Impact of Selected Finishing Treatments on Strength Properties of Trouser Materials

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Abstract - *Washing and finishing treatments for trouser materials are required for the purpose of improving comfort and visual appearance to match occasion. Simultaneously consumers expect an improvement of performance characteristics and durability of garments or at least to remain as it was before the treatment. According to the previous research work and experience of the industrialists washing and finishing treatments affect physical properties of the woven garments.*

In this study, the effect of different washing treatments such as enzyme, stone, bleaching, permanganate spray and normal garment washing on the denim, corduroy, drill and twill fabric materials was investigated. Tearing strength and breaking strength of the fabric before and after each treatment were measured and compared. The results show that all such treatments carried out with the objective of obtaining worn appearance and aged look of the garments have resulted in reduction of the breaking and tearing strengths. Further, it has revealed that all the investigated washing and finishing treatments except the normal garment washing resulted in higher levels of reduction of warp yarn strength than that of the weft yarn strength.

It was evident that the bleaching and stone washing treatments were the most aggressive affecting the strength properties of the fabrics to the highest levels. Longer the duration of the treatment, the higher is the decrease of both tearing and breaking strengths.

It is advisable to follow washing or finishing procedures without bleaching treatment. To ensure a lesser effect on the performance characteristics of the garments, the treatment conditions have to be optimized.

Key words: *Washing and Finishing treatments, Trouser material, Breaking Strength, Tearing strength.*

Nomenclature

BS – Breaking strength under tensile force in kilogram force (Kgf)

TS – Tearing strength in gram force (gf)

GW – Normal garment wash

GSM – Area density in grams per square meter

ori – strength values of untreated (original) fabric

1 INTRODUCTION

In the garment industry, different washing and finishing treatments are carried out very often on complete garments in order to obtain various finishing effects, improving comfort etc. Washed/finished garments have become a fashion and at present of very high demand. Most of these washing and finishing treatments are done in aqueous medium with chemicals; for example enzyme washing, stone washing, bleaching, permanganate spray, normal garment washing [Anthony P *et al*., (2001), Militky J *et al*., (1997), Pederson L. *et al*., (1994)]. Some other treatments are physical treatments such as brushing, sanding etc., which are dry process involving only physical changes in the garments. It is reported that washing and finishing treatments do not only improve the aesthetics and comfort properties as demanded by the consumer but also significantly affect the fabric mechanical properties negatively [Faouzi K. *et al*., (2009), Ayanna C *et al*. (2006)]. The most important mechanical property which affects the performance as well as durability characteristics of a garment is the strength of the fabric out of which the garment is made. In the case of woven fabrics, both tensile strength and tearing strength are considered in the evaluation of fabric strength. According to the Danija and Manisha, (2007) tearing strength, which is usually measured as the force required to propagate a tear, may often be used to give a reasonably direct assessment of serviceability. A fabric with low tearing strength is considered generally as an inferior product.

Faouzi K. et al., (2009) reported that bleach-treatment on denim fabrics reduces the breaking strength (BS) by 12% and tearing strength by (TS) by 29% in warp direction. TS of denim fabrics subjected to bleaching depend on the duration of the treatment. It is reported that treating of fabrics over 10 and 30 minute durations resulted in a warp way reduction of tensile strength in 8% and 35% while weft way reductions were 2% and 11% respectively. After subjecting the same fabrics to sanding with potassium permanganate treatment, TS was decreased by 2% in warp direction and 1.3% in weft direction.

However, the normal garment washing treatment has increased the Tensile Strength by 12% in warp direction and by 9% in weft direction in Denim fabrics [Faouzi K. et al., (2009)].

It appears that the warp yarns are weakened more than the weft yarns by different treatments. In the case of 3/1 twill fabrics, the abrasion is concentrated more on warp yarns than on weft yarns. When fabrics are subjected to stone and enzyme wash, the surface fibres of the fabric are aggressively damaged and removed causing more degradation and decreasing of mechanical properties (Faouzi K. et al., 2009).

The fibres are damaged more by enzyme washing than by stone washing due to hydrolysis of cellulose molecules [Weltrowski, (1995) and Pederse, (1993)]. Charles T (1992) stated that bleaching of cotton fabrics with oxidizing agents cause degradation of cellulose molecules in the fibre. His suggestion was to optimize bleaching conditions to optimize whiteness while minimizing fiber damage (Charles T, 1992).

Broad objective of this study was to determine the effect of finishing treatments on the strength properties of different trouser materials and to make recommendations for optimizing treatment condition to minimize strength reduction.

The trouser materials used for this research have similar structures to those used by previous researchers, but different in area density. Some of the treatment conditions such as treatment duration and concentration of the chemical baths were different. But the treatment sequences were same as in previous research.

1.1 Objectives

The broad objective of the study was to investigate the influence of some selected finishing treatments on the strength properties of trouser materials used in Sri Lankan garment industry. Followings are the specific objectives of this study:

- To study the influence of enzyme treatment and normal garment wash treatments on breaking strength (BS) and tearing strength (TS) of corduroy and twill trouser materials
- To study the influence of enzyme wash, stone wash with enzyme and normal garment wash treatments on breaking strength (BS) and tearing strength (TS) of drill trouser material
- To study the influence enzyme wash, stone wash with enzyme, bleaching, sanding with permanganate spray and normal garment washing treatment on breaking strength (BS) and tearing strength (TS) of denim trouser material.

