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Investigation of the Effect of Continuous Finishing on the Mechanical Properties and the Handle of Wool Fabrics

D. Sun* and G. K. Stylios

School of Textiles and Design, Heriot-Watt University, Edinburgh, UK

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Abstract: The effect of scouring, bleaching and dyeing on the low stress mechanical and surface properties of wool woven fabrics was studied. Fabric properties were measured by the KES-FB system. In general, mechanical properties of the treated fabrics are greatly affected by scouring, moderately by dyeing and least by bleaching.

Keywords: Wool fabric, Finishing, Dyeing, Fabric hand evaluation, KES-FB evaluation

Introduction

Fabric handle is a term used to describe the combination of stimuli subjectively derived from the tactile assessment of the mechanical properties of the fabric [1]. It is one of the most important factors in the textile and garment manufacturing and retailing industry for assessment of fabric and garment qualities. Hand properties describe the performance of a fabric on skin contact, and depend on the fibre type and content, the fabric construction (surface structure) and the fabric finishing stages undertaken.

Traditionally, in the textile and clothing industries, the assessment of fabric handle is made subjectively by individual judges. Objective specification of the fabric qualities may be traced back to some early works [2-5]. Significant progress has been reported in the application of objective evaluation of fabric with low stress mechanical properties on finishing stages [6-9]. The effect of mechanical and surface properties of wool fabric on fabric handle during the continuous pre-finishing and dyeing processes have not yet been investigated. In this study, the degree of change in low mechanical properties such as compression, bending, shear, tensile and surface properties and the fabric handle of wool woven fabrics during the pre-finishing processes, are being investigated quantitatively using the KES-FB objective evaluation system.

Experimental

Methodology

Preparation of wool usually involves desizing of the material for removing the warp yarn starches during warping (for desized fabric), scouring of the material to remove the natural impurities, followed by a bleaching process which imparts whiteness by destroying the natural colouring matters and enhancing the fabric wettability, and finally the dyeing process which chemically bond the dye with the fibre molecules by covalent bonding.

Two different control fabrics A and B were used in continuous pre-finishing and dyeing treatments in this study. Details of these fabrics are given in Table 1. Control loom state wool fabrics A and B (stage 1) were scoured (stage 2), bleached (stage 3) and dyed (stage 4) under different specific solutions, processing temperatures and treatment times.

Samples for each finishing stage were taken across the entire fabric in a way that such samples should not contain any identical warp and weft threads. For each of the finishing stage, three samples, each 20 cm × 20 cm, were measured from each of the entire piece of fabrics.

The applications of aqueous dilution of fabrics are carried out in a Fluidised Bed Rotadyer dyeing machine, based on the principle of 'constant circulation of liquor around fabric samples'. The machine is electrically heated and provides a good temperature control by an electrical controller. The treated samples at each stage of treatment were measured by Kawabata Evaluation System (KES-FB) in a standard laboratory condition (21 °C, 65 % RH). The results of surface, bending, compression, shear and tensile properties of fabrics A and B at different processing stages, as well as the converted primary and total hand values of the fabrics during each stage of treatment are reported and discussed below.

Scouring

The loom state wool fabrics were scoured with synthetic detergent 1 % SYNPERONIC BD 100 (produced by UNIVAR Ltd.) solution, at scouring time of 40 minutes in temperature of 40 °C, using 1:20 material to liquor ratio. Thorough washing is followed after treatment. The scoured samples were finally dried in an oven.

Table 1. Sample specifications

Samples	Yarn count (Tex)		Density		Weight (g/m^2)
	Warp	Weft	Warp (ends/cm)	Weft (picks/cm)	
A	47 × 3	40 × 2	10	11.6	249
B	70	70	17.6	13.8	222.8

*Corresponding author: d.sun@hw.ac.uk

Bleaching

The bleaching of scoured wool fabrics was carried out in a bath containing 15 m*l*/*l* Hydrogen Peroxide (H_2O_2), 1 g/*l* stabiliser C (sodium pyrophosphate) in the bleaching bath. The reaction of this reagent with wool protein is slow and it is usually effective in removing the pigment [10]. The application temperature was 50 °C and the treatment has continued for a period of 120 minutes in the material to liquor ratio 1:20 bath. After bleaching the treated samples were washed thoroughly with warm water, followed by cold water rinse, then hand squeezed and dried in an oven.

