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Studies on the Pressure Behavior of Crepe Bandage on Repeated Usage and Washing

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ABSTRACT - *In the present work, commercially available crepe bandage fabrics are investigated for contribution of the structural parameters on stretch behavior of crepe bandages. This study aims to define that in how much time the crepe bandage loses its efficacy to maintain the pressure and needs rewrapping or replacement for further usage. The variation in the sub bandage pressure with time at various stretch levels is studied for reusage and rewashing. The bandaging technique used is 50% overlap to calculate the pre-defined length of bandage layer before applying to achieve the uniform stretch property while wrapping. Based on the stretch (%) value, the length of the fabric required to wrap the limb can be pre-calculated by using an equation to quantify the amount of stretch in the fabric during application for the two layer used in this bandaging technique. The results show that with increase in stretch (%) the sub bandage pressure also increasing but for different type of structures the change in pressure is different. Moreover the instantaneous pressure and the pressure reduction percentage are high in the bandage with high fabric weight per meter square. Also the bandages can be reused for up to 3-4 times in case of 2 up 2 down structures and up to 2-3 times in one up one downbefore washing. Further all the bandages show an increase in sub bandage pressure on washing and can be used upto four washing cycles comfortably without any loss in pressure.*

Keywords: Bandage fabric, before and after washing, leg ulcer, sub-bandage pressure, tensile properties.

1. Introduction

Bandage fabrics in particular are designed to perform a variety of specific function depending on the type of wounds. Among the different types of bandages, compression bandages are used to treat the parts of the body affected by venous ulcers, lymph edema or varicose veins [1]. Up to one percent of people in industrialized countries will suffer from a leg ulcer at some time.These ulcers are associated with increased cost and reduced health related quality of life for patients [2]. Leg ulcers arising from venous problems are called venous (or varicose or stasis) ulcers. The main treatment is the application of a firm compression garment (bandage or stocking) in order to aid venous return. Graduated compression from the ankle to the calf is the principle treatment for venous leg ulceration [3]. Insufficient or non-sustained compression will be less effective and excessive pressure can lead to tissue damage, pressure sores and necrosis. Limb damage or treatment failure may result in limb amputation [4].

A study by Cheng et al. demonstrated that there is a gradual decrease in skinandgarment interfacial pressure when patients wear the pressure garments over a period of time[5]. Views ofdoctors, therapists, and patients support theirfindings. Slackening occurs in pressure garmentswhen the patient wears them for a long time becausethe tension of the fabrics is time-dependent[6].The knowledge of interface pressure profile generated by compression bandage overtime is of prime importance as it would help to know after how much time the bandage loses its efficacy and needs re-wrapping or replacement for further compression treatment [7,8]. The material type, the yarn or thread density and the applied tension could influence relaxation behavior of a bandage and hence could determine interface pressure variation overtime. The yarn tex, yarn twist, fiber staple length, temperature, humidity, dynamic movement influence the relaxation behavior of textile structure and hence can influence interface pressure drop over time[9,10]. Therefore, it is essential for pressure garments to have the well holding capacity during application and also be suitable for repeated usages. Furthermore, these properties can be improved if the creep behavior and constructional parameters of fabrics are optimized to give the required levels of pressure for specific ailments. In earlier research, commercially available crepe bandage fabrics were investigated and it has been tried to correlate the structural parameters contribution on stretch property of bandage fabrics. Creep behavior of the crepe bandages , tension value (T), stretch value under same tension for the prediction of sub bandage pressure by using Laplace's Law have also been studied.

In the present work, firstly an attempt has been made to study the relationship between constructional parameters of crepe bandages and the pressure generated. Secondly, the effect of different stretch% on the pressure behavior of crepe bandages during the processes of repeated usage and repeated washing operations. Finally, the variation of interfacial pressure and pressure reduction of crepe bandage fabrics with respect to time is studied to understand that after how much time the bandages lose their efficacy and needs re-wrapping or replacement for further compression treatment. This will be beneficial for the user with regard to getting an idea before applying crepe bandage about its reusage before and after wash.

2. Materials and methods

Six short stretch bandages which are available commercially were taken and analyzed in the laboratory.The detail information of short stretch bandage samples tested is shown in Table 1.

