Reduction of Fibrillation of Lyocell Fabric in Continuous Dyeing

Noor Ahmed* and Nazakat Ali
Department of Textile Engineering, Balochistan University of Information Technology, Engineering & Management Sciences, Quetta

Abstract

Lyocell is one of the recent regenerated cellulosic fibres. It is produced by an environmentally-friendly process from wood pulp. Chemical structure of lyocell is similar to that of cotton and other regenerated fibres. The main difference is of the length of polymer chains (degree of polymerization). The main technical problem with this fiber is its ease of fibrillation. Fibrillation becomes apparent when fiber is abraded in wet state during pre-treatment and dyeing. The reason of such change of lyocell fibre surface is due to its physical structure (i.e. arrangement of polymer chains in amorphous and crystalline regions). Lyocell fabrics were processed by continuous dyeing method to observe the fibrillation effects. Cross-linking agents were applied before and after dyeing to see their effect on fibrillation. The fibrillation was assessed by observing the fiber morphology on Scanning Electron Microscope (SEM). The samples were also tested for color fastness to washing. Further, the color assessment k/s was performed to compare color yield of dyed, dyed cross-linked and cross-linked samples. The cross-linked dyed and dyed cross-linked samples were found to have reduced fibrillation. There was not any significant difference in colorfastness of dyed, dyed cross-linked and cross-linked dyed fabrics and the fastness was generally very good to excellent.

Key words: Lyocell, Fibrillation, Cross-linking agent, Continuous Dyeing.

*Corresponding Authors’ email: noor.ahmed@buitms.edu.pk

INTRODUCTION

Lyocell is the first in new generation of cellulosic fibers. TENCEL® is the registered trade name for lyocell which is a biodegradable fabric made from wood pulp Cellulose. It is produced by environmentally-friendly process from wood pulp. It is comfortable and popular in clothing because of absorbent nature and high strength. Lyocell is regenerated and it is 100% cellulosic fiber (Patrick, 2001). It is durable and has low shrinkage as compare to other regenerated cellulosic fibers (Bates et al., 2008). Lyocell is a fiber spun from organic solvents. Commercially, lyocell fibers are regenerated cellulose fibers spun from a cellulose solution in a mixture of N-methylmorpholine N-oxide (NMMO) and water. Lyocell is more environment friendly fiber (Renfrew and Philips, 2003). The method involves dissolving cellulose in N-methyl morpholin-N-oxide (NMMO) and filament is extruded into spinning bath solution followed by washing, drying and cutting (Bates et al., 2004). After drying material is passed to finishing section for the application of lubrication. This may be silicon, soap or any other agent (Martin et al., 1998). In wet state lyocell fibers fibrillates when they are rubbed or agitated during wet-processing, the micro fibrils are formed on the fiber surface. It affects lyocell to greater degree than cotton, flax and viscose (Chaudemanche and Patrick, 2010). Dyeing with Bi-functional reactive dyes help to reduce fibrillation problem (Nicolai et al. 1996). Fibrillated lyocell produces darker shades which means higher color uptake as compare to non-fibrillated it may be due to low light scattering on fibrillated surface (Goswani et al., 2007). The fibrillation tendency of lyocell can be reduced by chemical reagent which contains at least two aliphatic aldehyde groups, capable of reacting with each other (Wang et al., 2003). Different types of finishes have been used for...
cross-linking cellulose fibers. DMDHEU (Dimethylol dihydroxyethyleneurea) is most important reactant resin. DMEU (Dimethylol ethylene urea) is a reactive resin of high reactivity. It is suitable for the production of resin finishes on cotton/polyester blends. DMDHEU is very stable to hydrolysis, having bad colour fastness against chlorine. The finished effects are fast to boiling wash treatments. (Rouette, 2000). The aim of this research work was to control the problems of fibrillation during wet processing of lyocell fabric and minimize the fibrillations by using cross-linking agents.

