Development of Union Fabrics using Short Fine Wool Yarn and Cotton Yarn

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An alternate value addition for short fine wool was done in this study. Two types of wool-cotton union fabric were produced using two different counts of wool yarns spun from short fine wool as weft and coloured cotton yarns as warp. The woollen part of the fabrics was cross dyed using 1:2 metal complex dyes to uniform shade followed by finishing with a cationic softener. The performance of finished union fabrics were compared with the 100% wool control fabric to find their suitability as blankets for tropical winter season. The stiffness, linearity of compression (LC), resilience of compression (RC) and air resistance of the grey fabrics were improved by about 30%, 10%, 10% and 40%, respectively, due to better dyeing and finishing. The union fabrics showed 40% to 50% reduced felting shrinkage compared to 100% wool control fabric.

Keywords: Cotton warp; Cross dyeing; Dimensional properties; Polymer application; Wool weft

INTRODUCTION

The short staple fine wool produced in India especially in North Temperate Region, ie, Jammu and Kashmir, Himachal Pradesh and Uttaranchal and in some parts of South India is a medium type fine fibre having 22 µ to 28 µ diameter and 4 cm to 5 cm staple length with high CV% and having less than 10% medullation. The quantity available of such wool is about 4 million kg1. This type of wool is lacking proper value addition due to limited availability in non-wool producing regions and its short staple length. This wool is also not suitable for worsted spinning system and hence, processed on different non-conventional spinning systems like modified cotton spinning, woollen spinning systems for the production of coarse products like blanket, felt, etc. Several researchers have attempted to find out the suitable value addition to this type of wool by blending it with medium type wool, Angora wool, silk waste and synthetic fibres, like, polyester and viscose and made different viable and cost effective products out of them2-4. However in all the above cases, the conventional spinning system has to be modified to produce a blended yarn. In this research, an attempt has been made to utilize this wool as such for producing 2 Nm and 4 Nm (500 tex and 250 tex) woollen yarns without any blending using woollen spinning system and the developed yarns are used as a weft to produce union fabrics with cotton warp followed by dyeing and finishing. This type of product development does not need any modification in the existing spinning and processing systems but provides several end use performance advantages. A wool-cotton union fabric of this nature would have greater value than 100% cotton item in terms of thermal resistance for the usage as a blanket for moderate winter season. Such fabric could be cleaned on the washing machine due to reduced felting shrinkage which is the serious limitation of all wool fabric. Similarly, the cost of this union fabric will be lesser than that of comparable 100% woollen materials. It is well established that stiffness, compression and resilience of compression properties of the fabrics influence the handle of the fabric. Therefore, an attempt has also been made to study effect of dyeing and polymer application on the handle of the union fabrics by measuring linearity of compression (LC) and resilience of compression (RC), using Kawabata evaluation system as well as flexural rigidity.

MATERIALS AND METHODS

Wool

Wool fibre having 4 cm to 5 cm staple length (CV% – 25), 22.54 µ diameter with less than 1% medullation, 8.33 g/tex bundle strength and 21.78% elongation was used. The wool was scoured in a series of troughs using nonionic detergent (1%) and Na2CO3 (0.5%) at 50°C followed by two warm and cold washes. The scoured material was air dried in the sunlight. The scouring yield was 50%.

Preparation of Yarn

The scoured wool was carded in roller clearer card in three passages. The cylinder speed was 40 rpm with doffer speed of 2 rpm. A suitable roving of 2 Nm (500 tex) and 4 Nm (250 tex) linear densities were prepared using 15 mm and 10 mm condensers attached in the third passage of roller clearer card. The roving was then twisted on ring twister without any drafting. The spindle speed was kept at 2000 rpm and the yarns of 500 tex (Yarn-A) and 250 tex (Yarn-B) were prepared. Two qualities of coloured ply and sized cotton yarns, ie, 2/10 Ne (118 tex) in yellow colour and 2/17 Ne (69 tex) in blue colour having 1900 and 2100 CSP, respectively, were used.

