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Effect of washing treatment on residual bagging height of denim fabrics

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The effect of various washing processes carried out under industrial conditions on the bagging properties of denim fabrics has been studiedin order to understand why residual bagging height behavior remains after garment uses due to internal stress, shrinkage, and excessive extensions. Three different washes have been used for denim samples, already dyed with vat indigo. To evaluate the washing treatment contributions to the bagging behaviors of all studied samples, the residual bagging height characteristic is investigated. It is studied before and after each washing treatment (desizing, enzyme washing, and bleaching). The results show that the residual bagging height increases after all types of washing treatments except for the bleaching ones. Nevertheless, the washed elastomeric denim fabrics (within elastane filament percentages) present significant recovery rates of bagged fabrics after all applied washes. By comparing the results obtained in this study, it may be concluded that the applied enzymatic washing process affects more the bagging behavior of denim fabrics than those of the desizing and bleaching treatments.

Keywords: Bleaching treatment, Denim fabric, Desizing, Enzymatic washing, Residual bagging height

Nowadays, washed denim is one of the widest garments in the textile industry. Moreover, it may be the most considered cloth of style today. Without washing, the denim was only a work garment since it was uncomfortable to wear, due to its weaving and dyeing effects. However, thanks to the different types of washing treatments, such as desizing, stone washing, enzyme washing, mixed wash, and bleaching, denim becomes softer, more flexible, smoother, fashionable, and more comfortable. These qualities and others give denim garments attractive demands in the fashion and regular garment markets.

Furthermore, among different washing techniques applied to garments, desizing is an essential treatment since the warp of denim is usually glued to decrease yarn breakages during weaving. Stone washing is the most recent treatment for denim fabric and it includes the use of stone with the fabric samples to be washed into an industrial drum washing machine[2].

At the time of washing, the stones rub against the fabric and remove some of the dye to obtain the white-blue speckled effect characteristic of the denim clothes. Using pumice stone causes wear and tear on the garments, paper, and machine surface. Hence, the use of enzymatic washing, such as Laccase's enzyme[3,4], was started. However, Maryan and Montazer[5] concluded that using amylase and cellulase limited the attacks of cellulase to cellulose due to the presence of sizes that improved the abrasion resistance. The benefits of enzymatic washing are more important than stone washing. However, the stone has a different irregular effect on clothes, which is very difficult to achieve with an enzyme. Therefore, the bleaching treatments by hypochlorite are widely used in the textile industry, because they have been successful in achieving desirable color shade and soft hand feels of denim fabric.

Notwithstanding, many studies focused on the enzymatic washing effect on the physical, mechanical, and color properties of denim garments, such as elongation-at-break, tensile strength, weight loss, stiffness, water absorption, shrinkage, color fading, and morphological values[1,2,6,7]. Based on literature survey, it has been shown that tensile strength, color shade, and stiffness decrease after cellulase treatment. The mass of fabric obtained with cellulase washing is higher than that with pre-washing. It could be explained by the shrinkage in the warp fabric direction. Otherwise, hydrolysis of the cotton denim garments caused an enhanced softness, water absorption, color fading, and elongation; meanwhile, tensile strength is decreased[1]. Patra *et al.*[7] studied the effect of neutral and acid enzymatic treatments in terms of decrease in color depth and weight loss. Its findings showed that the effect on weight loss was more pronounced in the case of acid cellulase due to its stronger action than that of neutral cellulase[7]. Therefore, the tensile strength decreases after washing, while the elongation-at-break increases[6]. For bleaching treatment, Khan *et al.*[8] have studied the effect of bleach concentration,

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temperature, and time on the physical, and mechanical properties of denim fabrics. They showed that increasing the concentration of KIC bleach type causes the decrease of tensile strength, stiffness, weight of the fabric, and shade of color. In addition, they reported that unwashed denim samples are almost smoother, stiffer, harder and less water absorbent than cotton garments treated with bleach[8].

Overall published studies still focus on the effects of finishing treatment on the mechanical, physical, and sensorial properties of some fabrics. However, no studies are dealing with the effect of finishing treatment on the multi-directional deformations of denim fabric as a bagging phenomenon, which causes an unaesthetic and undesirable appearance at the knee and elbow parts of the garment after many uses. Several studies are required in the area of prediction, modeling, and evaluation of the residual bagging properties as a function of input parameters tied to studied samples[9–15]. Recently, researchers have published some works related to residual bagging behaviors and their results showed that the input parameter effects of studied fabrics contribute to the bagging fatigue by investigating their bagging load[16]. As for the fabric deformation degree, different test procedures were applied and the cover factor of deformed and un-deformed fabric images was investigated by the image analysis method. They calculated bagging force, work, fatigue, resistance, hysteresis, and residual height to model the bagging behavior of worsted fabrics using response surface methodology[16–18]. Dehghani *et al.*[17] tried to study the bagging behavior by adding another part to the denim fabric, either adhesive interlining or lining fabrics. They found that by adding lining fabric, the residual bagging height of the fabric decreases, while the fatigue percentage increases. Whilst, adding the interlining adhesives to the fabric would increase the amount of bagging fatigue percentage[17].

