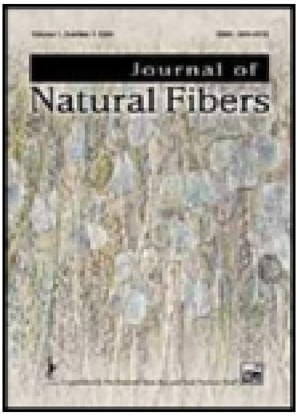

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A Novel Chemical Finishing Process for Cashmere/PVA-Blended Yarn-Made Cashmere Fabric

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Cashmere fiber has to be blended with either nylon or water-soluble Polyvinyl alcohol (PVA) as a carrier fiber for spinning on worsted spinning system. The spun yarn is used for producing high--end fashion fabrics. The nylon or PVA portion is then removed from the fabric by treating with hydrochloric acid or hot water. The PVA based process is considered eco-friendly as compared to nylon-based process. However, the whiteness and handle of such fabric is inferior as compared to cashmere fabric produced from nylon-based process. This study attempts to improve the whiteness and handle of the fabric by using dilute sulfuric acid in place of hot water to remove PVA. The fabric produced from newly developed process shows improvement in whiteness index (28%) and handle (20%) than fabric of hot water-based process. It exhibits similar handle like that of cashmere fabric produced from nylon-based process. The new process uses only mild concentration of acid and can be considered as eco-friendly as hot water-based process. The sulfuric acid facilitates easy dissolution of PVA from the fabric and prevents the redeposition of the same.

KEYWORDS *cashmere, carrier spinning, nylon, PVA, handle, whiteness index*

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羊绒纤维必须配合与尼龙或水溶性PVA作为对精纺纺纱系统纺载体纤维。纺出的纱线用于生产高档时装面料。尼龙或PVA部分然后用盐酸或热水处理织物的去除。相比尼龙的过程，PVA的过程被认为是环保的。然而，这种织物的白度和手柄差相比，　是羊绒面料生产的尼龙为基础的进程。本研究试图改善白度和处理的织物通过用稀硫酸代替热水除去的PVA　。新开发的过程中产生的织物显示了比热水为基础的进程的纤维的白度指数（28%）和手柄（20%）的改善。它表现出类似的手柄一样，羊绒面料生产基于尼龙的过程。新方法使用只有轻微的酸的浓度可作为环保型水基过程热硫酸促进PVA易溶解于织物和预防同沉积。

关键词：羊绒纺纱，载体，尼龙，PVA，手柄处理，　白度指数

INTRODUCTION

Cashmere fiber is one of the finest animal fiber having special attributes like softness, smoothness, whiteness, unique handle, etc., when compared to sheep wool. The fiber is popularly known as "Pashmina" produced from the down coat of domesticated goat C*apra* hircus indigenous to Asia. It is one of the costliest fibers in the world. The fiber is used to prepare high-end fashion fabrics. The total cashmere fiber production in the world is about 15,000 tons per year. China and Mongolia are the major producing countries with 90% share. The rest 10% of total production is from other countries like Iran, India, Afghanistan, Nepal, etc. (Wani and Wani 2007). India contributes less than 1% of the total cashmere production. However, the fiber produced from local goat called "Changthangi" in Leh and Ladakh region situated at 3,000–5,000 m above sea level is considered as superior quality. The fiber produced in this region has 12–13 μ diameter with 55–60 mm length available in white, gray, and brown colors. The proportion of under coat to guard hair is 40–50%. The harvested fibers are traditionally spun by hand spinning wheel in to the yarn of R 25/2 tex and used for making light weight shawl (Ishrat et al. 2012). The hand spinning process is laborious and time consuming. The weaving of handspun yarn is also very difficult due to frequent breaking of yarn (Nazir et al. 2012).

