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Effect of different processing stages on mechanical and surface properties of cotton knitted fabrics

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The influence of different processing stages on the low stress mechanical and surface properties of cotton knitted fabrics has been studied. The KES-FB system has been used for the measurements of low stress tensile, shear, bending, compression and surface properties. The results show remarkable changes in mechanical and surface properties of knitted fabrics after processing stages, such as bleaching, dyeing and softening.

Keywords: Cotton, Knitted fabric, Mechanical properties, Surface properties

1 Introduction

The tailoring quality of fabrics and the design of garments as well as automated handling are greatly influenced by the fabric physical and low stress mechanical properties, such as bending, tensile, shear, compression and surface properties. Objective measurement of these characteristics leads to making rational decisions in selecting fabrics in order to minimize the tailoring problems and improve the quality of finished garment. The KES-FB (Kawabata Evaluation System for Fabrics) system, primarily developed for an objective evaluation of fabric handle, has now been widely accepted for the investigation of low stress mechanical and surface properties[1].

In textiles, raw material, yarn structure, fabric structure, finishing and processing stages affect the fabric hand and its overall performance. During finishing, internal stresses stored during spinning, warping and knitting are removed and fabrics attain an almost fully relaxed state. The amount of changes occurred in thickness, loop density, tightness factor and mechanical parameters of fabric during finishing and processing makes the subject complicated. By using various finishing and processing treatments, different kinds of end products in a sense of aesthetic and utility properties can be produced from the same unfinished textile fabric[2]. In order to improve the fabric hand and dimensional stability, various finishing and processing stages are undertaken from knitting mill fabric to the final finished state. In case of knitted fabrics, the effect of these stages is significant. There are very few data available on the knitted fabrics as well as on the effect of a finishing and processing procedure on the quality of knits[3,4]. In the present study, the effect of different processing conditions (bleaching, dyeing and softening) on the fabric mechanical characteristics such as tensile, bending, shearing, compression, and surface properties has been studied.

2 Materials and Methods

Fourteen knitted fabrics with similar tightness factor were produced on a single jersey circular knitting machine (Mayer & Cie, E28, 30”). Cotton yarns of 50 Nm and 750 tpm were also spun on a conventional ring spinning machine. The effect of following processing stages on the mechanical and surface properties of the cotton knitted fabrics was investigated:

- Bleaching process — Knitted fabrics were bleached in two different conditions, namely normal and intensive bleaching.
- Dyeing process — Knitted fabrics were dyed after bleaching or washing processes using a reactive dyestuff.
- Softening — Knitted fabrics were softened after bleaching and dyeing processes using different softeners; for a specified softener, two different softener percentages were used.

The conditions of processing stages used in this study are shown in Table 1 and details of the treated

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fabrics are given in Table 2. The basic mechanical properties, such as tensile, bending, shearing, compression, and surface properties of the fabric samples were measured by KES-FB system[5] using the set-up of knits standard sensitivity[6]. For each processing stage, each measurement was made twice on three separate samples cut from the center of the knitted fabrics, and five resulting values were averaged. Standard size samples of 200 mm × 200 mm were tested in wale and course directions. Because anisotropy is a consideration in knitted fabrics, eleven of the tests (tensile, bending, shear and surface properties) were measured in both course and wale directions. Average values of the wale and course measurements were taken for further analysis. Specimen preparation, pre-conditioning, and testing involved standard atmospheric conditions of 20°C±2°C temperature and 65%±2% relative humidity.

Table 1—Processing stages of knitted fabrics

Processing stage	Chemical used	Temp. °C	Time min
Normal bleaching	H_2O_2 (1.5%)	80	30
Intensive bleaching	H_2O_2 (1.5%)	98	60
Dyeing	Bezative orange S-RL 150[a]	60	75
Softening			
(i) cationic softener	Tubingal KRE[b]	40	20
(ii) non-ionic softener	Tubingal 220[b]	40	20
(iii) micro-emulsion softener	Tubingal MSQ[b]	30-40	20

[a]Reactive dye.
[b]Softener produced by CHT company, Germany.

