Designing terry fabric for improved serviceability

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Various terry fabrics (cotton) having different constructional parameters have been designed and the effect of washing treatment on water absorbency, surface characteristics and compression characteristics are studied. To establish the optimum loop length and loop density of terry fabrics at which they can withstand maximum number of washing cycles without affecting water absorbency, surface characteristics and compression characteristics, terry fabrics having the same yarn and fabric parameters are washed under industrial conditions for 10 washing cycles. After each cycle, the rate of water absorption, total amount of water absorbed, surface characteristics and compression characteristics are evaluated by gravimetric absorbency testing system, image analysis techniques and KES-FB-3 testing system respectively. Another group of cotton terry fabrics having different loop length and loop density have been studied to optimise these two important fabric parameters to increase the life of fabric. It is observed that the rate of water absorption, the total amount of water absorbed and the surface characteristics improve with increase in washing cycle, but after 8th washing cycle these parameters start deteriorating. Maximum possible loop density and loop length of 15 - 17 mm give maximum life of terry fabric i.e. the fabric can perform well even after 10 washing cycles. This study will certainly help in increasing the life of terry fabric, developing high quality towel fabric by providing information on absorbency, surface characteristics and compression characteristics of fabric before and after washing along with the values of loop length and loop density.

Keywords: Absorbency, Compressional characteristics, Cotton, Fractal dimension, Fast fourier transforms, Gray level co-occurrence matrix, Loop density, Loop length, Pile fabric, Terry fabric

1 Introduction

Terry fabrics belong to the group of pile fabrics, in which an additional yarn is introduced to form loop (called as pile) to give special function and distinct appearance. Wetting characteristic of fibrous materials are important to their chemical processing and functional performance. Liquid must wet the fibre surface before being transported through the inter fibre pores by means of capillary action. The capillary force decides the way in which the liquid flows through pores.

Absorbency characteristic of fibre assemblies depends on the geometry of fibre assemblies, especially surface roughness as well as pore size distribution[1]. The amount of water absorbed by the terry fabric is important for its end use. However, this does not give any idea on how quickly a terry fabric absorbs the water, or how water absorption changes with time. This aspect of water absorbency is particularly known as rate of water absorption, which is also an important parameter. Another important factor influencing the rate of absorption is the fabric surface[2].

Life of any product plays a crucial role in its costing and sale. A customer may declare a fabric unusable if it loses its aesthetic appeal. A fabric may be uglied out soon rather than worn out. The effect of different fabric softeners on water absorbency of terry fabric has been studied by many researchers [3, 4]. The average water sorption after washing [5, 6] increases by over 10%. Static water absorption increases up to 2.2 times after washing grey terry fabric with detergent and softening[7]. Liquid retention capacity increases after washing[8]. In addition to absorbency, other properties such as texture, appearance, compression, friction, etc are also the requirements of the current age. Repeated washing of fabric affects the water absorbing and retaining capacity of fabric. Home laundering also affects other properties such as texture, appearance, compression, friction, etc of terry fabric. This particular aspect of home laundering has never got much attention until now, but in the current changing scenario these properties have also got their importance. Therefore, the present research has been directed towards the investigation of effect of home

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laundering on all the properties of terry fabric so that manufacturer may come to know the key structural and material parameters which may be altered to improve their performance.

2 Materials and Methods

2.1 Materials

Different terry fabrics with various constructional parameters have been produced using 100% cotton fibre (J-34). Details of the samples used are given in Table 1. In all, there are 7 groups and each group contains 5 samples.

2.2 Washing

All the samples were washed for ten cycles and after every cycle, compression, texture and hand were evaluated. Washing details are as under:

- Washing machine used−Whirlpool top loading
- Wash time − 12 min
- Spin time − 6 min
- Water temperature − 40°C
- Rinsing temperature − 30°C
- Detergent − ECE detergent
- Drying − Tumbler

2.3 Absorbency

Absorbency of the samples was tested using gravimetric absorbency testing system which works on porous plate method[9]. Total amount of water absorbed and rate of water absorption were measured.

2.4 Compression

Compression properties were measured on KES-FB3 compression tester. This instrument gives linearity of compression, compression energy and compression resilience apart from thickness of the sample. The testing was carried out using the conditions: compression area 2 cm^2, compression velocity 0.02 mm/s, and process rate 2.5 s.

