

Effect of Laundering on Dynamic Elastic Behavior of Cotton and Cotton/Spandex Knitted Fabrics

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ABSTRACT

Elastic fabrics are mostly used for tight fit sportswear manufacturing because of easy body movement and quick energy recovery. These garments are normally used for short duration sports activities wherever the person requires unrestricted energy and power. Analysis of laundering effect on the functional activities of the fabrics or garments is necessary because all the elastic garments are not the use and throw products. Assessment of dynamic work recovery (DWR) and stress value for applied extension is necessary to study the energy loss or power gain by the sports person wearing the elastic garment. The present study is to analyze the effect of laundering on dynamic elastic behavior of the cotton and cotton / spandex fabrics. The laundering cycles such as no wash, first wash, second wash, fifth wash, tenth wash and twentieth wash were selected and the laundering effect was studied by comparing cotton / spandex knitted fabric with 100 % cotton fabric. It is concluded that the laundering effect doesn't influence the DWR and stress values at specific extension of the cotton and cotton / spandex knitted fabrics. This study will help to improve the laundering performance of the elastic fabrics.

Keywords: cotton / spandex knitted fabric, dynamic work recovery, elastic hysteresis, laundering, tight fit sportswear

1. INTRODUCTION

Elastic fabrics are mostly used for tight fit sportswear manufacturing because of easy body movement and quick energy recovery. These garments are normally used for short duration sports activities wherever the person requires unrestricted energy and power ¹. Evaluation of the functional characteristics of these fabrics is normally carried out at fabric finishing stage. Analysis of laundering effect on the functional activities of the fabrics or garments is necessary because all the elastic garments are not the use and throw products. There

are many literatures available related to laundering effect on dimensional stability of knitted fabrics but hardly any on elastic behavior of elastic fabrics. To increase the economics of the elastic garments usages, it is necessary to improve the laundering cycles.

Anand ² studied the effect of laundering on dimensional stability of the knitted fabric by analyzing 100% cotton fabric with different structures such as plain single jersey, rib and interlock. They were subjected to five washing cycles and drying regimes. They concluded that the plain single jersey

requires more attention when laundering, because plain structure is so unbalanced. It would be unwise to launder the fabric under the same conditions as those applied to the rib and interlock structures. The loops of all three structures become distorted and bend in the third dimension after laundering.

Sharma *et al.*³ studied the laundering effect on dimensional stability of plain knitted fabric and stated that the fully relaxed state of a plain knitted fabric is reached only after a thorough wetting, brief hydro extraction, and tumble drying for a period of 70 to 90 minutes at 70⁰C. After drying and relaxing, the fabric is not able to reach a strain-free state because of frictional forces at the intermeshing points of the loops. In the full relaxation process, however water acts as a lubricating agent, which reduces the friction at interlocking points. The extra energy supplied to overcome this frictional force is in the form of rotational motion of the tumble drier. Ultimately the loops attain the state of minimum strain, and fabric attains the dimensional stability, independent of relaxation time.

Postle⁴ stated that the tumbling at elevated temperatures has an effect on the dimensional properties of synthetic fiber fabrics similar to the effect of static wet relaxation on the dimensional properties of hydrophilic fiber fabrics. These treatments however, do not remove all the potential relaxation shrinkage and changes in the dimensional properties of knitted fabric. The dimensional stability was achieved by wet relaxation at 100⁰C with gentle agitation, followed by tumble drying at 80⁰C.

Elizabeth and Bruce⁵ studied the laundering effect on dimensional changes and appearance of stretch knitted fabrics. The study was carried out up to 10 washes. Shrinkage was significant at only first wash. After that the shrinkage gradually reduced. Appearance was not affected by the method of drying as there was no change in the fabric smoothness and color change and there was no adverse fuzziness.

Chathura and Bok⁶ studied the dimensional characteristics of rib knitted fabrics made from spandex core cotton spun yarns under laundering regimes till 10th washing cycle. Cotton/ spandex rib fabric became more stable after 10th laundering under the experimental conditions. Cotton did not come to such a state, even after the laundering cycles increased. Tightness factor and relaxation treatment effect on the fabric parameters such as length, width shrinkage and spirality changes of cotton / spandex and cotton rib fabrics significantly. Therefore, increasing washing cycle from two to three did not give any significant effect.