Dyeing

The dyeing of wool fabric was carried out by placing the specimens in the dye-bath containing 5 % glauber's salt, 1 % acid dye Neolan Red P at 1:20 liquor ratio. Samples were heated to the recommended dyeing temperature 100 °C at the heating rate of 5 °C/minute from room temperature. Then samples were dyed for 90 minutes at boiling point.

Results and Discussion

Fabric Thickness and Weight

Fabric thickness TO and weight W are shown in Figure 1. There is a marked increase in fabric thickness TO and weight W for both fabrics. Fabric A, exhibits 8.9 %, 6.2 % and 8.5 % increase in TO and 7.4 %, 3.4 % and 2.2 % increase in W, in scouring, bleaching and dyeing stages, respectively. This is caused by the relaxation shrink and felting shrink of wool and further tightening of the structure of the treated fabrics at each treatment stage.

Bending Properties

The results of the bending properties of wool fabrics at different stages are shown in Figure 2, and including bending stiffness B and bending hysteresis 2HB. Bending rigidity reflects the flexibility of the fabric and higher B values indicate greater resistance to bending motions. Bending hysteresis indicates the ability of the fabric to recover after being bent. The smaller the 2HB value the better the bending recovery ability of the fabric. There is a remarkable decrease in bending stiffness B and bending hysteresis 2HB after scouring of wool fabrics. It shows 9.4 %, 26 % and 10.3 % of decrease in B and 46.5 %, 64.5 % and 56.7 % decrease in 2HB of the treated fabrics A and B respectively, in comparison with that of the loom state wool fabrics. This is due to the reduction of the residual tension in the scoured fabric which enhances the mobility of the constituent yarns and fibres. The influence of bleaching in bending properties is small. There is a 3.2 % and an 8.9 % decrease in B and 2HB after dyeing of fabric A. Wool fibre degradation occurs during wool dyeing in high temperature [11]. It is probably the degradation of the dyed fibres that imparts softening effect on the dyed fibres, resulting in the reduction in bending rigidity and bending hysteresis of the dyed fabrics.

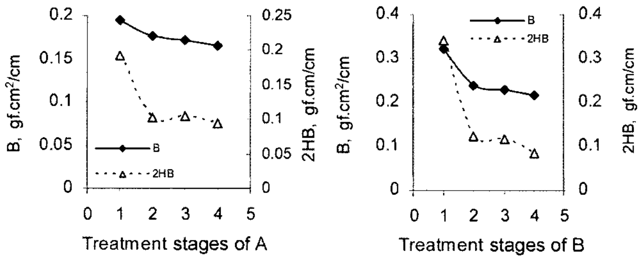

Figure 2. Changes of bending properties of fabric A and B throughout the finishing stages (1: loom state, 2: scoured, 3: bleached, 4: dyed).

Surface Properties

The surface properties of the treated wool fabric are shown in Figure 3, which contains the friction coefficient MIU, the mean deviation of friction MMD and the geometrical roughness SMD. MIU indicates fabric smoothness, roughness and crispness. Higher MIU values correspond to greater friction or resistance to drag. Surface properties have not shown much change during the finishing stages of wool fabrics. The values of friction coefficient MIU increased in scouring and dyeing stages for all treated samples. This might be caused by the increased intrinsic thickness of the fabric. The increased thickness in turn causes a compressible and flexible fabric with an increase in friction resulted by the greater area of contact between the testing probe and the fabrics. Friction is determined not only by the contact surface, but also by the

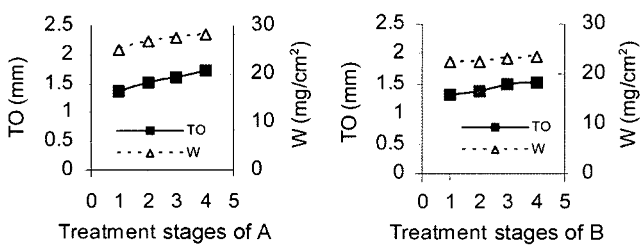

Figure 1. Changes of thickness and weight of samples A and B throughout the finishing stages (1: loom state, 2: scoured, 3: bleached, 4: dyed).