2.5 Texture Evaluation

Textures of the samples were evaluated using digital image processing techniques[10-14]. Energy, entropy, and inertia were calculated using gray level co-occurrence matrix (GLCM). Fractal dimension was calculated using fast fourier transform (FFT). Uniformity index (UI) was calculated using GLCM. Energy is multiplied by a factor 10^4 and entropy is divided by a factor 10^2 to represent the data graphically.

2.6 Subjective Evaluation

A group of 25 experts from the industry and institutes was selected for subjective evaluation of hand and texture[10, 11, 14]. Samples were supplied to them one by one and they were told to rank the samples according to the intensity of feeling of total hand. Total hands were ranked from 0-5 (5 being the best). Subjective evaluation of surface texture (uniformity and orientation) [15] has been done by 25 judges and will be given by subjective surface rating (SSR). Mean value of rating given by all the judges has been taken for further analysis. Ranks were given on the scale of 0 - 5 (0 being the smooth and 5 being the most rough). To check the degree of agreement among the experts, coefficient of concordance was calculated using the following equation:

$$W = \frac{12 \sum \left\{ SR^2 - n\left(\frac{SR}{n}\right)^2 \right\}}{k^2(n^3 - n)} \qquad \ldots(1)$$

where SR is the rank sum ; k, the number of judges; and n, the number of samples.

3 Results and Discussion

3.1 Effect of Washing Cycles on Terry Fabric Properties

Terry fabric Sample Group No. 7 has been washed under the condition mentioned above and the effect of washing of the fabric is studied (Figs 1 − 4).

3.1.1 Effect of Washing Cycles on Water Absorbency

To investigate the general effect of washing on absorbency of terry fabric, the samples were washed 10 times and after every two washes the samples were

Table 1— Fabric samples details

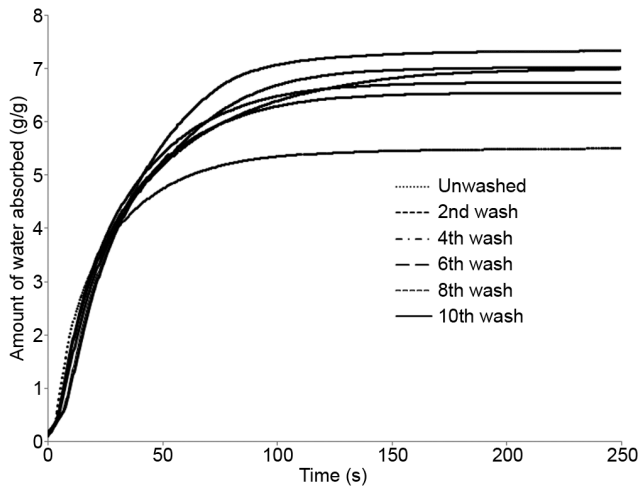| Sample group No	Weft density, picks/cm	Loop length, mm	Weft count, Ne	Loop density, loops/inch^2	Pile ratio
1	13	15	12	41	7.72
2	16	15	12	45	7.71
3	19	15	12	50	7.67
4	16	10	12	45	5.53
5	16	13	12	45	6.48
6	16	18	12	45	9.77
7	15	15	12	44	6.76