Table 2—Details of treated fabrics

Code	Stitch density/cm²	Processing stage	Softener amount, %
A01	247	Knitting mill fabric	-
A02	300	Intensive bleaching	-
A03	320	Intensive bleaching + softening (Tubingal 220)	2
A04	320	Intensive bleaching + softening (Tubingal MSQ)	2
A05	320	Intensive bleaching + softening (Tubingal MSQ)	4
A06	320	Intensive bleaching + softening (Tubingal KRE)	2
A07	300	Normal bleaching	-
A08	310	Normal bleaching + softening (Tubingal 220)	2
A09	310	Normal bleaching + softening (Tubingal MSQ)	2
A10	310	Normal bleaching + softening (Tubingal MSQ)	4
A11	310	Normal bleaching + softening (Tubingal KRE)	2
A12	315	Washing + dyeing	-
A13	315	Normal bleaching + dyeing	-
A14	315	Normal bleaching + dyeing + softening (Tubingal KRE)	2

3 Results and Discussion

3.1 Effect of Processing Stages on Bending Properties

Changes in bending characteristics of the cotton knitted fabrics through the processing stages are shown in Fig. 1. Bending rigidity reflects the flexibility of the fabric and higher bending rigidity (*B*) values indicate greater resistance to bending motions. Bending hysteresis indicates the ability of the fabric to recover after being bent. The smaller the bending hysteresis (2 *HB*) value, the better is the bending recovery ability of the fabric[1]. For the cotton knitted fabric, there is a large increase in fabric bending rigidity values after bleaching and dyeing as compared to raw knitted fabric. This is explained in terms of the relaxation shrinkage in both course and wale directions. The fabric shrinkage gives a smaller space for bending. The results reveal that the dyed fabric represents the highest values of bending rigidity and bending hysteresis as compared to other fabrics. This can be attributed to higher relaxation shrinkage and higher knit density after dyeing in comparison with other processing stages. In case of intensive bleaching, the bending properties increase higher than in the normal bleaching, because this stage was performed at higher temperature and time. Therefore, an intensive bleached fabric is stiffer than a normal bleached fabric.

The softeners can reduce inner friction between fibres and yarns in the fabric structure and in this way, the bending properties are greatly reduced. Naturally in this case, the type of softener plays an important role. The reduction in bending rigidity and bending hysteresis values for softening with Tubingal KRE is larger than that for softening with Tubingal MSQ and Tubingal 220. Furthermore, the results reveal that regardless the fabric bleaching method, the softener concentration also affects remarkably the bending properties.

3.2 Effect of Processing Stages on Tensile Properties

Tensile properties of cotton knitted fabrics obtained from KES-FB are shown in Fig. 2, interpreted in term

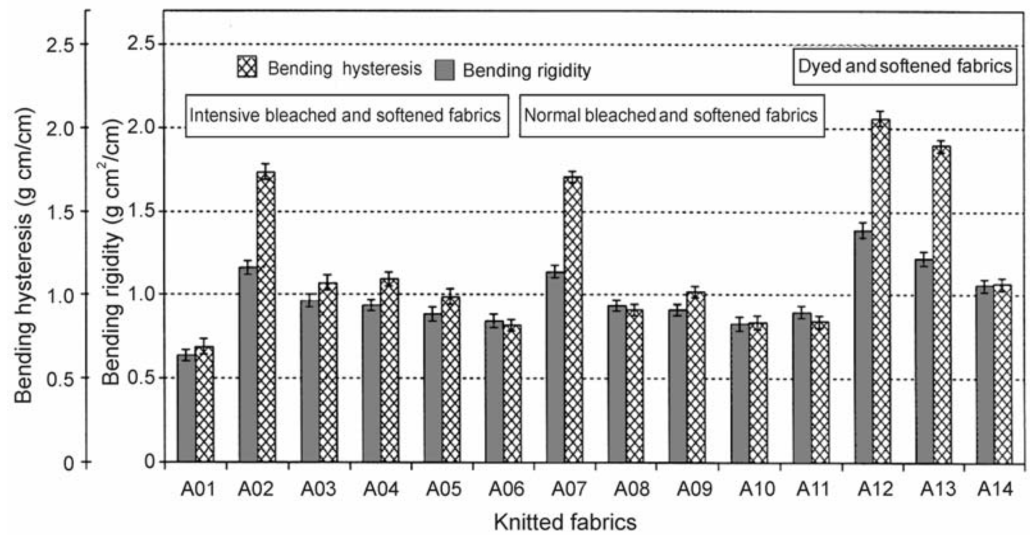

Fig. 1—Effect of different processing stages on bending properties of knitted fabrics

