Development of Protective Clothing for Pesticide Operation

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Abstract - *Coating of jute-cotton union fabric with polyurethane and engage rubber has been carried out for evaluating attainable changes in the fabric property such as air permeability, moisture vapor transmission, water repellency, oil repellency, tensile properties, wrinkle recovery and flexural rigidity. Results showed that jute-cotton union fabric has to be a lighter effective alternative to the fluorocarbon finished denim fabric. Engage rubber coated jute-cotton fabric shows excellent water repellency and oil impermeability however, it was rated low because of its poor ability to permeate air and water through it. Polyurethane coated breathable Jute-cotton fabric appears to be the best fabric considered in this study as it offers moderate to high level of water vapor transmission rate (WVTR) and moisture regain along with high level of water repellency and oil impermeability. Fabric used in this study has the potential enough to be an alternate source for fluoropolymer finished denim fabric keeping in mind, high level of water and oil permeability of the latter.*

***Key Words*: Jute-cotton union fabric, engage rubber, polyurethane, water repellency, coating.**

1. INTRODUCTION

Growing concern regarding health and safety of workers in various sectors of the industry has generated regulations and standards, environmental and engineering control as well as vigorous research and development in the area of personal protective equipment (PPE). Pesticide is used for prevention of agricultural produce and food from the attack of undesirable organisms. The hazardous effect of pesticide on non-targeted environment is a matter of great concern to us. Pesticides can enter into human body [1] through mouth, lungs and skin during mixing, loading, application and equipment maintenance in the pesticides manufacturing industry causing short term as well as long term diseases [2] such as mental confusion, drowsiness, nausea, eye and skin irritation, headache, cancer, and many other. Of the three routes of pesticide entry into the human body dermal exposure is considered the primary mechanism [3]. Hence, while manufacturing or applying pesticides the use of protective clothing is recommended [1-3] to prevent dermal exposure as it acts as a physical barrier between skin and pesticide.

Pesticides are either water based or emulsifiable oil based concentrates. So in order to prevent their penetration through the protective clothing an oil and water repellent finish to the protective clothing is found to be satisfactory. If the surface energy of the protective clothing is lowered substantially employing fluorochemical finish the clothing is reported to perform effectively for prevention of penetration of pesticide through them [4]. Fluro carbon repellent finishes have been found to be excellent barrier finishes against pesticides [5]. Fluoro carbon repellent finished polyester – viscose fabrics are the best choice for use in disposable garment for protection against pesticides [6]. It has been reported that non-woven fabrics in general perform better than most woven fabrics; however, heavy woven fabrics of twill construction such as denim when suitably finished with fluoro polymers have performed quite well [7]-[8]. Inspite of better protective performance of non-woven fabrics agricultural workers have identified denim jeans and coveralls as preferred apparel for pesticide application in view of its good barrier and excellent comfort properties.

Use of such fluoro chemical finished denim fabric by the workers in the pesticide industry and by the farmer is an expensive proposition altogether for a country like India. In view of the above it would be interesting to investigate the role of polyurethane and ethylene-octene-rubber when coated for jute-cotton fabric for assessing barrier effectiveness and providing comfort to the wearer. Therefore, our study is aimed at coating Jute-cotton union fabric with polyurethane and engage rubber and evaluating attainable changes in the fabric property.

2. MATERIAL AND METHODS

2.1 Materials

Twill weave cotton fabric (Denim) with 276 ends/dm, 170 picks/dm, 98.4 tex warp, 90.8 tex weft and having an average areal density of 440 g/m^2 was used for the present study. Twill jute-cotton union fabric with cotton yarn as warp and jute yarn as weft with the following specification was also used for the study –189 ends/dm, 114 picks/dm, 59 tex warp, 169.5 tex weft with an average areal density of 296 g/m^2.

2.2 Chemicals

DESMOPAN 200, a poly ether based thermoplastic polyurethane obtained from M/S Bayer Company Limited Germany. Ethylene-octene co-polymerised elastomer supplied by M/S Dupont Dow Elastomers Limited with 3% comonomer (octene content) was used. The density of the polymer used for the study 0.868 g/cm^3. Fluoro polymer obtained from M/S Asahi Chemicals Limited, Japan procured from M/S Bengal Water proof limited having a characteristic structure as $CH_2=CRCO_2CH_2CH_2N$ where R=H, CH_3, co-polymers with methyl methacrylate and C_nF_{2n+1} $(CH_2CF_2)_m$ $CH_2CH_2O_2CH=CH_2$, n= 12, m= 3 was used. Dimethylol-dihydroxy-ethylene-urea (DMDHEU) obtained from M/S Sandoz company limited with 50% soild content was used. Other chemicals used for the present study were of laboratory reagent grade obtained from local supplier.

