Dimensional characteristics of jute and jute-rayon blended fabrics crosslinked with DMDHEU

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Jute and jute-rayon blended fabrics were crosslinked with 1,3-dimethylol-4,5-dihydroxyethylene urea (DMDHEU) using metal salt catalysts [MgCl₂, ZnCl₂ and Zn(NO₃)₂], acid catalysts (HCl and CH₃COOH) and mixed catalysts (MgCl₂/HCl and MgCl₂/CH₃COOH) by the usual pad-dry-cure method and their dimensional characteristics assessed. The crosslinking treatment reduced the % area shrinkage, i.e. improved the dimensional stability of jute and jute-rayon blended fabrics significantly. The improved dimensional behaviour of treated fabrics has been attributed to the reduction in the elastic property of amorphous regions of cellulose structure. Crosslinking makes such regions behave like orderly oriented regions.

Keywords: Crosslinking, Dimensional characteristics, Jute, Jute-rayon blended fabric, Dimethylol-dihydroxyethylene urea

1 Introduction
The dimensional stability, i.e. resistance to shrinkage or extension on washing, has always been considered important for textile fabrics. It has become much critical in recent years with the increasing demand for dimensionally stable fabrics for dress materials, furnishings, upholsteries, etc. Cellulose fabrics such as cotton and rayon undergo considerable shrinkage after washing. Shrinkage or extension depends upon many factors such as the structure of fibre, construction of fabric, distortions and tension imposed on the fabric during manufacture and wet processing. The changes in dimensional stability can be reduced by fixing the dimension of the fabric in a comprehensive shrinkage machine, a popular process known as "Sanforizing". In chemical fixation, the cellulose chains of the fabric are crosslinked with suitable reagents to improve the dimensional stability. It has been observed that jute fabrics shrink approximately 5-12% in width and 4-15% in length. The differential shrinkage in warp and weft directions of jute fabric is perhaps caused due to the rather high warp-wise tensions to which the fabrics are subjected during wet processing, whereas the dimensional behaviour of grey fabric shows uniform shrinkage in both warp and weft directions (Table 1). In view of our earlier studies showing improved wrinkle recovery properties of jute fabrics modified by crosslinking with few resins in presence of catalyst, it was considered worthwhile to study the dimensional behaviour of jute and jute-rayon blended fabrics after crosslinking them with DMDHEU in presence of different types of catalyst. Hence, the present study.

2 Materials and Methods

2.1 Materials

2.1.1 Fabrics
Grey jute fabric (plain weave, 228 g/m², 48 x 48 ends and picks/dm), bleached jute fabric (plain weave, 325 g/m², 60 x 48 ends and picks/dm), and bleached jute-rayon (60:40) blended fabric (plain weave, 325 g/m², 68 x 72 ends and picks/dm) were used.

Bleached fabrics were prepared as follows. The fabric was cleaned by scouring with 2% sodium carbonate (owf) at 80°C for 30 min. It was then bleached in a laboratory jigger with alkaline hydrogen peroxide. This was followed by washing with water and neutralization with acetic acid to give fabric pH of 6-6.5.

2.1.2 Chemicals
Ahuramine YX, an aqueous product containing 51% solid 1,3-dimethylol-4,5-dihydroxyethylene urea (DMDHEU) was used as the crosslinking agent.

Magnesium chloride, zinc chloride, zinc nitrate,
Table I - Shrinkage behaviour of grey and bleached jute fabrics

