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Cotton Fabric Tear Strength Under the Influence of Different Permanent Press Finishes

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Abstract. Today is the time of fashion in dressing. It is the desire of every one to wear a dress that retains just iron shape. Permanent press finishes meet this demand by providing a wrinkle free and soft look to the fabric. The current study was made to manufacture fabric free from wrinkle using permanent press finishes. Texicil DC, Knittex RCT, Arkofix NEC and Arkofix ELF, anti-wrinkle finishes were applied on the fabric with different concentrations. Pad-dry, pad-dry cure and pad-flash-cure finish applying techniques were used to apply these finishes on pure cotton fabric. The process optimization was obtained regarding the tear strength of the fabric. The overall results revealed very minor impact of various finish applying techniques and finish types on the tear strength of the fabric however, pad-flash-cure method showed fairly better results for both warp wise tear strength (8.0556 N) and weft wise tear strength (7.0607 N) of fabric as compared to other techniques. Similarly, Arkofix ELF permanent press finish put slightly better impact on the tear strength of the fabric (8.1251 N and 7.3186 N) for warp and weft wise respectively at low concentration (60 g/L).

Keywords: permanent press finishes, finish applying techniques, cotton fabric, fabric tear strength and wrinkle free

Introduction

Durable press garments being the state-of-the-art fashion trend pool up the advantages of after wash easy care and little maintenance with the retention of their comfort properties (Wang *et al*., 2017). Cotton fibre has exceptional comfort properties and is one of the most prevalent textile materials. Pure cotton fabrics do not have wrinkle resistance properties and needs ironing after washing, while applying wrinkle free or permanent press finishes on cotton fabric retain its aesthetic beauty after washing without ironing. Hence during able press finishes are being applied on many cotton fabric for the sack of their easy handling (Schramm and Rinderer, 2015). These finishes reinforce the linkage and increase the elasticity of molecular chains of cotton cellulose (Sahin *et al*., 2009). Initially formaldehyde based anti-crease finishes were used that could be associated with environmental risk and might cause eczema and allergic reactions (Choi and Yong, 2001). Today low formaldehyde based or formaldehyde free anti-wrinkle finishing agents are available (Wang *et al*., 2017). Few of them includes dimethyl dihydroxy ethylene urea (DMDHEU), dihydroxy dimethyl imidazolidinone (DHDMI), citric acid and butane tetracarboxylic acid using hyposphosphite salts, sodium maleate, sodium citrate as catalysts, and for extender, citric acid is used (Sahin *et al*., 2009). The main agents of this group was dimethyl dihydroxy ethylene urea (DMDHEU) (Dehaabadi *et al*., 2013). Even at present DMDHEU is considered the most efficient and cost effective wrinkle resistance finishing agent for cotton fabrics (Ibrahim *et al*., 2018 and Lao *et al*., 2017).

In the garment market for the last few years, wrinkle resistance cotton shirts have gaining the pace with increasing demand because the life style of the consumer is changing and he/she is demanding value added products. Moreover, the trend of life is converting towards natural products instead of synthetics. All this made naturally looking, full of comfort, having crease recovery properties and attractive garments more desirable to the consumers. When permanent press finishes are applied on the fabric surface, they enhance their anti-crease ability along with some negative impact on its strength related characteristics. However, these finishes increases compactness of the fabric surface fibres and results ultimately reduction in the pilling due to limiting of surface fibres movement (Can *et al*., 2009). Usually the anti-wrinkle properties in the fabric are achieved by coating the cotton fabric with resin or cross linked by reacting with the hydroxyl group of cotton cellulose molecules (Qi *et al*., 2016). There exists

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hydrogen bonding in these hydroxyl with weak secondary forces, particularly in the amorphous region, that can be easily contorted by external forces during laundering or some other actions during wearing which cause wrinkle in the fabric (Laio *et al*., 2017). The anti-wrinkle finishes reacts with the hydroxyl groups and create covalent crosslinks between adjacent cellulose molecules. Consumption of hydroxyl groups is carried out during this crosslinking that results in easy movement of cellulose molecules and fibrils that prevents wrinkle formation in the fabric. (Qi *et al*., 2016).

Most commonly finish applying technique on cotton fabric is padding. Padding is carried out mainly by pad dry, pad-dry-cure and pad-flash-cure techniques in industry. But under varying techniques fabric quality especially its strength related properties vary. Hence, the current research work endeavors to sightsee the ultimate impacts of these techniques for variant concentration of durable press finishes free from formaldehyde on cotton fabric tear strength value. Moreover, the work paves the path to achieve optimum levels of the selected variables for making best quality permanent press finished cotton fabric.