It is very difficult to spin cashmere fiber using machine due to its soft, short, and slippery scale which creates lapping due to development of static charges during carding and spinning process (Raja et al. 2011). Several attempts have been made to spin the cashmere wool using machine by carrier spinning method (Shakyawar et al. 2012). Under this method, the cashmere fiber is blended either with nylon or water-soluble polyvinyl alcohol fibers and spun into yarn. The blended yarn is then used for weaving-suitable fabric. Finally, the cashmere/carrier blended fabric is treated with suitable solvent to remove the nylon or polyvinyl alcohol fibers. The Polyvinyl alcohol (PVA)-based carrier spinning method requires the use of hot water for removal of carrier fiber whereas nylon-based process requires concentrated hydrochloric acid. The PVA-based process is considered as eco-friendly when it is compared with nylon based process due to the use of hot water and easy handling (Zhou et al. 2011). However one of the problems associated with cashmere/PVA blended yarn made fabric is that reduction in handle of such fabric coupled with yellowness/dullness in color due to the presence of residual PVA in the fabric. The cashmere fabric made from cashmere/nylon-blended yarn exhibits similar handle as well as whiteness like that of fabric made out of traditionally spun yarn. Wool-processing industries are reluctant to adopt the cashmere/PVA-blending-based fabric making technique even though the process is easy and eco-friendly compared to cashmere-nylon-based fabric. In the present study, attempts have been made to develop suitable finishing process to solve the handle and whiteness-related problems associated with cashmere fabric made out of cashmere/PVA-blended yarn.

EXPERIMENTAL

A cashmere/PVA-blended fabric is taken for the study. The fabric is prepared by the following process sequence. Briefly, the dehaired and carded sliver of cashmere fiber obtained from Changthangi goat of Leh and Ladakh region of India is passed through gill box 3–four times to remove the short fibers and to parallelize them. At this stage, the PVA fiber in sliver form is blended with the cashmere fiber in the proportion of 40:60 and allowed to undergo—five to six passages in gill box for proper blending. The resultant sliver is then converted into roving on bobbiner. The roving is taken to ring frame for spinning. The produced yarn is doubled to get the required strength which is then used for weaving on Handloom. The fineness of the yarn is R 50/2 tex. The weaving of cashmere yarn into shawl is carried out in special type of handloom. Before weaving, the yarn is sized with locally made pounded rice gum. The ends and picks per inch of shawls are generally kept between 50–60 and 46-56, respectively. The area density of the fabric is 0.120–0.13 kg m^{-2}. A cashmere/nylon-blended fabric in the 50:50 proportion of equal dimension is also taken for the study as reference fabric.

Removal of Carrier Fibers

The PVA present in the fabric is removed using two methods. In the first method, the fabric is treated with only hot water at 90°C for 10 min using material to liquor ratio of 1:30. This method is conventionally used in the industrial sector. In the second method, 0.5kg m^{-3} sulfuric acid is added to dissolution bath and then treated at 90°C for 10 min using material to liquor ratio of 1:30. In the case of nylon-blended fabric, the nylon portion is removed by treating with 20% hydrochloric acid in three consecutive baths as described elsewhere (Raja et al. 2011). The weight loss in the fabrics due to the removal of carrier fibers in terms of percentage is calculated by taking initial and final weights before and after dissolution.

Scanning Electron Microscopy

The two types of cashmere fabrics obtained from cashmere/PVA fabric through hot water treatment, and sulfuric acid treatment were analyzed for their surface morphology using Philips XL-30 model Scanning Electron Microscope (SEM) (Philips, Amsterdam, Netherlands). The SEM study was conducted to know about the presence of residual PVA in the fabric and the changes in cashmere cuticle surface.

Determination of Whiteness Index

The whiteness of the all the three treated fabrics were determined using Jay Pak 4802 spectrophotometer with color-matching system (Jay Instruments & Systems Ltd, Mumbai, India) and the CIE whiteness index was measured using the standard procedure (per AATCC test method 110–2005).

Objective and Subjective Handle Analysis

The handle related properties of the treated fabrics were determined by using SiroFAST method. The parameters such as surface thickness (ST), bending rigidity, and shear rigidity were taken for the comparative purpose of the taken fabrics (Goud 2012). The subjective handle of the treated fabrics were analyzed by 20 expert consumers. They were asked to award rank to the fabrics from 1-5 in terms of softness, whiteness, and overall handle. The rank of 5 implies excellent handle with very good softness, smoothness, and whiteness. The ranks 4, 3, 2, and 1 denote very good, good, average, and poor, respectively.