Mukhopadhyay *et al.*⁷ studied the effect of laundering on extension and recovery characteristics of cotton / spandex knitted fabric. The changes in extension and recovery characteristics are prominent at initial laundering cycles and after that the changes become insignificant. Laundering reduces the elastic properties of fabrics as the immediate recovery and resiliency of fabric tend to reduce, whereas, delayed recovery and permanent set value become higher.

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M In the case of elastic fabrics, the role of spandex and its behavior is important when they are subjected to laundering. Normally, the elastomeric fibers do not immediately return to their original length as the retractive force drops to zero at 10 - 20% elongation after cycling to 300% elongation. This set is not permanent, because a simple relaxed heat treatment, for example, in boiling water, restores the fiber practically to its original length. Set is not due to polymer flow but to a delayed recovery of the deformed network, which retains some orientation⁸.

Assessment of dynamic work recovery and stress value for applied extension is necessary to study the energy loss or power gain by the sports person wearing the tight fit elastic garment. The recovery behavior of the fabric or garment is important to

enhance the power of the sports person involved in strenuous sports activity⁹. In general, elastic textile material will give minimum work energy loss which can be

calculated by assessing dynamic work recovery (Figure 1).

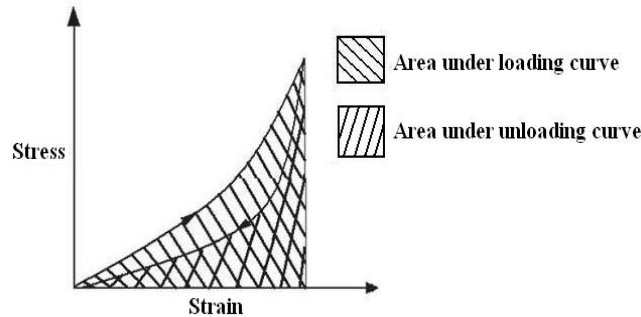


Figure 1. Dynamic work recovery

Dynamic Work Recovery (DWR) of the fabric is calculated by the eq. (1).

$$\text{Dynamic work recovery \%} = \frac{\text{Area under the unloading curve}}{\text{Area under the loading curve}} \times 100 \quad (1)$$

The present study is to analyze the effect of laundering on dynamic elastic behavior of the cotton and cotton / spandex fabrics. The laundering cycles such as no wash, first wash, second wash, fifth wash, tenth wash and twentieth wash were selected and the laundering effect was studied by comparing cotton / spandex knitted fabric with 100 % cotton fabric.

2. MATERIALS AND METHODS

2.1 Fabric Production

In order to study the dynamic elastic behavior of the cotton and cotton / spandex fabric, the 14.76 tex cotton yarn was used to produce 100% cotton knitted fabric. The 14.76 tex cotton yarn and 30 denier spandex (at 5% spandex feed) were used to produce cotton / spandex fabric by the plating method. The fabrics were produced using circular weft knitting machine. The specifications of the machine are given in Table 1.

Table 1. Knitting machine specifications

Model	MV 4 - Mayer and Cie (2001)
Machine gauge (Needles per Inch)	24
Machine diameter (inches)	24
Number of feeders used	72
Machine speed (rpm)	20 – 30

The cotton / spandex single jersey knitted fabric was heat set at 200⁰C using heating chamber (ASKME Make, chamber length of

228.6 cm and fabric stretch at width wise direction is 25% of machine diameter). Cotton fabric was n't heat set. Then, both

the fabrics were dyed, compacted and tested for their geometrical characteristics.

The knitted fabrics were first bleached using hydrogen peroxide bleaching for two hours. Then peroxide nutrition treatment was given for one hour. Wetting oil was added to dye bath. The fabric samples were dyed with 2% shade hot brand reactive dyes. The fabric was soaked in the dye bath for four hours. Again the samples were treated with salt & soda and steamed at 65°C temperature. Then, the sample was treated with soap solution and acetic nutrition treatment for one hour.

These fabrics were compacted using tubular compacting machine (Albert make, Speed of 4 meters per minute, Chamber length of 1 meter, 26 % over feed, Fabric stretch in width wise direction was kept at 11% of machine diameter and at the temperature of 94°C). Then, the fabrics were relaxed for 48 hours¹⁰.