A preliminary survey done on the testing reports from testing laboratories in Sri Lanka revealed that physical property failures are higher than other defects after subjecting the trouser materials to various finishing treatments. Among those physical properties, strength reduction in breaking strength and tearing strength are at the first place. Thus, selected fabrics denim, twill, drill, corduroy and the selected finishing treatments are currently heavily used by the Sri Lankan garment industry to give various finishing effects.

2 METHODOLOGY

2.1 Materials

Table 1 shows the selected fabric types, their composition, woven structure and area density (GSM). The selected fabrics differ by their area density, material composition; weave type, and warp and weft densities.

Table 1 Specifications of the selected fabric samples

Fabric type	notation	Composition and weave (warp and weft density/inch)	Area density (g/m^2)
Denim	F1	100% Cotton, weave 3/1(88x60)	265
Drill	F2	98% Cotton,2% Elastane, weave 3/1(80x41)	373
Corduroy -Blue (CB)	F3	98%Cotton, 2%Elastane, weft cut pile (136x42)	290
Corduroy –White (CW)	F4	99% cotton, 1%Elastane, weft cut pile (96x60)	345
Twill (White)	F5	99% Cotton, 1%Elastane, weave 2/1 (105x48)	227
Twill (Blue)	F6	100% Cotton, weave 2/1 (126x56)	202
Twill (Red)	F7	52% Cotton , 48% Polyester, weave 2/1 (124x59)	216

2.2 Treatment procedures

Samples were prepared as trouser legs, which had 17'' length and 8'' tubular width. There were a total of 111 leg-shaped samples prepared for this study (three leg shaped samples for each finishing treatment). Table 2 shows the finishing treatments, treatment conditions and the duration applied for different fabric types.

Table 2 Treatment variables

Treatment	Condition	Time
Enzyme wash (T1)	Temperature=55^{o}C Enzyme: Acid Enzyme(pH-5) for Denim Neutral Enzyme for Twill, Corduroy	30 min., 60 min. and 90 min.
Stone + enzyme wash (T2)	Temperature:55^{o}C Stone: New stones and worn out stone 1Kg of sample/ 2Kg stone	30 min., 60 min., and 90 min.
Sanding (T3) Permanganate spray	Rotation peed: 120 rpm (round/min.) Pressure:2.5 bars Distance of pulverization:40-50 cm Spray capacity 50 to 65 ml for a surface of 0.2 m^2	20 min. Depend on design
Bleaching (T4)	Product: 75.ml/l of water of (70% chlorinate) +stone	Depending on fabric type 10min. & 30min.
Normal garment washing and rinsing (T5)	Eco softener (10-10), 1/10 in water in room temperature)	10 min.

All different fabrics given in the table 1 were not treated by all the finishing treatments described in the Table 2. The finishing treatments applied to different fabrics depend on the type of fabric and the final properties and characteristics expected from them. Hence

each fabric type was treated only by those treatments which are usually applied to that particular fabric by the industry. The table 3 gives the treatments applied for different fabrics (F1 – F7).

Table 3 The treatments applied to different fabrics

	F1	F2	F3	F4	F5	F6	F7
Enzyme wash, T1	√	√	√	√	√	√	√
Stone enzyme wash, T2	√	√					
Sanding, Permanganate spray, T3	√						
Bleaching, T4	√						
Normal Washing, T5	√	√	√	√	√	√	√

TS and BS of untreated and treated fabric samples were measured in warp and weft directions. There were 84 test results obtained from the fabric samples before treatment (7X2X2X3 = 84) and 444 specimens were used to measure the strength of treated fabrics (111 samples x 2 –warp & weft directions- x 2 –TS and BS-= 444). Therefore, 528 (84+444) fabric specimens were prepared for the whole series of strength testing. Specimens were properly dried and conditioned under standard atmospheric conditions after the treatments prior to testing. T. S. and BS were measured according to the standards ASTM D1424 and ASTM D5034 respectively.

3 RESULTS AND DISCUSSION

3.1 Effect of enzyme and normal garment wash treatments on Tearing Strength and Tensile Breaking Strength of Corduroy Fabrics (F3 and F4)

Fig. 1 shows how TS in warp and weft directions of corduroy blue and white fabrics is affected by enzyme (T1) and Normal wash treatments (T7), GW. Corduroy blue (CB) shows higher TS in warp direction than that in weft direction before the treatments. But in the case of corduroy white it shows opposite behavior.

In all the fabrics, TS is generally increased by 10 minute normal washing treatments in both warp and weft directions.

Same tendency can be observed in both fabrics after the application of 30 minute enzyme wash treatment.