RESULTS AND DISCUSSION

PVA is the polymer of vinyl alcohol. It is formed by carbon–carbon bond and strong inter and intra molecular hydrogen bonding. PVA is soluble in water and biodegradable. However, the solubility depends on the degree of polymerization, molecular weight of the polymer, and temperature. PVA with higher molecular weight is soluble in water at relatively high temperature (70°C). During hydrolysis the strong hydrogen bonding present in the polymer is disturbed and the hydrogen bonding between polymer and water enhanced as depicted in Figure 1.

The PVA fiber used for the carrier spinning is of higher molecular weight and hence required higher temperature for dissolving in water (Hassan and Peppas 2010). In the present study, hot water and hot water along with 0.5kg m^{-3} sulfuric acid are used to remove the PVA. The weight loss due to the removal of carrier fibers by hot water method and sulfuric acid method is 43% and is 44.8%, respectively. The presence of sulfuric acid in dissolution medium influences the hydrolysis of PVA positively. Hence, the fabric treated with sulfuric acid effectively removed majority of residual PVA which resulted in higher weight loss compared to hot water method.

The SEM of treated fabrics, shown in Figure 2 clarifies that simply hot water-treated fabric contains higher proportion of residual PVA in discrete places compared to sulfuric acid-treated fabric. In the sulfuric acid-treated fabric, the presence of residual PVA is less and the cuticle scales are clearly observed compared to hot water method. In the case of hot water method, more amount of dissolved PVA is redeposited on the cashmere portion, whereas, in the sulfuric acid method, the redeposition of PVA is entirely diminished.

The whiteness index of the treated fabrics is given in Figure 3. The results indicate that sulfuric acid-treated fabric has 28% more whiteness than hot water-treated one. The whiteness index is even more than the cashmere fabric produced from cashmere/nylon-blended yarn. The change in whiteness is significant. The predominant removal of residual PVA due to the sulfuric acid treatment is the reason for higher whiteness.

The handle-related properties of the treated fabrics such as surface, shear, and bending rigidity are determined using SIROFAST method. The ST, released ST, and formability of treated and reference fabrics are shown in Figure 4. The ST of sulfuric acid-treated cashmere fabric is 17% lower than hot water treated and reference cashmere fabric. The results show that the consolidation is significantly low in the case sulfuric acid-treated cashmere fabric compared to hot water-treated fabric and reference fabric. The consolidation in cashmere fabric during treatment which leads to mat appearance is considered as disadvantageous in the processing industries. The difference between ST and released surface thickness (STR) which indicates the

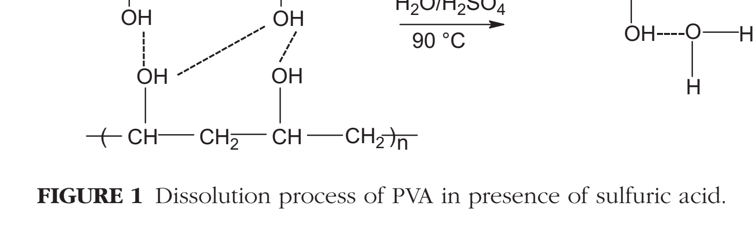

FIGURE 1 Dissolution process of PVA in presence of sulfuric acid.

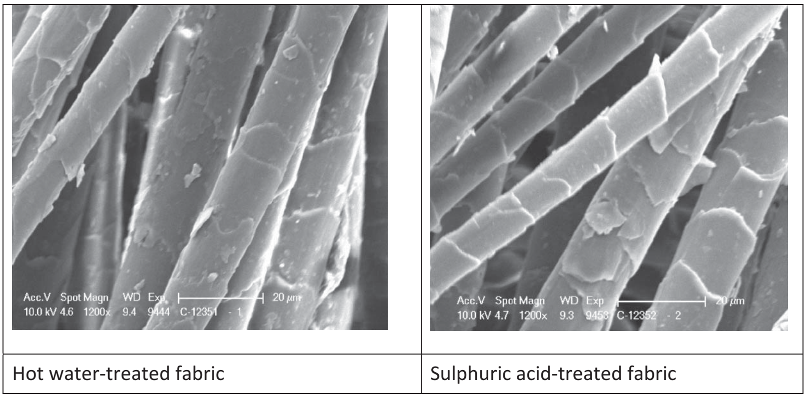

FIGURE 2 SEM images of cashmere fabric.