Table 1. Constructional parameters of short stretch bandage samples

Sample No	Constituent fibre		Yarn Linear Density(Tex)		Thread Density per cm		Fabric weight /m^2	Crimp%		Warp yarn length in one wavy unit(cm)
	warp	Weft	warp	weft	Epcm	Ppcm		warp	weft	
S-1 (2/2 weave)	Cotton	Viscose	46	72	18	18	280	150	6.4	0.38
S-2 (2/2 weave)	Cotton	Viscose	59	70	19	28	544	190	12	0.408
S-3 (2/2 weave)	Cotton	Viscose	59	76	19	21	497	184	15	0.525
S-4 (2/2 weave)	Cotton	Viscose	46	75	17	29	490	222	13	0.447
S-5 (1/1 weave)	Cotton	Cotton	45	58	14	16	317	220	34	0.405
S-6 (1/1 weave)	Cotton	Cotton	46	68	13	13	249	162	10	0.409

3. Testing method for fabric

3.1 construction parameters : Fibre identification test was done according to ASTM D276. Yarn properties like yarn linear density (yarn count), and yarn twist and tests regarding structural design of fabric, weight/unit area, thickness of fabric, and ends and pick spacing are also done in a standard testing environment using standard testing methods.

3.2 Measurement of Tensile Characteristics of Fabric

AIMIL 410KL tensile testing instrument was used to measure the tensile properties of bandage fabrics using ASTM D 5034 standard.The breaking load and breaking extension were obtained at gauge length 150 mm at an extension rate of 300 mm/min in warp direction.

3.3Pressure Measuring Device and Method

Kikuhimepneumatic pressure sensor[11] is used for measuring bandages pressure.The sensor connected to the display unit is positioned beneath a bandage for an accurate (+/- 1mmHg) determination of pressure exerted

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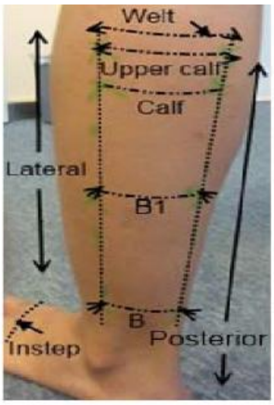
on the sensor. In order to prove the changes in the interfacial pressure under a steady amount of stretch in the warp fabric direction over a prolonged the period of time, i.e. 10min up to 1000min, the tests are performed. Each test is repeated in six times.In order to study of the interfacial pressure changes after this repeated usages and relaxations, the samples are prepared again on different stretch%. After each stage, the samples are placed on a smooth surface under zero stresses for 48 hours. Then the length of each sample is measured after 48 hour relaxation. For the repeated use of the bandage, it has to be washed and cleaned. The bandage is put in a mild detergent for 10-15 minutes and then rinsed softly with hand and it is left in a cool dry place for drying. The same tests were performed again on the same samples after repeated washings. After the samples were washed and dried, the lengths of specimen are measured for shrinkage. After each washing the interfacial pressure is measured.In the present study, the bandages are applied at B-1 position (Circumference 26.5 cm) and at calf position (Circumference 38cm). The wooden leg wrapped well prepared with foam like the structure of the human limb are used for this experimental work as shown in Fig. 1 (a) and (b).



(a) (b)

Fig.: 1 (a) position of human leg and (b) Simulated model of human leg for testing

3.4Sub-Bandage Pressure Calculation

Relationship between fabric stretch, circumference of bandaging surface and bandage fabric thickness is examined by equation (1) [12]**.** In the present study, 50% overlap, spiral pattern bandaging technique is used. In the same way the length of the bandage sample ('l') in relaxed state, 1st layer L-1 and 2nd layer L-2 can be calculated based on different stretch levels using following equation (1) as:

For 50% overlap,

$$\mathrm{L} = \frac{1/2\sqrt{4\{(2\pi \quad + 2\pi(n-1)t\}^2 + \mathrm{w}2}}{1 + S/100} \quad (1)$$

In the present study, the width of the bandage for all samples is 10 cm (w=10cm), and number of layers are two (n=2) for all samples. At calf position, circumference is 38 cm and above ankle B-1 position 26.5 cm is used while calculation of their respective predefined length.

