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STUDIES ON GEOMETRICAL, PERFORMANCE AND COMFORT PROPERTIES OF BAMBOO AND BAMBOO BLENDED FABRICS.

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Abstract

Bamboo fibres are a new kind of regenerated fibres introduced in to the textile field due to some of their unique properties. Bamboo belongs to bast fibres produced from bamboo pulp similar to viscose rayon. Bamboo as a raw material is remarkably sustainable and versatile and the bamboo fibres are often labeled as, biodegradable, eco-friendly antibacterial, antimicrobial, with good UV blocking properties.

In the present work bamboo and bamboo and blended fabrics were produced using five different set of yarns viz: bamboo/cotton (65:35), bamboo /polyester (65:35), 100% bamboo, 100% cotton and 100% polyester. The physical parameters of yarns viz., strength, CSP, RKM (gms/tex), breaking extension (%), U%, CV%, thick places, etc., were analyzed. It was found that 100% polyester yarns have higher RKM and high CSP and 100% cotton yarns has lowest RKM and CSP. The yarns produced from 100% bamboo are stronger than 100% cotton but weaker than 100% polyester. Tensile properties of blended yarns lie almost in between 100% polyester, 100% cotton and 100% bamboo viscose yarns. The Five varieties of yarn samples were woven on sample loom of model CCI SEDIT 2, single rigid rapier loom running with a speed of 60 picks/minutes. Geometrical, performance and comfort properties of all the fabrics were evaluated at standard testing atmospheric conditions as per ASTM standards. From the results of performance properties, 100% polyester fabrics shows the higher tensile, tearing and bursting strength values compared to other four varieties of fabrics. The 100% polyester fabric also shows good abrasion resistance, good pilling performance, crease recovery & flame retardance characteristics. Bamboo fabric shows better tensile, tearing, bursting strength, abrasion resistance, pilling, crease recovery and flame retardant characteristics compared to cotton fabric. Cotton fabric shows lower tensile, tearing & bursting strength Abrasion resistance & pilling performance characteristics of bamboo fabrics are better than 100% cotton fabrics.

Key words: Bamboo, Bamboo blended fabrics, performance properties

Introduction

With the growing demand in the recent years for more comfortable, healthier and environmental friendly products, the research activities in textile Industry have focused on the utilization of renewable and bio-degradable resources and environmentally sound manufacturing processes [1]. In the beginning of 21st century environment conservation regulations have given lot of importance to the natural materials [2]. Now a days people's life standard is getting higher and demanding for new generation textile materials with improved properties which are required for higher comfort or industrial use. The environmental regulations when developing new fibres are strict and stringent than before & the popular petroleum based synthetic fibres do not meet the criteria because they are ecologically unfriendly. Important synthetic fibres e.g. polyester, polypropylene and poly-acrylic etc. are hazardous to the environment. The problems with synthetic polymers are that they are non-degradable and non-renewable. Recent evidences proved that the polyester is most frequently used among all fibres, taking over from cotton. The fossil fuels like oil and petroleum are non-renewable and with this rate of consumption they are expected to last for another 55-60 years [3].

Bamboo is a perennial evergreen plant belongs to grass family. It is a fastest growing plant and reaches nearly 119cm height in 24 hours and it is a rich renewable resource for developing many useful products. Probably bamboo is the world's most sustainable resource and abundantly available. Bamboo does not require fertilizers and pesticides and no doubt growing bamboo is significantly beneficial to the environment [5]

Bamboo comprises over 1500 species including 87 genera worldwide and its rhizome structure is responsible for its rapid growth. Bamboo grows naturally in all continents except Europe and not evenly distributed in humid, tropical, subtropical and temperate regions [6]. China is the largest producer of bamboo products in the world. India is the second largest country in the world next to china with high diversity of bamboo products. In India nearly 18 genera & 136 species are grown and cover about 8.96 million hectares of land including forest, homesteads and private plantations which accounts nearly half of the total bamboo cultivation in Asia.