Weaving

Two type of union fabrics (UF-X and UF-Y) were prepared.
using the developed woollen yarns as weft and two ply cotton yarns as warp. The UF-X was prepared using woolen Yarn-A as weft and 2/10 Ne (118 tex) yellow coloured cotton yarn as warp. The UF-Y was prepared using woolen Yarn-B as weft and 2/17 Ne (69 tex) blue coloured cotton yarn as warp. An all wool control fabric was produced using 4 Nm wool yarn as warp (Yarn-B) and 2 Nm (500 tex) wool yarn as weft. All the weaving operation was carried out in handloom with 2x1 twill twist.

**Dyeing and Polymer Application**

The developed product was thoroughly washed to remove any contaminants acquired during weaving using alkaline soap solution. The wool portions of the union fabrics were cross-dyed with 1:2 metal complex dyes, *i.e.* Lasanyn navy blue SDNLI and Lasanyn yellow GLNI (Clariant India Ltd) for UF-X and UF-Y, respectively, using following formulae.

\[
\begin{align*}
\text{Dye, } \% & : x \\
\text{Wetting agent, gp} & : 1 \\
\text{Formic acid, } \% & : 3 \\
\text{pH} & : 4.5 \\
\text{Temperature} & : \text{at boil} \\
\text{MLR} & : 1.50 \\
\text{Time, min} & : 90
\end{align*}
\]

The control all wool fabric was dyed with Lasanyn yellow GLNI, metal complex dye using the above formulae. After dyeing, the materials were thoroughly washed with nonionic detergent at 50°C to remove the loosely adhered dyes in the cotton portion of the union fabric. The washing fastness of the dye was determined using ISO 105(CO₂)₃ method. Finally, all the fabrics were finished with 3% cationic softening polymer (Zylon PLI, Rossari Chemicals India Ltd) at slightly acidic condition (pH : 6 to 6.5) in the padding mangle using pad-dry-cure technique. The fabric was cured at 100°C.

**Testing of Woollen Yarns and Fabrics**

**Yarn Characteristics**

The produced woollen yarns were tested for different physical properties like count by weighing method, twist by twist tester, breaking force, elongation and tenacity using yarn tensile tester (CRT type) and evenness by Uster evenness tester applying following standard methods.

**Fabric Constructional Properties**

Ends/mm, Picks/mm were determined using pick glass while the thickness measured thickness gauge at 0.703 g/mm². Weight/m² and the weight proportions of woollen yarns and cotton yarns in the union fabric were determined by weighing.

**Fabric Performance Characteristics**

The breaking force and extension of fabrics were determined using fabric tensile strength tester (CRT type). Bending length and flexural rigidity were determined by using stiffness tester (cantilever principle), while the crease recovery angle by Shirley crease recovery tester using standard methods described elsewhere. The thermal conductivity of the fabric was tested using Lee’s method. The thermal resistance (R) value is determined by the inverse of thermal conductivity multiplied by thickness. The air resistance values of the fabrics were tested using Kawabata system: KES-FB air permeability tester. The relaxation shrinkage was measured by agitating the wetted material with water for 1 h in domestic washing machine. The felting shrinkage was measured according to AATCC test method 135-1992, (dimensional changes in automatic home laundering of woven and knitted fabrics) using a IFB washing machine.

**RESULTS AND DISCUSSION**

**Yarn Characteristics**

The properties of the yarns are shown in Table 1. There was no problem encountered during spinning operation. Yarn-B, *i.e.* 4 Nm (250 tex) yarn consists of higher strength (43%) and slightly lesser evenness (10%) than Yarn-A due to its fineness and high twist. Table 1 shows the different yarn properties for two type of yarns.

**Fabric Constructional Properties**

The results are given in Table 2. The developed products are light weight and combine the versatile properties of the two natural fibres. The two ply cotton warp is used to provide dimensional stability to the union fabrics. The variations in thickness, cover factor and wt/m² between the union fabrics and control fabric depend on the values of EPI, PPI and their corresponding yarn qualities used for weaving.

