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RESEARCH

Mechanical and Tribological Behavior of Woven Sisal Fabric

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A B S T R A C T

A study has been carried out to investigate the Mechanical and Tribological Properties of Woven Sisal Fabric. Two Plain fabrics were prepared by changing gram per unit area (GSM), and one weft rib fabric is prepared to understand the effect of woven structure on mechanical and wear properties. These fabrics textile properties were determined as per textile ASTM standards. The tensile properties of these fabrics were studied in both warp and weft directions. Further, pilling resistance, abrasion resistance and wear properties of these fabrics were studied using L_{27} Taguchi Orthogonal Array. The tensile properties were found to be better in weft direction as compared to warp direction in all type of fabrics. The pilling resistances were found better in weft rib fabrics. The abrasion resistance is exhibited better at higher GSM. From the results, it also reveals that higher the crimp value more the resistance against adhesion wear using Pin on disk method. More the yarn linear density more the resistance for adhesion wear. However, the wear load, woven pattern and traveling distance have a significant impact on weight loss and frictional force.

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1. INTRODUCTION

Nowadays the world is moving towards eco-friendly reinforcement in composites and products for their regular usage. The woven fabrics attract researchers due to their ease of processing during the fabrication of composites with improved mechanical properties. The woven fabrics covers many of the industrial applications including apparels, safety belts and nets, airbags, seat covers, textile-reinforced concrete, fiber and textile-based bridging cables and elements, erosion and landslide protection systems, textile reinforcement of dykes and other water management systems, fiber-based light, flexible and durable piping and canalization, performance fiber-based textiles used in balloons, parachutes, sails, nets and ropes, aircraft wing and body structures or boat rumps made of fiber and textile-based composites, inflatable components of satellites or other spacecraft, composites are underway or expected in the near future across all transportation system fields [1-4]. In these applications fabrics are subjected to axial, tearing, wear and bursting loading conditions. Beata et al. studied tearing strength of cotton blends with synthetic fibers under static and dynamic loading conditions and observed that weft direction having better tear strength than warp [5]. These woven fabrics were used to prepare composites using various polymers. Rajasekar et al. worked on bridging fiber on mode I interlaminar fracture toughness of carbon aramid epoxy intra-ply hybrid laminate and found that it has more effective fracture resistance [6]. Feyzullahoglu studied the effect of filler on adhesion wear of woven fiber reinforced polyester composite and found that polymethylmethylacrylate (PMMA) filled samples exhibited most volume loss and Glass beads (GB) filled composite exhibited less volume loss [7]. Balogun et al. worked on Mannii Fiber Polypropylene Matrix Composites and found that with chemical treatment mechanical properties improved [8]. Besnea et al. worked on wear behavior of polyphenylene sulfide composite with glass/carbon reinforcement and observed that the particles of graphite and Polytetrafluoroethylene (PTFE) produce the decrease in friction between the contacting surfaces [9]. Alshammari et al. studied the influence of woven jute fiber orientation on Tribological properties and Wear resistance of the composites and found to be better in the antiparallel orientation followed by parallel and then normal [10]. Udaya Kumar et al. studied Mechanical and Tribological properties of Vinyl Ester alkali-treated coir fibers, silanated aramid fibers Composites and found that hybrid composite possess better mechanical and wear properties [11]. Some of the researchers observed the mechanical properties of woven banana polyvinyl alcohol [12] composites and found that mechanical properties improved by treatment and weaving [13]. Spiridon investigated compaction and bending variability of 3D composite textile and observed that fabrics are subjected to maximum shearing loads at 90^0 during bending [14]. Jin et al. worked on the effect of natural fiber nonwoven mats reinforcement of bio-composites. In nonwoven composite tearing of fiber plays a major role [15]. Sathishkumar et al. studied the mechanical properties of snake grass fiber composite and Scanning Electron Microscopy fractured fiber micro image analysis has revealed that fibers fail due to tear loading [16]. Panayiotis et al. studied that flexural behavior of flax reinforced unidirectional composites and found that unidirectional composites also subjected to tearing loads [17]. Arjmandi et al. studied the Wear of 3D woven fabric using simulation tool UMESHMOTION and ABAQUS [18,19]. Anand Chelliah worked on abrasion wear of basalt woven fabric and found that by increasing filler Titanium Carbide weight loss was decreases [20].

1.1 Purpose of the study

From literature, it is clear that, the fabric in composite resisting tensile loads than the matrix materials. But, the properties of the fabrics studied and reported were found to be very limited in the literature. Hence, there is a need to study and analyze the role of fabric material in enhancing composite properties. In that view, this paper focuses on the study of mechanical and Tribological properties of fabrics.

Further, the textile properties like yarn linear density, yarn crimp, cover factor influence the tensile properties and wear properties. Initially the pilling resistance, abrasion resistance were analyzed. The effect of adhesion wear was analyzed on the woven pattern, loading direction of fabric (warp, weft and 45° to warp and weft), speed, load, distance traveled using a pin on disk adhesive wear testing machine.

2. MATERIALS AND METHODS

2.1 Materials

Sisal fibers extracted from plants in the southern part of Karnataka, India. These sisal fibers were used to prepare two plain and one weft rib in M/s. OM Textile Industries, Bengaluru, India. The sisal fibers have been extracted from the leaves of the same plantation to get similar properties of all fibers. These fibers are sun-dried for seven days and washed for several trials using freshwater and further sun-dried for four days under normal climatic conditions. The extracted fibers were converted into yarn, and these yarns were then converted into fabric by the hand-weaving process. The schematic diagram of plain-woven and weft rib fabric structures are shown in Fig. 1. However, weft rib also comes under the category of plain woven, but two weft yarns were crossed with one warp yarns. Three sisal woven fabrics are designated as Plain 1 (P1), Plain 2 (P2) and weft rib (WR). Fig. 2 shows the actual picture of P1, P2 and WR woven sisal fabrics for the study.

