Pigment Dyeing and Finishing of Cotton /Polyester Fabrics with a Modified Dihydroxyethyleneurea and Various Softeners

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Abstract: The present study was conducted to develop a compatible ecofriendly pigment colouration system for simultaneous dyeing and finishing of Cotton/Polyester blended fabric. The pigment dyeing was carried out on Thermosole Laboratory Padder by double dip double nip technique with a wet pick up of 70% followed by drying and curing. In the first phase the fabrics were padded with an aqueous formulation containing pigment colourant, an acrylic binder, dispersing agent, modified DHEU as crosslinker, and magnesium chloride as catalyst. The recipes were applied on P/C fabrics with commercially available softeners each time at constant process parameters and various characteristics evaluated. According to the findings the colourfastness to wash and rubbing grades were very good for dyed P/C fabrics treated with a softener based on fatty acid amide condensation product. In terms of tensile strength and tear strength almost all the softening agents performed very well with a distinctive percentage increase in tear strength induced by micro emulsion concentrate of a quarternary polydimethyle siloxane and Polyethylene dispersion. The maximum abrasion resistance was attained by the fabric with amino functional polysiloxane constituted softener and micro emulsion concentrate of a quarternary polydimethyle siloxane. The flexural rigidity of all the treated fabrics reduced more in warp direction as compared to weft -indicating a softer feel. The flexural rigidity that was raised by high binder ratio (optimized at preliminary stage) and crosslinking treatment with dihydroxyethylene urea seemed to be minimized with softener application especially with silicon elastomer however one of the softener (macro emulsion) contributed increased stiffness surprisingly. The overall investigation indicate that colouration with resin bonded pigment dyeing and softener finishing is a feasible option for P/C fabrics provided that appropriate selection of softener be carried out to achieve desirable characteristics. The wet rubbing fastness technically needs to be improved.

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Key words: Pigment dye, DHEU, silicon softeners

Introduction

Polyester /cotton blends are widely accepted textile fabrics by consumers due to their user friendly performance. Despite of their limitations, both fibres are adequately balanced in a blend with desirable performance. However due to different natures of both components as a textile product it causes some problems in the dyeing process (Najafi H *et al.,* 2009). The hydrophobic nature of polyester resist swelling in water bath and the absorption of the dye to the inside of substrate are quite difficult (Arsalan *et al.*, 2001). Conversly the hydrophilic nature of cellulose fibres (cotton) permit the diffusion of dyestuff into the core of the fibre easily (Legrini *et al.*, 1993). Due to their different chemical characters it is required to use a common method applicable to both in the same formulation apart from conventional methods of dyeing. The difficulty can be overcome by pigment dyeing which bears a unique coloration system as it is not fibre specific and has the ability to adhere to a wide range of textile products whether natural or synthetic (Smith SE 2003-2011). One of the qualities of coloration with pigment dyeing is that post wash treatment is not required and waste water load is minimized (Cao Q 2013).

Pigments are small insoluble particles which have little or no affinity for fibres and thus for direct penetration it has to be bonded to fabric by special treatments. There are synthetic organic and some in-organic pigments which are used for coloration of textile products, usually in the form of pigment dispersions (Cardozo B 1995). A conventional pigment dyeing system for cellulose textile materials contains pigment, anionic binders and an acid librating catalyst along with other additives. The film forming binders and pigment coloratnts firmly fixed on textile substrate by drying the dyed material at high temperature (Technical Bulletin 2004). The speed of film fixation on the substrate depends upon the particle size and the chemical nature of the polymer applied (Miles W C *et al.,* 2003).