Twenty first century is an era seeking environment protection and bamboo is one such kind of new green environmental friendly natural fibre recently entered the market. Bamboo regenerated cellulose fibre known as bamboo viscose recently entered the market for apparel, home furnishing, sanitary pads and medical applications such as mask,

bandage cloth, surgical cloths and gowns [7]. Its unique properties such as antibacterial, wearability, moisture absorption, ventilation, excellent comfort, quick drying etc, made the bamboo fabrics more attractive and useful in many textile applications. Bamboo fibre is also called as breathing fibre as it absorbs sweat quickly and evaporates and wearer feels more comfortable. Objective of the present work was to produce bamboo/cotton (65:35), bamboo/polyester (65:35), 100% bamboo, 100% cotton and 100% polyester fabrics and determination of their geometrical, performance, comfort and low stress mechanical properties.

Brief details on bamboo, cotton and polyester fibres.

a. Bamboo viscose fibre

Bamboo viscose fibre is a regenerated cellulosic fibre obtained from bamboo plant which is rich and renewable. Bamboo viscose fibres obtained from phyllostachys hetero cycla pubescence a species popularly known as moso bamboo was chosen for the study. The high moisture absorption capacity, breathability and fast drying behaviour due to its unique micro structure, bamboo fibres ensures good comfort in various applications[1].

b. Cotton

Cotton is the oldest and most important natural cellulosic fibre and it accounts nearly for about 50% of the total fibre production of the world. Cotton is the purest form of the cellulose [14]. Cotton is the most popular and widely used natural cellulosic fibre in apparel and home furnishing due to its several advantages such as moisture absorption and comfort and anti allergic properties.

c. Polyester

Polyester is the important leading man-made fibre in production volume and popular due to its versatility alone or as a blended fibre in textile products. It is used in woven, knitted, home furnishing and industrial applications. Polyester fibres are usually smooth and rod like with round or trilobal cross section. The fibre is extremely strong, relatively stiff and possesses excellent resiliency and recovery from bending deformation and quite hydrophobic[14].

Experimental

Materials

Materials used for the present study were bamboo, cotton and polyester fibres. Brahma cotton of fibre of 32mm staple length & strength of 2.4gpd was procured from Sri. Anjaneya Cotton mills Davangere, bamboo fibres of staple length 35mm and fibre strength of 1.5gpd from Gokak Mills Limited, Gokak, Belagavi, Karnataka, and polyester

fibres of 36mm and fibre strength of 4gpd from Reliance Industries Limited, Patalaganga, Mumbai, Maharashtra

Bamboo, cotton and polyester fibres were processed on conventional Laxmi Reiter spinning line to produce following five varities of yarns. The fibres were opened thoroughly and blended homogenously to produce the following required set of yarns.

Testing of yarns

Tensile properties of yarn

a. Lea strength

Lea strength tester works on the principle of constant rate of extension (CRE). The machine is designed on the pendulum lever principle and the force applied is directly proportional to $\sin\theta$ of the deflection of the angle of the weight lever. The Lea strength of all five varieties was evaluated using Eureka Lea strength tester as per ASTMD 1578 standards. Twenty readings were taken and their mean was calculated

b. Count Strength Product (CSP): CSP (count strength product) of the yarns was found out by determining the product of lea strength in lbs and count of yarn in Ne.

c. Tensile Strength of Single Yarn. (Rupture kilometer)

In this experiment Hounse field Universal Testing Machine was used to determine the yarn tenacity and breaking elongation. The instrument works on the CRE principle a yarn specimen of length 500 mm is clamped between the movable upper jaw & a fixed lower jaw. The cross head speed can be varied 50-500mm/min and the maximum capacity of the machine is 500kg. Ten readings were taken and the mean was calculated as per ASTMD- 5035-90 procedure.

d. Yarn evenness testing

The Uster Evenness Tester gives an output of the unevenness (U %) of the test strands of sliver, rovings and the imperfections in yarn.