The sub-bandage pressure 'P' may be calculated as follows

$$P \qquad (m \qquad) = \frac{T \qquad (K \quad) \times 4620 \times n}{Ci \qquad (c \quad) \times B \qquad h(c \quad)} \quad (2)$$

For a single layer of bandage (where *n*=1) the equation produces a value for K of 4620. The equation (2) is usually used by the doctor to predict the sub bandage pressure in term of mm of Hg and is known as Laplace equation.

4. Results and discussion

4.1Predefined length of bandage samples in relaxed state for wrapping

The values of predefined length shown for sample S-1(2/2 weave) and S-5(1/1 weave) in Table 2 and similarly for other samples predefined length are calculated using the above equation (1).

Table 2 - Predefined Length of bandage samples in relaxed state of Sample No.1 and 5

Sample No.	Circumference of bandaging surface	stretch%	Fabric thickness (cm)	Length of bandage L in relaxed state(cm)	
				L-1	L-2
S-1	B-1, 26.5cm	40%	0.124	19.26	19.80
	Calf, 38cm		0.124	27.37	27.92
	B-1, 26.5cm	50%	0.124	17.97	18.48
	Calf, 38cm		0.124	25.55	26.06
	B-1, 26.5cm	60%	0.124	16.85	17.33
	Calf, 38cm		0.124	23.95	24.43
	B-1, 26.5cm	70%	0.124	15.86	16.31
	Calf, 38cm		0.124	22.54	23.00
S-5	B-1, 26.5cm	40%	0.152	19.26	19.93
	Calf, 38cm		0.152	27.37	28.05
	B-1, 26.5cm	50%	0.152	17.97	18.60
	Calf, 38cm		0.152	25.55	26.18
	B-1, 26.5cm	60%	0.152	16.85	17.44
	Calf, 38cm		0.152	23.95	24.54
	B-1, 26.5cm	70%	0.152	15.86	16.41
	Calf, 38cm		0.152	22.54	23.10

From the Table 2 it can be observed that the relaxed length is much less than the actual circumferential length. As the number of layer increases, the bandaging circumference is also increased and corresponding to this circumference, the relaxed length of bandage sample *'l'* to get uniform stretch for the layer also increased. When the 1st layer applied, thickness of bandage fabric is negligible in using the formula given in equation (1). This calculated length is now used for marking on the bandage to get the experimental pressure values at different positions on the limb.

4.2 Tensile Behavior of Crepe Bandages

All six commercially available crepe bandages are tested on AIMIL Tensile Testing Tester. The fabrics are extended in their warp directions on the machine.The tensile behavior of the crepe bandage fabric under study is shown in Fig.2. It is observed that tension steadily increases with rate of extension. It is also observed that the tension in Kgf for sample S-4 shows sharp increase as compared to other samples at different stretch %.

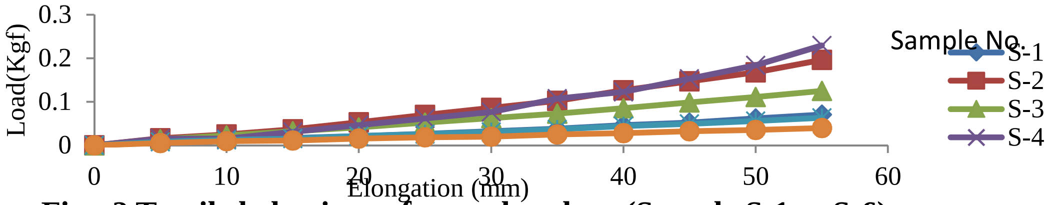


Fig.- 2 Tensile behaviour of crepe bandage (Sample S-1 to S-6)