Various monomers generally used as binders for pigment dyeing include butadiene, acrylate, vinyle acetalye and styrene etc. The most common binders are acrylate copolymers that polymerized by an emulsion polymerization technique with the aid of an aqueous dispersion medium (Hammonds AG 1995). Many important characteristics of the resultant product are attributed to the binder like color fastness to washing and crocking, handle etc (Hammonds AG 1995). Another important factor influencing the crock fastness and adhesion of the binder film to the substrate is the cross-linking tendency of the applied binder (Shenai 2002). If the binder molecules have no self cross-linking groups, external cross- linkers like urea Formaldehyde or Melamine Formaldehyde condensate are included in the binder set up to impart easy care finishing (Chakarborty 2010, Iqbal *et al.,* 2012). Some benefits of formaldehyde as a cross-linking agent consist of low cost and high finish stability, however the process is considered to be disreputable for its deteriorating effect on strength (Ramachandran *et al.,* 2009).

As the bond between substrate and pigment colorants is stabilized with additional cross-linkers and binders during dyeing process, increased fabric stiffness is observed especially in deep shades (Hussain 2009). To obtain improved resin finishing effects with soft handle the softening agents can be added in the formulations for fabric dyeing the softener treatment for the durable press finished cotton fabric avoid adverse effects like harsh hand and strength loss (Li S 2008). Textile fabrics are treated with Silicones to provide initial softening to the fabric. It is considered that softening emerge due to the flexibility of siloxane backbone and the freedom of rotation along the Si-O bonds. This allows exposure of the low interacting methyl groups, reducing fiber-to-fiber interactions and impart softness (Hebereder P 2002*)*. The tear strength and crease recovery performance of 100% cotton fabric has been enhanced by an after treatment of modified N-methyl dihydroxyethylene urea and Polyethylene softener at constant variables. It has been suggested that same modal can be developed for other types of cross-linking agents combinations with better tear strength retention and crease recovery angle (Hussain *et al*., 2010).

The aim of the current study is to establish a compatible pigment coloration system for dyeing cotton/polyester blends with enhanced performance characteristics by incorporating an appropriate softener with modified resin treatment in the same formulation. It is hoped that combined treatment of modified dihydroxyethylene urea coupled with a suitable softener in pigment coloration system with improved performance would compensate partially or completely the adverse affects of the resin treatment on fabrics. Moreover by using pad-dry-cure technique for simultaneous dyeing and finishing of cotton/ polyester blends will be an attraction for all those dyers who are striving for eco friendly and energy saving dyeing system.

Material and Methods

The fabric specimen cotton/polyester (P/C) in its 65/35 blend was used in the current research project,woven in 83 ends and 53 picks per inch, having 108 gm/m^2 The grey fabric was desized by industrial pad batch method, while scoured and bleached by pad-steam method prior to the dyeing.

Dyes and chemicals

The colourant and the binder used in this study, Helizarin pigment orange and Helizarine binder CFF based on acrylic dispersion were provided by BASF chemical company, Pakistan. The dispersing agent, Setamol-BL based on sodium salt of a condensation product of naphthalene sulphonic acid and formaldehyde was supplied by BASF chemical company. The crosslinking agent i.e Knittex RCT (modified dihydroxy ethylene urea, DHEU) was supplied by Huntsman. Various type of softeners with their chemical constitution that were applied with pigment formulations are mentioned in Table 1.The other chemicals acetic acid, (10%), magnesium chloride($6H_2O$),sodium hydroxide, sodium carbonate were of commercial grade.

Dyeing and Finishing

The pigment dyeing was carried out on Thermosole Laboratory Padder Model VPM-250, Nippon-bashi, Japan and drying/curing on over feed Pin Tenter of Model No. OPT-1 from Tsuji dyeing machine manufacturing Co. Ltd. The essential features of the apparatus include mangle roller, pre heater, fluid beck etc. In the first phase the fabrics were padded by double dip double nip technique with a wet pick up of 70% with an aqueous formulation containing pigment colourant (200g/L), Helizarin binder CFF (50 g/L), Knittex RCT as crosslinker (100 g/L), crystalline megnesium chloride hexahydrate as catalyst(20-25% on the amount of crosskinker) and setamol dispersing agent(1-2ml /L) to prevent agglomeration. In the second phase dyeing was carried out by incorporating various softeners (30g/L individually) in each formulation at the same process parameters as stated earlier.