Materials and Methods

The current work was carried out basically in Fibre and Textile Technology Department of University of Agriculture Faisalabad with the partnership of Sitara Textile Mills Ltd. (a renowned textile processing unit) in Faisalabad, Pakistan. The schematic flow chart of the work carried out is as under (Fig.1)

The grey fabric selected for this study was made of pure cotton with plain 1/1 weave having 60, 60 number of ends and picks with 20s, 20s warp and weft yarn count having 125 g/m^2 GSM of fabric.

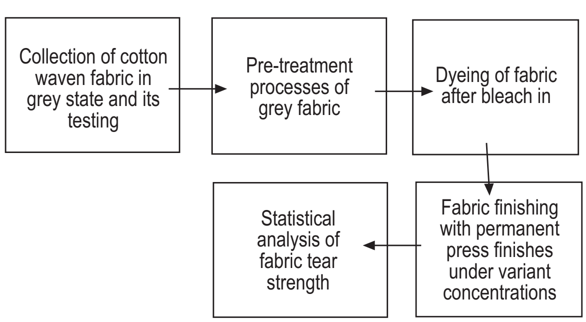

Fig. 1. Schematic flow chart of work being carried out during the present study.

Following pretreatments were given to the fabric before dyeing and finishing:

Singeing. In cotton fabric there exists the problem of short protruding fibres on the fabric surface which reflect ugly appearance of the fabric. For removing these short fibres, singeing process is carried out. In this process the fabric is passed over the flame having specific intensity with controlled speed. In current work the cotton fabric was singed with following singeing settings:

Flame intensity= 17; Temperature= 125 °C; Speed= 80 m/min

Desizing. During weaving process, the yarn needs some extra strength to bear external forces. In this respect some sizing material like starch, poly vinyl alcohol (PVA) *etc*. is applied on the yarn to impart strength (Madaras *et al*., 1993). But in presence of this material on the yarn surface, the dyeing of the fabric is difficult due to the lack of dye absorbency. Hence, prior to dyeing, this sizing material is removed by desizing process. In present research work TS-10 (amylase based enzymatic desizing agent) was used as desizing agent with 14 g/L concentration, while MIR was used in 10 g/L as detergent and 4 g/L of wetting agent with 7.5 pH and 85 °C temperature of the solution.

Bleaching after scouring. During fabric manufacturing at weaving machine fabric gains many kinds of stains of oil or other coloured materials which need to be cleaned before dyeing. For this purpose the fabric is washed out thoroughly in detergent and then bleached. In present study, the fabric was scoured and bleached using following recipes for scouring and bleaching process.

Scouring. The fabric was carried out using 30g/L caustic soda (sodium hydroxide) with 5 g/L soap applying 2g/L EDTA (ethylenediamine-tetra-acetic acid) as Sequestring agent. Moreover, soda ash was also used with the quantity 4 g/L. All the process was carried out at 95 °C temperature.

Bleach of fabric. After scouring beleaching was carried out with 32 g/L H_2O_2 with 50 % concentration and NaOH (50%) was added in the ratio of 13g/L in bleaching solution along with 3g/L P/N (alkyl aryl sodium sulphonate) as wetting agent, 2g/L EDTA (ethylenediamine-tetra acetic acid) as sequestring agent and 12 g/L Axel SIFA (organic stabilizer for hydrogen peroxide bleaching bath) as stabilizer under at 95 °C temperature.

After scouring and bleaching, the fabric dyeing process was carried out by of using two reactive dyes, Drim blue and Jack L yellow with 2.92 g/L and 1 g/L concentrations respectively. In dyeing solution 25 g/L anti-migrating agent and 20 g/L dye leveling agent were also added. Moreover, 100 g/L Urea was also included in the solution as wetting agent. First washing of fabric was done at room temperature, while 2nd and 3rd washing were made at 40 °C and 65 °C respectively. At the end 4th washing was also carried out at room temperature.

Dyeing procedure. Continuous dyeing mechanism was applied to dye the fabric with selected reactive dyes. After padding of the fabric at 30 °C, it was dyed with reactive dye solution prepared according the above mentioned recipe. The urea application in dye bath facilitates the dye diffusion in the fabric along with dye detachment and swelling of fabric. Fabric was dried for avoiding any dye migration. Curing of the fabric was made 150 °C for 60 sec for enhancing fabric dye interaction. Then in order to remove unfixed dye from the fabric and to improve its dye fastness, the fabric was washed out with detergent.