2.3 Application method for Fluoro chemical on Cotton fabric (Denim)

Application of fluro chemicals and DMDHEU on 100% cotton fabric was done by padding technique in a laboratory padding mangle following a two dip two nip sequential process. The aqueous formulation contains 120 g/L DMDHEU, 60 g/L magnesium chloride. The padded and squeezed fabric was dried at 100^0C for 5 minutes and subsequently cured at 140^0C for 5 minutes in a laboratory drying and curing chamber. The cured fabric was then finally soap washed following ISO 2 washing method [8].

2.4Coating of Jute-cotton union fabric with Thermoplastic Polyurethane (TPU)

Coating of jute-cotton fabric with TPU was done following a spreading technique in a knife over roll coating machine. Compounding of coating polymer was done using N-N di methyl formamide (DMF) as solvent and toluene as diluent. The solublisation of TPU was done employing a laboratory stirrer using a mixture of DMF, Methyl-ethyl-ketone (MEK) and toluene in suitable proportion where MEK served the purpose of a low boiling solvent. The coated fabric was then dried at 100^0C for 5 minutes. The coating followed by drying process was repeated for three times successively to obtain a final TPU coated jute-cotton fabric.

2.5Coating of Jute-cotton union fabric with Ethylene-octene Elastomer

Coating of jute-cotton union fabric with ethylene octene elastomer was done in a three roll calendar machine. Ethylene octene elastomer granules was converted into dow (sheet) in a two roll open mill mixing machine prior to the coating operation at a temperature of 70^0C. Ethylene octene sheet thus obtained was fed in the subsequent process into the bank of a pair rolls of the three roll calender machine and for coating jute-cotton union fabric. The coating temperature was kept at 70^0C in the calender machine and a single coating was done on jute-cotton union fabric.

2.6 Tenacity and Elongation at break

Tenacity and Elongation at break of fabrics were measured according to a method prescribed by IS 1969 – 68 using an Instron Universal Tensile testing machine [9]. The results obtained are based on an average of 5 tests in the warp direction of each sample. The test strip specimens were raveled to a size of 200 × 50 mm^2 between the jaws of the machine and the tests were performed with a traverse speed of 460 mm/min.

2.7 Tear Strength

Tear strength of the fabric samples were done according to a method prescribed in ASTMD 2261-64T [10].

2.8 Wrinkle Recovery Angle

Dry Wrinkle recovery angle (warp + weft) of samples was determined according to a method prescribed by ASTMD 1295-67 using a SASMIRA wrinkle recovery tester with a specimen size of 25 × 20 mm^2 [11].

2.9 Flexural Rigidity

Flexural rigidity of the fabrics were measured according to IS6490 1971 cantilever test in a SASMIRA stiffness tester with the specimen size of 25 × 200 mm^2 [9].

2.10 Water Repellency

Water repellency was measured using spray test in quantitative terms in accordance with IS 390 test method [1]. The repellency was measured on the basis of area of specimen weighted by the spray of water on a six point photographic test rating scale.

2.11 Air-permeability

Prolific Air-permeability tester was used to measure air-permeability of fabrics as per BIS 5536-1978 test method [1]. The air-permeability was measured in terms of volume of air in m^3 that passes per minute through 1 m^2 of the fabric at a pressure difference of 10 mm of water column.

2.12 Analysis of Oil Repellency and Penetration

Oil repellency and penetration of different fabrics as specified was done following methods prescribed in ASTMD 202-1997 using castor oil. 1 ml of oil was dropped from a micro pipette on to the test fabric from a height of 10 mm. The spreading and penetration of oil are noted after 5 hours. In case of penetration through the fabric the oil will have a stain of it on the filter paper placed at the other side of the fabric.

2.13 Analysis of Water Vapor Transmission Rate

Water vapor transmission rate (WVTR) of selected fabrics was done at 38^{0}C and 90% relative humidity in a LYSSY WVTR testing machine, Switzerland. The results are expressed in terms of gram of water vapor transmitted through 1 m2 of the material in 24 hours.