Drying and curing. An over feed pin tenter of Model No. OPT-1 from Tsuji Dyeing Machine manufacturing Co, Ltd was used in this study for drying (150°C for 3 minutes) and curing (170°C for 2 minutes) after padding.

Evaluation Methods

All the fabric specimens were subjected to various physico-mechanical tests,before and after treatment to assess the results according to the standard test procedure as following.

Colour Fastness to Washing: Color fastness to washing was tested following the standard method described in AATCC-61.

Colour Fastness to rubbing: The Colour Fastness to wet and dry rubbing was assessed on Crockmeter in accordance with the standard, AATCC-08.

Tear strength: The test was conducted on Elmendorf Apparatus 1 following the Standard Test method for Tearing Strength of Fabrics by Falling- Pendulum Type, D 1424-96.

Tensile Strength and Elongation: The tensile Strength of fabric samples in both warp and weft direction was determined on Testometric 220 D testing machine in accordance with ASTM standard D, 5035-06, Breaking Force and Elongation of Textile Fabrics (strip method).

Abrasion Resistance: The resistance of the P/C fabric to abrasion was evaluated on the Martindale Abrasion Tester (Abrasion machine mark II) following the procedure described in American Standard Test Method, D4966-98(Reapproved 2007).

Flexural rigidity: The flexural rigidity in terms of stiffness of in warp and weft directions of fabric was carried out on Shirley Stiffness Tester according to the method given in ASTM, D 1388-08.

Results

The P/C fabrics were pigment dyed with dihydroxyethylene urea commercially available softeners at constant process parameters and various characteristics evaluated.The results regarding various quality characteristics of dyed P/C fabrics are as following.

Effect of Softeners on the Cumulative Colourfastness properties of Crosslinked, Pigment Dyed P/C Fabrics:-

The results in respect of cumulative colorfastness i.e wash and rub fastness of combined dyed and finished P/C blends are shown in Table 2. It is apparent that Sapamine SFC softener (a fatty acid amide condensation product) amazingly enhanced the colorfastness of the simultaneous pigment dyed and cross linked P/C fabrics(Figure1). The grading of Perapret F-PEB NEW based on polyethylene and Ultratex UM NEW- macro emulsion of a functional polydimethyle siloxane remained unchanged before and after softener treatment. On the other hand an adverse effect by few of softeners was also reported, but with a negligible difference in ranking.

Effect of Softeners on the Tear Strength of Crosslinked, Pigment Dyed P/C Fabrics:-

The data regarding tear strength performance of P/C fabric pigment dyed, resin and softener treated in one bath are presented in Table 3. It can be clearly depicted from the (Figure 2) that the tear strength improved tremendously by the application of softeners. No noticeable adverse effects were observed in this regard. Siligen softener FF-SI based on amino functional polysiloxane and Siligen SIH Nano, the modified polysiloxane gave almost the same results, 13.63 percent increase while Ultratex UM New showed no difference in tear strength at all. However one of the crosslinkable Silicon Elastorner (Ultratex MHT CONC) strengthened the treated fabris profoundly by inducing a high percentage i.e. 59.09 in warp direction. In the weft of P/C fabric the cross linker DHEU, with almost all the softeners seemed to be the best combinations with the pigment dyeing except fatty acid amide condensation (Sapamine SFC) which showed a slight decline in tear strength with a 4.34 % loss. Table 4 exhibits the statistical analysis regarding difference between mean tear strength values of treated and untreated P/C fabrics with various softeners. According to the results a highly significant difference found between mean tear strength of fabrics in warp direction representing improvement in strength after softener treatment.