Fig. 1 — Effect of washing cycles on water absorbency
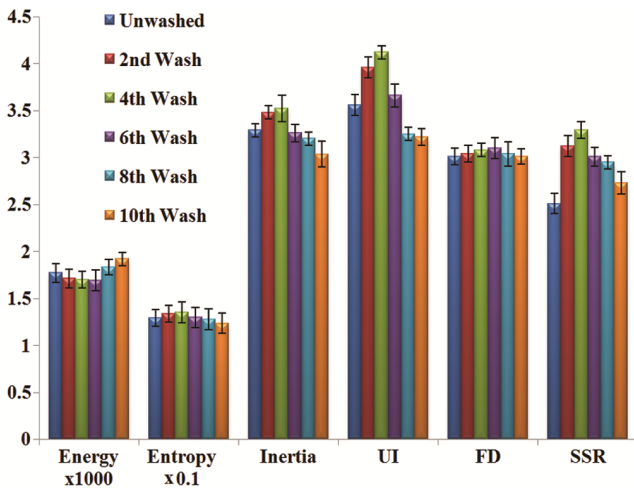
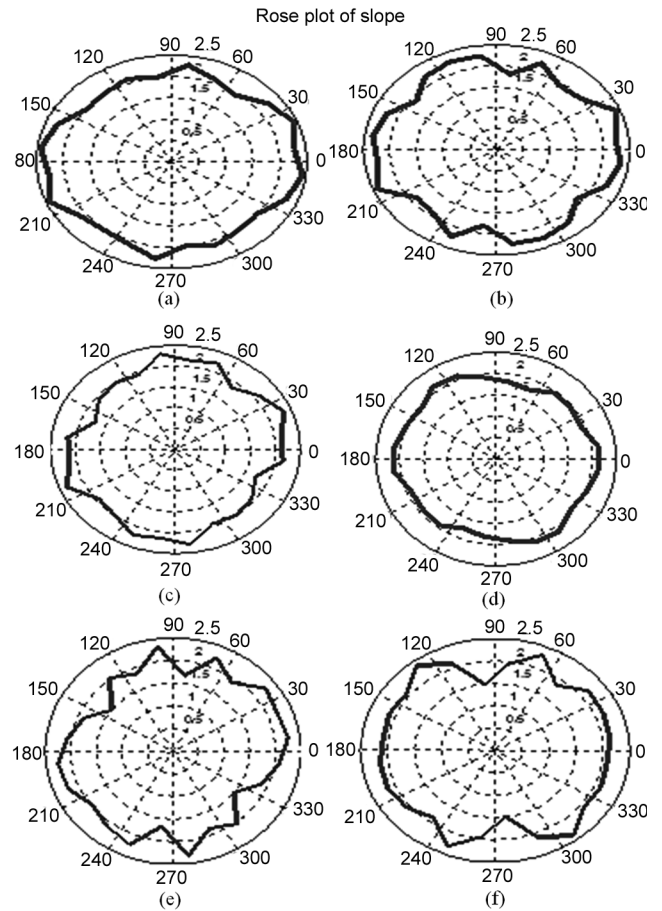Fig. 2 — Effect of washing treatment on surface texture

Fig. 3 — Rose plot of fractal dimension in different direction showing the effect of washing on fabric surface (a) unwashed fabric, (b) 2nd wash fabric, (c) 4th wash fabric, (d) 6th wash fabric, (e) 8th wash fabric, and (f) 10th wash fabric
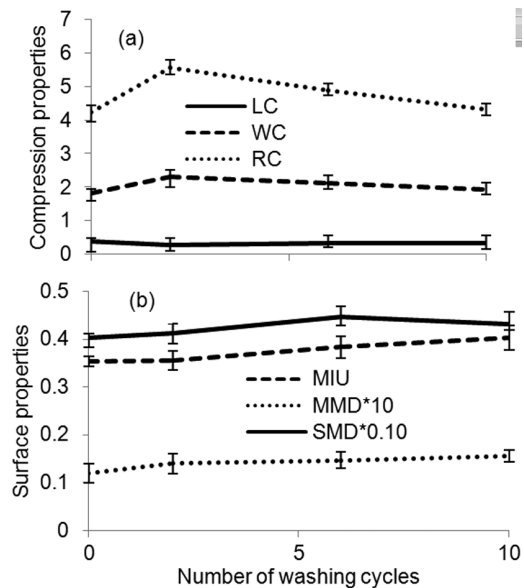

Fig. 4 — Effect of washing on compression and surface properties (a) compression properties and (b) surface properties

tested for absorbency following the method mentioned above. The results of absorbency performance are plotted in Fig. 1.

The rate of water absorption and the total amount of water absorbed increases with washing cycle but after 8th washing cycle it starts decreasing. This may be attributed to the increased discontinuity of the capillaries and reduced air spaces inside the fabric after repeated washing. The falling of the loops on the fabric surface after more number of washes is also responsible for reduction in absorbency after 10 washes.

3.1.2 Effect of Washing Cycles on Surface Texture

Results displayed in Fig. 2 show that the energy of the texture reduces till 6th wash and then it starts increasing, which means that up to 6th washes the

surface smoothness reduces and then increases afterwards. Entropy increases till 4th wash and then starts decreasing which means that the surface disorder increases till 4th wash. Similar trend is also observed with inertia which depicts that the local variations increase till 4th wash. Fractal dimension keeps on increasing till 6th wash and then starts decreasing. These changes may be attributed to the fact that the washing treatment disturbs the loop geometry and their orientation, which causes the fabric surface more random. Uniformity index increases till 4th wash and then it starts decreasing. This is due to the falling of loops on fabric surface and matting.