Table 1: The specific dyes for Tri-chromatic combination and their grams per liter

<table>
<thead>
<tr>
<th>Grams/liter</th>
<th>Drimaren K dyes</th>
<th>Drimaren CL dyes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.7 g/l</td>
<td>Yellow K2R = 1 g/l</td>
<td>Yellow C12R = 1 g/l</td>
</tr>
<tr>
<td></td>
<td>Red K4BL = 0.5 g/l</td>
<td>Red C14BN = 0.5 g/l</td>
</tr>
<tr>
<td></td>
<td>Blue K2RL = 0.2 g/l</td>
<td>Navy CLR = 0.2 g/l</td>
</tr>
<tr>
<td>13 g/l</td>
<td>Yellow K2R = 6 g/l</td>
<td>Yellow C12R = 6 g/l</td>
</tr>
<tr>
<td></td>
<td>Red K4BL = 3 g/l</td>
<td>Red C14BN = 3 g/l</td>
</tr>
<tr>
<td></td>
<td>Blue K2RL = 4 g/l</td>
<td>Navy CLR = 4 g/l</td>
</tr>
</tbody>
</table>

Preparation of Gray Lyocell Fabric for Dyeing

Desizing and bleaching.

Desizing process was carried out by pad-batch process using Desizer HT 100 (Enzymatic). Lyocell fabric rolled in the form of small batch for 12 hours. After 12 hours washing cycle was carried out in multiple sections; such as hot wash (90 - 95°C) for 15 min, warm wash (60 - 70°C) for 10 min. Finally the fabric dried in dryer. The bleaching process of the fabric was carried out using mild chemical concentrations as per recommendation of Clariant Pakistan Ltd.

Process Sequences for Dyeing and Finishing of Lyocell Fabric.

The process sequences for dyeing and finishing in this study are given by chart.

1. Dyeing with Drimaren CL & K dyes each 1.7 & 13 g/l shades
3. Finishing and dyeing with Drimaren CL & K dyes each 1.7 & 13g/l shades
2. Dyeing and finishing Drimaren CL & K dyes each 1.7 & 13g/l shades

Figure 1: Schematic of Lyocell manufacturing (Patrick, 2001)

Figure 2: process sequence for dyeing and finishing of lyocell fabrics by chart.
Dyeing of Lyocell Fabric with Reactive Dyes

Continuous dyeing was carried out for assessment of fibrillation properties. Drimaren K and Drimaren CL dyes were applied for comparative analysis. Continuous dyeing process was carried out on the fabric which was pre-treated. Twelve samples were dyed through continuous dyeing. Six samples of each Drimaren K dyes and Drimaren CL dyes dyed in two different concentrations 1.7g/l and 13g/l. Drimaren K and Cl dyes auxiliaries; wetting agent (Leonil EHC) anti migrating agent (Solidikol N), fixing agent (Na₂CO₃) and the dyes were used. The Fabric Was Padded at 75 % Pick up. It Was Dried at 120°C for 2 Min and Cured at 160°C for 1 Min.

Finishing of Lyocell Fabric

Fabric Was Padded in the Recipe Containing Arkofix XLF, Mgcl₂, and Ceranine HCS at 75% Pick up. After Drying of Lyocell Fabric at 120°C, It Was Cured for 3 Minutes at 185°C.

Color Fastness to Washing Test (ISO 105-c03)

Samples Were Treated According to ISO 105-CO3. First Bulk Solution for Washing Prepared with 50:1 in Each Washing Container. Then Fabric Pieces (10x4 Cm²) Dipped in Containers and These Containers Fixed into the Laundro-meter. Machine Was Run at 60°C for 30 Minutes. After That, Samples Taken Out, Rinsed with Cold Water and Dried.

Colour Difference Test (Aatcc 173-2005)

Dyed and Finished Samples Were Tested on Spectrophotometer after Conditioning at 21±1°C Temperature and 65±2% Relative Humidity. Spectrophotometer Was Calibrated First with White, Black and Green Colored Tiles. The Samples Sequentially Assessed for the Color Strength (K/s) Values.

Scanning Electron Microscope (Sem) Analysis

The Images of Lyocell Samples Were Captured on Scanning Electron Microscope (JE-OL Japan Model No. JSM- 6380A) at the Magnification of 100-500. Samples for SEM Analysis Were Coated on Auto Coater (JE-OL Japan Model No. Jfc- 1500). The Coating Was of Gold and Samples Were Coated up to 300°a.