2.2 Laundering Procedure

Laundering was carried out using front loading machine under normal agitation with a machine speed of 30 rpm. Each washing cycle includes wash, rinse, spin and tumble dry steps. Washing temperature was set at 40°C and the fabric samples were rinsed with cold water. Detergent was taken in the ratio of 0.1 gram / liter while material to liquor ratio was kept as 1: 10. The washing cycle was proceeded till 20th cycle and after each selected washing cycle, the samples were tumble dried at around 70 °C for 90 minutes. Samples were conditioned in

a conditioning cabinet keeping the temperature as 21°C ±1°C and relative humidity as 65% ± 2 % for 24 hours before conducting the tests at the selected washing cycles.

These fabrics were tested for their dynamic elastic behavior such as dynamic work recovery and stress at specific extension based on ASTM D 4964 – 96 method at 50% extension. Normally, human body movement expands the skin by 10 to 50% at different parts. The DWR and Stress at specific extension test results have to be analyzed from 10 % to 50% extensions. But, the DWR values of the fabrics showed predominant difference only at 50 % extension. The applied load was 5 KN at a speed of 500 millimeters per minute for 10 cycles, 10 sample size and gauge length of 100 mm. Laundering effect was studied by comparing cotton / spandex fabric with 100% cotton fabric using AATCC 150 - 1995 test method.

3. RESULTS AND DISCUSSION

In order to study the laundering effect on the cotton / spandex fabric for their dynamic elastic behavior such as DWR and stress at specific extension, a comparative study was carried out between cotton / spandex knitted fabric and 100% cotton knitted fabric.

3.1 Geometrical Characteristics

Effect of laundering on geometrical characteristics of knitted fabrics were analyzed and are given in Figure 2.

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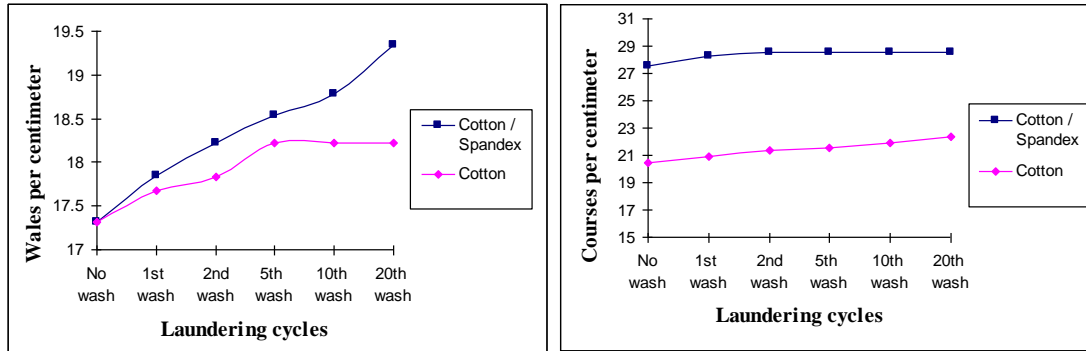


Figure 2. Effect of laundering on geometrical characteristics of cotton and cotton / spandex fabrics

Gradual increase in courses per centimeter of cotton / spandex fabric up to second washing cycle is observed and after that there is no change in the dimension of the fabric from 5th wash to 20th wash. The wales per centimeter of fabric increases continuously up to 20th wash. It doesn't reach its stability for the selected range of washing cycles. In the case of cotton fabric, the course per centimeter increases continuously up to 20th wash. The wales per centimeter of the fabric are increased up to 5th wash and after that there is no much change in the trend.

3.2 Elastic Hysteresis

In order to study the dynamic elastic behavior such as dynamic work recovery and stress at specific extension, the elastic hysteresis of the cotton and cotton / spandex fabrics were analyzed. Elastic hysteresis of these fabrics at 50% extension level in wale wise and in course wise directions are shown in Figures 3 and 4 respectively. Normally, simple and ordinary body movement expands the skin by about 10 to 50%. The dynamic elastic behavior of fabrics has no significant effect from 20 % to 40% extension. When the fabric

laundering cycles increase from first wash to twentieth washing cycle, the slope of fabric hysteresis also increases in both walewise and coursewise directions.