**Effect of Dyeing and Finishing on Fabric Handle**

The colour fastness for washing the materials is very good and values of the ratings are four for UF-X and four to five for both UF-Y and all wool fabric control. The flexural rigidity values of loom state, dyed and polymer finished fabrics are presented in Figure 1. As expected the union fabrics in loom state, dyed and polymer finished fabrics are presented in Table 2. The developed products are light weight and combine the versatile properties of the two natural fibres. The two ply cotton warp is used to provide dimensional stability to the union fabrics. The variations in thickness, cover factor and wt/m² between the union fabrics and control fabric depend on the values of EPI, PPI and their corresponding yarn qualities used for weaving.

**Table 1 Yarn properties**

<table>
<thead>
<tr>
<th>Parameters [n=10]</th>
<th>Yarn-A</th>
<th>Yarn-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count, Nm</td>
<td>2.182</td>
<td>3.92</td>
</tr>
<tr>
<td>Count, tex</td>
<td>458</td>
<td>255</td>
</tr>
<tr>
<td>Twist, turns/mm</td>
<td>1.77</td>
<td>2.12</td>
</tr>
<tr>
<td>Breackng elongation, %</td>
<td>20.24</td>
<td>18.22</td>
</tr>
<tr>
<td>Tenacity, g/tex</td>
<td>2.301</td>
<td>4.001</td>
</tr>
<tr>
<td>Yarn evenness CV% (cut length – 20 mm)</td>
<td>17.67</td>
<td>19.58</td>
</tr>
</tbody>
</table>

Note : values in within parenthesis are CV% and n is the number of tests
The subsequent dyeing decrease the stiffness values by about 30% due to the removal of sizing materials present in the warp yarns, decrease in inter yarn friction, relaxing of stresses acquired during weaving and increase in cohesion between warp and weft. The slight increase in stiffness after polymer application may be due to the flattening of fabrics structure during finishing. Thus, the union fabrics have been made into soft and pliable nature by dyeing and finishing operations. The flexural rigidity of UF-X is comparable to the control of all woollen fabrics. The flexural rigidity of UF-X is about 80% higher than UF-Y due to the variations in fabric construction parameters like wt/m², ends/mm, picks/mm and also due to the use of bulk 2/10 Ne (118 tex) cotton yarn used as warp. Lower flexural rigidity of UF-Y may be attributed to the higher ends/mm in that fabric which creates two opposing effects in warp and weft directional bending. In the warp direction, UF-Y has more load bearing threads (warp) than loading (weft). Therefore, there is less bending in the warp direction. On the contrary, in the weft direction, higher ends/mm means more number of loading threads than load bearing threads (weft). Therefore, the fabric is expected to bend more in the weft direction. Hence, the overall result of flexural rigidity is lower for UF-Y.

The linearity of compression (LC) and resilience of compression (RC) values of union fabrics and control wool fabrics are shown in Figures 2 and 3. In general, LC and RC values of union fabrics are increased by 10% to 12% over the loom state fabrics after dyeing and finishing which provide better compressibility and resilience characteristics equivalent to that of 100% woollen fabric control. The LC and RC values of both the fabrics increase by about 17% after the dyeing, i.e., increase in elasticity and resilience of the products. This may be due to the removal of sizing materials present in the cotton yarn during dyeing which in turn enhance the elasticity of the wool yarn. The LC values get reduced by 4% to 5% after polymer application due to the flattening of fabric structure as well as felting of wool state are stiffer than control fabric. The subsequent dyeing decrease the stiffness values by about 30% due to the removal of sizing materials present in the warp yarns, decrease in inter yarn friction, relaxing of stresses acquired during weaving and increase in cohesion between warp and weft. The slight increase in stiffness after polymer application may be due to the flattening of fabrics structure during finishing. Thus, the union fabrics have been made into soft and pliable nature by dyeing and finishing operations. The flexural rigidity of UF-Y is comparable to the control of all woollen fabrics. The flexural rigidity of UF-X is about 80% higher than UF-Y due to the variations in fabric construction parameters like wt/m², ends/mm, picks/mm and also due to the use of bulk 2/10 Ne (118 tex) cotton yarn used as warp. Lower flexural rigidity of UF-Y may be attributed to the higher ends/mm in that fabric which creates two opposing effects in warp and weft directional bending. In the warp direction, UF-Y has more load bearing threads (warp) than loading (weft). Therefore, there is less bending in the warp direction. On the contrary, in the weft direction, higher ends/mm means more number of loading threads than load bearing threads (weft). Therefore, the fabric is expected to bend more in the weft direction. Hence, the overall result of flexural rigidity is lower for UF-Y.