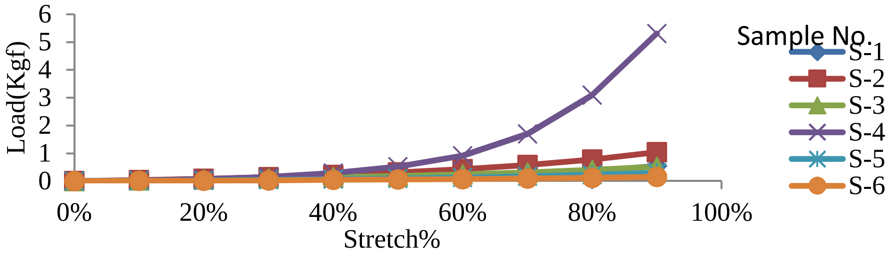


Fig.- 3 Effect of Stretch% on Load of Sample S-1 to S-6

It is observed that in case of 2/2 samples maximum load is required for the sample S-4 to apply it at 70% extension as compared to other samples. Rest of the bandage develops much lower tension forces when the bandage is extended upto 70%. These forces are not sufficient to generate the sub bandage pressure in the range desired for compression. This suggests that to generate pressure in the desired range we need to apply these bandage beyond 70% elongation which will need much more effort from the user and also cause locking of the crepe bandage structure. Furthermore, bandages are always selected based on their ability to apply high levels of pressure with minimum stretch. In order to design bandages, the stretch in the bandage should be minimized as much as possible to reduce the design challenges. Also over a period of time when the swelling reduces these bandages are unable to maintain the desired level of pressure owing to very low load value at lower extensions. In case of 2/2 structures the load value is higher as compared to 1/1 structures which may be attributed to its close structure and high thread density. It also observed that a closer construction both in case of 2/2 and 1/1 samples provides better holding capacity and a more homogeneous pressure distribution.

4.3 Effect of stretch level on sub bandage pressure at two positions

The instantaneous pressure was noted for different bandage samples by varying the stretch% above ankle-B1 position and calf position in each sample as shown in Table 3.It is observed form the Fig. 4 that with increase in stretch (%) level the sub bandage pressure values also increases for all the bandage samples. With the increase in stretch (%), the tension generated in the fabric will be more and this leads to increase in sub bandage pressure both at calf and ankle position. But different samples behave differently with increase in stretch (%). It is observed that Sample S-4 is showing steep increase in pressure values at any stretch as compared to other samples. The warp yarn length in one wavy unit of Sample S-4 is related to its high ppcm and this makes it a compact structure than Sample S-1 which is having same Epcm and less Ppcm. The instantaneous pressure of S-4 is higher than S-1 at two different position of limb owing to the higher GSM of the structure.

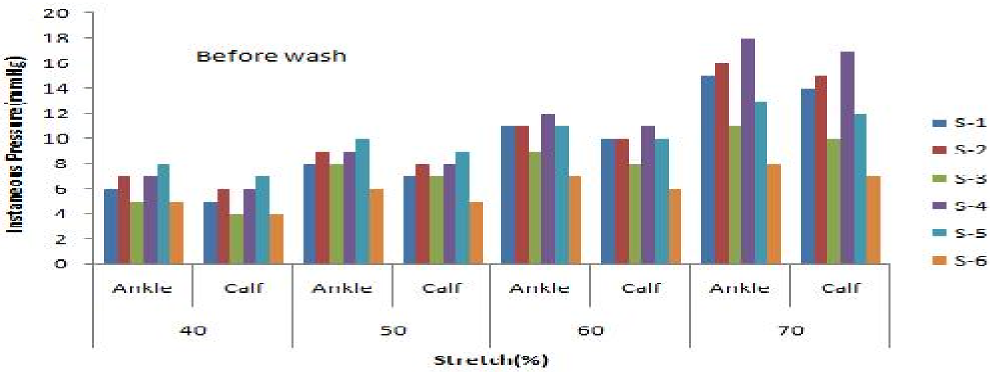


Fig.- 4 Experimental Instantaneous Pressure Values of bandage samples on various stretch level at two different position of limb before use and wash

In case of Sample S-2 and Sample S-3, for the same reason, the instantaneous pressure of S-2 is higher than S-3 at two different position of limb.

In case of Sample S-6 and Sample S-5 for the same reason, the instantaneous pressure of S-5 is higher than S-6 at two different position of limb.

4.4The Effect of Stretch% on Interfacial Pressure (10min) and Pressure Reduction (100 min) and (1000 min) before use/wash

The pressure reduction percentage for 100 min is calculated by using the following Equation (3)and similarly it can be calculated for 1000min by simply replacing P_1^i by P_1^i .

For 100 min Pressure Reduction % = $\left(\frac{P_1^i - P_1^i}{P_1^i}\right) * 100$ (3)

Where P_{10} = the pressure value after 10 minutes (first measuring)

P_{100} = the pressure value after 100 minutes

P_{1000} =the pressure value after 1000 minutes

i = number of washes.