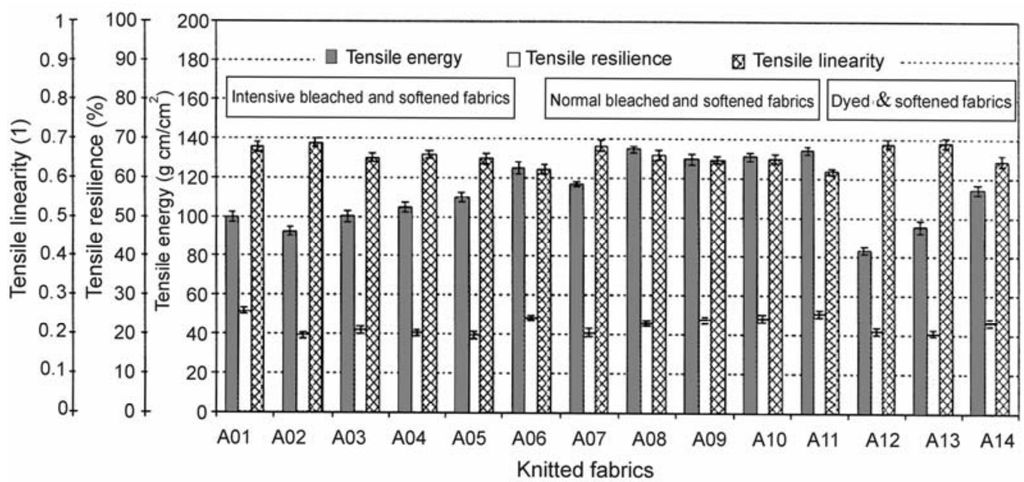

Fig. 2—Effect of different processing stages on tensile properties of knitted fabrics

of tensile linearity (*LT*), tensile energy (*WT*), and tensile resilience (*RT*). Tensile linearity reflects the elasticity of the fabric; the higher the *LT* value the stiffer is the material. Tensile energy is the work done during extending the fabric, and a greater tensile energy value responds to a higher tensile strength of the fabric. Tensile resilience reflects the recovery ability of a fabric after being extended[1].

The results reveal that the tensile energy and tensile resilience values of knitted fabrics tend to decrease after both normal and intensive bleaching and also dyeing processes as compared to knitting mill fabric. This means that the fabrics become stiffer as well as less stretchable. It is attributed to higher shrinkage of knitted fabrics after bleaching and dyeing. The increasing order of the tensile energy values is: dyed fabrics < intensive-bleached fabrics < normal-bleached fabrics. The tensile linearity values of the bleached and dyed fabric are found to be higher than that of the knitting mill fabric. This is associated with the increase in fabric stiffness.

The results show a large increase in tensile energy values and a reduction in tensile linearity values after softening as compared to the bleached and dyed knitted fabrics. It can be explained due to the reduction in friction between the stitches. This means that the fabrics become more stretchable and more energy is needed to attain the same tensile load. The increasing order of tensile energy values is: Tubingal 220 < Tubingal MSQ < Tubingal KRE. An increase in softener concentration increases the tensile energy and tensile resilience values. The increase in extensibility which occurs during softening of the knitted fabrics could improve the tailorability, especially from the viewpoint of shaping and sewing.

3.3 Effect of Processing Parameters on Shear Properties

Changes in shear characteristics of the cotton knitted fabrics through the processing stages are shown in Fig. 3. The shear stiffness and hysteresis are affected by the slipperiness at loop intersections, the coefficient of friction, the contact length and the knit density. The shrinkage of the knitted fabrics during bleaching and dyeing decreases the slippage between yarns or fibres and increases the knit density as well as the yarn contact in the loop intersections. Therefore, it is expected that the bleached and dyed fabrics lead to a higher shear stiffness and hysteresis as compared to the raw fabric. The shear stiffness of samples decreases in the order: dyed knitted fabrics > intensive-bleached fabric > normal-bleached fabric. This is attributed to different stitch densities which are achieved after processing.