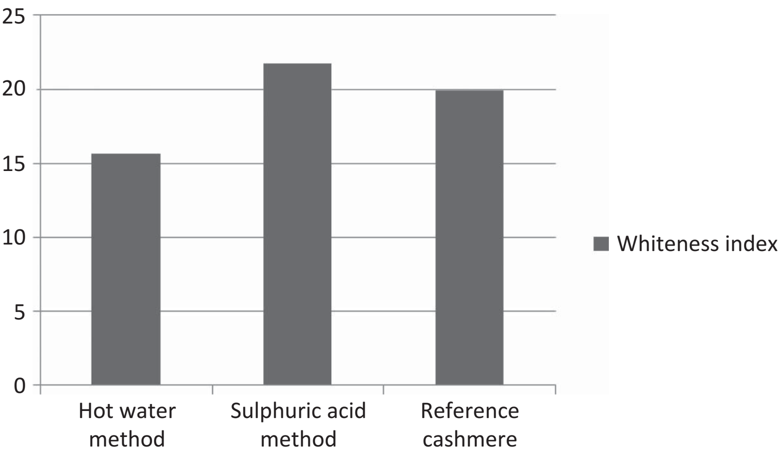

FIGURE 3 Whiteness index of treated cashmere fabrics.

stability of surface finish is 8% in sulfuric acid-treated fabric compared to 11% in the cases of hot water-treated and reference fabrics. The lower value of the difference between ST and STR indicates higher the stability of surface finish. From the results, it is inferred that the surface finish obtained by sulfuric acid-treated cashmere fabric is stable. The formability of sulfuric acid-treated cashmere fabric is 17% higher compared to hot water-treated fabric. However, the formability value is close to the reference cashmere fabric taken in this study. Hence, it can be concluded that sulfuric acid treatment produces advantageous ST properties on cashmere fabrics than hot water treatment.

The bending rigidity, shear rigidity values of the treated and reference fabrics are given in Figure 5. The bending rigidity of sulfuric acid-treated cashmere fabric is close to the reference cashmere fabric. However, it is 22%

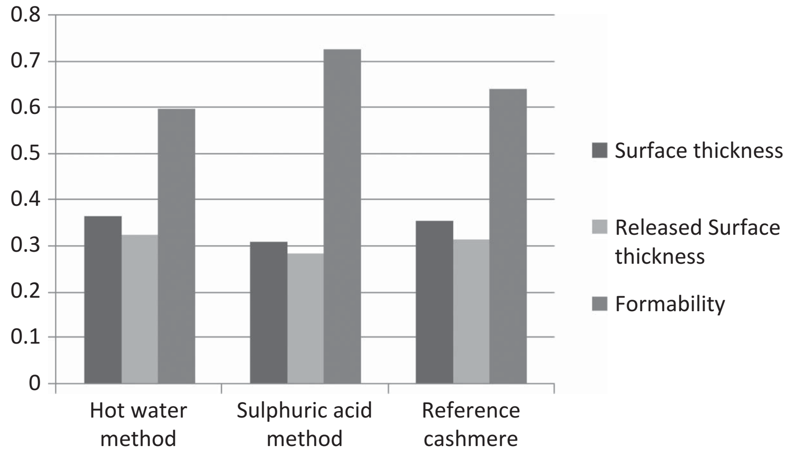

FIGURE 4 Surface properties of treated cashmere fabrics.