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than UF-X due to its compact fabric structure. Air resistance
finishing operations. The air resistance value of UF-Y is more
increased by 40% compared to their grey counterparts due
during padding operation. Similar reductions in the LC values
are found by related studies also[^10].

It is observed from Figure 4 that the air resistance values of
the dyed and finished union fabrics UF-X and UF-Y have
increased by 40% compared to their grey counterparts due
to the compacting of fabric structure during dyeing and
finishing operations. The air resistance value of UF-Y is more
than UF-X due to its compact fabric structure. Air resistance
values of the union fabrics UF-X and UF-Y show 64% and
48% lower values, respectively, compared to control 100%
wool fabric. Only wool has the ability to felt during processing,
therefore, the presence of 35% cotton in the union fabrics is
the reason for reduced air resistance of those union fabrics.

**Fabric Performance Properties**

The overall properties are depicted in Table 3. The developed
fabrics have sufficient strength and the values are similar to
all wool fabrics. The strength of UF-Y is 40% higher than
UF-X due to the fine count of the wool weft as well as cotton
warp. The crease recovery angle of both the UF-X and UF-
Y was 20% and 50% less compared to the value (140°) of
the control for 100% wool materials. The use of cotton and
short staple wool in the developed fabrics resulted in low
value of crease recovery angle. It is recognized that when
fibres are too short, fibre to fibre cohesion in yarns is low
and folding may displace fibres in the yarn so that their failure
to return to the original position produces permanent
deforation an hence result in low crease recovery angle.

The relaxation shrinkage of products are within the limits of
the standard value (4%) based on BIS (Bureau of Indian
Standards) specifications and do not differ significantly
among the products. The felting shrinkage of all the union
fabrics is low by 40% to 50% compared to 100% wool control
fabric which exhibits about 20% shrinkage. The reduced
values for all the developed union fabrics are due to the
physical barrier exhibited by the cotton yarn for any friction
between adjacent wool weft yarns. The friction between the
fibres and yarns is responsible for higher values of felting
shrinkage in 100% wool materials.

**Thermal Resistance**

The thermal resistance (R) value of developed wool-cotton
union fabrics is in the medium level with 65 to 70 $\times 10^{-3}$
m²k/w (Table 3) as compared to the control wool fabric. The
R value of 115 $\times 10^{-3}$ m²k/w at 50% RH represent the warmth
of the particular material which keeps a sedentary man
indefinitely comfortable[^11] at 21°C. Based on the above it is
proposed that the developed wool-cotton union fabrics could
be used as blankets for moderate winter season of tropical
countries and summer season of temperate and subtropical
regions where the temperature is around 25°C.

**CONCLUSION**

- An alternate method of utilizing short fine wool is
  proposed in this study.
- The short fine wool is spun into 2 Nm (500 tex) and 4 Nm (250 tex) woollen yarns and used as weft for producing two types of union fabrics using 2/10Ne (118 tex) and 2/17Ne (69 tex) coloured cotton yarns as warp followed by cross dyeing wool portion with 1:2 metal complex dyes (colour fastness to washing rating of 4 to 5) and cationic polymer treatment.
- The high stiffness resulted in lack of handle in grey fabrics
  is reduced by 30% by dyeing and polymer application treatments.
- The relaxation and felting shrinkage of the developed
  wool-cotton union fabrics are 40% to 50% less compared to
  the control all wool materials due to the presence of
  cotton warp.
- The thermal and air resistance values of the wool-cotton
  union fabrics show that they can be used as blankets for
  moderate winter seasons in tropical countries.

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[^10]: Values in within parenthesis are CV% and n is the number of tests

[^11]: Based on the above it is proposed that the developed wool-cotton union fabrics could be used as blankets for moderate winter season of tropical countries and summer season of temperate and sub temperate regions where the temperature is around 25°C.
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