The effect of softening is directly related to the level of inter-yarn pressure and frictional resistance to shear formation[1]. The softeners facilitate the slippage of yarns in the fabric structure and consequently the shear stiffness (*G*), shear hysteresis at 0.5° (2 *HG)* and shear hysteresis at 5° (2 *HG5)* values decrease. The decreasing order of shear properties values for the used softeners is: Tubingal MSQ > Tubingal 220 > Tubingal KRE. Naturally, the percentage of the softener affects the shear properties. An increase in the softener concentration decreases the shear properties of knitted fabrics.

3.4 Effect of Processing Stages on Thickness and Weight

Fabric thickness (*T*) and weight (*W*) are shown in Fig. 4. It is obsereved that the fabric thickness changes slightly after the softening treatment. All dyed and bleached fabrics undergo minimum decrease in thickness, which could be due to further tightening of the structure as a result of increased adhesion between fabric structural elements. The fabric weight is affected by the shrinkage during the processing stages. The more the number of processing stages, the higher is the degree of shrinkage. This results in higher knit density and consequently higher weight of the fabric. The softening process makes the fabrics more voluminous and thicker. Naturally, the increase in fabric volume through the softening depends on the type and percentage of the softener.

3.5 Effect of Processing Stages on Compression Properties

The compressional properties of cotton fabric after various processing stages are presented in Fig. 5, considering 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[7]. Compression resilience is the percentage of the extent of recovery or the regain in fabric thickness when the applied force is removed. The greater the *RC* value, the better is the retention ability of the fullness of the fabric after compression[8].

The results reveal that the greatest decrease in *WC* and *LC* occurs during bleaching and dyeing. This means that the knitted fabrics will be less fluffier after bleaching and dyeing as compared to a knitting mill

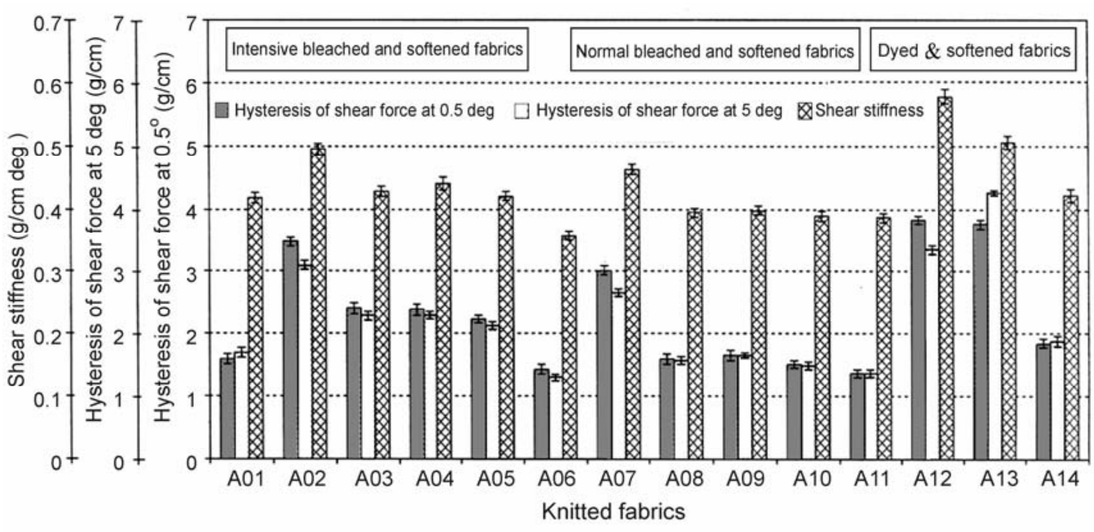

Fig. 3—Effect of different processing stages on shear properties of knitted fabrics