The instrument works on the capacitance principle. The textile strand is passed through a parallel plate capacitor. U %, CV%, Relative count, evenness, total imperfections, neps were analyzed on USTER Evenness tester (UT-3) in Saranya Spinning Mills Limited, Coimbatore. The testing of all yarns was carried out in standard testing atmospheric conditions.

Production of fabrics

Five varieties of yarn samples were woven on sample loom of model CCI SEDIT 2, single rigid rapier loom running with a speed of 60 picks/minutes. The loom consists of 20 heald frames, pneumatic shedding, and positive electronic let-off and take-off with electronic dobby. The loom had reed width of 25" and the maximum length of the fabric

which could be produced was 2.75mts. The bamboo and bamboo blended plain fabrics were produced on the above loom. Geometrical, performance and comfort properties of bamboo/cotton, bamboo /polyester, 100% bamboo, 100% cotton and 100% polyester blended fabrics were evaluated in the laboratory at standard testing atmospheric conditions following ASTM standards.

Testing of fabrics

a. Yarn Count

The warp and weft yarn count was found out using Beasley's balance. This apparatus can be used to determine the yarn count in cotton, worsted and woollen system as per BS 2010 standards. Ten readings were taken and the mean was calculated

b. Cover factor

For woven fabric two cover factors are considered i.e. warp cover factors and weft cover factor. In cotton system the cover factor is the ratio of the number of threads/inch to the square root of the cotton yarn count. The cloth cover factor is calculated by adding the warp cover factor and weft cover factor.

$$\text{Cover Factor} = n/\sqrt{N}$$

Where n=threads/inch , N = cotton count,

Cloth cover factor was calculated using the formula

$$K_1 + K_2 - \left(\frac{K_1 \times K_2}{28}\right)$$

c. Tensile strength

The tensile strength of all the five varieties of fabrics was tested on AMIL Universal Tensile Strength Testing Instrument as per ASTM (D-5035-90) standards. The instrument works on CRE principle, gauge length used was 20 cm and a cross head speed was of 200m/min.

d. Tearing strength

Tearing strength of the bamboo and bamboo blended fabrics were tested using Elmendorf Tearing Strength Tester as per ASTM D 142496 RG-04 standards. The fabric specimen is cut according to the template size and the force required to tear the fabric was noted down. Five readings were taken and the mean was found out.

e. Bursting strength

The following fabric samples were tested on MAG digi bursting strength tester as per ASTM D-3786 standards. Test specimen of size was 30.5 mm diameter and the

capacity of the machine was 3-70kg/cm^2.. Five readings were taken out and their mean was found out.

f. Abrasion Resistance

. Abrasion resistance of bamboo and bamboo blended fabrics was found using Martindale Abrasion Resistance Tester as per ASTM (D-3884-01E01) standards. The samples were cut according to the template size & abraded against a rough surface multi-directionally and difference between initial weight & final weight of the sample was measured. Five readings were taken and their mean was found out.

g. Pilling Test

The pilling tendency of bamboo and bamboo blended fabrics were found out using I.C.I Pilling tester as per ASTM (D-3512-05) standards. The samples were cut to the size of 5" x 5" and stitched to a rubber tube of 6" long and 1 l/4" outside diameter and 1/8" thick. . The extent of pilling was assessed visually, by comparing with pilling arbitrary standards (1 to 5) and the samples were rated accordingly.

h. Crease Recovery

The fabrics were tested for warp and weft crease recovery using Eureka Crease Recovery Tester as per ASTMD 1296 standards. The samples were cut with size of 2" x 1" in warp way and weft way. The tests were conducted both in warp and weft way direction and five readings were taken and the average was found. Fabric crease recovery angle was found out by adding warp and weft crease recovery angles.

i. Flammability

The flammability of bamboo and bamboo blended fabrics were tested on Paramount Flammability Tester as per ASTM D1230-94R01 standards. The fabric samples were conditioned in a standard atmosphere for 24 hours. The fabric sample was cut according to a standard size i.e. 50 × 150 mm and then fixed into sample holder firmly. After the completion of the burning of the fabric, the stop motion device stops the instrument due to the thread break by flame and stop motion device gets sensed and the time taken in seconds to burn the fabric was noted down. Five readings were taken and the mean was noted down.