Until now, there is no sufficient information concerning the contribution of finishing treatments on the bagging behavior of denim fabrics. This can evaluate the effect of finishing treatments on the washed fabrics behavior and could explain accurately some potential phenomena, such as mechanical and chemical behaviors that happen after solicitations.

This paper reports an investigation of the effect of desizing, enzyme washing, and bleaching treatments on the residual bagging height behavior of denim garments. Besides, the optimum washing treatment that could minimize the bagging recovery is also discussed and reported. The suitable choice of the washing treatment, which decreases the unaesthetic phenomenon on denim garments, will help industrials to prevent some residual bagging properties before use.

Experimental

Materials

Ten woven finished denim fabric samples with different blend ratios were prepared. These specimens have the same twill 3/1 weave design within different specifications and characteristics (Table 1).

Methods

Desizing

The specimens of denim fabrics were first treated with 1.5% (o.w.f) ECOPREP and 1.5g/L anti-redeposing agent at *p*H 7 and temperature 60°C for 15 min using bath ratio of 1:5 to remove sizing agents from the fabric. Finally, they were rinsed with water for 2 min at ambient temperature (30°C), dewatered and dried at 90°C.

Enzyme Washing

This process can be carried out with neutral or acidic cellulase. The treatment in a near-neutral *p*H (6-7) is better for jeans colored with indigo, since the reduction of dye at this *p*H is very low (by electrostatic repulsion) and the decrease in the mechanical strength of the fabric is relatively limited. The only problem with this type of enzyme is the slowness of its action. Hence, it was thought to treat the fabric with 2% (o.w.f) of the enzyme (Neozime 166) and 1.5 g/L anti-redeposing agents at *p*H 7 and at 60 °C temperature for 30 min using a bath ratio of 1:5. The denim fabrics were then rinsed in water for

Table 1 — Fabrics characteristics

Samples	Cotton/Polyester/ Elastane	Mass g/m²	Weft density cm^{-1}	Thickness mm
1	Cotton	500	18	0.97
2	91.5/7/1.5	367	18	0.78
3	89/9/2	303	22	0.73
4	89/9/2	306	22	0.64
5	87/11/2	387	18	0.79
6	92/6.5/1.5	359	22	0.72
7	98.5/0/1.5	339	22	0.73
8	91.5/7/1.5	346	19	0.72
9	Cotton	386	21	0.8
10	90/8.5/1.5	377	21	0.79

10 min at ambient temperature (30°C). Then the enzyme was deactivated with carbonate followed by another rinsing. The denim fabrics were squeezed to remove water and dried at 90°C.

Bleaching Treatment

A whitening effect can be added to fade jeans to increase the effect of the fabric used. This can be achieved using one of the two most common methods, namely use of hydrogen peroxide or sodium hypochlorite (bleach). However, to achieve specific intensities, we used hydrogen peroxide bleach, or combination treatment, often in the presence of a protective agent that protects some oxidizing accessories by avoiding their oxidation[19]. In the present study, we used a 10g/L bleach concentration, 50°C temperature, 15min treatment time, and 1:10 bath ratio. The denim garments were then rinsed and neutrally washed with sodium metabisulfite (2 g/L) for 5 min at 40°C. Then, double rinsing followed by squeezing and drying at 90°C were carried out.

Instrumentals

The washing tests were performed using an industrial washing machine type C1200 Lapauw. This machine is characterized by the use of steam for heating, 2 inputs for water, 1 device of evacuation, 1 count-liters, a variable speed ranging between 4rpm and 450rpm, a porthole for the extraction of the samples, and 2 tanks for chemical products. The drum and the denim fabric samples are in contact with the treatment bath. The machine is equipped with a processor and TFT LCD touch screen, with an automatic control of all functions. After applying washing, the specimens were dried using a rotary drum dryer for 45 min at 90 °C. All specimens were conditioned for 24 h in the same experimental laboratory conditions according to French Standards (AFNOR, 1985).

The dimensions of each specimen prepared for the bagging test were 100 mm×50mm (AFNOR NF G 07-213, 2001). According to the French Standard NF G 07-213 (AFNOR NF G 07-213, 2001), bagging tester type Sodemat was used (Fig. 1) to measure residual bagging height.