<table>
<thead>
<tr>
<th>SI No.</th>
<th>Fabric specifications</th>
<th>% Shrinkage after</th>
<th>1st wash</th>
<th>2nd wash</th>
<th>3rd wash</th>
<th>4th wash</th>
<th>5th wash</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Warp way</td>
<td>Weft way</td>
<td>Warp way</td>
<td>Weft way</td>
<td>Warp way</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Warp way</td>
<td>Weft way</td>
<td>Warp way</td>
<td>Weft way</td>
<td>Warp way</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Warp way</td>
<td>Weft way</td>
<td>Warp way</td>
<td>Weft way</td>
<td>Warp way</td>
</tr>
<tr>
<td>1</td>
<td>Grey</td>
<td></td>
<td>7.4</td>
<td>8.5</td>
<td>8.2</td>
<td>8.5</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td>Ends x picks/dm. 48 x 48</td>
<td>Plain weave</td>
<td>228 g/m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bleached</td>
<td></td>
<td>6.0</td>
<td>7.0</td>
<td>6.5</td>
<td>7.2</td>
<td>7.3</td>
</tr>
<tr>
<td></td>
<td>Ends x picks/dm. 60 x 48</td>
<td>Plain weave</td>
<td>325 g/m²</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

acetic acid and hydrochloric acid (analytical grade) were used as catalysts.

2.2 Methods

2.2.1 Measurement of Length-wise and Width-wise Shrinkage

The dimensional changes, i.e. shrinkage or extension on washing, of the following samples were studied.

1 (a) Jute fabric crosslinked with 2% DMDHEU and 0.5% MgCl₂, cured at 150°C for 5 min, washed and dried.
(b) Same as 1(a) but crosslinked with 4% DMDHEU and 1% MgCl₂.
(c) Same as 1(a) but crosslinked with 6% DMDHEU and 1.5% MgCl₂.
(d) Same as 1(a) but crosslinked with 8% DMDHEU and 2% MgCl₂.
(e) Same as 1(a) but crosslinked with 10% DMDHEU and 2.5% MgCl₂.
(f) Same as 1(a) but crosslinked with 12% DMDHEU and 3% MgCl₂.

2 Jute-rayon (60:40) fabric samples crosslinked as per samples 1(a)-(f).

3 (a) Jute fabric crosslinked with 6% DMDHEU and 2.4% ZnCl₂ catalyst, cured at 150°C for 5 min, washed and dried.
(b) Same as 3(a) using 2.4% zinc nitrate catalyst.
(c) Jute fabric crosslinked with 6% DMDHEU and acetic acid catalyst (pH of the bath adjusted to 2.5), cured at 150°C for 5 min, washed and dried.
(d) Jute fabric crosslinked with 6% DMDHEU and hydrochloric acid catalyst (pH of the bath adjusted to 2.5), cured at 150°C for 5 min, washed and dried.
(e) Jute fabric crosslinked with 6% DMDHEU and mixed catalyst containing 1% magnesium chloride and acetic acid (pH of the bath adjusted to 2.5), cured at 150°C for 5 min, washed and dried.

(f) Jute fabric crosslinked with 6% DMDHEU and mixed catalyst containing 1% magnesium chloride and hydrochloric acid (pH of the bath adjusted to 2.5), cured at 150°C for 5 min, washed and dried.

4 Jute-rayon (60:40) fabric samples crosslinked as per samples 3(a)-(f).

The fabric samples 1(a)-(f) and 2(a)-(f) were tested for the % area shrinkage.

The fabric samples of 60 cm x 60 cm were stitched in all four edges to avoid slippage or distortion of the fabric during tests. Samples were marked 45 cm distance apart in both warp and weft directions. Five markings were made in both the directions so that almost entire area of the fabric samples was covered. All markings were made at least 2.5 cm away from the edges of the test specimen. The samples were washed in a wash wheel having false bottom container and forward and reverse rotation using 5 g/l neutral soap (material-to-liquor ratio, 1:100) at 60°C for 30 min. After washing, the soap solution was drained out and the samples were rinsed twice with water (each time for 10 min) at room temperature. The samples were then taken out, hydroextracted, dried in a flat bed presser drier (AMERESCO), and conditioned at 67% RH and 25°C. The shrinkage after the first and subsequent washes and drying cycle was calculated as follows:

\[
\text{% Length-wise shrinkage} = \frac{\text{Original length} - \text{Final length}}{\text{Original length}} \times 100
\]

\[
\text{% Width-wise shrinkage} = \frac{\text{Original width} - \text{Final width}}{\text{Original width}} \times 100
\]
The average values of 3 tests are reported in the results.