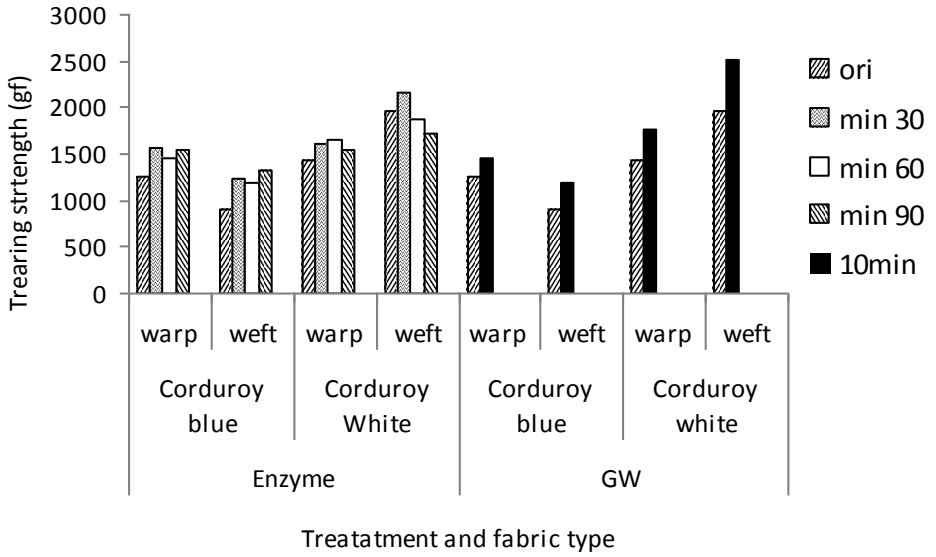

Fig. 1 Effect of enzyme and normal garment wash (GW) treatments on tearing strength of corduroy white and blue fabrics

After the 30 minute- enzyme wash treatment, TS of CB fabrics have increased in 24% and 36% in warp and weft directions respectively. After the 60 minute- enzyme washing TS in warp and weft directions of CB fabric has decreased in 8% and 4% respectively, compared to the values after 30 –minute treatment. However the 90 minute- enzyme wash treatment has reduced the TS of CB fabrics only in the almost same amounts as in the case of 30 minute treatment. The increases of TS in warp and weft directions of the CB fabric after GW treatment are 16.7% and 32.1 % respectively. In contrast to CB fabric, corduroy white (CW) fabric shows higher TS values in warp direction in comparison to the TS in weft direction. Both 30-minute enzyme wash and 10 minute GW treatments increase the TS in both warp and weft directions. After 30 minute-enzyme wash treatment, TS of CW fabric shows the increases of 12.65% and 9.39% in warp and weft directions respectively. However, 60 minute enzyme wash treatment does not change the TS in warp direction in comparison to 30 minute treatment, but, 5.23% drop in TS is indicated in weft direction. Increase of enzyme treatment duration to 90 min. results in further decreases of TS in 6.6% and 21.8% in warp and weft directions respectively in comparison to the TS values after 30-minute treatment.

The 10-minute normal wash treatment of CW fabric causes the increases of TS in 23.38% and 27.7% respectively in warp and weft directions compared to the TS values of the untreated fabrics.

Accordingly, enzyme treatment of 30 min. gives the maximum increase of the TS in both weft and warp directions of both blue corduroy and white corduroy fabrics.

Fig. 2 shows how BS in warp and weft directions of coduroy blue and white fabrics is affected by enzyme (T1) and Normal wash treatments (T7),

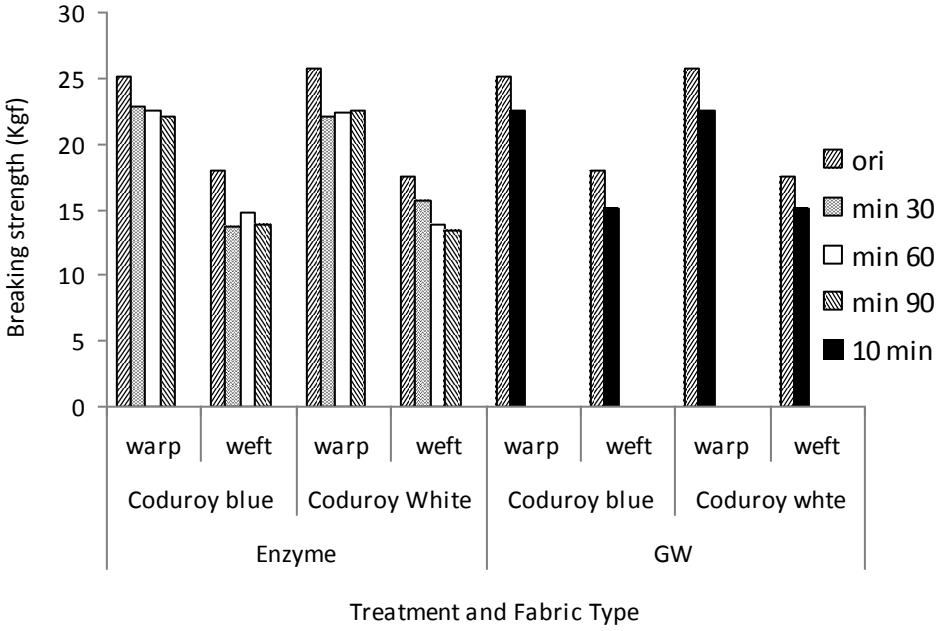

Fig. 2 Effect of enzyme and normal wash treatments on breaking strength of corduroy white and blue fabrics

According to the Fig. 2, breaking strengths under tensile load in both warp and weft directions of both types of fabrics after enzyme treatment have decreased in comparison to strength of the untreated fabrics. These reductions amount to 9-15% in warp direction and 10-24% in weft direction. Reason for the reduction can be the damage to the cellulose molecules in the Cotton fibre**.** However the variation of the duration of the enzyme treatment from 30 minute to 90 minute has no significant effect on the BS of both CB and CW fabrics except on the weft way strength of CW fabric.