RESULTS AND DISCUSSION

This Section Presents Experimental Results and Analytical Discussion on Technical Fibrillation Problem of the Lyocell Fabric. The Section Focused on the Effect of Dyeing Processes on Fibrillation and Other Related Properties of Lyocell Dyed Fabric. The Improvements by Pre and Post Cross-linking Processes Have Also Been Reported in This Section.

Comparative Study of Dyed, Dyed Cross-linked and Cross-linked Dyed Samples

Colour fastness to washing:

It was observed that up to 13 g/l of dark shades lyocell dyed samples gave good results. Reasons of good result were due to stable covalent bond formation between cellulose and reactive dyes. It was also observed that Drimaren K dyed samples have better washing results in comparison to Drimaren CL dyes on lyocell fabrics.
**Color strength (K/S)**

It was observed that, in general colour strength values increases by the increasing in concentration of dye applied. It was generally observed that dyed and cross-linked dyed display higher colour yield.

**Surface Analysis of Lyocell Fabric:**

It was observed from following figures that at magnification of x100 and x 500 dyed samples have higher fibrillation problem as compare to dyed cross-linked and cross-linked dyed lyocell samples. In both types of dyes (CL and K) at different concentrations fibrillation of dyed samples was higher. The problem of fibrillation was reduced, using cross-linking agents. Reason of this was that Reactive dyeing processes and resin finishing reduce fibrillation of lyocell fibers (Wang et al., 2003).

**Figure 4:** colour strength at maximum absorption of dyed, dyed cross-linked and cross-linked dyed samples by chart.

**Figure 5:** Scanning electron micrographs of Drimaren K 1.7g/l (a) dyed, (b) dyed cross-linked (c) cross-linked dyed at magnification of x100 and (A) dyed, (B) dyed cross-linked (C) cross-linked dyed at magnification of x500.
REDUCTION OF FIBRILLATION OF LYOCELL FABRIC IN CONTINUOUS DYEING

Fig 6: Scanning electron micrographs of Drimaren CL 1.7g/l (a) dyed, (b) dyed cross-linked (c) cross-linked dyed at magnification of x100 and (A) dyed, (B) dyed cross-linked (C) cross-linked dyed at magnification of x500.
Fig 7: Scanning electron micrographs of Drimaren K 13g/l (a) dyed, (b) dyed cross-linked (c) cross-linked dyed at magnification of x100 and (A) dyed, (B) dyed cross-linked (C) cross-linked dyed at magnification of x500.
Fig 8: Scanning electron micrographs of Drimaren CL 13g/l (a) dyed, (b) dyed cross-linked (c) cross-linked dyed at magnification of x100 and (A) dyed, (B) dyed cross-linked (C) cross-linked dyed at magnification of x500.
CONCLUSION
This study showed that regenerated cellulosic lyocell fiber has the technical problem of fibrillation generation during processing. Pre-treated lyocell fabric was found to have excellent absorbency. It was found in this study that the fibrillation problem increased as the lyocell fabric passed through further processes such as dyeing and washing. It was further concluded from the results obtained that the fibrillation can be controlled by the application of internal polymer cross-linking agent, which acts as a linking bridge between cellulosic polymer chains. After application of cross-linking agent, dye sites are disturbed because cross-linking agents attach at hydroxyl group of cellulose which is also the dye site for reactive dye. Thus, there are always chances for cross-linking agent to occupy the dye site and compete with reactive dye molecules. This may affect the color strength. Fiber surface analysis showed that the surfaces of fibers were smoothened after application of cross-linking agents but shade depth and hue changed slightly. If pre-treatment cost of natural cellulosic fabrics and lyocell fabrics is compared for similar whiteness and absorbency level then it can be concluded that lyocell pre-treatment was economical. This is because of less processes and low chemical concentrations required for pre-treatment of lyocell fabric. Further, lyocell fabric has higher absorbency, thus, having more dye-uptake and less dye wastage than the other cellulosic fibres. The lyocell fabrics attained peach-skin effect during wet-processing, which is an advantageous factor over natural cotton and other regenerated cellulose fibres.

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