2.2.2 Measurement of % Area Shrinkage

The fabric samples of 60 cm x 60 cm were used for % area shrinkage measurement. An area of 30 cm x 30 cm was marked on the fabric samples and then the samples were washed in a wash wheel as reported in 2.2.1. The % area shrinkage in each sample was calculated as follows:

\[
\text{% Area shrinkage} = \left( \frac{\text{Original area} - \text{Changed area}}{\text{Original area}} \right) \times 100
\]

The average values of 3 tests are reported in the results.

3 Results and Discussion

Jute and jute-rayon (60:40) fabrics crosslinked with a range of DMDHEU add-on using magnesium chloride as catalyst were assessed for their dimensional stability after each and successive five washings. Fig. 1 shows the effect of concentration of crosslinking agent on shrinkage of jute and jute-rayon (60:40) fabrics. For all the concentrations, the degree of stabilization in both the warp and weft directions was found to be very high. 6-8% DMDHEU add-on was found to be adequate since further increase in DMDHEU did not contribute significantly to further shrinkage control. In the case of jute-rayon blended fabric, the degree of stabilization was marginally lower at equivalent treatment than that of 100% jute fabric and good shrinkage control was obtained at 8% DMDHEU conc. The rayon fibre swells and shrinks considerably more than the jute fibre and accordingly in blended fabric the resultant shrinkage is higher than that in jute fabric. For this reason, a higher amount of crosslinking is required to dimensionally set the jute-rayon fabric.

The effect of DMDHEU conc. on shrinkage of jute and jute-rayon fabrics on successive washings is shown in Figs 2 and 3 respectively. It is observed from these figures that in the fabrics cross-linked with more than 4% DMDHEU, the shrinkage practically ceased after second wash and the fabrics approached to stable dimensions.

The effects of crosslinking 6% DMDHEU with jute and 8% DMDHEU with jute-rayon blended fabrics using different types of catalysts on dimensional stability are shown in Table 2. It is observed from the table that with all the catalysts, the degree of stabilization of dimension in both types of fabrics is very good, particularly in warp direction. However, the shrinkage in weft direction is higher than that in warp direction and it becomes stable in successive washes, i.e. in subse-
Table 2 – Effect of crosslinking treatment with DMDHEU\(^a\) using various types of catalyst on shrinkage property of 100% jute fabric\(^b\) and jute-rayon (60:40) blended fabric\(^c\)

<table>
<thead>
<tr>
<th>Catalyst conc. (w/v)</th>
<th>% Shrinkage after</th>
<th>Jute</th>
<th>Jute-rayon</th>
<th>Jute</th>
<th>Jute-rayon</th>
<th>Jute</th>
<th>Jute-rayon</th>
<th>Jute</th>
<th>Jute-rayon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st wash</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2nd wash</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3rd wash</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZnCl(_2) (2.4%)</td>
<td>0</td>
<td>0.78</td>
<td>0.80</td>
<td>1.17</td>
<td>0.40</td>
<td>0.82</td>
<td>0.85</td>
<td>1.20</td>
<td>0.40</td>
</tr>
<tr>
<td>Zn(NO(_3))(_2) (2.4%)</td>
<td>1.03</td>
<td>1.06</td>
<td>1.25</td>
<td>1.03</td>
<td>1.05</td>
<td>1.06</td>
<td>1.03</td>
<td>1.03</td>
<td>1.05</td>
</tr>
<tr>
<td>Acetic acid (pH 2.5)</td>
<td>0.9</td>
<td>1.03</td>
<td>1.06</td>
<td>1.07</td>
<td>1.02</td>
<td>1.04</td>
<td>1.06</td>
<td>1.75</td>
<td>1.02</td>
</tr>
<tr>
<td>Hydrochloric acid (pH 2.5)</td>
<td>0.85</td>
<td>0.76</td>
<td>1.17</td>
<td>0.05</td>
<td>0.09</td>
<td>0.80</td>
<td>1.02</td>
<td>0.015</td>
<td>0.09</td>
</tr>
<tr>
<td>MgCl(_2) (1%) + acetic acid (pH 2.5)</td>
<td>1.10</td>
<td>1.02</td>
<td>1.02</td>
<td>1.05</td>
<td>1.02</td>
<td>1.25</td>
<td>1.35</td>
<td>1.70</td>
<td>1.25</td>
</tr>
<tr>
<td>MgCl(_2) (1%) + hydrochloric acid</td>
<td>0.80</td>
<td>1.03</td>
<td>1.00</td>
<td>1.04</td>
<td>1.00</td>
<td>1.05</td>
<td>1.03</td>
<td>1.05</td>
<td>1.05</td>
</tr>
</tbody>
</table>