Finishing of fabric. After dyeing, the fabric finishing was carried out, the following variables (Table 1) were selected for finishing of fabric in this study

Table 1. Selected variables

Finishes (F)	Application methods (T)	Concentrations (g/L) (C)
F_1 = Texicil DC	T_1 = Pad-dry method	$C_1 = 60$
F_2 = Knittex RCT	T_2 = Pad-dry-cure method	$C_2 = 80$
F_3 = Arkofix NEC	T_3 = Pad-flash-cure method	$C_3 = 100$
F_4= Arkofix ELF		$C_4 = 120$

Here F1=Texicil DC; F2=Knittex RCT; F3=Arkofix NEC; F4=Arkofix ELF are various finish types with their chemical names; T1=Pad-dry; T2=Pad-dry-cure; T3=Pad-flash-cure are three different finish applying methods selected for this study; C1= 60; C2=80; C3=100; C4=120 are different concentration levels with which the selected finishes applied, g/L= gram per litter that is the unit of the concentrations of applied finishes.

The details of the finishes used in this research are given below:

Fabric quality analysis in respect of its tear strength. The tear strength of the fabric was measured in Newton (N) adopting ASTM standard methods (ASTM, 2008). Following apparatus was used:

Cutting die; Calibration weights; Falling pendulum (Elmendorf) tester of SDL Atlas; air Pressure regulator, capable of controlling gauge air pressure between 60 psi; and 90 psi (410 kpa and 620 kpa), for air clamps. The test was carried in lab under standard atmospheric conditions *i.e.* 65±5% relative humidity and 20±2 °C temperature.

Statistical analysis. The data obtained was statistically analyzed using Statistical package for social sciences (SPSS) software using three factor factorial design (Montgomery, 2013).

Results and Discussion

Fabric warp-wise tear strength. The data regarding the statistical analysis of fabric warp wise tearing strength, for selected four types of finishes under various concentrations and applying using three different techniques, is presented in Table 3. The results very clearly disclose significant impacts of all selected variables on fabric warp wise tear strength. All the interactions showed non-significant effects except FxC that reflected significant effect.

Table 2. Details of the finishes used

Chemical with company name	Chemical nature	Reactivity	Dosage g/L	Temp. time	Content of formaldehyde
Texicil DC (ICI)	Modified n-methyl dihydroxy ethylene urea	Cross linking agent	90	130 °C 3 min	>75 PPM
Knittex RCT (Huntsman)	Modified n-methyl dihydroxy ethylene urea	Cross linking agent	90	130 °C 3 min	>75 PPM
Arkofix NEC (Archroma)	Modified n-methyl dihydroxy ethylene urea	Cross linking agent	40	150 °C 2 mint	>75 PPM
Arkofix ELF (Archroma)	Modified n-methyl dihydroxy ethylene urea	Cross linking agent	60	175 °C 30 sec.	>75 PPM

ICI, Humntsman, archroma are the names of chemical manufacturing companies.

Table 3. Analysis of variance for warp wise tear strength

S. O. V.	D. F.	S. S.	M. S.	F. Value	Prob.
F	3	0.45740	0.15247	362.17	0.0000**
T	2	0.02567	0.01284	30.49	0.0000**
C	3	0.69232	0.23077	548.19	0.0000**
FxT	6	0.00578	0.00096	2.29	0.0811NS
FxC	9	0.16914	0.01879	44.64	0.0000**
TxC	6	0.00408	0.00068	1.62	0.1998 NS
FxTxC	18	0.1179	0.00065	1.56	0.0964NS
Error	18	0.00758	0.00042		
Total	65	1.37376			

C. V. = 0.26 %; Here * = Significant; N.S = Non-significant; **= Highly Significant; S.O.V= Source of variation; D.F= Degree of freedom; S.S= sum of squares due to the source; M.S= Mean sum of squares due to the source; F. Value= variation between sample means/variation within the samples; Prob= Probability level. All acronyms used in Table 3 are statistical terms used in ANOVA (analysis of variance) test.

Table 4. Comparison of individual treatment mean values for warp wise tear strength (N)

Finishes	Concentration	Application Methods
F1 = 7.9016c	C1= 8.1760a	T1 = 7.9994c
F2 = 7.9678b	C2 = 8.0970b	T2 = 8.0333b
F3 = 8.1233a	C3 = 7.9884c	T3 = 8.0556a
F4 = 8.1251a	C4 = 7.8562d	

Different letters on mean values indicate significant difference among the values at probability level of 0.05%.

The individual comparison of mean values for fabric warp-wise tear strength under selected variables is given in Table 4. The results reveal that all the variables put significant effects on the warp wise tear strength of the fabric.

It is clear from the data that the fabric warp wise tear strength, under the finish Arkofix ELF (F4) at the minimum concentration level 60g/L (C1) when applied through Pad-flash-cure method (T3), was fairly well as compared to other combinations. These findings are in line with the conclusions that the fabric tear strength decreases under the application of high concentration of finishes (Hua *et al*., 2007; El-Tahlawy *et al*., 2005). Similarly in a previous study (Datta *et al*., 2010), when finishes were applied through pad-dry, pad-cure –dry and pad –flash- cure techniques, it was observed that pad- flash- cure technique reflected good results in respect of fabric strength. The graphical representation of the findings during the present research study is shown below (Fig. 2) that clearly indicates the results as mentioned above.