It can be observed a reduction of BS in weft direction of CW fabric with the increase the duration of the enzyme treatment from 30 minutes to 60 minutes and then to 90 min.

Normal washing treatment of 10 minutes duration brings about an almost similar reduction of BS in both warp 9.59% -12.23% and weft 13.88% -15.34% directions for both CW and CB fabrics. This may be due to the lesser ground weft densities than the ground warp densities in corduroy fabrics.

3.2 Effect of enzyme and normal garment wash treatments on tearing strength and breaking strength of twill Fabrics (F5, F6 and)

Fig. 3 shows how TS in warp and weft directions of Twill white, Twill blue and Twill red fabrics is affected by enzyme (T1) and normal wash treatments (T7), GW. According to the Fig. 3 and the table given in Appendix 6**,** TS of twill fabric samples have increased in both warp and weft directions after both the treatments (T1 and T7) in comparison to TS of untreated original fabrics.

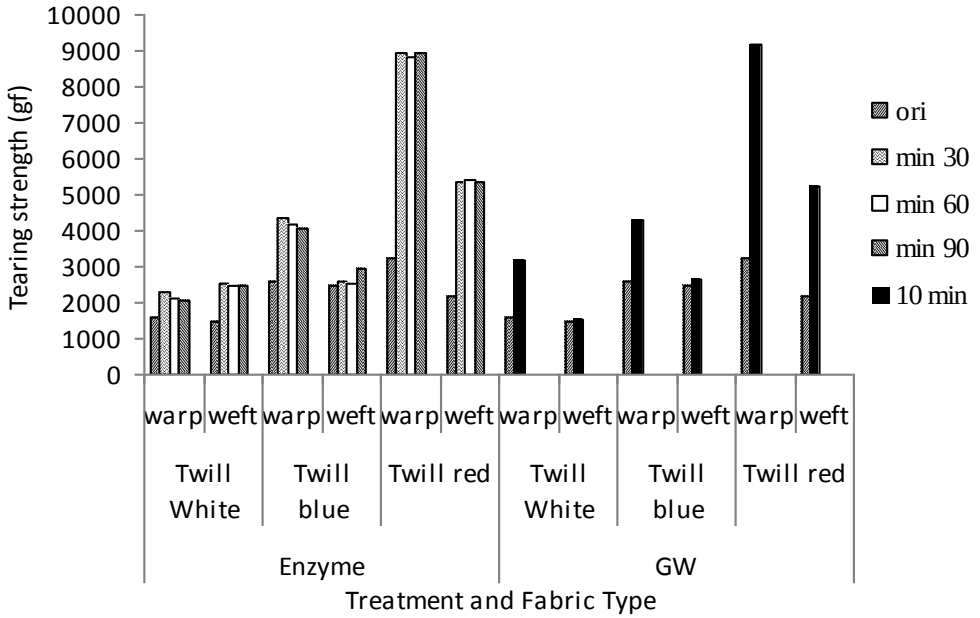

Fig. 3 Effect of enzyme and normal wash treatments on tearing strength of twill fabrics

It can be observed that the TS in warp and weft directions of all three twill fabrics have slightly decreased with increasing of the duration of enzyme wash treatment from 30 min. to 60 min. and then to 90 min., where as in the TS values in weft direction do not show such a trend. The TS of red colour twill fabric has exhibited an increase of more than 100% in both warp and weft directions compared to the TS of untreated fabric. This behavior must be analyzed in depth in relation to the fabric construction details.

Fig. 4 shows the effect of enzyme and normal (GW) wash treatments on BS in both in warp and weft directions of twill fabrics. BS under tensile loading in warp direction is higher than that in the weft direction for all three types of fabrics. When comparing three fabrics, BS in warp direction of the red twill fabric is much higher than the BS values in warp direction of the other two fabrics. Hence, red twill fabric shows higher BS in warp direction even after the two different treatments.

In contrary to the behavior of TS, BS in warp and weft directions of all twill fabrics have decreased after the two types of treatments. The decrease range gave 13-24% in warp direction and 23-40% in weft directions of twill fabric samples.

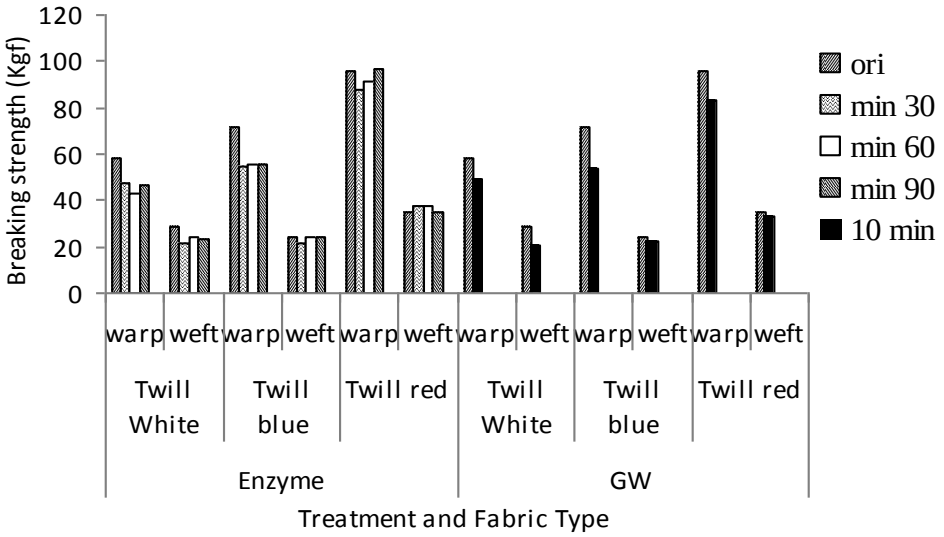

Fig. 4 Effect of enzyme and normal garment wash treatments on breaking strength of twill fabrics

It appears that enzyme treatment even at 90 minute duration does not affect the strength properties of the fabrics significantly. Even the normal washing treatment can have effects of similar magnitude. Hence we can conclude that the enzyme treatment under above conditions can be used without any hesitation to achieve the required comfort or aesthetic style features.