Effect of Softeners on the Tensile Strength of Crosslinked, Pigment Dyed P/C Fabrics:-

The effect of softeners in a single phase dyeing with helizarine pigment orange, and a cross linker (modified dihydroxyethylene urea) on cotton /polyester blends was analyzed for tensile strength and the results displayed in Table 4. The dyed fabrics in combined treatment with Siligen softener FF-SI based on amino functional polysiloxane, Sapamine SFC based on fatty acid amide condensation and Perapret F-PEB NEW, a secondry polyethylene dispersion resulted a slight difference in strength values while Ultratex MHT CONC showed no change at all(Figure 3). As far as the weft direction is concerned, in this case the majority of the P/C fabrics exhibited better tensile strength. The P/C fabrics with the application of Siligen softener FF-SI, a crosslinkable silicone elastomer i.e.Ultratex MHT CONC and Ultratex UM New were found to be strengthened by 22.67 and 39.71 and 57.83 % increased values respectively. The maximum increase in the tensile strength can be clearly depicted by the fabric treated with Ultratex UM New. The Siligen softener FF-SI and Siligen SIH nano based on a micro emulsion concentrate of quaternary ammonium polydimethylsiloxane caused a reduction in tensile strength of P/C fabric by 49.17 and 15.25 percent respectively as compared to the reference fabric.

Effect of Softeners on the Abrasion Resistance of Crosslinked, Pigment Dyed P/C Fabrics:

Abrasion is an important index to determine the durability of a fabric. In combined dyeing and cross linking an additional treatment with softeners was given to P/C fabrics followed by an analysis of abrasion resistance. The treated fabrics were subjected to abrasive action under recommended procedure and the percentage change in abrasion behavior is presented in Table 5 while the pictorial representation in Figure 4.The results presents that the cross linking fabrics adversely responded to the abrasion behavior but with the application of softeners the trend was found to be reverted, as few of the fabrics revealed high percentage increase in abrasion cycles.

It is demonstrated in figure-X that Siligen Softener FF-SI (amino functional Polysiloxane) provoked highest abrasion resistance to P/C fabrics with almost a cent percent increased value. Another Softener Ultratex MHT CONC comprising of a micro emulsion concentrate of a quaternary polydimethyle siloxane abraded the fabric at maximum number of cycles with a remarkable percent change (Figure 4). The ultratex MHT CONC based on macro emulsion of polydimethylsiloxane,Silicon Siligen S-1H nano, a modified polysiloxane and, a fatty acid amide condensation took the brunt of abrasive action adversely but not with a striking difference in treated and untreated value, only a slight devaluation of -4.88 and -15.344 percent occurred respectively. The P/C fabric which showed -31.81 percent reductions in abrasion resistance compared to reference fabric, exhibited by Perapret F-PEB NEW that was composed of polyethylene dispersion. The combined dyed and softener treated fabric with ultratex UM new silicon elastomer revealed the same value as it was prior to the softener treatment. The statistical analysis regarding difference between mean abrasion resistance values of treated and untreated P/C fabrics is given in Table 6.The T value at alpha 0.05 provided an insufficient evidence for a significant difference in mean abrasion resistance values of treated and untreated P/C fabrics therefore we conclude that softeners had both a positive and slightly adverse effects on fabrics and a few softeners decreased the number of cycles to wear off the specimen.

Effect of Softeners on the Flexural Rigidity of Crosslinked, Pigment Dyed P/C Fabrics:-

The flexural rigidity of the simultaneous dyed, cross linked and softeners treated P/C fabric is shown in Table 8. The treated fabrics showed a slight change in the flexural rigidity of all the fabrics, though the rate of change appears to be decreased or increased sometimes. In warp direction the softeners developed a resistance to the flexural rigidity of fabrics, the percent change being ranged from 2.99 to 8.8 percent. The P/C fabric with Siligen FF SI and Siligen S-I H Nano increased in flexural rigidity only with a negligible difference i.e. 2.91 & 4.70 percent respectively. Similarly Ultratex UM New based on macro emulsion of polydimethyle siloxane brought about no change in the stiffness of fabrics. Similarly Sapamine SFC and Perapret F-PEB NEW, a Polyethylene dispersion enhanced the stiffness level of dyed P/C fabrics slightly.One of softening chemical i.e. micro emulsion concentrate of a quaternary polydimethyle siloxane) caused a reduction of 18.82 percent in flexural rigidity maintaining a softening feel in fabric. The effect of softening reagents in the weft direction of P/C fabric is given Table 5 while graphs plotted in figure 5.It is self evident that amongst all the assorted softeners the Ultratex MHT silicon concentrate of a quaternary polydimethyl siloxane, resulted in the greatest decrease in the flexural rigidity of pigment dyed P/C fabric that was crosslinked with modified DHEU as well as softener treated in the same dye bath simultaneously. Here the effect of softening chemical was positive is in the sense that application remained successful to produce a softer handle in the fabric by reducing the stiffeness levels to almost 45.19 percent. Table 5 shows that the remaining fabrics too showed a decline in the flexural rigidity percentage as compared to the reference fabric. The plotted figure 5 indicates the reduction in flexural rigidity of fabrics by various softening chemicals corresponding to Sapamine SFC,Ultratex UM New silicone softener and polyethylene dispersion (S-6) in the decreasing order of stiffness respectively.