The statistical analysis of the collected data regarding fabric weft wise tear strength for selected variables is presented in Table 5. The results disclose that all the variables put considerable effects on weft wise tear strength of the fabric. The interaction FxC showed significant impact while all other interactions reflected non-significant effects on fabric tear strength.

The comparison of individual means for fabric weft wise tear strength is given in Table 6.

The data in the Table 6 very clearly narrated that all the selected variables put significant effect on the tear strength of the fabric. The finish Arkofix ELF (F4) at

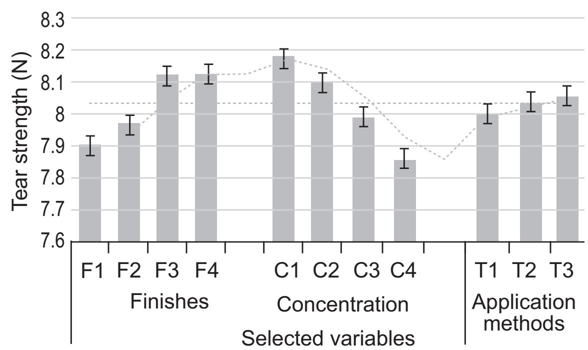

Fig. 2. Tear strength of the fabric (warp wise) for different selected variables.

Table 5. Analysis of variance for weft wise tear strength

S. O. V.	D. F.	S. S.	M. S.	F. Value	Prob.
F	3	2.59569	0.86522	538.04	0.0000**
T	2	0.15917	0.07958	49.49	0.0000**
C	3	2.19971	0.73324	455.96	0.0000**
FxT	6	0.02072	0.00345	2.15	0.0977 NS
FxC	9	0.073307	0.00812	5.05	0.0017**
TxC	6	0.01092	0.00182	1.13	0.3837 NS
FxTxC	18	0.02898	0.00307	1.91	0.2641 NS
Error	18	0.02895	0.0061		
Total	65	5.11717			

C. V. = 0.57 %; Here * = Significant; N.S = Non-significant; **= Highly Significant; S.O.V= Source of variation; D.F= Degree of freedom; S.S= Sum of squares due to the source; M.S= Mean Sum of squares due to the source; F. Value= variation between sample means/variation within the samples; Prob= Probability level. All acronyms used in Table.5 are statistical terms used in ANOVA (analysis of variance) test.

Table 6. Comparisons of individual treatment mean values for weft wise tear strength (N)

Finishes	Concentration	Application methods
F1 = 6.7125^d	C1= 7.2589^a	T1 = 6.9201^c
F2 = 6.8477^c	C2 = 7.1042^b	T2 = 6.999^b
F3 = 7.0956^b	C3 = 6.9282^c	T3 = 7.0607^a
F4 = 7.3186^a	C4 = 6.6831^d	

Different letters on mean values indicate significant difference among the values at probability level of 0.05%

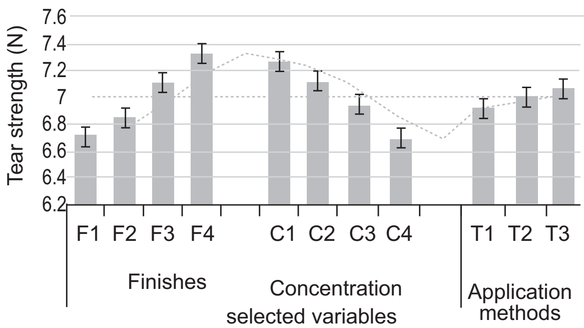

Fig. 3. Tear strength of the fabric (Weft wise) for different selected variables.

the minimum concentration level 60g/L (C1) when applied through Pad-flash-cure method (T3), put positive impact on the weft wise tear strength of the fabric as compared to other combinations. Same kind of results were noted in fabric warp wise tear strength of the fabric. Hence, it can be concluded that cotton fabric tear strength (Both warp and wet wise) was slightly improved when it was made anti-wrinkle using Arko fix ELF cross linking agent at low concentration with pad-flash-cure finish applying method. These results are also narrated in graphical form as under (Fig. 3)

Conclusion

From the current research study following conclusions are derived: Permanent press finish with Arkofix ELF cross linking agent put progressive impact in respect of improving the tear strength of the cotton fabric, both warp and weft wise, when applied in low concentration (60 g/L), using Pad-flash-cure finish applying technique.

Conflict of Interest. The authors declare they have no conflict of interest.

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