After certain number of washes, the loops do not remain in standing position due to loss of fibres and bending rigidity. This flattening of the loops makes fabric surface smoother and the fabric becomes less water absorbent.

Figure 3 clearly shows the changes taking place in the surface of the terry fabric after washing treatment. The rose plot of the fractal dimension in different directions shows that the fractal dimension keeps on increasing and their uniformity keeps improving till 6th wash but after that the uniformity deteriorates. This may be attributed to the fact that after 6 washes, flattening of the loops starts i.e. the loops no longer remain in standing position.

3.1.3 Effect of Washing Cycles on Compression and Surface Properties

It is clear from Fig. 4 (a) that the compression resiliency and energy increase till 2nd wash and then it decreases. Linearity of compression curve decreases upto 2nd wash then increases upto 6th wash and afterwards becomes almost constant.

Figure 4 (b) shows that the geometrical roughness, coefficient of friction and its standard deviation keep on increasing as the number of wash increases. These changes may be attributed to the fact that during first two washes the yarn and the loops geometry remain in undisturbed state and their openness increases due to some fibre loss. During further washes, great disturbance takes place in the loop geometry and its orientation due to high loss of fibres and bending rigidity, causing permanent flattening of loops.

3.2 Effect of Fabric Parameters on After Wash Performance

Fabric samples varying in two important terry fabric parameters i.e. loop density and loop length, are washed for different cycles and their properties are studied after every two washes. The results are shown in Figs 5 and 6.

3.2.1 Effect of Loop Density on After Wash Performance

Samples of three level of loop density are analysed for change in texture after wash. This experiment shows that the general trend discussed in earlier section can be improved by changing the fabric constructional parameters. Figure 5 shows that with increasing loop density, after wash performance of terry fabric improves. It is very clear that the quality of the fabric with lower loop density deteriorates with less number of washes, whereas fabric with higher loop density can withstand more number of washes without losing their required properties.

This improved performance may be attributed to the fact that high loop density helps the loops to remain in standing position by supporting each other, as there is less space between the loops due to which the washing action can not disturb the loop geometry and its orientation easily.

3.2.2 Effect of Loop Length on After Wash Performance

Samples with four levels of loop length have been investigated for change in texture after wash. This experiment shows that the general trend discussed in earlier section can be improved by changing the fabric constructional parameters.

Four samples having different loop lengths (10, 13, 15, 18 mm) have been washed for different number of washes, and after every wash the textural and hand parameters are evaluated [Figs 6 (a) - (f)]. The results show that there is an optimum level of loop length at which the general trend mentioned in previous section can be improved. Fig 6(a) shows that the rate of increase of texture energy after 6th wash is lower for the sample having 15 mm loop length. This rate of increase becomes higher at 18 mm loop length, which means that the fabric having loop length 18 mm or more will show very rapid matting of loops after 6 wash. But the fabric having loop length 15 mm shows considerably good resistance to matting. Sharp increase in energy of the texture can only be explained by flattening of the loop. Figure 6(b) shows that the rate of decrease in the entropy after 6th wash is lower for fabric with 15 mm loop length than with 18 mm, which explains that fabric having 15 mm loop length performs better.