2.14 Analysis of Moisture Regain

Determination of moisture regain of a known weight of fabric sample, the dry weight (W_1) and weight of the fabric specimen conditioned at 27^{0}C in an atmosphere of 65% relative humidity (W_2) were recorded and moisture regain was calculated using the equation below,

$$\text{Moisture Regain, \%} = \frac{(W_2\text{-}W_1)}{W_1}\times 100$$

3. RESULTS AND DISCUSSION

3.1 Comparison of properties of Jute-cotton and Denim fabric

Table 1 shows property profile of 100% cotton (denim) fabric and jute-cotton union fabric. The jute-cotton union fabric is lighter and thinner than the denim fabric for having thinner warp yarn and less number of warp and weft yarns per unit area. It also resulted the jute-cotton fabric more permeable to air. Jute-cotton fabric appears to be stronger and less extensible in the weft direction and weaker and less extensible in the warp direction than the denim fabric. It is due to the presence of thicker warp yarn in the denim fabric and thicker and less extensible jute yarn in the weft direction of the jute-cotton union fabric. The wrinkle recovery angle, however, for both the above fabrics appear to be comparable with denim fabric being marginally more wrinkle resistant as evident from Table 1.

Flexural rigidity of both the fabrics done in warp direction only shows that jute-cotton union fabric is more flexible than the denim fabric. This may be due to less areal density and presence of heavier jute yarn in the weft direction.

Table 1 also shows that the tear resistance of jute-cotton fabric is higher than that of denim fabric. The higher tear strength of jute-cotton union fabric despite having finer and fewer yarns in the warp direction when compared with denim fabric is the consequence of having higher ease of deformability [10] of the fabric structure of the former. Jute and cotton both being fairly hydrophilic, denim and jute-cotton union fabric commonly show 0% water repellency in their untreated form as evident from Table 1.

Table-1: Properties of Jute-cotton Union and Denim fabric

Type of fabric		Jute-cotton union fabric	Cotton denim
Areal Density G.S.M		296	440
Thickness (mm)		0.59	0.81
Count in Tex	**Warp**	59	98.4
	Weft	169.5	90.8
Ends/ dm		189	276
Picks/ dm		114	170
Air-permeability ($m^3/m^2/min$)		32.78	2.36
Breaking Load (N)	**Warp**	60.54	130.85
	Weft	92.37	65.83
Breaking Elongation(%)	**Warp**	9.06	25.54
	Weft	3.6	14.6
Wrinkle Recovery Angle (warp + weft)		175^0	180^0
Flexural Rigidity (mg.cm)		603.08	687.5
Tear Strength (weft) in N		25.5	18.19
Water Repellency (%)		0	0

3.2 Functional properties

Jute-cotton union fabric coated with engage polymer and thermoplastic polyurethane commonly show significant lowering of air-permeability owing to the coating of fabric with films of the polymer. Denim fabric finished with fluoro chemical however, shows good air-permeability in consequent to discontinuous and discrete deposition of fluoro-polymers on the cotton fibres of the denim fabric that hardly block the interstices of the fabric structure.

Table 2 shows that jute-cotton union fabric coated with different rubbers as specified have become 100% water repellency while that of fluoropolymer finished denim fabric shows 70%.

As far as oil repellency is concerned, jute-cotton union fabric coated with ethylene-octene rubber and thermoplastic polyurethane did not allow castor oil to permeate through the fabric. On the other hand a drop of castor oil though did not spread on the fluoro chemical finished denim fabric, it permeated through the finished denim fabric to get absorbed on the filter placed on the other side of the test fabric. Spreading of castor oil on both the coated jute-cotton union fabrics become apparent when noted after 5 hrs. Moisture regain of jute-cotton fabric coated with ethylene-octene rubber and polyurethane are found to be marginally less than that of finished with fluoropolymers.

Table-2: Functional properties of Coated Jute-cotton and Finished Denim fabric

Fabric	Jute-cotton union fabric coated with Ethylene-octene rubber (Engage)	Jute-cotton union fabric coated with Thermoplastic polyurethane	Denim fabric finished with fluoro polymer and DMDHEU
Air-permeability ($m^3/m^2/min$)	0.55	0.65	1.583
Water Repellency (%)	100	100	70
Moisture Regain (%)	7.17	7.92	9.6
Oil-Repellency and Penetration in 5 hours (subjective)	No penetration But spreading	No penetration But spreading	No spreading But penetration
Water Vapour Transmission Rate ($g/m^2/day$)	7.28	6042	10500