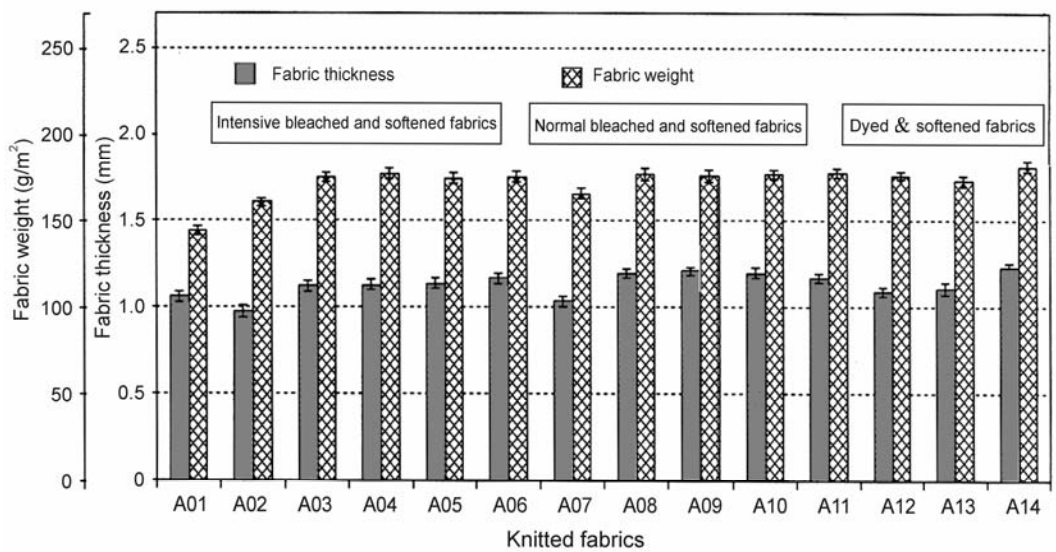

Fig. 4—Effect of different processing stages on weight and thickness of knitted fabrics

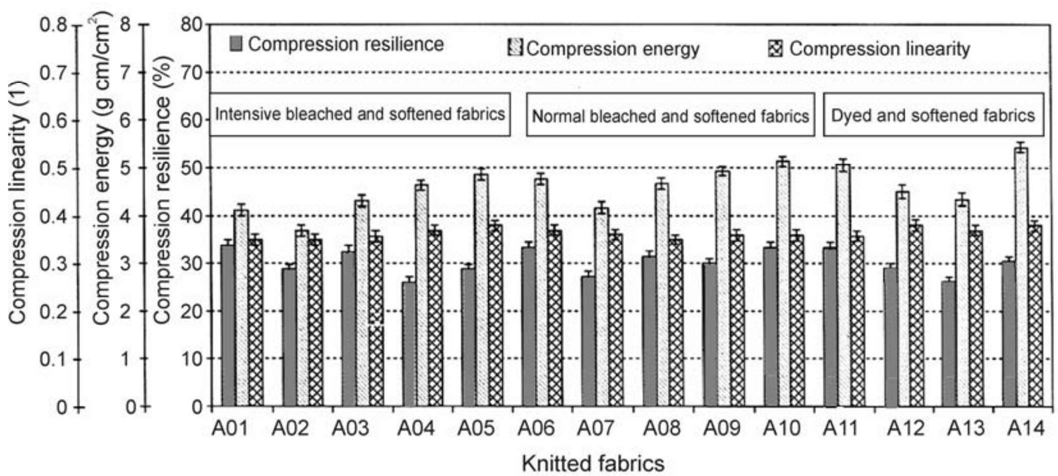

Fig. 5—Effect of different processing stages on compressional properties of knitted fabrics

fabric. In contrast, the values of *WC* and *LC* increase after softening. This could be due to the slight decrease in fabric thickness after dyeing and bleaching and the increase in fabric volume and thickness after softening. Knitted fabrics which were bleached by normal bleaching method and softened represent higher values of the compressional characteristics than the knitted fabrics which were bleached by intensive bleaching method and softened. Regardless to bleaching method, an increase in softener percentage makes the fabrics more voluminous and consequently they represent higher compressional properties.