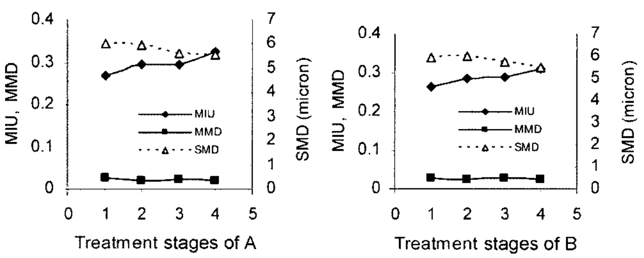

Figure 3. Changes of bending properties of fabrics A and B throughout the finishing stages (1: loom state, 2: scoured, 3: bleached, 4: dyed).

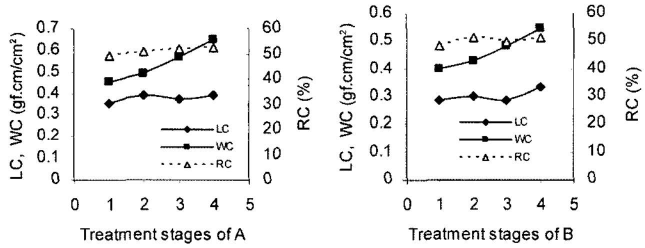

Figure 4. Changes of compression properties of fabrics A and B throughout the finishing stages (1: loom state,. 2: scoured, 3: bleached, 4: dyed).

deformation at the contact points. Another reason for the higher MIU value in the dyed fabrics is that the dyes are bonded to wool fibres, causing changes in fabric structure and physicomechanical properties during the dyeing treatment.

Compression Properties

The compressional properties of wool fabric after various finishing agents' treatment are presented in Figure 4, containing compression energy WC, compression resilience RC and compression linearity LC. The compression energy WC reflects the fluffy feeling of the fabric, the fabric will appear fluffier when the value of compression energy is increased [12]. In this study, WC increased during each finishing stage. In fabric A, compression energy WC increased by 7.7 %, 15.3 % and 14.9 % are observed in scouring, bleaching and dyeing stages respectively. Compression resilience RC is the percentage of the extent of recovery, or the regain in fabric thickness when the applied force is removed. The greater the value RC the better retention ability of the fullness of the fabric after compression. The change of RC between the two finishing stages is small. On the whole, RC increased from the loom state wool (49.4 for fabric A) to the final finished wool fabric (52.2 % for fabric A).

Shear Properties

Results of shear properties of wool fabric at different finishing stages are shown in Figure 5, containing shear stiffness G, shear hysteresis at 0.5 degree angle 2HG and

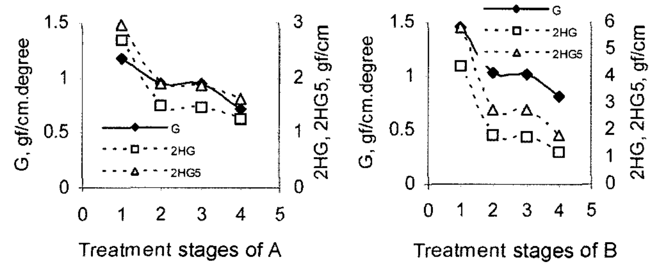

Figure 5. Changes of surface properties of samples A and B throughout finishing stages (1: loom state, 2: scoured, 3: bleached, 4: dyed).

shear hysteresis at 5 degree angle 2HG5. Shear stiffness is the resistance of a material to deformation at various angles to the direction of the individual yarns to pull against one another. Lower value indicates less resistance to the shearing movement, corresponding to a softer material having better drape. The hysteresis 2HG is the energy loss in the final shear deformation in cooperation with the initial part of the deformation. The easier the yarns glide over each other, the smaller the fabric hysteresis.