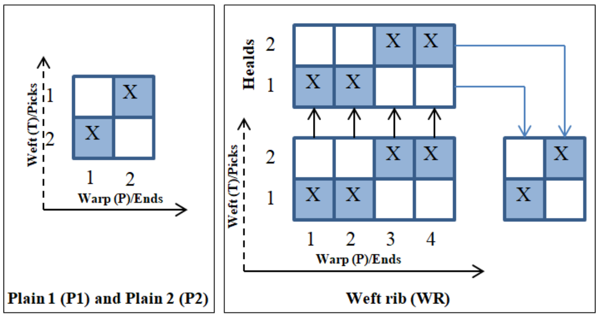

Fig. 1. The textile schematic design of plain and weft rib weave fabric structure and cross-section views.

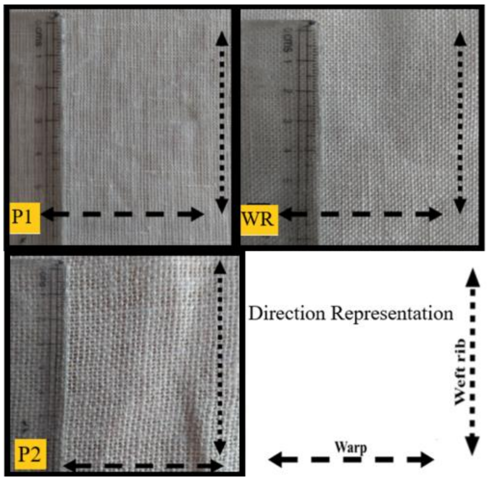

Fig. 2. Woven sisal fabric used for this work.

Woven sisal fabrics were characterized through physical properties like the weight of fabric (mass per unit area), thickness, fabric density or fabric count. The sisal yarns were characterized for its yarn size (linear density) and crimp (for warp and weft). Textile standards used to characterize all the three woven sisal fabrics, at Department of Fashion and Apparel Design, Acharya Institute, Bengaluru and Central Silk Technological Research Institute, Bengaluru.

2.2 Characterization of yarn

Yarn fabric cut into 1 m length and it was weighed using a digital weighing balance. Yarn linear density was measured according to ASTM D1907 in tex. The yarn length was measured in the fabric (Length of yarn in the fabric - Y1) from measuring scale, then yarns are unraveled from the fabric and measured the length of the yarn without exerting extreme force - Y2 (known as yarn crimp). The yarn crimp measured according to ASTM D3883. The yarn crimp, C, was calculated using the relation.

$$\text{Yarn crimp (C) in \%} = \left[\frac{(Y_2 - Y_1)}{Y_1} \right] \times 100$$

2.3 Characterization of fabric

The yarn spacing refers to the compactness of fabric/fabric density and it is measured according to ASTM D3775. The fabric weight was measured in GSM and fabric thickness was measured using Askhi fabric thickness indicator which was having least count of 0.01 mm according to ASTM D1777. These properties for three different fabrics have been measured and given in Table 1.

The influence of these physical properties on mechanical properties of the fabric is explained in detail in Section 3. Tensile properties of the fabric are determined by the Universal Testing Machine (Instron 3360) according to IS 1969 - 1985. The samples are fixed such a way that load was equally distributed on each yarn by maintaining gauge length of 200 mm, and width 50 mm, crosshead speed 3 mm/min.

2.4 Pilling resistance

Pilling is a state that arises in wear due to the formation of small 'pills' of entangled fiber clinging to the fabric surface giving it an unattractive appearance at the outer shell. Pills are formed by a rubbing action on loose fibers which are present on the fabric surface. Fiber propensity to surface fuzzing and pilling measured by ICI Box method, Place the fabric with its longer edges along the weft direction/warp direction facing downward on a plain surface according to IS 10971 –1984 of 125X125 mm. Each fabric sliding against with rubber tube under even tension having Shore A hardness of 55 to 60. The pilling resistances were measured for 18000 revolutions. Sisal fabrics were taken out from the pilling box and compared them with the photograph rating standards of 110 X 95 mm in size, numbered as 1 to 5 showing varying degrees of pilling from very severe pilling to no pilling. Pilling resistance of 4 to 5 rating, 4 rating slight pilling (slight surface fuzzing) and 5 no pilling (no visual change).

Table 1. Textile properties of different fabrics.

Sl. No	Woven type	Fabric thickness (mm)	GSM (g/m²)	Cover factor (%)		Yarn Count (Tex)		Yarn crimp (%)		Number of yarns per cm	
				Warp (**P**)	Weft (**T**)	Warp (**P**)	Weft (**T**)	Warp (**P**)	Weft (**T**)	Warp (**P**)	Weft (**T**)
1	**Plain 1**	0.42	161.02 ±0.17	79.18 ±0.46	91.78 ±0.69	80.1 ±0.56	85.1 ±1.67	7.23 ±0.26	9.54 ±1.12	18 ±0.95	20 ±1.06
2	**Plain 2**	0.73	296.60 ±1.75	74.28 ±2.80	80.24 ±3.75	182.3 ±4.43	166.8 ±8.41	6.53 ±0.97	11.06 ±1.09	12 ±0.74	12 ±0.67
3	**Weft rib**	0.72	300.45 ±1.67	82.12 ±3.09	53.01 ±3.06	65.3 ±2.51	182.9 ±4.04	10.05 ±0.94	5.96 ±1.22	22 ±1.03	11 ±1.05

Note: Standard deviations are in (±) for 10 trials.

