system with Polyethylene terephthalate (PET) is very high and the regent attacks the polymer matrix, disintegrates and finally dissolves out the PET at about 25% (w/v) concentration in 5 minutes at room temperature condition [17–21]. It is expected that at certain lower concentration of TCAMC treatment, the compact structure of PET opens up and as a result, molecular rearrangements may take place. Due to this polymeric change, several physico-chemical properties of the yarn could be modified. Accordingly it can be explained that the solubility parameter of TCAMC reagent is very close to the solubility parameter of PET. It was hypothesised that at certain lower concentrations of TCAMC treatment the compact structure of polyester opens up [17–21]. The effect of TCAMC on cellulosics such as cotton yarns were published elsewhere [11]. It is concluded that the TCAMC reagent modifies the internal structure of the cellulose and consequently this alters the mechanical and physical properties of the fibres. In this article, the influence of TCAMC reagent on fabrics made from bamboo, normal cotton, organic cotton and their blends with polyester are discussed. It is expected that the action of the TCAMC reagent on bamboo and cotton would not be the same because the bamboo, being a bast fibre, contains not only pure cellulose but also significant amount of non-cellulosic constituents that include lignin. This significantly affects the abrasive wear resistance of materials. It should be stressed that the change in wear resistance of fabrics due to TCAMC treatment has been thoroughly investigated but the effect of the reagent on pilling has not been studied although abrasive wear leads to pilling.

2. Experimental

2.1. Materials

Plain woven fabrics that possess the following dimensional properties (Table 1) were procured in the UK.

2.2. TCAMC treatment

The laboratory grade Trichloroacetic acid ($CCl_3.COOH$), Methylene chloride ($CH_2.Cl_2$), and Acetone ($CH_3.CO.CH_3$) were used for treating the fabrics. To prepare the reagent, desired amount of trichloroacetic acid is weighed and added into 100 ml of methylene chloride. For example, 1% concentration is prepared by mixing 1 g of trichloroacetic acid with 100 ml of methylene chloride. The fabric specimens of 100 mm × 100 mm were prepared and weighed. Pre-treatment of these fabrics with reagent was carried out in a specially made closed trough at room temperature (20°C). The fabric specimens were immersed in the reagent of desired concentrations of 1%, 5% and 10% (w/v) for 5, 30, and 60 min durations. The fabrics to solvent ratio were maintained at 1:100 and the contents were shaken manually at regular intervals to ensure uniform treatment. After the treatment, the specimens were rinsed with pure methylene chloride followed by acetone to remove any adhering reagent on the fabrics. The treated fabrics were squeezed and air dried at atmospheric condition, taking advantage of the quick evaporation of acetone at room temperature [22].

2.3. Abrasive test specimen preparation and testing

The test was performed using Martindale Abrasion Tester (James Heal Abrasive Cloth SM25) (Fig. 1) in accordance with EN ISO 12947-2:198. Standard wool abradant fabrics were used which is plain weave with warp 17 yarns/cm and weft 13 yarns/cm. The abradant was kept same for each sample but the new abradant was used for every new sample. The abrasion test was carried out at five replicates for each sample. Before testing, the fabrics were conditioned for 24 hours at atmospheric conditions of 20 °C and 65% RH. The abrasive wear test determines the resistance to abrasion of textile fabrics. The measurement of the resistance to abrasion of textile fabrics relies on several parameters such as the mechanical properties of the fibres, the dimensions of the fibres, the structure of the yarns, the construction of the fabrics, the type and kind of finishing [22–23].

Firstly the treated and untreated fabrics specimens were cut into circular specimens of 38 mm diameter using a press cutter and placed on the specimen holder. The test was performed at a pressure of 9 kPa and during that time the machine speed was maintained at 50 rubs per minute. After every 1000 rubs, samples were weighed to determine the weight loss due to abrasion. The frequency at which the test was stopped at every 1000 rubs has been optimised from previous experience by utilising similar fabrics on Martindale Abrasion Tester. The endpoint was determined by a

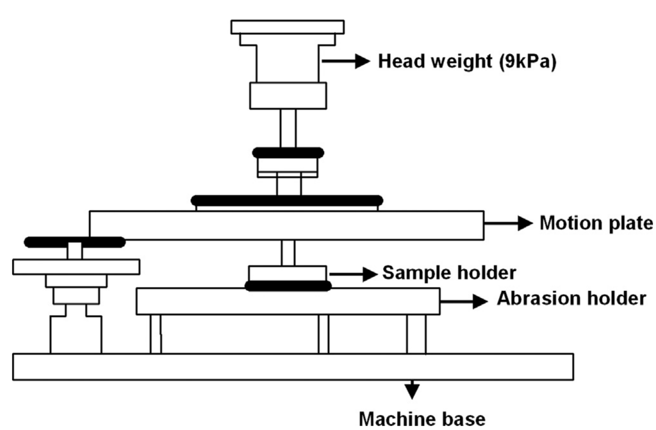

Fig. 1. Martindale abrasion tester.

Table 1
Fabric properties.

Fabrics	100% Bamboo	100% Cotton	100%Organic Cotton	100% Polyester	70% Bamboo 30% Cotton	65%Polyester 35%Cotton
Weight (g/m^2)	177.56	160.94	157.72	213.92	199.23	200.15
Height (mm)	0.20	0.45	0.35	0.45	0.25	0.15
Bulk density (g/m^3)	0.888	0.358	0.451	0.856	0.443	1.334