In the case of normal cotton fabric, there is no rise in stress values for the initially applied extensions in the loading curve. The rise was predominantly seen in the case of tenth and twentieth washing cycles. Then, the stress value starts increasing during further loading up to 50 % extension. Yarn slips from its cross over points smoothly due to continuous laundering. i.e., yarn loop deformation. Similarly, the recovery curve (unloading curve) drops quickly to zero stress when the fabric is subjected to forced recovery. The stretched yarn in the structural cell was only recovered quickly during recovery cycle. But, the deformed loop will take time to recover. The forced recovery doesn't help to bring back the loop deformation to original position. No significant evident is found in loss of energy during laundering cycles. Since, the water interacts with the fabric act as lubricant, it reduces the inter yarn friction. This helps the yarn loops to compress the fabric dimension quickly.

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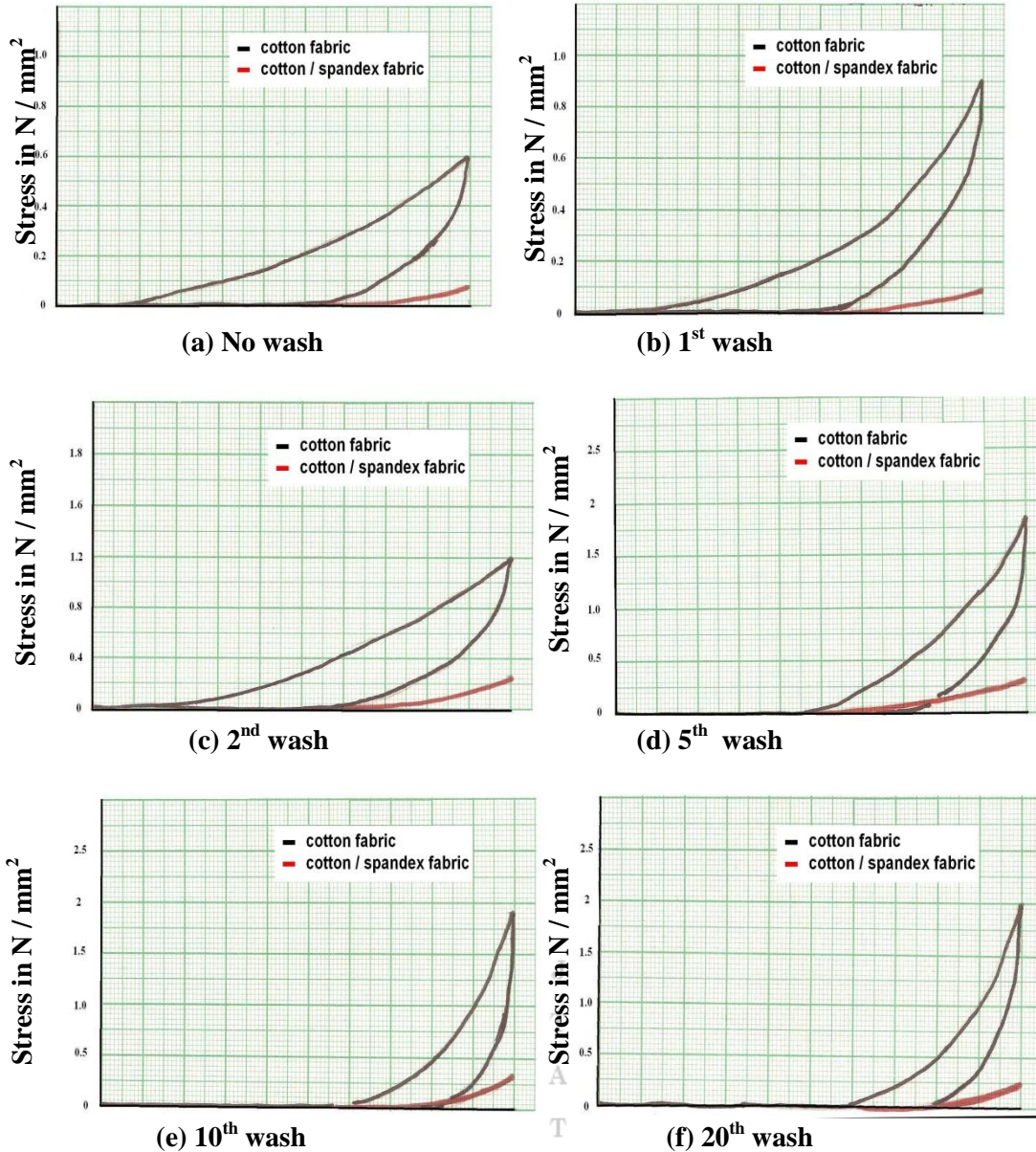


Figure 3. Elastic hysteresis of cotton and cotton / spandex fabrics-wale direction

Cotton / spandex fabric has very low stress value for the given extension in both walewise and coursewise directions for all the laundering cycles. The fabric was almost in jammed state due to the yarn loop lateral compression. As the stress initiated from initial extension gives minimum elastic

hysteresis slope, this causes minimum stress level (less than 0.2 N / mm^2) for all the laundering cycles in both directions. Spandex pulls back the yarn loops in fabric for quick dimension recovery. But, the trend is not found in the case of cotton fabric.