2.5 Rotary abrasion resistance

Abrasion resistance was measured according to IS 12673 -1989 or Martindale method – specimen break off. The abrasion resistance of circular specimens of 38 mm diameter fabric is abraded of zero emery paper under 30 g/cm² pressure on an apparatus giving a motion which is the resultant of two simple harmonic motions at right angles to each other; the resistance to abrasion is estimated by two threads starts breakage, The number of rubs required before breakage was recorded.

2.6 Dry sliding wear test

Pin on disk (M/s Ducom Instruments Pvt Ltd, Bengaluru, India) wear testing machine is used to study the wear behavior of fabric, the test is conducted according to ASTM G-99 standards. Adhesive wear of fabric described as fabric material rub against hardened EN31 steel disk having a hardness of 62 HRC. The fabric samples are mounted on the pin on disk tester using steel rod as shown in Fig. 3. To prevent any stretching of the fabrics during the experiments, specimens were fixed to the holder using polymeric (vinyl ester) resin. The 8 mm X 8 mm fabric surface contact with a disk made of alloy steel. The weight of the sample before and after the test is measured using a digital weighing balance with high accuracy of 0.0001g.

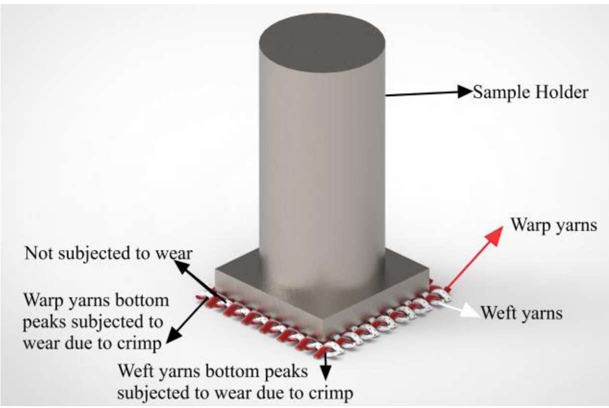

Fig. 3. Representatives wear sample and its details.

Design of experiments technique enables us to carry out modeling and analysis of the influence of wear process variables on the response variables. The wear parameters chosen for the experiment are applied load (L), sliding speed and (S) and sliding distance (D). The process parameters and their levels are shown in Table 2. Based on Taguchi method, the experiments are carried out as per the standard L_{27} orthogonal array.

2.7 Scanning electron microscopy of wear surface

After wear test, the surfaces of fabrics were analyzed using Scanning Electron Microscopy (SME) at B.M.S College of Engineering, Bengaluru. TESCAN Vega 3 LMU instrument manufactured by the Czech Republic used to analyze the wear images.

3. RESULTS AND DISCUSSION

3.1 Tensile properties of fabrics

Different fabrics considered for this study are cut to the required dimensions and tested for the loading on warp and weft directions. The tensile properties were measured at the ultimate stress. Figure 4 shows the stress-strain curves for loading along warp and weft direction for all the fabrics considered. In P1 type of fabric weft direction exhibit better ultimate tensile strength (1.36 times) and higher strain value (1.42 times) than the warp direction. This increase in the ultimate tensile strength depends on yarn count, more in weft (85.1) as compared to warp (80.1). The higher strain can be attributed to higher yarn crimp percentage associated with the weft direction. The similar trend observed in P2 woven fabric, weft direction exhibit better ultimate tensile strength (1.1 times) and higher strain value (1.23 times) than the warp direction. However, the yarn count is 166.8 in the weft which was little lesser then warp, even though ultimate tensile stress was more in the weft as compared to warp. This was mainly due to the textile fabrication [21].

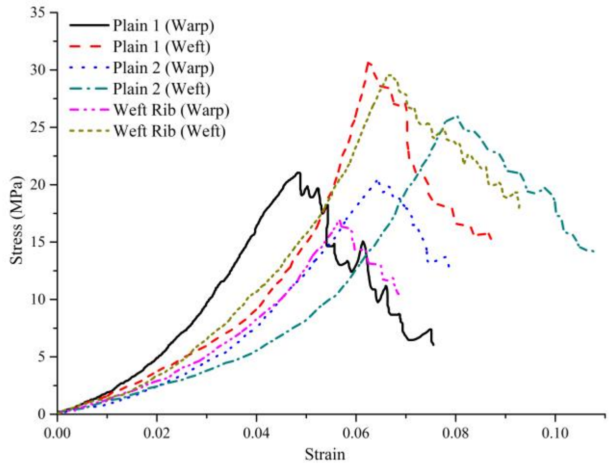

Fig. 4. Tensile properties of sisal woven fabric in both warp and weft direction.

In comparison with P1 and P2, P2 fabric is having 1.81 times in warp and 1.45 times in weft load withstanding capacity. This clearly shows GSM is directly proportional to load carrying capacity and finer fabric with higher cover factor exhibit better tensile Modulus. In WR woven fabric the weft direction (1.6 times) shows better properties than the warp direction. This may be due to the influence of yarn density. This could clearly show that woven structure properties of fabric also having a significant impact on tensile properties of the fabrics.

3.2 Pilling resistance

All these sisal woven fabrics were further tested for the tendency towards pilling using the Martindale method. The pilling resistance rating of P1 type fabric varies from 4 to 5. This is due to yarn diameter (yarn linear density), the thickness of the fabric and cover factor refers to Table 1. The P2 and WR types of fabrics are rated as 5, this is due to the fabric yarn linear density, the thickness of both the fabrics are 0.73 and 0.72 mm. This effect was concluded by using fabric GSM is 296.60 g/m^2 and 300.45 g/m^2. As compared to P1 (161.02 g/m^2) type of fabric, The P2 (296.60 g/m^2) and WR (300.45 g/m^2) types of fabrics are higher pilling resistance. This change in pilling rate due to yarn diameter, cover factor and weight of the fabric.