3.3 Effect of enzyme wash, stone enzyme wash and normal garment wash on tearing strength of drill Fabrics (F2 fabric)

Fig. 5 shows the effect of enzyme wash (T1), stone enzyme wash (T2) and normal garment wash (T6, GW) on the TS of drill fabrics.

The TS in weft direction is lower than that in warp direction before and even after all three different treatments. Due to enzyme treatment, TS in warp direction of the drill fabric (F2) has increased by 12%- 14.5% but the TS in weft direction has decreased by 10.5% -13.5%.

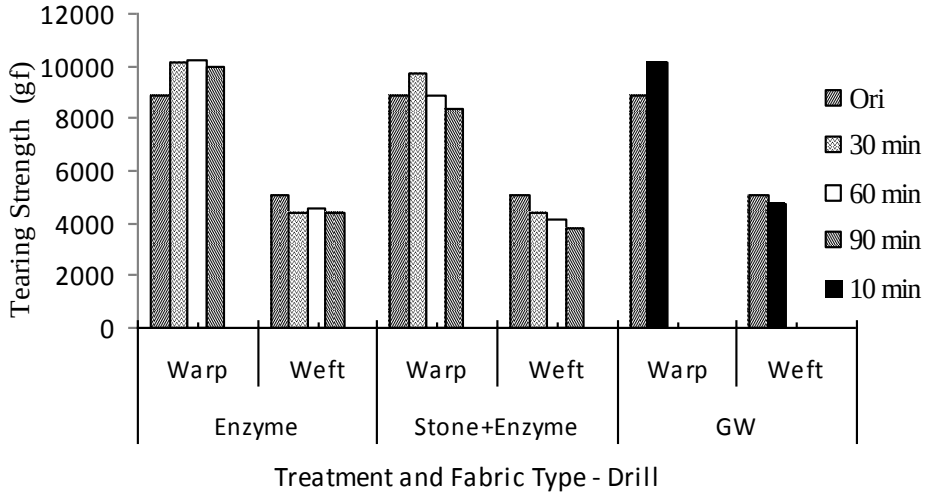

Fig. 5 Effect of enzymes, stone enzyme wash and normal wash on tearing strength of drill fabrics

The change of duration of the enzyme wash treatment from 30 minutes to 90 minutes does not cause any significant differences.

Enzyme stone wash treatment carried out under different durations brings about differences in tearing strength in both warp and weft directions. 30 minute enzyme stone wash treatment has increased the TS in warp direction of drill fabric by 9.5%-, but increasing of the duration to 60 and 90 minutes has decreased the TS in warp direction by 0.56% and 5.6% respectively in comparison to the tearing strength of untreated fabric. It is also observed that the TS in weft direction of the drill fabric has decreased by 12.6%, 18.4 % and 25.5% after 30 min., 60 min. and 90 min. durations of the enzyme stone wash treatment.

Normal (GW) wash treatment increases the TS in warp direction of the drill fabric but decreases the TS in weft direction. Fig. 6 illustrates the effects of enzyme wash, stone enzyme wash and normal garment wash (GW) t on the BS under tensional loads of the drill fabric.

Fig. 6 shows that the drill fabric has a higher breaking strength in warp direction than that of weft direction irrespective of the treatment condition. Thus, BS in warp direction of the drill fabric has slightly increased by 3.1% due to 30 minute application of enzyme wash treatment. However, 60 and 90 minute enzyme treatments have slightly reduced the BS in warp direction compared to the strength of the fabric treated 30 minutes duration. Effect of the duration of enzyme treatment varying from 30 to 60 and then to 90 min. on weft way BS is insignificant.

Application of enzyme stone wash treatment to the drill fabric also has a very small effect on the BS on both warp and weft direction. The BS has decreased in 5.6% - 6.3% (in average) compared to the value of untreated fabric.