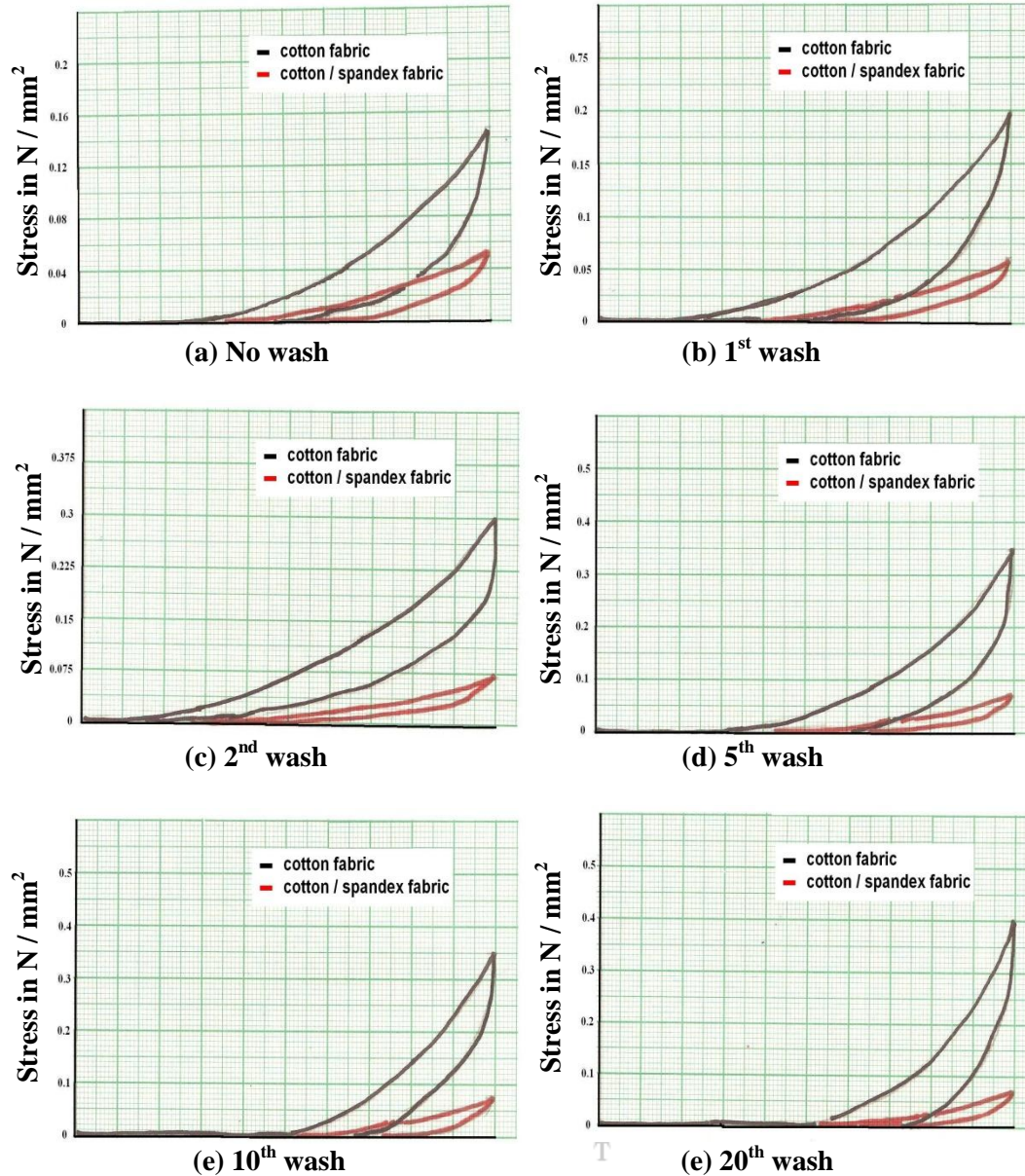


Figure 4. Elastic hysteresis of cotton and cotton / spandex fabrics—course direction

3.3 Dynamic Work Recovery

The effect of laundering on dynamic elastic behavior such as dynamic work recovery (DWR) and stress at specific extension of the cotton and cotton / spandex knitted fabric has been discussed. The DWR of

these fabrics were assessed using the elastic hysteresis.