The results of shear properties of fabrics A and B are similar. In fabric A, 19.5 %, 44.8 % and 36 % reduction in G, 2HG and 2HG5 after scouring are observed. These results are indicative of the greatly reduced inter-yarn friction in fabrics and reduced number of fibre to fibre contacts at yarn crossover points. There is no significant change between scouring and bleaching stages in all the treated fabrics. Dyeing of the samples has also reduced their shear properties. 24 %, 13.7 % and 12.4 % reduction in G, 2HG and 2HG5 are observed in dyed wool fabric A. Fibre degradation occurs during high temperature dyeing of wool fabric [11], due to thermal decomposition and chain scission. Wool fibres become more flexible under force. The low shear rigidity and shear hysteresis of the dyed wool fabrics can be attributed to this modification in their constituent fibre properties.

Tensile Properties

Tensile properties of wool fabrics obtained from KES-FB are presented in Figure 6, interpreted in tensile linearity LT, tensile energy WT, tensile resilience RT and elongation EMT. Tensile linearity LT reflects the elasticity of the fabric, the higher the LT value the stiffer the material. There is marginal decrease in LT after each treatment stage. Tensile energy is the work done during extending of the fabric, and a greater WT value responds to a higher tensile strength of the fabric. WT increased for all the treated two fabrics after scouring. Small changes are found during bleaching and dyeing stages. WT increased 116 % after scouring for fabric A. Generally, factors that affect fabric strength include fibre type, yarn count and its twist as well as the structure of the fabric. Relaxation shrinkage and felt shrinkage occur in wool fabric during scouring, and these shrinkages cause an increase in yarn count and fabric thickness, which result in

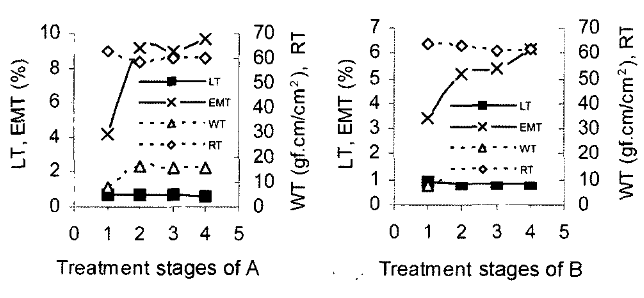

Figure 6. Tensile properties of various finishing agents treated wool samples (1: loom state, 2: scoured, 3: bleached, 4: dyed).

the increase in tensile energy WT. Degradation of the fibres during wool fabric dyeing caused reduction in WT, whilst the increased thickness and weight of the dyed wool fabric, in turn, replenish any reduction in WT.

Tensile resilience reflects the recovery ability of a fabric after being extended. There is 7.1 % decrease in RT of fabric A after scouring. This might be caused by the reduction of the interaction between fibres and yarns during scouring of the wool samples. It doesn't show much change after bleaching and dyeing treatment.

Fabric extensibility EMT is the percent strain at maximum applied force (500 gf/cm in this experiment). Similar effects are observed in fabrics A and B. There is a great increase in fabric extensibility after scouring for all treated wool fabrics, they are 122 % and 52 % in fabric A and B respectively. This can be explained by the increase in yarn crimp after scouring which results in an increase in extensibility. EMT value shows not much change between the scouring and bleaching stages. There is 7.2 % and 14.7 % increase after dyeing of fabric A and B, respectively. This might be due to the high temperature dyeing of the wool fabrics which causes degradation and bond breakage of the molecule chains of the wool fibres, fibres are more flexible under tension, resulting to an increase in EMT.

Primary Hand Value of Fabric

The fabric hand value (HV) is a quantified "feel" parameter based on the determination of the mechanical properties. It reflects the stiffness, fullness, softness as well as crispness of the fabric. Figure 7 shows the results of primary hand values of wool fabric determined using the regression equations developed by Kawabata [13] for men's winter suits, which consist of KOSHI (stiffness), NUMERI (smoothness) and FUKURAMI (softness and fullness).