Figure 6(c) shows that the rate of decrease of texture inertia after 6th wash is lower for the sample
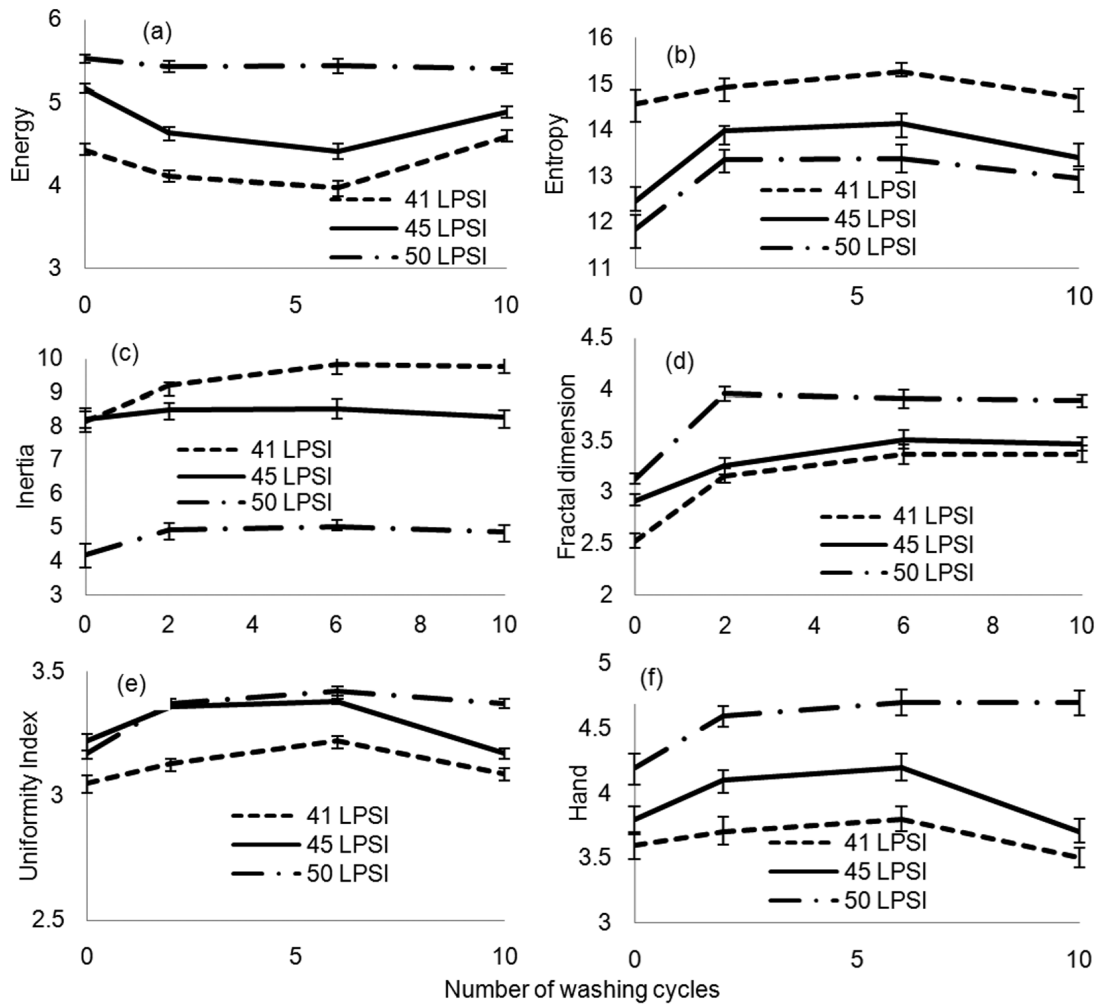
Fig. 5 — Effect of loop density on the after wash performance (a) energy, (b) entropy, (c) inertia, (d) fractal dimension, (e) uniformity index, and (f) fabric hand

having 15 mm loop length. This rate of decrease becomes higher at 18 mm loop length, which means that the fabric having loop length 18 mm or more will show very high local variation after 6 wash. But the fabric having loop length 15 mm shows considerably good local variation. Figure 6(d) shows that rate of decrease in the fractal dimension after 6th wash is lower for fabric with 15 mm loop length than with 18 mm, which explains that fabric having 15 mm loop length performs better.

Figure 6(e) shows that the rate of decrease in the uniformity index after 6th wash is lower for fabric with 15 mm loop length than with 18 mm, which explains that the fabric having 15 mm loop length performs better. Figure 6(f) shows that the rate of decrease in fabric hand after 6th wash is lower for the

sample having 15 mm loop length. This rate of decrease becomes higher at 18 mm loop length, which means that the fabric having loop length 18 mm or more will show very rapid loss of hand value after 6 wash. But the fabric having loop length 15 mm shows considerably good hand value.