The laundering effect was studied by varying the washing cycles such as first wash, second wash, fifth wash, tenth wash and twentieth washes. The DWR values of the fabrics are given in Table 2 and Figure 5.

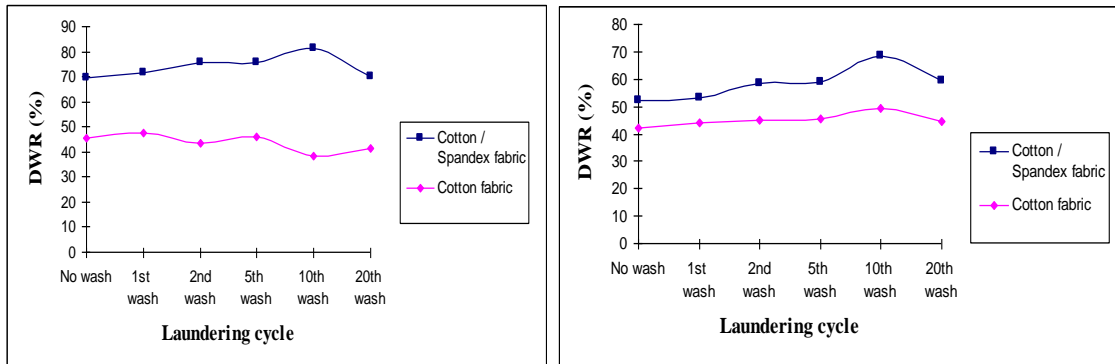
Table 2. DWR of cotton and cotton / spandex fabrics with various laundering cycles

Fabric specifications	No wash	1 st wash	2 nd wash	5 th wash	10 th wash	20 th wash
CS – Wale direction	69.54	71.82	75.48	75.49	81.26	70.29
NC – Wale direction	45.67	47.67	43.47	46.14	38.41	41.43
CS – Coarse direction	52.15	53.24	58.29	58.91	68.56	59.19
NC – Coarse direction	42.32	43.89	44.94	41.60	49.34	44.32

CS = Cotton / Spandex fabric, NC = Normal Cotton fabric

The DWR of cotton / spandex fabric is higher than that of normal cotton fabric for all the washing cycles in both walewise and coursewise directions. That is, the cotton /

spandex fabric has nearly 40 % higher DWR in walewise direction and nearly 24 % higher DWR in coursewise direction, than that of the cotton fabric.



(a) Wale direction **(b) Course direction**
Figure 5. Effects of laundering on DWR of cotton and cotton / spandex fabrics

In the case of normal cotton fabric, the DWR value falls in between 40 % to 50% in both walewise and in coursewise directions and no trend is found on DWR with increasing laundering cycles up to 20 washes. Laundering cycle doesn't reduce the DWR of the cotton fabric. This is due to the fact that the cotton fabric frictional forces at the intermeshing points of the loops are higher, and they restrict the free yarn loop movements.

In the case of the cotton / spandex fabric, DWR of the fabric increases with increasing washing cycles from the first wash to the tenth wash and after which, it decreases at 20th wash. This interesting trend was observed in both the walewise and coursewise direction. DWR of the cotton / spandex fabric in walewise direction is

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higher than that of DWR in coursewise direction. The DWR value is mainly influenced by inter yarn friction in the loops intermeshing points.

Higher the yarn loop lateral compression, lower the hysteresis which leads to minimum stress at specific extension of the fabric. The unloading curve with quick recovery is obtained because of spandex residual energy and smoother yarn surface. Normally, laundering process affects the residual energy of the spandex. But, in this case, water interacts with the cotton yarn in the fabric and acts as a lubricating agent, which reduces the friction at cotton yarn intermeshing points during laundering. This may be the reason for increasing DWR value up to ten washing cycle. After that, the DWR diminishes from 10th wash to 20th

wash, which may be due to the loss of residual energy of the spandex in the fabric after 20th wash cycles.