It is observed that in case of stretch 40% & 70%, with increased in stretch %, the instantaneous pressure value increases and also increased in pressure reduction % through 1000 min except Sample S-5. S-5 applied under sufficient tension typically maintain pressure up to 1000 min and so its 70% pressure reduction% is less than its 40%. The sub bandage pressure has to be sustained for the effective treatment and higher stretch % is preferred to get the optimum level of pressure performance so a time study is done for change in pressure at 40 % and 70% stretch as shown in Figs 5(a) and (b). It is observed that the bandage with higher mass per unit area, i.e. bandage S-2(GSM= 544), the internal pressure applied by the bandages decreases at a higher rate than the bandage of lower mass per unit area, i.e. bandage S-3. This may be partially due to the lower extensibility and relatively higher initial modulus of the bandage S-3 than bandage S-2.

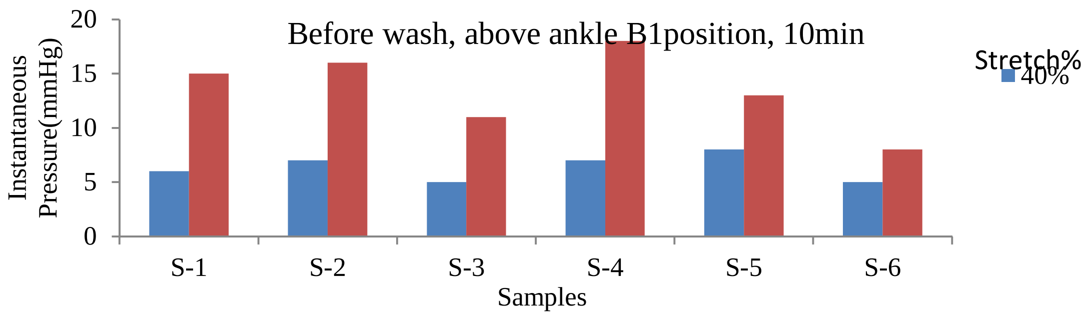


Fig.- 5 (a) Instantaneous Pressure before use/wash

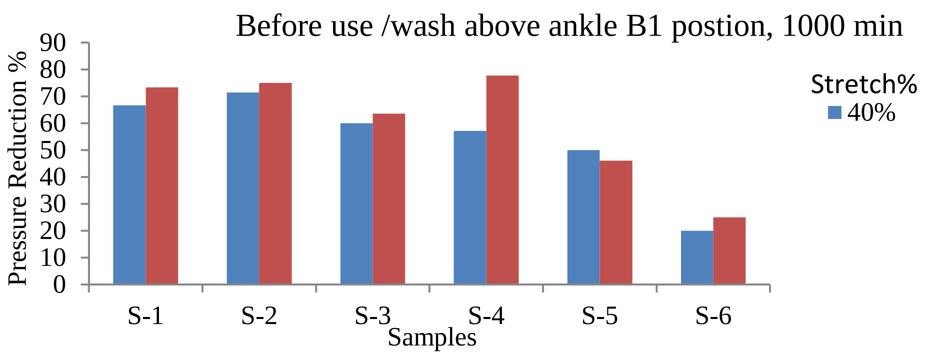


Fig.- 5(b) Pressure Reduction% (1000min) before use /wash

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The presence parameters of higher crimp and due to other structural parameters, the bandage S-2 showed rapid stress relaxation. These resulted in higher drop in internal pressure of bandage S-2

In case of the bandage S-4, S-1,S-5 and S-6, similar observations were made.

4.6 The Effect of Repeated Usage on Instantaneous Interfacial Pressure

Table -3 Effect of stretch % on Instantaneous pressure before and after uses on sample S-1 and S-5

Sample No.	Stretch %	Pressure Before Use (mm Hg)	Pressure After 1st Use(mm Hg)	Pressure After 2nd Use(mm Hg)	Pressure After 3rd Use(mm Hg)	Pressure After 4th Use(mm Hg)	Pressure After 5th Use(mm Hg)	Pressure After 6th Use(mm Hg)
S-1	40%	6	6	6	6	5	5	5
	50%	8	8	8	8	7	7	7
	60%	11	11	11	11	9	8	7
	70%	15	15	15	15	13	10	8
S-5	40%	8	8	8	8	8	7	6
	50%	10	10	10	10	10	9	8
	60%	11	11	11	10	9	8	7
	70%	13	13	13	12	11	10	9