3.3 Abrasion resistance

The resistance to abrasion is affected by many factors, such as the inherent mechanical properties of the fibers, dimensions of the fibers, the structure of the yarns, construction of the fabrics, and the type, kind, and amount of finishing material added to the fibers, yarns or fabric. P1 type of fabric having better resistance to abrasion up to 85 number of rubs no rupture is observed. But P2 fabrics can sustain up to 105 number of rubs without any failure. As yarn linear density of P2 is more than P1, P2 takes a higher number of rubs to break off two yarns. The WR woven fabric observes failure at 55 number of rubs, as yarn linear density is less in the warp direction. So warp yarns fails earlier than the weft yarns.

3.4 Optimum dry sliding

A total of 27 experiments were performed based on the run order generated by the Taguchi model shown in Table 3. The response to the model is weight loss and change in frictional force. The objective of the model is to minimize weight loss and frictional force. The responses were tabulated and results were subjected to Analysis of Variance (ANOVA). The schematic representation of the fabric sample shown in Fig. 5.

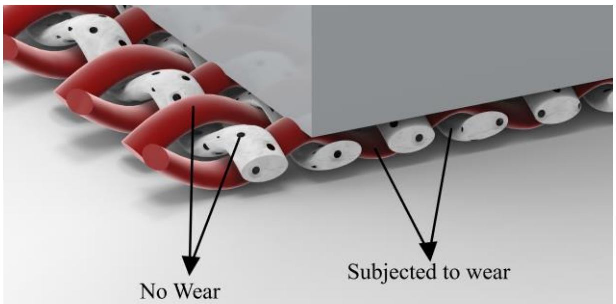

Fig. 5. Fabric samples under the wear loading.

Table 2. Factors used to wear studies using pin on disk wear tester.

Factors	Woven	Direction of wear (degree)	Disk speed (rpm)	Load (N)	Distance traveled (Km)
Level 1	Plain 1 (161.02 GSM)	0°	500	5	4
Level 2	Plain 2 (296.6 GSM)	90°	1000	10	8
Level 3	Weft Rib (300.45 GSM)	45°	1500	15	12

Table 3. Taguchi L_{27} orthogonal array with input factors and output characteristics.

Number of runs	Woven	Direction of wear (degree)	Disk speed (rpm)	Load (N)	Distance traveled (Km)	Fabric Weight loss (grams)	Frictional force (N)
1	P1	0°	200	5	4	0.0162	2.25
2	P1	0°	400	10	8	0.0231	3.46
3	P1	0°	600	15	12	0.0347	4.21
4	P1	90°	200	10	8	0.0124	3.21
5	P1	90°	400	15	12	0.0179	4.31
6	P1	90°	600	5	4	0.0262	2.45
7	P1	45°	200	15	12	0.0183	4.16
8	P1	45°	400	5	4	0.0262	2.64
9	P1	45°	600	10	8	0.0391	3.15
10	P2	0°	200	10	12	0.0196	2.78
11	P2	0°	400	15	4	0.0164	3.83
12	P2	0°	600	5	8	0.0126	0.92
13	P2	90°	200	15	4	0.0147	3.98
14	P2	90°	400	10	8	0.0189	2.84
15	P2	90°	600	5	12	0.0137	1.02
16	P2	45°	200	5	8	0.0125	0.92
17	P2	45°	400	10	12	0.0196	2.64
18	P2	45°	600	15	4	0.0169	3.82
19	WR	0°	200	15	8	0.0215	3.64
20	WR	0°	400	5	12	0.0196	0.98
21	WR	0°	600	10	4	0.0155	2.54
22	WR	90°	200	5	12	0.0178	0.86
23	WR	90°	400	10	4	0.0152	2.45
24	WR	90°	600	15	8	0.0167	3.54
25	WR	45°	200	10	4	0.0124	2.67
26	WR	45°	400	15	8	0.0142	3.84
27	WR	45°	600	5	12	0.0165	0.97

Table 4. Analysis of variance for means.

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% C	Significant level
Woven	2	1.14479	1.14479	0.57240	47.72	0.000	13.45	High
Direction of wear	2	0.00064	0.00064	0.00032	0.03	0.974	0.007	No
Disk speed	2	0.26527	0.03802	0.01901	1.59	0.235	3.12	less
Loads	2	6.74251	6.57427	3.28714	274.07	0.000	79.23	High
Distance traveled	2	0.16480	0.16480	0.08240	6.87	0.007	1.94	Marginally less
Residual Error	16	0.19190	0.19190	0.01199			2.25	
Total	26	8.50991						

Table 5. Response table for means.