Disscussion

Culmulative colour fastness: According to the data Perapret F-PEB NEW based on fatty acid amide condensation product and Ultratex UM NEW were graded with high fastness values that was basically contributed by wash fastness rating. A study by Chattopandhay D P (2006) on dyed cotton fabric samples was conducted to both conventional and silicon nano emulsions and the results compared for colorfastness properties such as washing and sunlight exposure. According to the result nano emulsion induced less reduction in the fastness properties of the dyed samples compared to conventional emulsion silicon. In current study the findings reverted because in this case macro emulsion conc. (Ultra UM New) was found to be better in wash fastness. The results in respect of dry and wet rub fastness were found to be acceptable in fastness level as compared to reference fabric.

Tear strength: In the current study the cross linkable softener, Ultratex MHT CONC (composed of silicon lastomer) and Perapret F-PEB NEW (based on Polyethylene dispersion) gave the highest percentage increment in tear strength (figure 2). The loss in tear strength of P/C fabric resulted due to crosslinking finish but remarkably improved by treatment of polyethylene dispersion and Ultratex MHT CONC softeners. In another study by Hussain. T *et al* 2010 the strength as a result of crosslinking was recovered by treatment with polyethylene softener due to improved chain slippage. The overall results show that tear strength of dyed P/C fabric was decreased by treatment of modified dihydroxyethylene urea but when the same formulation was applied by incorporating softening agent the strength was found to be improved.

Tensile strength: According to earlier mentioned results the raised value of tensile strength was recorded in the fabric,treated with (Ultratex UM New) a softener composed of a macroemulsion of a functional Polydimethyl siloxane. The findings are in agreement with emulsification mechanism of softeners explained by Hammonds AG 1995, who reported that high tensile strength may be attributed to the emulsification mechanism of the softener. The film integrity of acrylic binder being enhanced by hydrogen bonding during polymerization and by additional softener treatment on /C fabric in combination with pigment formulation the mechanical stability increased further. By the micro emulsion deposit on the surface of fabric the adhesion increased thus making the fabric strong.

From the overall results, it can be considered that the combination of acrylate copolymer binder with pigment dye, the cross linker (modified dihydroxylethylene urea) and the earlier mentioned assorted softeners in the dye bath formulation showed a compatibility of the products with each other and thus resulted in a handsome increase in durability, especially the tensile strength of P/C fabrics. Though the strength had been lowered down with various softeners in weft direction but the change was not very significant.

Abrasion resistance: The present findings show that one of a softener Ultratex MHT CONC comprising of a micro emulsion concentrate of a quaternary polydimethyle siloxane abraded at highest number of rubs with a remarkable percent change. The results concur with the statement given by Nostadt K and Zyschka R 1997 that silicon microemulsion provide an excellent inner softeness to textiles and a unique surface smoothness. The technological characteristics like abrasion resistance can be improved by these softener due to their convenient penetration in the interior of fibre/ fabric matrix.