Results and Discussion

To study the effect of washing on denim fabric samples, 3 different treatments have been applied, viz desizing, enzymatic wash, and bleaching.The residual bagging heights of treated and untreated denim are examined using testing equipment. The results obtained are summarized in Table 2. Based on these findings, it is observed that the residual bagging height increases after different types of washing treatment for all items, except after bleaching treatment. Bleaching treatment has a significant influence on the decrease of the residual bagging height values. Indeed, our findings show that Sample 2 presents the highest decrease value (equals to -12.22%) of the residual bagging height. This result can be explained by the bleaching treatment effect with sodium hypochlorite. It has a considerable and significant influence on the dimensional stability of cotton fabrics. Moreover, this influence may be justified by the existence of a remarkable shrinkage in

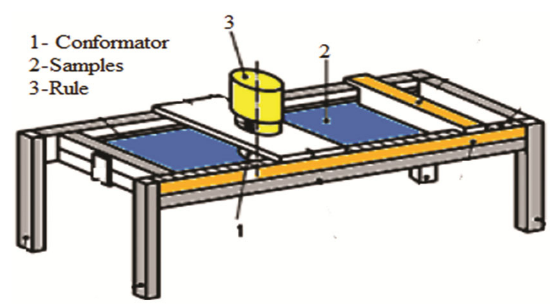

Fig. 1 — Bagging tester type Sodemat (AFNOR NF G 07-213, 2001)

Table 2─Results of residual bagging height

Sample	R_{bh} before washing, mm	R_{bh} after desizing, mm	R_{bh} after enzymatic washing, mm	R_{bh} after bleaching treatment, mm
1	11	13.3 (17.29%)	15 (26.67%)	10.8 (-1.85%)
2	10.1	11 (8.18%)	12.5 (19.2%)	9 (-12.22%)
3	10.1	11.5 (12.17%)	12 (15.83%)	9.5 (-6.32%)
4	9.1	10 (9%)	11.4 (20.17%)	8.9 (-2.25%)
5	9.8	11 (10.91%)	12 (18.33%)	9.5 (-3.16%)
6	10.4	11.7 (11.11%)	12 (13.33%)	9.5 (-9.47%)
7	9.7	10 (3%)	12 (19.17%)	9.3 (-4.3%)
8	9.3	10.4 (10.58%)	11.5 (19.13%)	8.75 (-6.29%)
9	11.4	13 (14.04%)	14.6 (21.92%)	11.2 (-1.79%)
10	9.8	10.5 (6.67%)	12 (18.33%)	9.6 (-2.08%)

Values in parentheses are percentage of bagging deformation.

warp and weft fabric directions after bleaching treatment[20]. The increase in shrinkage increases the weft density. Gazzah's[21,22] study showed that the increase in the weft density causes a reduction in the residual bagging height. Thus, the bleaching treatment has a very important effect on the decrease of the residual bagging height values.

In addition, based on the results obtained, the enzyme washing imparts a significant change in the residual bagging height which has been found to increase up to 26.67% (from 11 mm to 15 mm). While the desizing is fewer aggressive than enzymatic wash, it can explain the least increase in the residual bagging height which is between 2.56% and 17.29% as compared to enzymatic washing (13.33-26.67%).

Desizing Treatment Effect

Table 2 shows the variations in residual bagging height values (R_{bh}) before and after desizing treatment. These specimens are chosen due to their different compositions, for example Sample 1 without elastane filament and Sample 7 consists of 98.5% of cotton and 1.5% of elastane.

Based on these results, the increase of the residual bagging height value is notable and remarkable when a desizing treatment is applied on two different denim fabric compositions (Samples 1 and 7). For example, the residual bagging height of Sample 1 is 11mm before desizing; and after treatment, it becomes 13.3mm (the increasing percentage equals 17.29%). In fact, during desizing, the glue materials (starch) are removed from the warp yarns. According to Mondal and Khan[1], it can be shown that during weaving, cotton fabrics are subjected to considerable tensions, particularly in the warp direction. In subsequent finishing processes, such as calendaring, this stretch is increased and temporarily set in the fabric. Hence, as a consequence, the fabric is in a state of dimensional instability. Subsequently, when the denim garment is thoroughly wetted in desizing, it tends to revert to its more stable dimension, which results in the contraction of the yarns. This effect is usually greater in the warp direction than in the weft direction[1], which is called a relaxation shrinkage property. As the warp density increases, the friction resistance grows immediately and causes the rise of the residual bagging height[21].