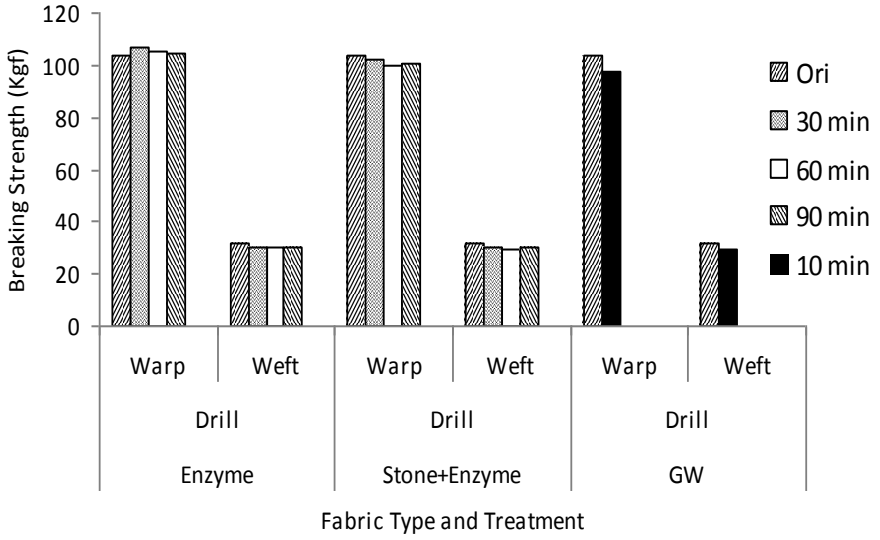

Fig. 6 Effect of enzyme, stone enzyme and normal wash treatments on breaking strength of drill fabric

Breaking strength of drill fabric decreases in both weft and warp directions in all treatments other than 30 minute of enzyme treatment. This may be due to breaking of cellulose molecules in cotton fibre structure, after reacting with the enzyme.

Depending on the required aesthetic and comfort characteristics, any of the above treatments can be employed as their effect on BS and TS are insignificant.

3.4 Effect of enzyme wash, stone enzyme wash, sanding with permanganate spray, bleaching and normal garment wash treatments on tearing strength and breaking strength of denim fabrics (F1 fabric s)

Fig. 7 shows the effect of enzyme wash, stone enzyme wash, bleaching, sanding with permanganate spray (SB+PS) and normal garment wash (GW) on TS of denim fabrics.

According to the Fig. 7, TS in warp direction of denim fabrics has decreased by 29% - 30.5% after subjecting to enzyme wash, enzyme stone wash, bleaching and (SB + PS) treatments compared to the TS of untreated fabric. The TS in weft direction of the denim fabric has increased by 5.5% - 7% due to the application of enzyme wash and enzyme stone wash treatment. Bleaching carried out over 10 minute duration has resulted in slightly lower TS reduction of about 4.99%**.** Bleaching of denim for 30 minutes has decreased the tearing strength in warp direction by 46.8% and but only 3.0% in weft direction. Application of (SB + PS) treatment on denim fabric has reduced TS in weft direction by 5.9 to 10.6% of the TS of untreated fabric.

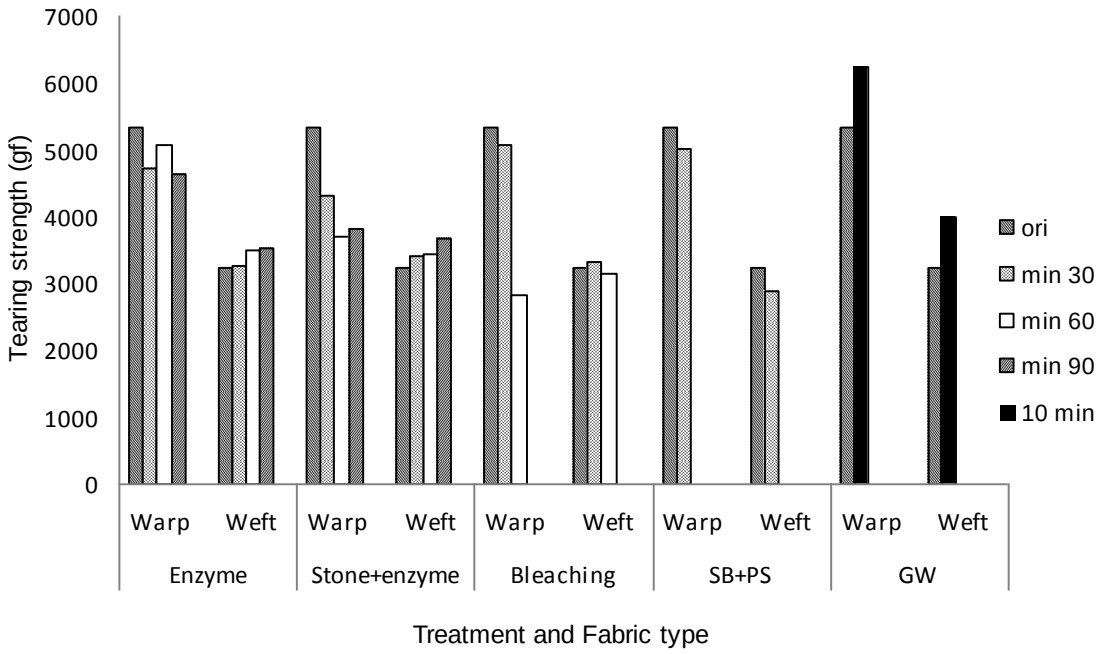

Fig. 7 Effects of enzyme wash, stone enzyme (stone + enzyme), bleaching, sanding with permanganate spray (SB+PS) and normal garment wash treatments on tearing strength of denim fabrics

Further, Fig. 7 shows that the TS in both, warp and weft directions have reduced in about 5% due to 30minute (SB + PS) treatment. TS in warp and weft directions of denim have increased by 16.88% and 23.16% respectively of untreated fabric due to normal wash treatment.