This better after wash performance of terry fabric having loop length of 15mm may be attributed to the fact that the geometrical stability of loops reduces due to very high loop length (18 mm) and unstable loop geometry causes early permanent flattening and disorientation of loops. Lower loop length (10 - 13 mm) gives stable loop geometry but the ground of fabric is easily visible since loops are unable to cover it properly hence the fabric performance deteriorates.
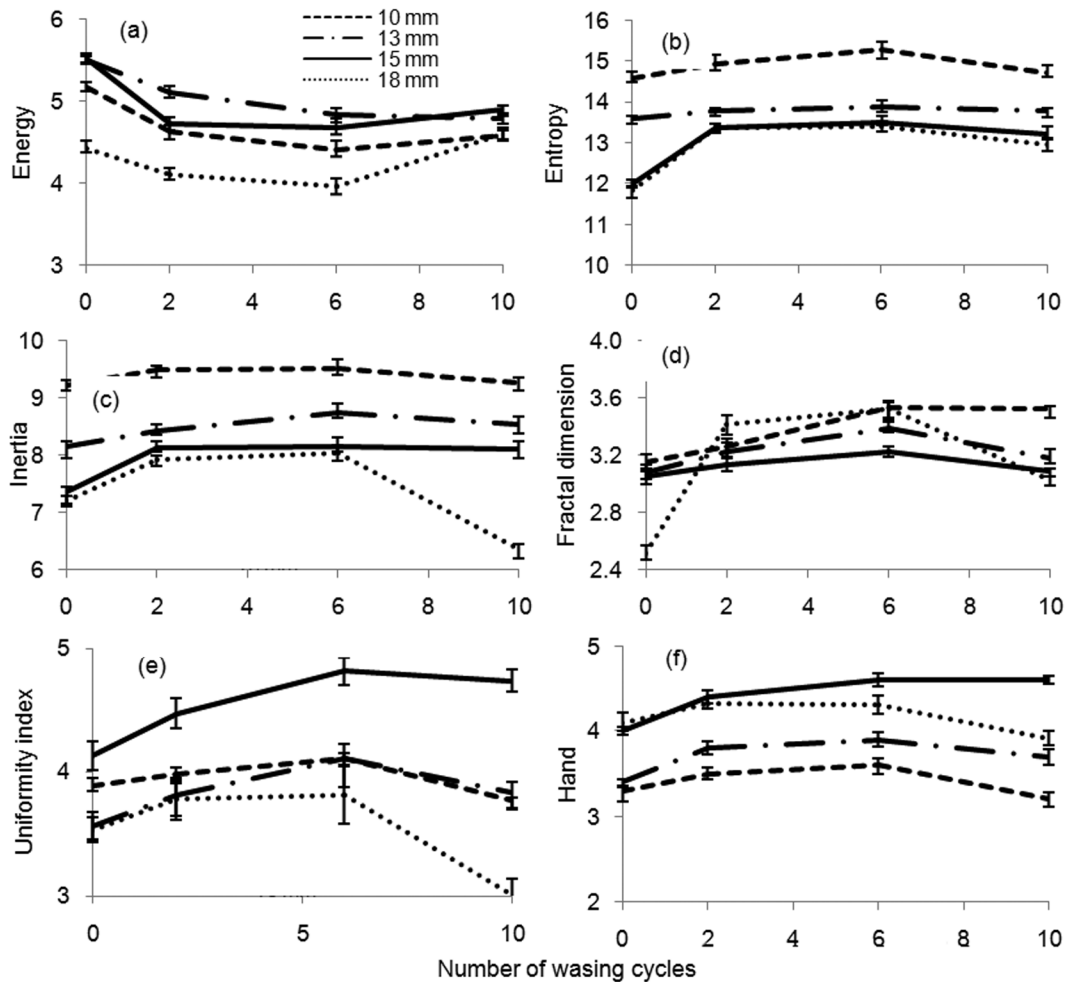
Fig. 6 ─ Effect of washing on properties of fabric having different loop lengths (a) energy, (b) entropy, (c) inertia, (d) fractal dimension, (e) uniformity index, and (f) fabric hand

4 Conclusion

Number of washing cycles has a very little influence on the rate of water absorption of terry fabric as it has been observed that the rate of water absorption increases slightly till fourth wash and then it decreases slowly with increasing number of washes.

The total amount of water absorbed increases with increasing number of washes but after 8th wash the total amount of water absorbed reduces along with the decrease in rate of absorption. On increasing the loop density on the fabric surface, the more number of washes can be withstood by the fabric without losing its properties.

Loop length should be kept at optimum level for achieving good after wash performance. In the experimental results the fabric having 15 mm loop length gives better after wash performance than the fabric having 18 mm and 13 mm loop length.

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