It is observed that S-1 to S-4 which are 2/2 structure, the bandage can be reused up to 3-4 times at various stretch levels. S-5 and S-6 which are 1/1 structure, the bandage cannot be used more than 2-3 times at various stretch levels. It was observed that when the bandage is applied at lower stretch %, the pressure can be maintained for longer period of time in case of all the samples they can be reused for more number of times as shown in Table 3.

4.7 The Effect of Repeated Washing on Instantaneous Interfacial Pressure

The increase in pressure can be maintained up to 3rd wash in all samples at different stretch%. After 3rd wash the pressure fall but still remain close to the instantaneous pressure value up to 5th wash and then starts falling and is shown in Fig.6.In all of these different crepe bandage samples, the interfacial pressure of washed samples is higher than the pressure before washing which may be due to shrinkage that takes place in the samples on washing.

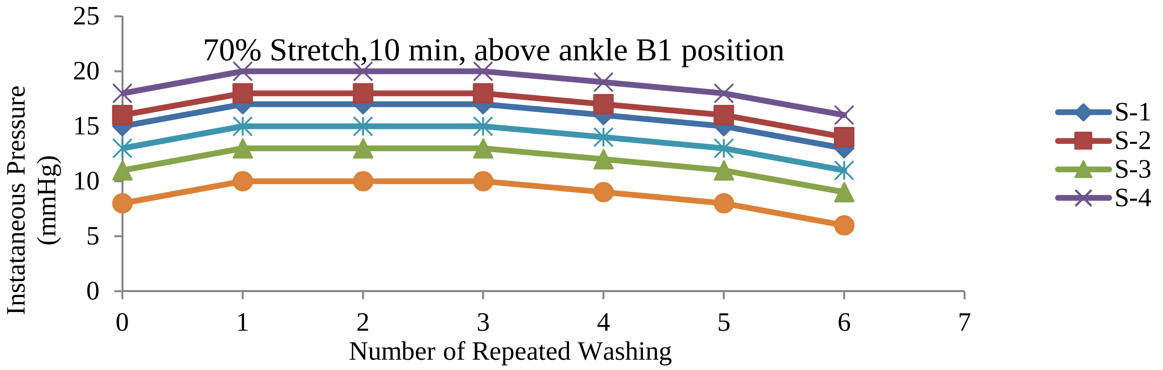

Fig.6 Instantaneous pressure values on the Repeated Washing

Conclusion:

Crepe bandage fabrics result reveal that sample with closer construction develops much higher tension force at low stretch value in comparison to the other bandage samples. The ability to apply high pressure with minimum stretch is achieved in case of bandage structure with higher ppcm(picks per centimeter). It is observed that with increase in stretch (%) level the sub bandage pressure values also increases for all the bandage samples both at calf and ankle position. But different samples behave differently with increase in stretch (%). TheSample S-4 is shows steep increase in pressure values at any stretch as compared to other samples. It is also observed that in the bandages with higher mass per unit area, the internal pressure applied by the bandage decreases at a higher rate than the bandage of lower mass per unit area. The samples S-1 to S-4 which are 2/2 structure, the bandage can be reused up to 3-4 times at various stretch levels whereas S-5 and S-6 which are 1/1 structure, the bandage cannot be used more than 2-3 times at various stretch levels. Also when the bandage is applied at lower stretch %, the pressure can be maintained for longer period of time in case of all the samples and they can be reused for more number of times.During the repeated washing operations of crepe bandage fabric, all of the samples at different stretch% show an increase in pressure due to shrinkage after wash as compared with its initial pressure at first stage. During rewash the increase in pressure can be maintained up to 3rd wash in all samples at different stretch%. After 3rd wash the pressure falls but still remains close to the instantaneous pressure value up to 5th wash and then starts falling. Moreover the 2/2 structures can be used further after six washes since they maintain their stretch and thus the efficacy but the 1/1 samples which are 100% cotton products lose their efficacy after sixth wash which may be due to the structure getting locked at 70% stretch.

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