Fig. 8 shows the effect of enzyme wash, stone enzyme wash, bleaching and sanding with permanganate spray (SB+PS) as well as normal wash (GW) treatments on BS of denim fabrics. It is evident that the BS in both weft and warp directions of denim fabric decreases in general after enzyme, stone enzyme, bleaching, sanding with permanganate spray and normal garment wash treatments. BS in warp direction of the denim fabric has shown a significant reduction due to 90 minute enzyme wash treatment in comparison to 30 minutes and 60 minutes duration treatments. However, it was not observed any effect of the duration of the enzyme treatment on the weft way strength of the denim fabric. As shown in the Fig. 8, BS in warp and weft directions of the denim fabric has decreased by 28% - 31% and by 5.5% - 6.5% respectively after subjecting to enzyme stone wash treatment. Reason may be that the warp yarns of the denim fabric with 3/1 weave are more intensively rubbed by stones during the treatment than the weft yarns as this is a warp fabric. However the time duration of the application of enzyme stone wash treatment has no effect on the strength in warp direction as rubbing of surface yarn (warp) has taken place during the first 30 minutes of treatment Thus, there can be no significant differences observed in weft direction samples compared to the values of untreated fabric. In addition, variations of BS in weft direction due to change of the duration of application of enzyme stone wash treatment are also insignificant.

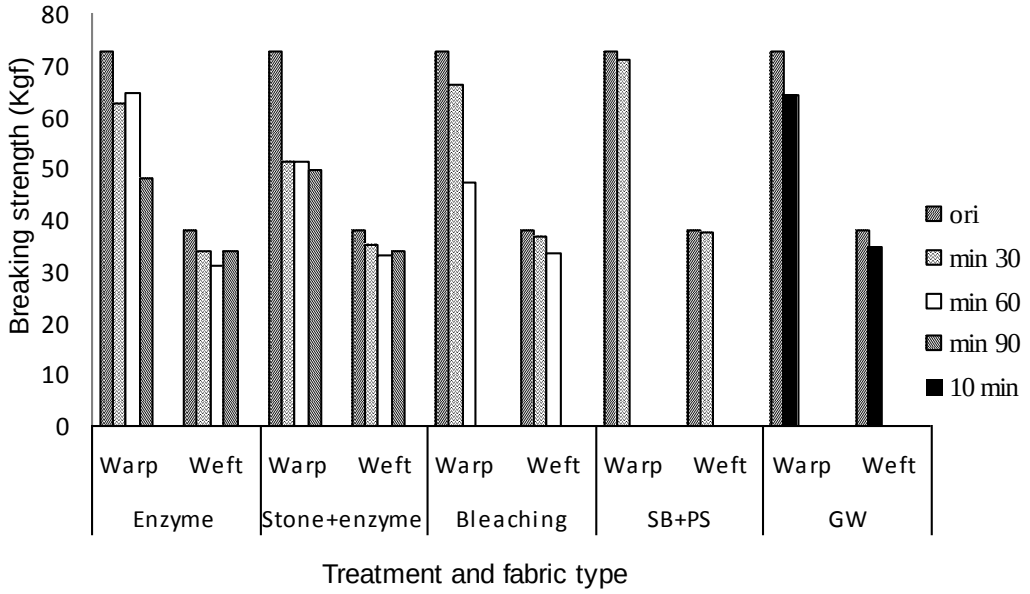

Fig.8 Effect of applying enzyme wash, stone enzyme (stone + enzyme), bleaching, sanding with permanganate spray (SB+PS) and normal garment wash treatment on the breaking strength of denim fabric

As shown in the Fig. 8, BS in warp direction of denim fabric is significantly affected by increased time of application of bleaching treatment. But, it appears that the weft way strength of the denim is affected to a lesser extent. According to Faouzi K. *et al.,* (2009), bleaching treatment weakens the BS in warp direction of denim by 12%.

Due to sanding and potassium permanganate spray treatment BS was decreased by 2% in warp direction and 1.3% in weft direction compared to the BS of untreated fabric. However normal garnet washing has a higher effect, because BS in warp and weft directions of denim has decreased by 12% and 9% respectively due to normal garment washing.

4 CONCLUSIONS

Finishing treatments of garments/fabrics are aimed at improving, visual and comfort characteristics. However, such treatments affect also the fabric performance characteristics such as tearing strength and breaking strength negatively or positively. This paper deals with the influence of some selected finishing treatments on tensile and tearing strength of some selected woven fabrics. The investigated finishing treatments affect both the breaking strength in warp and weft direction negatively. However, the normal garment washing treatment affects breaking strength in warp and weft direction positively. In general finishing treatments affect tearing strength in both warp and weft directions positively. The positive effect on tearing strength of treated twill fabric is higher in comparison to the effect on other fabrics. Bleaching treatment of 10 and 30 minutes duration has resulted in a reduction of tearing strength in warp direction more

than in weft direction. Longer bleaching and stone wash treatments cause weakening of the fabric. This may be due to the breakdown of cellulose molecules during bleaching and damaging of surface fibres due to stone washing. It is advisable to avoid finishing processes containing intensive bleaching for longer periods.