j. Fabric Stiffness

Bending length flexural rigidity (G), bending modulus (q) was measured using Eureka Bending Tester as per ASTM 1388 - 96 RG02 standards. A rectangular strip of fabric (6" × 1"size) was mounted on a horizontal platform and slide until the fabric over hangs like a cantilever. Bending length was measured for five samples and average was found. From these values bending length, flexural rigidity (G) and bending modulus (q)

was found using the following formula. Five readings were taken and the mean was found out. Flexural rigidity, $G = M \times C^3 \times 10^3$ mg-cm

M = GSM of fabric, C = bending length in mm

k. Drape Coefficient

The Eureka Drape Tester was used to measure the drape co-efficient as per BS 5058 standards. A sample size of 30 cm diameter was taken and the drape co-efficient of all the five varieties of bamboo and bamboo blended fabrics was calculated using the standard procedure. Five readings for each sample were taken and their mean was calculated.

l. Air Permeability

The air permeability of the fabric samples were tested using paramount air permeability tester as per ASTM D0737-04 standards. The fabrics were conditioned in standard testing atmosphere for 24 hours. For thick and dense fabric 10 cm dia and for light weight fabrics 4 cm dia rings were used. The suction was started to force the air through the fabric and the rate of flow of air was adjusted till pressure drops off 1cm water head across the fabric is indicated.

m. Moisture content and moisture regain

The moisture content and regain of fabrics were measured using Eureka moisture oven as per BS 4784 standards. Moisture content is the ratio between the weights of water present in the fabric with the total weight of the material expressed in percentage. Moisture regain is the ratio between the weights of water with the oven dry weight of the material expressed in percentage.

The moisture regain and moisture content were found out using the following formulae.

(i) Moisture regain $R = \frac{W}{D} \times 100$

(ii) Moisture content $M = \frac{W}{D+W} \times 100$

Where, R – Moisture regain, W – Amount of water

D – Oven dry weight, M – Moisture content.

n. Spray test .

A test specimen of 180mm square was held taut over a 150mm diameter embroidery hoop which was mounted at 45˚ to the horizontal. A funnel which was fitted with a standard nozzle containing 19 holes of a specified diameter was held 150mm above the fabric surface. Distilled water of 20℃ was poured into the funnel to give a continuous shower onto the fabric. After the water spray had finished, the hoop and specimen were

removed and tapped twice gently against a solid object on opposite points of the frame and the fabric was kept horizontal. This removes any large drops of water. Then the fabric was assigned with spray ratings comparing with the AATCC photographic standards.

Results and Discussion

Physical properties of Bamboo and bamboo blended yarns

The physical properties of all the five varieties of yarns viz: Count, TPI, TM, Lea strength (lbs), CSP, RKM (gms/tex), Breaking extension (%), U%, CV%, thick places thin places, Neps, TI and hairiness index values are presented in the **Table. 1**

Table .1 Physical Properties of Yarns

Physical Parameters	Bamboo/cotton (65:35)	Bamboo/polyester (65:35)	100% Bamboo	100% Cotton	100% Polyester
Nominal count (Ne)	30	30^s	30^s	30^s	30^s
Actual count (Ne)	29.2	30.02	29.95	29.86	30.05
TPI (twist/inch)	22.8	22.15	22.4	23.5	22.5
TM (twist multiplier)	4.22	3.91	4.22	4.30	4.10
Lea Strength (lbs)	84.10	94.10	88.1	78.7	104.9
CSP	2456	2842	2638	2349	3152
RKM (gms/tex)	16.2	18.5	17.5	16.5	23.5
Breaking extension (%)	9.8	15.7	13.2	5.3	19.5
U%	11	9.8	9.8	12.56	8.5
CV%	15.7	12.9	12.8	16.4	11.6
Thick places +50%	220	86	130	285	55
Thin places - 50%	20	16	17	22	14
Neps +200%	286	143	185	345	88
T I total imperfections	526	245	332	652	157
H I (hairiness index)	5.8	4.30	5.2	6.3	4.27