Contrary to Sample 1, Sample 7 presents a lower residual height value. This result is explained by the presence of the elastomeric (highly elastic) present inside the studied denim fabric (Sample 7). Indeed, due to their chemical compositions, the elastomeric encourages widely the blended structures to return more rapidly to their initial states after solicitation. This finding seems in good agreement with other researchers' findings[23-25]. In addition, their presence makes blend materials more extensible and stretchable during bagging tests. Referring to Kumar *et al.*[23] and El-Ghezal *et al.*[24] stretchable denim fabric usually incorporates an elastic component such as elastane into the fabric to allow a degree at least 85% of the segmented polyurethane characterized by a low melting temperature, a considerable ability of extension, an elongation and immediate shrinkage. This result is in good agreement with Özdil's finding, showing that the increase in percentage of elastane in the fabric samples decreases their appearance deformation values as well as their tendency to bagging[25]. To conclude, the amylase enzyme does not have an effect on the denim fabric. As the desizing treatment is the first finishing treatment of denim fabric, it causes the shrinking of the fabric, which itself causes the accentuation of bagging problem. The presence of elastane in the fabric samples promotes the reduction in deformation in appearance as well as in the tendency to bagging.

Enzymatic Wash Effect

Table 2 shows the variation in residual bagging height before and after enzymatic wash for Samples. It can be noted that Sample 1 represents the highest bagging deformation (26.67%) and Sample 6 represents the lowest bagging deformation (13.33%).

The use of enzymes has become a sustainable option to get the worn-out look in denim. The findings obtained reveal that the residual bagging height value for Sample 1 increases from 11mm to 15mm after enzymatic wash and for Sample 6 it increases from 10.4mm to 12mm. The enzyme damages the cellulose.

First, the enzyme penetrates the cotton cuticle through micropores or cuticular cracks and comes into contact with the primary wall. At this level and at the point of contact with the enzyme, the primary wall is hydrolyzed by the catalysis of cellulase enzymes. Then after the attack on the primary wall, the hydrolysis of the secondary wall occurs. Finally, the cellulase attacks the cellulose on the link 1,4β glucosique of the cellulose molecule. The hydrolysis of this link breaks the molecule into several pieces, which can themselves be divided[26]. Hence, a decrease in the degree of polymerization (DP) with a remarkable drop in mechanical strength is observed, which justifies the significant decrease in the resistance to bagging[22].

Therefore, we can explain the difference in residual bagging height between these two fabrics (Sample 1 composed of 100% cotton and Sample 6 with 92% cotton) by the enzyme effect, which attacks only the cellulosic fibres. Likewise, the elastomeric fibre (elastane) has a greater recovery power than that of cotton. Hence, the increase in elastane percentage decreases the residual bagging height.

In addition, enzymes remove hairiness from the surface of fabrics which will cause an increase in abrasion resistance[7]. From where the fibres on the surface of the fabric become more attached to each other and their movement in the yarn will be limited. For these reasons, it can be concluded that enzyme washing increases the abrasion resistance. The increase in abrasion resistance increases the residual bagging height. This finding is in ultimate accordance with Gazzah's findings[27].

Bleaching Treatment Effect

Table 2 shows widely the variation of the residual bagging height before and after the bleaching treatment. According to these results, unlike other types of washing, bleaching leads to a decrease in the residual bagging height for all tested denim fabric samples. Bleaching is done in a full bath using bleach, which is an oxidizing product for cotton. Treatment of denim fabric with sodium hypochlorite may affect the shear properties. Mean values for shear stiffness are dropping to 26.69%[20]. Similarly, shear hysteresis values are dropped after laundry cycles[20]. The reduction in these parameters causes the notable decrease of residual bagging height for two reasons[21]. Firstly, it can be explained by the denim fabric's tendency to release the temporary tensions applied during the weaving and fabric manufacturing processes. This kind of relaxation shrinkage causes the rate of shrinkage to increase rapidly at the beginning of washing. This shrinkage is in both the directions of warp and weft. The shrinkage of weft yarns forces warp yarns to become close together and enhance the frictional force between warp yarns[28]. Secondly, according to overall studies[28], the effect of the friction parameters on the residual bagging height is high and helps to understand the good relationship between the friction coefficient and the residual bagging properties. Indeed, when the friction resistance increases, the residual bagging height, and volume decrease accurately, thus affecting the fabric appearance and shape.

Conclusion

Garment washing is a technology incorporated by garment manufactures to be able to provide a product as per the consumer's requirements. The present study aims to evaluate the effect of different types of chemical washing on the residual bagging height of denim garments. The findings on recovery ability of specimens will allow industrialists to present the lowest residual bagging height. The findings obtained show that all types of washouts influence the bagging behavior of denim fabrics. Indeed, enzymatic washout is the most influential on bagging. It shows a significant change in the residual bagging height, which has increased up to 26.67% (from 11 mm to 15 mm). However, desizing is fewer aggressive than enzymatic wash. It shows the least increase in the residual bagging height, which is between 3% and 17.29%. The chemical treatments applied have a strong effect on bagging of denim fabric samples. Indeed, bleaching treatment has a very important effect on the decrease in the residual bagging height values for all specimens. This decrease is ranged from 1.79% to 12.22%.

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