Level	Woven	Direction of wear	Disk speed	Load	Distance traveled
1	1.6697	1.3772	1.3675	0.7317	1.4883
2	1.2719	1.3881	1.5089	1.4398	1.4273
3	1.2022	1.3785	1.2673	1.9723	1.2282
Delta	0.4675	0.0109	0.2416	1.2406	0.2601
Rank	2	5	4	1	3

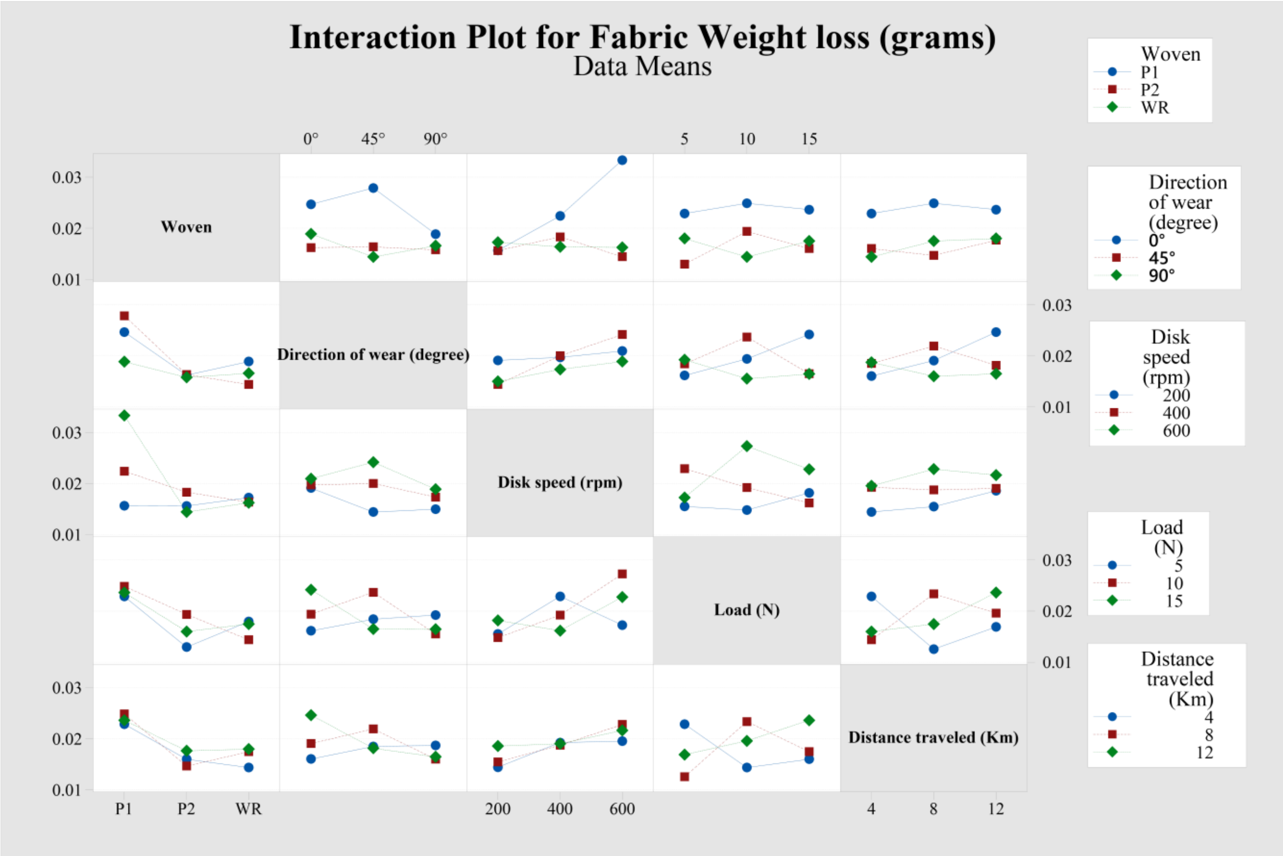

Fig. 6. Influence of input parameters on weight loss.