\(^a\)DMDHEU conc.: 6% for jute fabric and 8% for jute-rayon fabric.
\(^b\)Weight, 325 g/m\(^2\); ends \times picks/dm, 60 \times 48.
\(^c\)Weight, 325 g/m\(^2\); ends \times picks/dm, 60 \times 72.

quent washes the shrinkage value decreases gradually.

The shrinkage causes loss in fabric area since it occurs in both the directions. This is also known as area shrinkage. The shrinkage in warp direction is not equivalent to that in weft direction and the relationship between these two are not correlated. The effect of different concentrations of DMDHEU on area shrinkage was calculated on the basis of the change in area (30 cm \times 30 cm) after successive washings. The results are shown in Figs 4a-4c which indicate that the area shrinkage decreases gradually with the increase in DMDHEU concentration.

The change in area or dimensions of warp and weft of a textile woven material on wetting depends upon several factors which include (i) type of fibre, (ii) fabric geometry and (iii) the stress/strain applied to the fabric during mechanical and chemical processing. The principal cause of shrinkage of a fabric is the swelling of yarns in water or soap-water solution. The amount of swelling, i.e. increase in yarn diameter, is expected to be exactly proportional to the diametrical swelling of fibres in yarn. Since the shrinkage in jute yarn is negligible (less than 1%), the fabric shrinkage must come from the structural changes within the fabric. When the fabric is wet and the yarn swells, a greater length of warp yarn will be required to interweave the increased diameter of the swollen threads if the threads are to remain in the same position. Since in any of the existing woven structures such extra warp yarns are not available, it follows that contraction in warp direction occurs, resulting in length-wise shrinkage. The shrinkage of cloth in warp-way thus causes an increase in crimp of the warp threads. In a similar way, the weft crossing threads also resist extension and the cloth contracts weft-way.

It was earlier reported\(^3\) that the tensile strength of the fabric is reduced by crosslinking. Andrews et al\(^5\) reported that both the tensile strength and the elongation at break of the cotton fabric are reduced by crosslinking. The reason for this is that the crosslinking agent crosslinks between the hydroxyl groups of amorphous regions, filling the intramolecular spaces therein. Consequently, the jute fibres in the amorphous regions become less elastic and behave like orderly oriented regions, giving some compactness like that of crystalline region. This ultimately gives anti-shrink or anti-elongation properties in the treated fabrics. It is also postulated\(^6\) that the cross-
linking treatments restrict the swelling of the fibre in water and with the increase in resin add-on, the ability of fibre to swell in water decreases. As a result, the crosslinked fabric resists to change in dimensions. The results are in conformity with those of Andrews et al. on knitted fabric.

4 Conclusions
4.1 Crosslinking of jute and jute-rayon blended fabrics with DMDHEU reduces the shrinkage of fabrics after washing or laundering and the effect is pronounced for all the concentrations of DMDHEU studied. However, the optimum concentration of DMDHEU is 6% for all-jute fabric and 8% for jute-rayon fabric.
4.2 Jute-rayon blended fabric shows marginally higher shrinkage than all-jute fabric after crosslinking.
4.3 The catalyst type has no significant effect on the dimensional characteristics of jute and jute-rayon blended fabrics and all the catalysts studied impart good dimensional stability.
4.4 There is no relationship between warp-wise and weft-wise shrinkage. To describe dimensional stability of the fabric qualitatively, the % area shrinkage would be appropriate for jute and jute-rayon blended fabrics.

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References