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Appendices

Appendix 1: Breaking strength (BS), tearing strength (TS) and specification of fabric samples (F1 – F7) before treatment application

Fabric sample	Composition	Direction	Breaking Strength (Kgf)	Tearing strength (g)
F1- Denim	100% Cotton 3/1(88x60)	Warp	72.6	5333
		Weft	37.89	3242
F2- Drill	98% Cotton,2% Elastane 3/1(80x41)	Warp	103.6	8900
		Weft	31.37	5067
F3- Corduroy	Blue, 98%Cotton,2%Elastane, (42x136)	Warp	25.14	1254
		Weft	17.93	901
F4- Corduroy	White, 99% cotton,1%Elastane (60x96)	Warp	25.75	1439
		Weft	17.58	1970
F5- Twill	White, 99% Cotton, 1%Elastane 2/1(105x48)	Warp	58.00	1612
		Weft	28.65	1488
F6 -Twill	Blue, 100% Cotton 2/1(126x56)	Warp	71.8	2568
		Weft	29.65	2495
F7- Twill	Red,52% Cotton , 48% Polyester 2/1(124x59)	Warp	95.8	3525
		Weft	47.44	2192

Appendix 2: Breaking strength and tearing strength of Denim fabrics after bleaching, sanding and permanganate spray (Given also increase or decrease as percentage)

Treatment		Sandblasting + Permanganate		Bleaching			
Fabric type	Strength	30min	30min	10 min		30 min	
		Warp	Weft	Warp	Weft	Warp	Weft
F1	BS	69.3	35.4	66.2	36.8	47.1	33.4
	TS	5021	2900	5067	3338	2835	3145
F1	BS%	-4.55	-6.57	-8.82	-2.88	-35.12	-11.85
	TS%	-5.85	-10.55	-4.99	2.96	-46.84	-2.99

Appendix 3: Breaking strength and tearing strength of Denim and Drill after stone and enzyme wash treatment as percentage.

Treatment		Stone + Enzyme Wash			
Fabric type	Strength	30min	30min	60min	60min
		Warp	Weft	Warp	Weft
F1 Denim	BS	-29.06	-7.02	-29.06	-12.88
	TS	-18.79	5.49	-30.36	6.48
F2 Drill	BS	-1.45	-3.47	-3.47	-6.60
	TS	9.55	-12.61	-0.56	-18.45

Appendix 4: Increase or decrease of breaking strength (BS) and tearing (TS) of seven fabric samples (F1 – F7) after Enzyme treatments and Garment wash as percentage.

Treatment		Enzyme wash						Garment wash	
Fabric type	Strength	30min	30min	60min	60min	90min	90min	Normal wash time 10min	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
F1	BS%	-13.64	-9.77	-11.16	-17.87	-34.48	-10.27	-11.29	-8.81
	TS%	-11.55	0.96	-4.84	7.71	-12.83	8.42	16.88	23.16
F2	BS%	3.09	-4.43	1.64	-4.65	1.06	-2.52	-5.69	-6.34
	TS%	14.04	-12.57	14.61	-10.52	12.36	-13.80	14.04	-6.22
F3	BS%	-9.07	-23.20	-10.26	-17.51	-11.97	-22.64	-9.59	-15.34
	TS%	24.64	36.51	16.67	32.08	23.68	46.17	16.67	32.08
F4	BS%	-14.52	-10.35	-12.89	-21.05	-12.23	-23.38	-12.23	-13.88
	TS%	12.65	9.39	14.94	-5.23	6.60	-12.54	23.28	27.66
F5	BS%	-18.03	-24.19	-15.00	-15.01	-19.33	-17.52	-22.84	-23.00
	TS%	42.68	71.17	32.69	66.47	29.28	66.53	46.15	67.88
F6	BS%	-23.68	-27.42	-22.56	-19.63	-22.98	-19.29	-24.65	-25.53
	TS%	69.24	4.89	63.36	2.08	58.92	17.92	66.82	5.93
F7	BS%	-8.66	-19.84	-4.38	-20.68	-5.74	-26.75	-13.15	-30.44
	BS%	153.42	143.29	149.65	146.35	153.42	143.29	160.99	143.29

Appendix 5: Changes of TS and BS of twill fabrics after treatments

Treatment		Enzyme wash						Garment wash	
Fabric type	Strength	30min	30min	60min	60min	90min	90min	10 min wash time	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
F5	BS%	-18.03	-24.19	-15.00	-15.01	-19.33	-17.52	-22.84	-23.00
	TS%	42.68	71.17	32.69	66.47	29.28	66.53	46.15	67.88
F6	BS%	-23.68	-27.42	-22.56	-19.63	-22.98	-19.29	-24.65	-25.53
	TS%	69.24	4.89	63.36	2.08	58.92	17.92	66.82	5.93
F7	BS%	-8.66	-19.84	-4.38	-20.68	-5.74	-26.75	-13.15	-30.44
	TS%	153.42	143.29	149.65	146.35	153.42	143.29	160.99	143.29

Appendix 6: Changes of TS and BS of twill fabrics after treatments

Treatment		Enzyme wash						Garment wash	
Fabric type	Strength	30min	30min	60min	60min	90min	90min	10 min wash time	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
	BS%	-18.03	-24.19	-15.00	-15.01	-19.33	-17.52	-22.84	-23.00
F5	TS%	42.68	71.17	32.69	66.47	29.28	66.53	46.15	67.88
	BS%	-23.68	-27.42	-22.56	-19.63	-22.98	-19.29	-24.65	-25.53
F6	TS%	69.24	4.89	63.36	2.08	58.92	17.92	66.82	5.93
	BS%	-8.66	-19.84	-4.38	-20.68	-5.74	-26.75	-13.15	-30.44
F7	TS%	153.42	143.29	149.65	146.35	153.42	143.29	160.99	143.29