100% polyester yarns are stronger (23.5 gms/tex) and possesses good uniformity ratio, lower coefficient of variation, and less imperfections and hairiness (8.5, 11.6, 157 and 4.27 respectively) compared to 100% cotton (12.56, 16.4, 652 and 6.3 respectively) and 100% bamboo yarns (9.8, 12.8,332 and 5.2 respectively). The bamboo yarns are stronger (17.5gms/tex) than cotton (16.5gms/tex) and weaker than polyester (23.5 gms/tex). Tensile properties of bamboo, cotton and polyester blended yarns lie almost in between 100% polyester and 100% cotton yarns.

When mechanical properties of all the yarns were compared it was found that 100% polyester yarns have high RKM (23.5) and high CSP (3152) and 100% cotton yarn has lowest RKM (16.5) and CSP (2349). As polyester fibres are having higher tenacity (4.0gpd), the yarns produced from polyester fibres are stronger. As cotton fibres are weaker (2.4 gpd) compared to polyester and bamboo fibres and the yarns produced from the constituent fibres are also weaker. The yarns produced from 100% bamboo (RKM 17.5, and CSP 2638) are stronger than 100% cotton but weaker than 100% polyester. Tensile properties of blended yarns lie almost in between 100% polyester and 100% cotton yarns.

Uniformity ratio (U%), coefficient of variation (CV%) and total imperfections of polyester yarn (U% 8.5, CV 11.6 and TI 157) are least and 100% cotton yarns are maximum (U% 12.56, CV% 16.4, TI 652). 100% bamboo yarns also show lower U%, CV% and TI, (U% 9.8, CV%12.8, TI 332). This is due to the fact that the yarns produced from 100% Bamboo and 100% polyester are from cut staple fibres of uniform length and fineness. Hence irregularities in the resulting yarn is lower compared to 100% cotton yarns which are inherently less uniform with respect to fibre length and fibre fineness.

Hairiness index of 100% polyester and bamboo/polyester yarns is 4.27 and 5.8 respectively and it is found to be less than yarns made from 100% cotton and bamboo/cotton(65:35) blended yarns (6.3 and 5.8 respectively). This may be due to better packing of polyester and bamboo fibres in the yarns cross section compared to cotton fibres.

Table.2 Mechanical and Comfort properties

Sample / Fabric Specification	Bamboo/ Cotton	Bamboo/ Polyester	100% Bamboo	100% Cotton	100% polyester
Tensile strength (kgs)	55	82.5	70	30	87.5
Tearing strength (gms)	2400	2455	2416	1568	2560
Bursting Strength (Kg/cm^2)	9.82	17.65	13.38	7.9	20.1
Abrasion Resistance (wt. loss %)	3.4	2.8	3.0	4.0	1.2
Pilling	3	3	4	3	5
Crease Recovery (deg.) (Warf + Weft)	160	185	153	165	224
Flammability (seconds)	12.2	13.5	12.2	9.5	14.04
Fabric Stiffness (mg-cm)	74.64	64.12	37.44	109	138.46
Drape Coefficient	0.56	0.52	0.53	0.60	0.54
Air permeability (cc)	14.1	13.5	14.6	13.04	12.77
Moisture Regain (%)	11.1	7.8	12.1	7.5	0.45
Moisture Content (%)	9.9	7.23	10.79	9.11	0.447
Spray Test	0	50	0	0	50