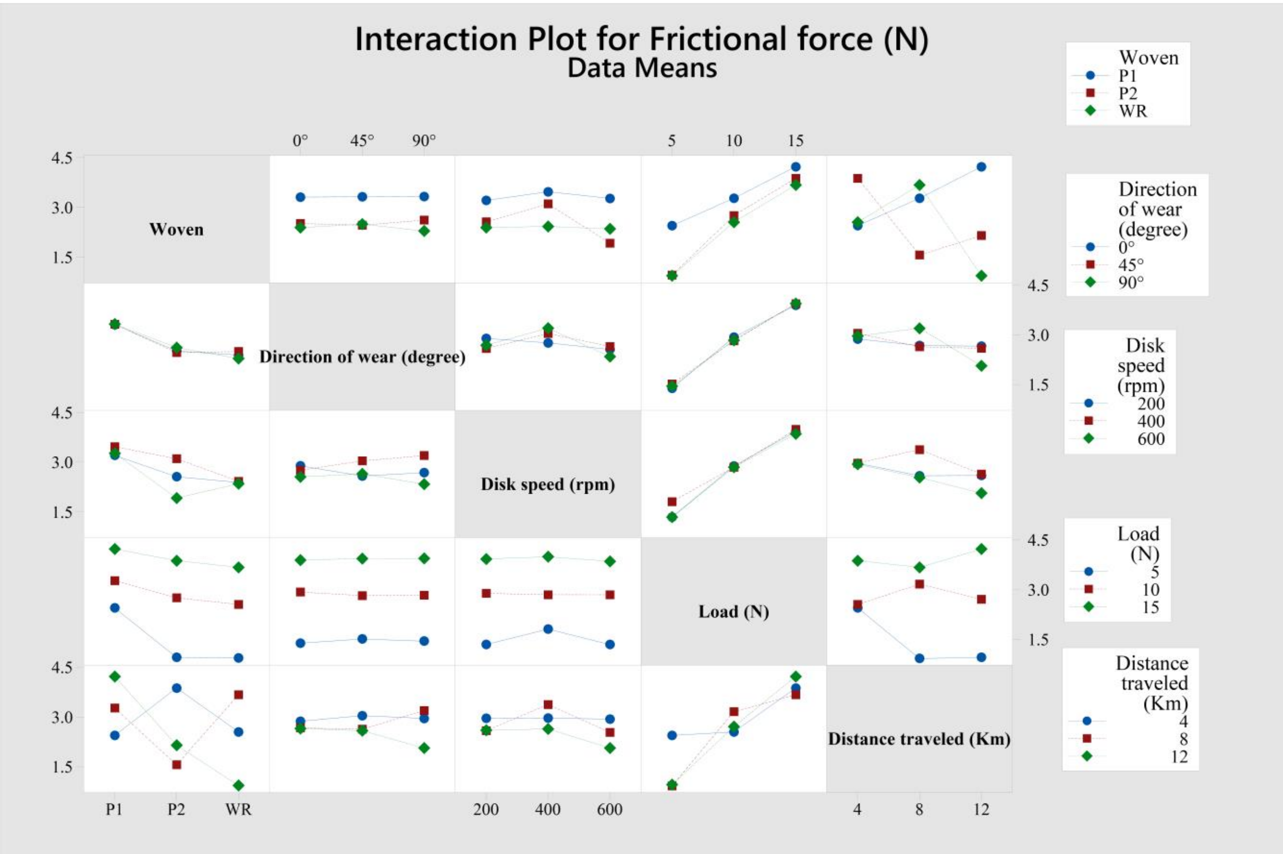

Fig. 7. Influence of input parameters on frictional force.

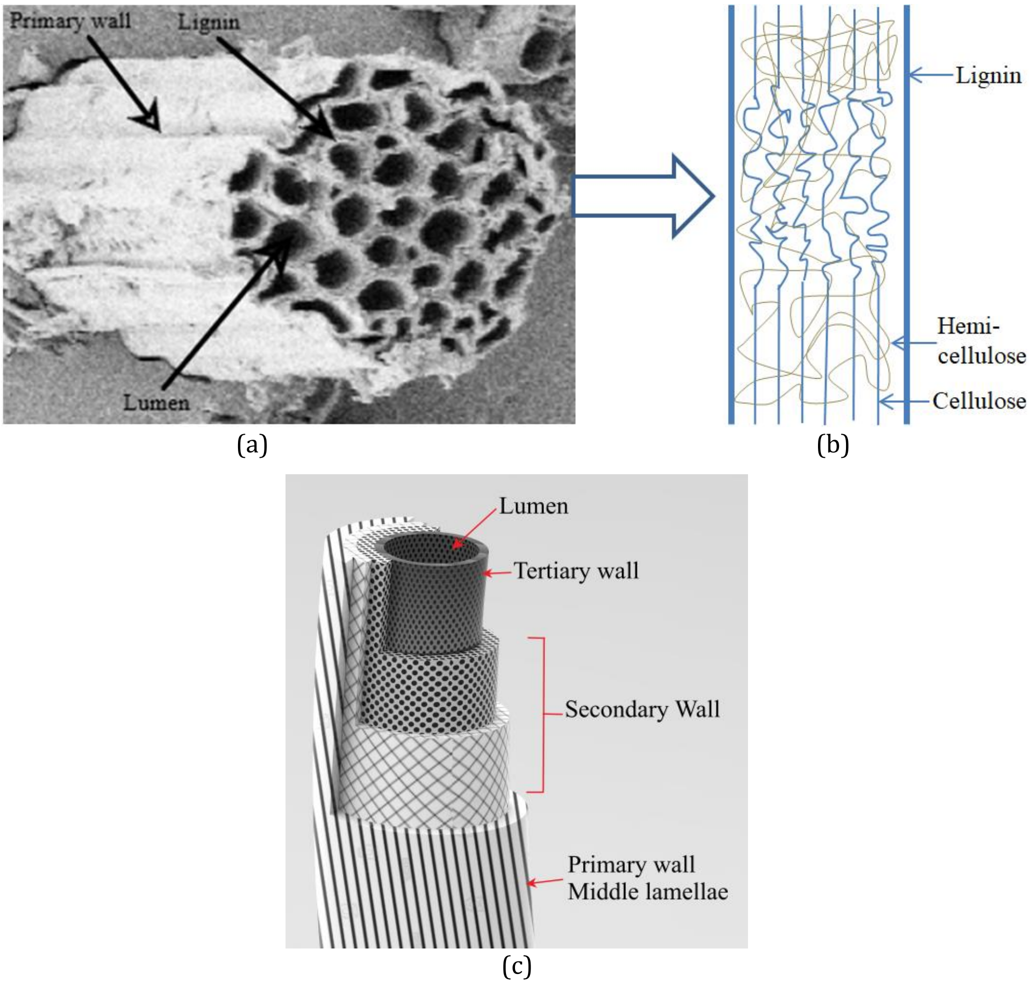

Fig. 8. Sisal fiber and its composition details (a) SEM image of sisal fiber used in this work, (b) Schematic representation of sisal fiber and its details, (c) Schematic drawing viewing the different layers of an individual fiber-cell [22].

Table 3 shows the experimental design for many input parameters. Table 4 shows the analysis of variance for means. P-value indicates that woven pattern (0.000), wear load (0.000) is having a highly significant effect on weight loss and frictional force. The distance traveled (0.007) also a significant effect on wear properties, but little less as compared to woven pattern and wear load. The disk speed (0.235) has a marginal influence on the wear properties of fabrics. However, the direction of wear doesn't have a significant effect on the wear properties of the fabric. The wear load shows the highest (79.23 %) contribution, the next contribution woven pattern (13.45 %), the disk speed (3.12 %) and distance traveled (1.94 %) very less contribution. However, the percentage contribution to the direction of wear is very less, so it is neglected.