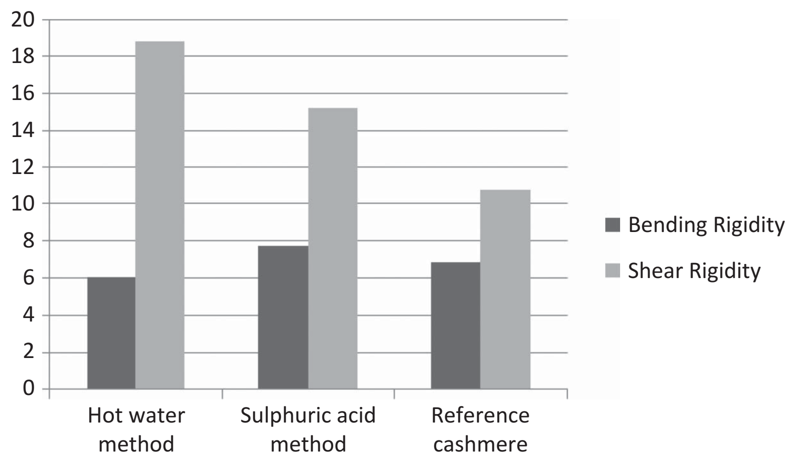

FIGURE 5 Bending and shear rigidity of treated cashmere fabrics.

higher compared to hot water-treated fabric. The shear rigidity of sulfuric acid-treated cashmere fabric is 24% lower compared to hot water-treated one and 28% higher compared to reference cashmere fabric. Shear rigidity is one of the good indicators of the softness of the fabric. The results show that the sulfuric acid-treated fabric has good softness than hot water-treated fabric. The overall handle of the fabric depends on the ST, formability, bending rigidity, and shear rigidity properties. From the results, it is inferred that the sulfuric acid treatment influences the handle-related fabric of cashmere fabric produced from cashmere/PVA-blended yarn. The sulfuric acid-treated fabric shows the values of above handle-related properties close to reference cashmere fabric except shear rigidity.

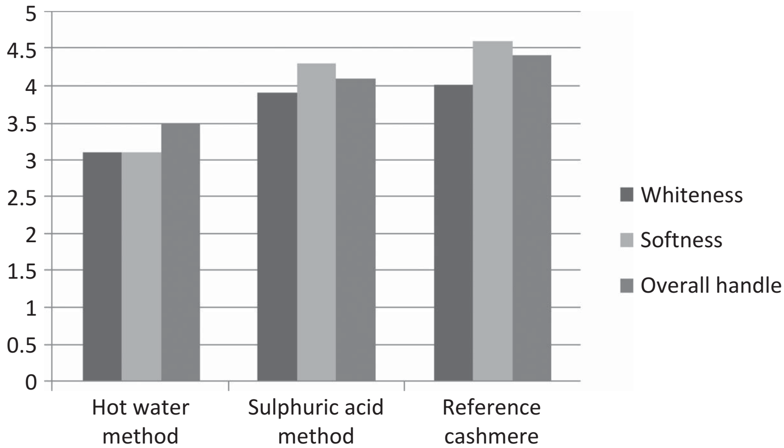

FIGURE 6 Subjective analysis ratings of treated cashmere fabrics.

The result of subjective analysis of the treated and reference fabrics is given in the Figure 6. The results indicate that the sulfuric acid-treated fabric get higher ranking by 20–25% in terms of softness, whiteness, and over all handle compared to hot water-treated one. The rankings of sulfuric acid-treated fabric are close to the reference cashmere fabric taken for this study. The subjective analysis result is in good agreement with objective analysis result.

CONCLUSION

Based on the results, it is concluded that handle-related problems associated with cashmere/PVA-blended yarn made cashmere fabric can be reduced by treating with 0.5 kg m^{-3} sulfuric acid at 90°C instead of simply using hot water. The sulfuric acid-treated cashmere fabrics showed 20–25% higher whiteness, softness, and handle-related properties compared to hot water-treated fabric. The whiteness and handle value of sulfuric acid-treated fabric is comparable with the reference cashmere fabric made from cashmere/nylon-blended yarn. The use of dilute sulfuric acid is not harmful to the cashmere fabric and theoretically considered as gentle as hot water treatment. The proposed treatment of dilute sulfuric acid preserves the eco-friendly characteristics of cashmere/PVA process as well as enhances the whiteness- and handle-related properties of such fabric.

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