The geometrical, performance and comfort properties of bamboo and bamboo blended fabrics were analyzed. From the results of performance properties the 100% polyester fabrics shows the higher tensile, tearing and bursting strength (87.5kg, 2560g and 20.1kg/cm^2 respectively) compared to other four varieties of fabrics. 100% polyester fabric also shows good abrasion resistance, good pilling performance, crease recovery & flame retardance (wt loss of 1.2%, pilling rating of 5.0, 224^0 and 14.04 sec respectively) characteristics. The reason is polyester fibres & yarns are stronger & the constituent fabrics are also stronger. Bamboo fabric shows better tensile, tearing, bursting strength, abrasion

resistance, pilling, crease recovery and flame retardant characteristics (70kg, 2416g, 13.38kg/cm^2, wt loss of 4%, pilling rating of 3, 153^0 and 12.2sec) compared to cotton fabric. Cotton fabric shows lower tensile, tearing & bursting strength (30kg, 1568g and 7.90 kg/cm^2). Abrasion resistance & pilling performance characteristics of bamboo fabrics are better than 100% cotton fabrics. From the results of crease recovery test bamboo & cotton fabrics shows moderate crease resistance whereas polyester fabric shows very good crease resistance compared to bamboo & cotton.

From the results of fabric comfort properties such as fabric stiffness, drape, air permeability, moisture properties and spray test 100% bamboo fabric shows good flexibility (37.44, mg-cm 0.53,13.10cc,12.10&10.79 %) and spray rating of 0.0 respectively) & the cotton fabrics are stiffer & exhibits higher flexural rigidity (109 mg-cm) and the cotton fabric shows slightly higher drape coefficient (0.60).

From the results & discussion it can be predicted that the bamboo and bamboo blended fabrics can be used for apparel purpose.

Conclusions

Physical and mechanical properties of all the five different yarns were found out. The geometrical, performance and comfort properties of bamboo and bamboo blended fabrics were evaluated using standard procedures.

From the tensile properties of yarn it was observed that the polyester yarns shows high RKM (23.5) and high CSP (3152) and the cotton yarns shows an lowest RKM (16.5) and CSP (2349). The yarn produced form the bamboo fibres shows RKM of (17.5) and CSP (2638). Tensile properties of bamboo/cotton and bamboo/polyester blended yarns lies almost inbetween 100%polyester and 100% cotton yarns. The reason is polyester fibres are having higher tenacity and the yarns produced from polyester fibres are stronger and the cotton fibres are weaker compared to polyester and bamboo fibres and the constituent yarns are also weaker.

Yarn evenness related properties of polyester and bamboo viscose reveals values of U%:8.5%, CV%:11.6 and TI 157. The 100% bamboo yarns shows lower U%:9.8%, CV%:12.8 and TI:332. The reason is, the yarns are produced from cut staple fibre of uniform length and fineness hence irregularities in the resulting yarn is lower compared to yarn produced from 100% cotton fibre which are inherently less uniform with respect to fibre length and fibre fineness. Hairiness index (HI) of polyester and bamboo/polyester yarns is 5.28 and 4.30 respectively and it is found to be less than yarns made from 100%

cotton and bamboo/cotton which is 6.3 and 5.8 respectively. This is due to the better packing of polyester and bamboo fibres in the yarn cross section compared to cotton fibers.

From the results of geometrical parameters of bamboo blended fabrics it was observed that there was no major difference in the geometrical parameters of fabrics. From the results of fabric performance properties it was observed that polyester fabrics shows higher tensile and tearing strength (87.5kg, and 2659 gms respectively) whereas cotton fabric shows lower tensile and tearing strength (30kg and 1658gms respectively) whereas bamboo fabric shows moderate tensile and tearing strength (70kg and 2416gms respectively). Polyester fabrics shows higher bursting strength (20.1kg/cm^2) compared to bamboo, cotton and other blended fabrics. The reason is that the polyester is stronger and flexible compared to cotton and bamboo. Polyester fabrics shows good abrasion resistance, crease recovery and flame retardant characteristics whereas bamboo fabrics shows better abrasion resistance, pilling rating, crease recovery, flame retardant characteristics compared to cotton fabrics. From the results of comfort properties bamboo fabrics shows good flexibility, low drape coefficient, good air permeability and moisture absorption characteristics.

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