The parameters that highly influence on the weight loss and frictional force have been determined by the rank value which has been obtained from the difference between the maximum and minimum value (delta) of the mean of S/N ratios. Table 5 shows the ranks of the parameters influencing the wear behavior of the fabric. Where wear load, woven pattern, sliding distance, speed and direction travel are raked 1 to 5 respectively. Figure 6 clearly shows P1 woven pattern exhibit higher wear then P2 and WR, due to the effect of GSM of the fabric. As gram per unit area increases with moderate crimp and yarn linear density the wear rate decreases. The direction of wear did not influence much on output factors, whereas the disk speed exhibits marginal changes in wear behavior. But wear load has the highest influence on wear properties of fabrics. The distance traveled also influenced on wear properties but it has similar behavior to the woven pattern. Moreover, as the values of the static load/force increases the pull out of a single fiber from the woven fabric also increases rapidly. Figure 7 clearly shows as the load increases the friction force also increases. But as distance traveled increases the frictional force decreases. The friction force remains nearly constant throughout the whole experimental runs/trials. On the basis of the observation made, this mechanism seems to be wear abrasion, as identified by many of the researchers. For higher contact pressure, the friction coefficient increases with respect to the load, thus suggesting that an additional wear mechanism has begun to operate. Experimental observations show that this mechanism is the plucking or shagging effect. Such mechanisms begin to operate when fiber rupture takes place and the fibers begin to tangle, giving rise to an accelerated degradation process.

The same observations were also found in SEM images (Figs. 12 and 13). As the normal load increases, yarns remain in closer contact, thus increasing the abrasive effects. This explains the monotonic increase in the value of the dynamic frictional force for the normal load 15 N. Further, rupture of fibers by degradation was observed after a relatively small number of cycles.

Figure 8 shows the single sisal fiber cross-sectional view and its detail composition. The mechanism of wear was divided into three stages. Initially, the primary wall (Fig. 8a) of the sisal fiber comes in contact with rubbing surface and it is softer compared to the other parts of sisal fiber. The primary surface of the sisal fiber is worn out and comes in contact with secondary fiber region called hemicellulose. In the secondary stage, the hemicelluloses starts to worn out, but the amount of weight loss was found to be very less. Because hemicellulose is harder compared to primary walls and offers more resistance to wear. In the last stage / third stage the cellulose part exhibits the highest resistance to wear. As wear load and speed increases, the fibers come out from the fabric and forms a bunch of cellulose fiber. This section was explained using SEM images. Because of this reason sisal fiber has excellent resistance to sliding wear. The chemical composition of extracted sisal fiber which is available in Karnataka, India has 62-76 % cellulose, 23-36 % hemicelluloses, 6-9 % lignin, 0.8-1.3 % wax and 5-10 % moisture. The average diameters of the sisal fiber were found to be varying from 100 to 350 micrometers. The characteristics of the fibers depend on the properties of individual constituents, the fibrillar structure, and lamellate matrix. The fiber is composed of numerous elongated fusiform fiber cells that taper towards the end. The fiber cells are linked together by means of middle lamellae, which consists of hemicelluloses, lignin, and pectin. Figure 8c shows the schematic sketch of a sisal fiber cell.

3.5 Scanning electron microscopy of wear surface

The tensile fractured surfaces of the fabrics were used to study the failure behavior of fabrics. Figure 9 shows the tensile fractured surface of P1 fabric and observed that concentration of stresses at thinner yarns and yields to yarns further becomes thinner and thinner. The cross-section of the yarns of the fabrics become more circular. Finally, the fiber in the yarns are broken one by one, this weakens the strength of yarn and rupture of thinner yarns. The same trends were observed in the P2 type of fabric shown in Fig. 10. But, as yarn linear density is more in both warp and weft direction failure of yarns is at a higher strain rate as compared to P1. This is due to the effect of “S” type yarn threads, which unravel during loading and possess higher strain rate. WR woven pattern also fails similar to P1 and P2. However, the number of yarns in one direction possess more strain rate than the other direction. In the case of tensile fracture, the yarns are subjected to shearing and fiber degradation.

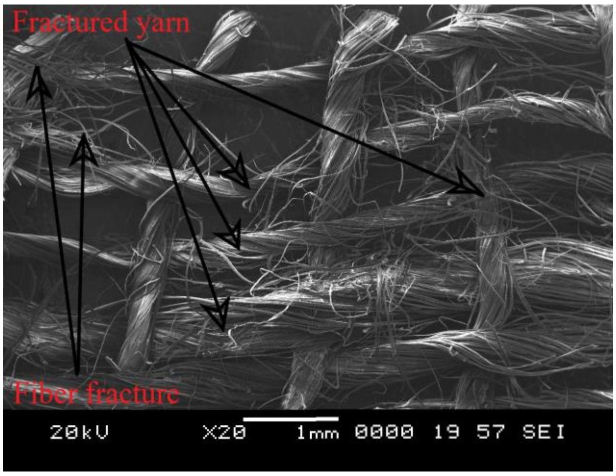

Fig. 9. Tensile failure of P1 fabric.

The wear samples of SEM images were analyzed for all three fabrics and are subjected to wear in the warp, weft and 45° to both warp and weft direction. The weight losses were found to vary less along weft direction in case of P1 and P2 fabrics. But more weight loss was found in the warp direction of WR fabric. This may be due to the effect of crimp of yarns, more crimp value in weft direction in case of P1, P2 and warp direction in case of WR fabric.