KOSHI is the stiff and springy property in bending, it also reflects to the stiffness of a fabric in shearing and compression properties and it is influenced by fabric weight. NUMERI is smoothness which is a mixed feeling relating to smoothness, limpness and softness. FUKURAMI is softness and fullness determined by bending, compression, shear and tensile properties. There is not much difference between the

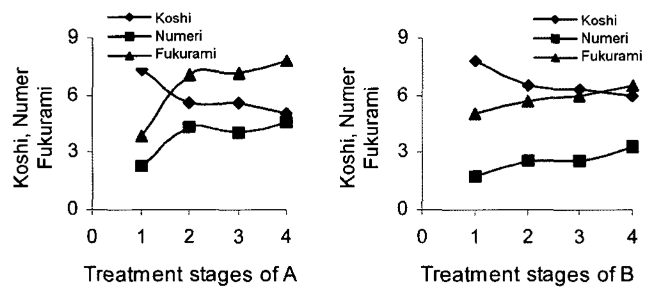

Figure 7. Changes of primary hand values of samples A and B throughout the finishing stages (1: loom state, 2: scoured, 3: bleached, 4: dyed).

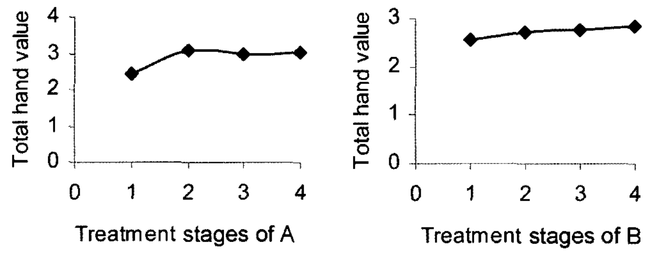

Figure 8. Changes of total hand values of samples A and B throughout the finishing stages (1: loom state, 2: scoured, 3: bleached, 4: dyed).

scoured and bleached wool samples in all primary hand values. KOSHI was decreased greatly by scouring and dyeing stages (23.7 % for fabric A). This change is caused by the decrease in bending and shearing properties. NUMERI and FUKURAMI are increased significantly after scouring, it shows 90.5 % in NUMERI and 81.3 % in FUKURAMI in fabric A. These changes are due to the decreased surface roughness SMD, bending and shear characteristics as well as the increased fabric thickness. NUMERI and FUKURAMI increased during dyeing by 15.4 % and 9.1 % in fabric A respectively.

Total Hand Value of Fabric

Changes in total hand value (THV) of fabric throughout the finishing stages are shown in Figure 8. HV can be translated into total hand value (THV) by the equation derived from the statistical analysis of experts' judgement [13]. It is a combined measure of fabric primary handle values. THV expresses the general handle value, is a parameter used for evaluating the fabric quality. The hand feel values were increased by scouring. These are caused by the increase in NUMERI and FUKURAMI and the decrease in KOSHI after scouring treatment. THV is moderately affected by bleaching and dyeing, in all the treated wool fabrics.

Conclusions

The scouring process is the most remarkable change that affects the low stress mechanical properties of wool fabrics. The values of bending rigidity B, bending hysteresis 2HB, shear stiffness G, shear hysteresis 2HG and 2HG5 have been significantly decreased after the scouring treatment of wool fabrics, while, tensile energy WT, tensile elongation EMT and surface friction MIU have been increased. There is no significant change in low stress mechanical properties of the bleached wool fabrics. There is considerable decrease in bending rigidity B, bending hysteresis 2HB, shear stiffness G, shear hysteresis 2HG and 2HG5, and an improvement in tensile elongation EMT during dyeing of wool. LT, RT, LC and RC are not quite sensitive during finishing processes. Fabric handle is influenced by fabric finishing processes suggesting that the desirable handle may be engineered.

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