Incorporation of hydrophobic coating polymer on the surface of the jute-cotton union fabric caused lowering of moisture regain on those fabric. Fluoropolymer on the other hand did not allow moisture regain of the cotton fabric to go down significantly due to the water binding capacity of the carboxyl group in the fluoropolymer. High rate of moisture transmission of the finished denim fabric is also evident from the Table 2 since the denim fabric finished with fluoropolymers does not have it's interstices completely or partially blocked. However, in case of coated jute-cotton union fabric, it's interstices and surface are completely masked by the coating polymer and the effect appears to be more prominent for engage coated jute-cotton union fabric allowing little or no moisture to be transmitted through it giving poor water vapor transmission rate (WVTR) value. Polyurethane coated jute-cotton union fabric appears to be breathable as evident from the Table 2 making the fabric appreciably comfortable for the wearer yet offering good level of water repellency and oil resistance. Use of combination of methyl-ethyl-ketone (MEK), toluene and DMF in the coating formulation has caused polyurethane to precipitate out on the surface of the jute-cotton in a highly porous form [10].

3.3 Mechanical Properties

Thickness and wrinkle recovery angle of the coated jute-cotton union fabrics and denim fabric finished with fluorocarbon are found to be comparable from the Table 3 with the denim fabric having highest thickness. However, wrinkle recovery angle for all the three fabrics are found to stay much above the respective unfinished fabrics and fair to good for use of such treated fabrics for the purpose of manufacturing protective clothing.

Table-3: Mechanical properties of Coated Jute-cotton and Finished Denim fabric

Fabric		Jute-cotton union fabric coated with Thermoplastic polyurethane	Jute-cotton union fabric coated with Ethylene-octene rubber (Engage)	Cotton Denim
Application (%)		24	33.78	5.45
Thickness (mm)		0.65	0.66	0.82
Breaking Load (N)	Warp	90.87	92.55	139.7
	Weft	94.48	129	70.48
Elongation at Break (%)	Warp	9.97	9.52	26.8
	Weft	4.58	4.88	14.73
Tear Strength (weft way) in N		17.88	22.52	17.92
Wrinkle Recovery Angle (warp + weft)		216^0	225^0	224^0
Flexural rigidity (mg.cm)		3021.37	6870.2	792.22

Deposition of coating polymers on jute-cotton union fabric commonly resulted in enhancement of breaking load as from Table 3 and the effect being more pronounced for ethylene octene rubber coated fabric. This is due to the improvement in fibre to fibre adhesion [10]. While fluoropolymer also shows improvement in breaking load. Breaking elongation for treated jute-cotton union fabrics are found to enhance commonly upon incorporation of elastomeric coating film with high extensibility. Application of fluoro chemicals on denim fabric could not alter the extensibility characteristic of denim fabric in a significant manner.

Tear strength of jute-cotton union fabric coated with elastomers and denim fabric finished with fluoro polymer are shown in Table 3. In both the cases of application of elastomers and fluoro polymers the tear strength is reduced as evident from the data shown in Tables 1 and 3. The extent of lowering of tearing strength is found to be much higher in case of jute-cotton union fabrics finished either with engage or with thermoplastic polyurethane than in case of finished denim fabric. This is because of the fact that due to low areal density and less yarn per unit area, the untreated jute-cotton union fabric was having initially a high level of ease of deformability which has been arrested substantially.

Flexural rigidity of the fabric samples coated and treated with different polymers are also shown in Table 3. It has been found earlier [10] that at the time of measurement of bending length if the coating is placed inside of the bend its effect on the stiffness of the structure is relatively small than when the coated side is placed outside the bend. As in the later case the coated polymer will be called upon to deform under extension. In this case also bending length follow a similar trend with a total overall reduction in flexibility of the jute-cotton fabric. The reduction in flexibility of the denim fabric upon finishing of the same with fluoropolymer with DMDHEU also shows an increase in the flexural rigidity because of the effect of cross linking [12] caused by DMDHEU.

4. CONCLUSIONS

Jute-cotton union fabric coated either with engage or with TPU to be a lighter effective alternative to the fluorocarbon finished denim fabric. Engage rubber coated jute-cotton fabric though shows excellent water repellency and oil impermeability may be rated low because of its poor ability to permeate air and water through it. Polyurethane coated breathable jute-cotton fabric appears to be the best fabric considered in this study as it offers moderate to high level of WVTR and moisture regain along with high level of water repellency and oil impermeability. Above fabric has the potential to be an alternate for fluoropolymer finished denim fabric in the view of high level of water and oil permeability of the latter.

Coating of Jute-cotton union fabric with polyurethane and engage rubber and evaluating attainable changes in the fabric property including air permeability, moisture vapor transmission, water repellency, oil repellency, tensile properties, wrinkle recovery and flexural rigidity.

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