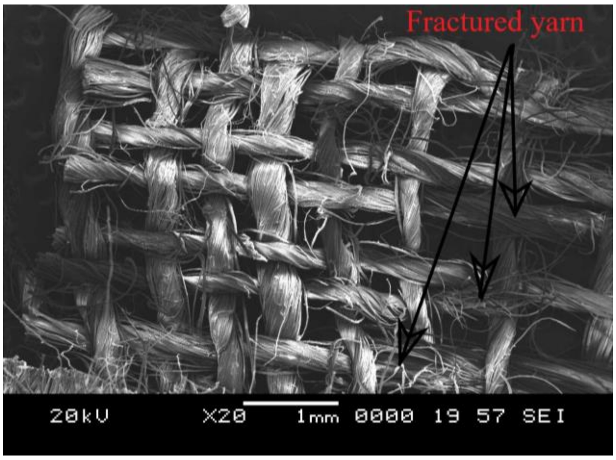

Fig. 10. Tensile failure of P2 fabric.

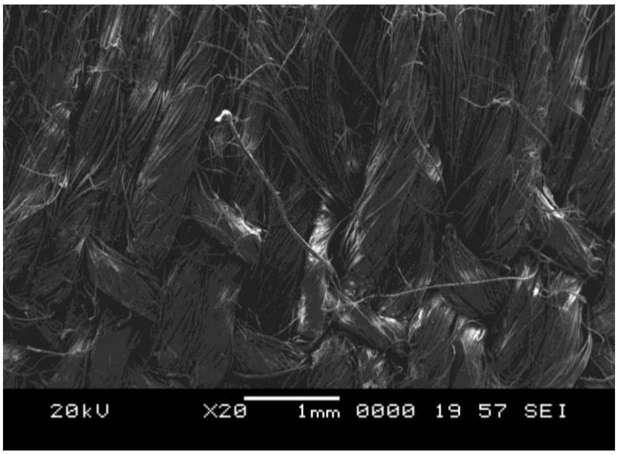

Fig. 11. Adhesion wear of WR fabric at 5 N @ 4 km sliding distance.

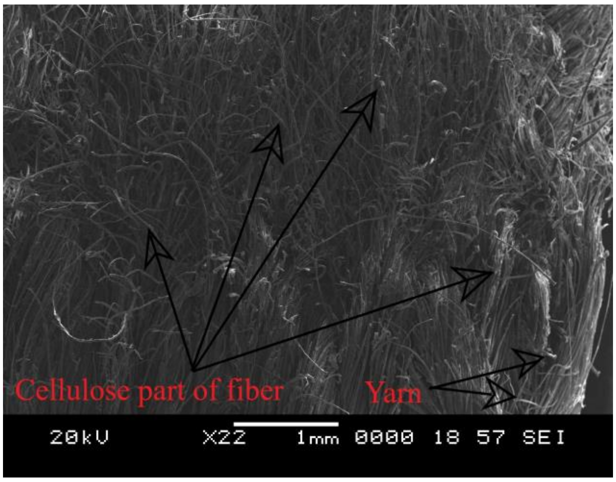

Fig. 12. Adhesions wear of P2 fabric at 15 N @ 12 km sliding distance.

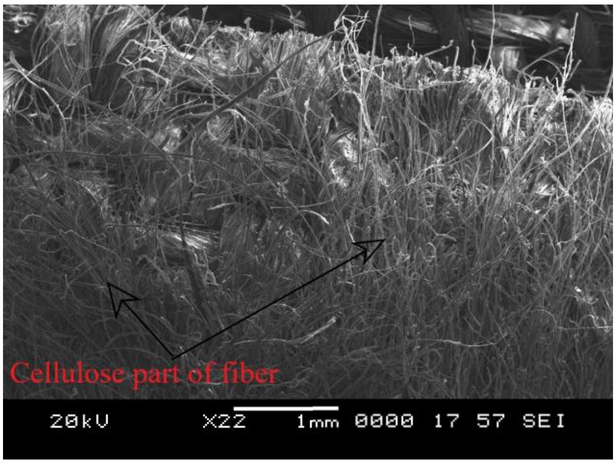

Fig. 13. Adhesion wear of P1 fabric at 15 N @ 12 km sliding distance.

Figure 11 shows the wear surface of fabrics and found that initially, fabric surface is in contact with peaks of crimp and initiation of wear. As fabric surfaces are continually contacted with alloy materials leads to tearing for fibers in the yarns and forms bunches of concentrated fibers. The scanning image of 5 N loaded with 4 km sliding distance as shown in Fig. 11. Figures 12 and 13 shows the P2 and P1 fabric at higher loading with 12 km slide sample.

4. CONCLUSIONS

The tensile properties, pilling resistance, adhesion resistance, and pin on disk dry sliding wear tests were determined for all three fabrics. The following observations were found:

1. Tensile properties of fabrics were found to be higher in the weft direction. As crimp increases the elongation at initial stage increases. As yarn linear density increases strength increases.
2. Pilling resistance increases as the fabric becomes coarse. P2 and WR fabric exhibit better pilling resistance.
3. Rotary Abrasion resistance increases as yarn linear density and crimp increases.
4. In pin on disk (dry sliding wear) method weight loss was found to be more in a direction (warp) and lesser in other direction (weft). This is due to the effect of crimp of the fabrics. As crimp increases wear rate decreases.
5. It was clearly observed that during sliding wear weft yarns are subjected to wear load

along the fibers and warp yarns are subjected to wear load 90° to the fiber direction. Due to this reason as the load increases the contact surface area also increases and leads to more frictional force.

6. Scanning electron image clearly shows yarns in fibers were torn and slit into smaller fibers and appear like bundles of fibers. Also observed that weight loss was due to wear out of the primary wall, lignin, and middle lamellae. The cellulose part of the fiber exhibit more resistance to dry sliding wear.
7. These fabrics have been used for the preparation of tents, bags, blankets, as well as reinforcement material for the polymer composites, vehicle seat covers, etc. In the above cited applications the wear of fabrics plays vital role in durability of fabric.

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