3.6 Effect of Processing Stages on Surface Properties of Knitted Fabrics

The surface properties of cotton fabric after various processing stages are presented in Fig. 6, considering coefficient of steel/fabric friction (*MIU*), mean deviation of *MIU* (*MMD*) and geometric roughness (*SMD*). The results reveal that the greatest increase in *MIU*, *MMD* and *SMD* occurs during bleaching and dyeing. This could be explained by the increase in disturbance in surface fibres as well as fabric surface irregularities after bleaching and dyeing processes. In contrast, the values of *MIU*, *MMD* and *SMD* increase by softening, because the softeners mask the irregularity of the knitted fabrics. After softening treatment the coefficient of friction between fabric surface and slip probe *MIU* is defined as the ratio of the sliding force to the compressional load and it increases in all cases.

Furthermore, the results reveal that an increase in softener concentration reduces the irregularity of the

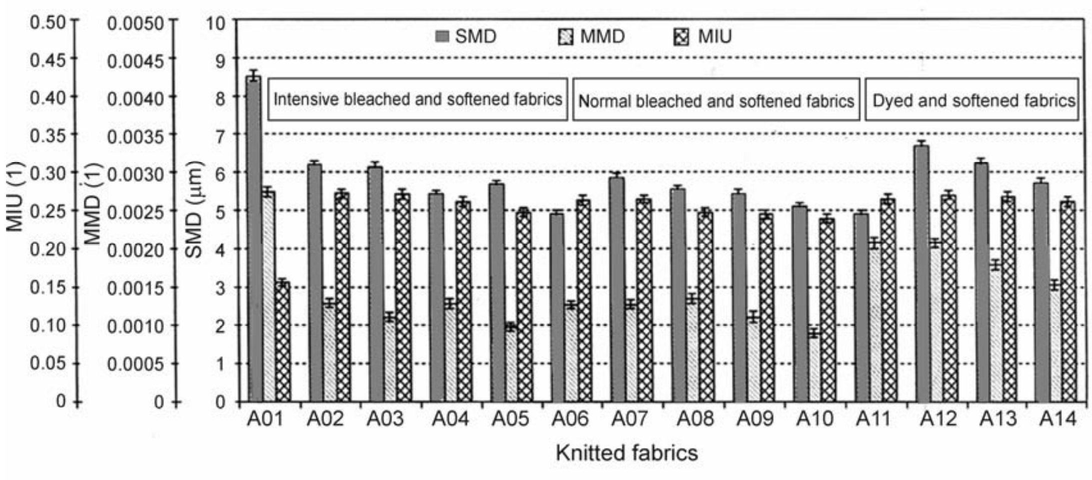

Fig. 6—Effect of different processing stages on surface properties of knitted fabrics

fabric surface and consequently the values of *SMD*, *MMD* and *MIU*[9]. The high temperature and relative movement between fabric and water in dye bath create an effect that contributes to fabric surface irregularity. Therefore, the dyed knitted fabrics represent the highest roughness value.

4 Conclusions

The results show remarkable changes after different processing stages, such as bleaching, dyeing and softening in mechanical and surface properties of knitted fabrics. For the knitted fabrics, there is a marked increase in both the rigidity and hysteresis in shear and bending properties as well as surface roughness after bleaching and dyeing. Also, an overall decrease is observed in fabric extensibilities and compressibility during bleaching for knitted fabrics. These changes could result a few problems from the viewpoint of shaping and sewing of fabric. As a consequence of these changes, the fabric will be stiffer, denser and rougher.

Three types of softeners namely cationic, non-ionic and micro-emulsion were used. It is found that the type of softener plays an important role to create desired changes in mechanical and surface properties of the knitted fabrics. There is a marked reduction in both the rigidity and hysteresis in shear and bending properties as well as surface roughness after softening. An overall increase in fabric extensibilities and compressibility is observed after softening for knitted fabrics. These changes could improve handle and tailorability of the fabrics. It is also inferred that the application of a cationic softener can improve handle and tailorability of fabrics more than a non-ionic softener and micro-emulsion softener. An increase in concentration of the softener makes the fabrics softer, more flexible and smoother, because the inner friction of fibres and yarns decreases more in fabric structure.

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