Effect of repeated laundering on dynamic work recovery of the knitted fabrics has no significant effect at both walewise and coursewise direction. $F_{observed} < F_{critical}$ at $F(1, 5) = 0.27$; $P > 0.05$ at walewise

direction and $F_{observed} < F_{critical}$ at $F(1, 5) = 4.27$; $P > 0.05$ at coursewise direction.

3.4 Stress at specific extension

Stress value of the cotton and cotton / spandex knitted fabrics at various washing cycles have been analyzed and the results are given in Table 9.3 and Figure 9.5.

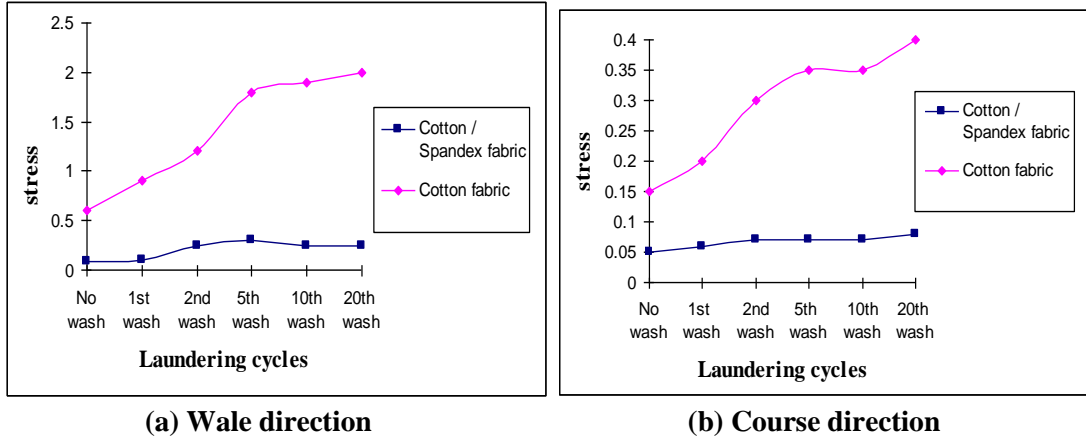


Figure 6. Effects of laundering on stress values of cotton and cotton / spandex fabrics

In the case of normal cotton fabric, the stress value increases with the increase in washing cycles. The stress value of cotton fabric increases rapidly with increasing washing cycle up to fifth wash cycle, after which the improvement is reduced for further washing cycles. This trend is observed in both walewise and coursewise directions. In the

case of cotton / spandex fabric, no special trend is observed between the stress values of different washing cycles in both walewise and coursewise directions. The stress level is less than 0.5 N/mm^2 in the case of cotton / spandex fabric. This range of stress values has no problem with respect to skin irritation during sports activity¹⁰.

Table 3. Stress values of cotton and cotton / spandex fabrics with various laundering cycles

Fabric specifications	No wash	1 st wash	2 nd wash	5 th wash	10 th wash	20 th wash
CS – Wale direction	0.08	0.1	0.25	0.3	0.24	0.25
NC –Wale direction	0.6	0.9	1.2	1.8	1.9	2
CS - Course direction	0.05	0.06	0.07	0.07	0.07	0.08
NC - Course direction	0.15	0.2	0.3	0.35	0.35	0.4

CS = Cotton / Spandex fabric, NC = Normal Cotton fabric

Effect of repeated laundering on stress at specific extension of the knitted fabrics has no significant effect at walewise and coursewise directions. $F_{observed} < F_{critical}$ at $F(1, 5) = 1.70$; $P > 0.05$ at walewise direction and $F_{observed} < F_{critical}$

critical at $F(1, 5) = 1.51$; $P > 0.05$ at coursewise direction.

4. CONCLUSION

The effect of laundering on dynamic elastic behavior of cotton / spandex fabric has been

analyzed. The laundering effect was studied by comparing the DWR of cotton / spandex knitted fabric with cotton fabric by varying washing cycles from first wash to twentieth wash. Dynamic work recovery of the cotton / spandex fabric is nearly 40 % higher in walewise direction and nearly 24 % higher in coursewise direction, than that of cotton fabric. The laundering effect doesn't influence the DWR and stress values at specific extension of the cotton and cotton / spandex knitted fabrics at both walewise and coursewise directions. This study will help to improve the laundering performance of the elastic fabrics.

5. ACKNOWLEDGEMENT

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