Table 1.Type of softeners used in pigment dyeing

	Type of softeners with Trade name &Source	Chemical Constitution	Ionic Nature
1	Siligen FF-SI from BASF Chemicals	Amino functional Polysiloxane	Nonionic
2	Siligen SIH Nano from BASF	Modified Polysiloxane	Nonionic
3	Perapret F-PEB NEW from BASF chemicals	Secondry Polyethylene dispersion	Weakly anionic
4	Ultratex MHT CONC.from Huntsman chemicals	Micro emulsion concentrate of a quartenary polydimethyle siloxane	Cationic/ Nonionic
5	Ultratex UM New from Huntsman chemicals	Macro emulsion of a functional Polydimethyle siloxane	Cationic/ Nonionic
6	Sapamine SFC from Huntsman chemicals	Fatty acid amide condensation product	Amphoteric/cationic with acid PH

Table 2. Cumulative Colourfastness properties of Cotton/Polyester Fabrics Dyed with Pigment Coloration System Containing Modified Dihydroxyethylene Urea and Assorted Softeners

Type of Softener	Crock Fastnes		Wash Fastness		Cumulative Fastness
	Dry Rubbing*	Wet Rubbing	Shade Change**	Staining	
Siligen FF-SI	3.5	2	4	3.5	13
Siligen SIH	3.5	2.5	4	3.5	13.5
Perapret F-P NEW	3	2.5	4.5	4.5	14.5
Ultratex MHT	3.5	2	4	4	13.5
Ultratex UM	3.5	2.5	4.5	4	14.5
Sapamine SFC	3.5	2.5	4.5	4.5	15
Reference	3.5	2.5	4.5	4	14.5

Grading according to * AATCC-61 & ** AATCC-08

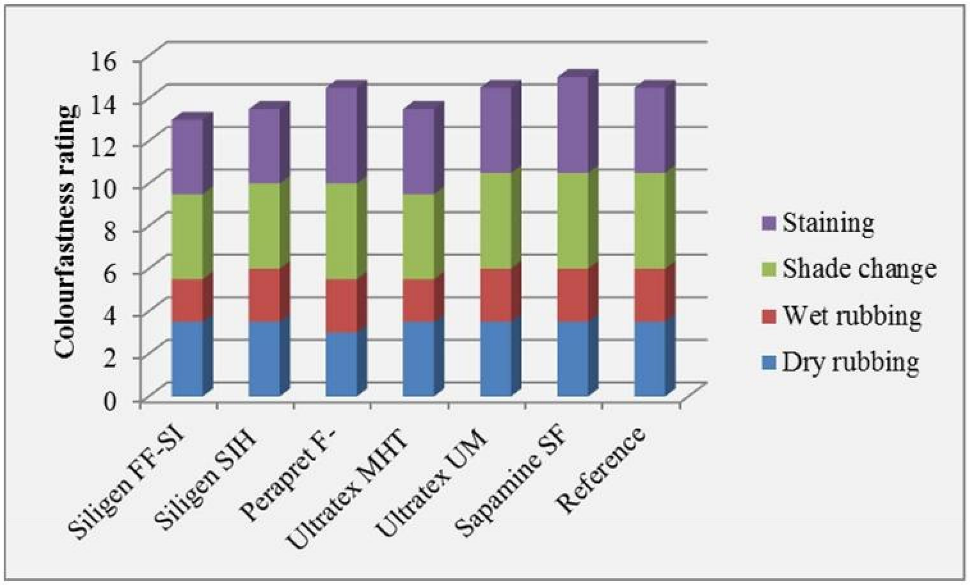

Figure 1. Effect of softeners on the cumulative colourfastness properties of cotton/polyester fabrics

Table 3. Percent Change in the Tear Strength of P/C Fabrics Dyed with Resin BondedPigment Colouration System

Type of Softener	Tear Strength (gm force)			
	Warp(actual)	%Change in tear strength	Weft (actual)	%Change in tear strength
Siligen softener FF-SI	1000	13.636	1840	33.333
Siligen SIH Nano	1000	13.636	1960	42.028
Perapret F-PEB NEW	920	4.545	2330	68.840
Ultratex MHT CONC	1400	59.090	2400	73.913
Ultratex UM New	880	0	1320	-4.347
Sapamine SFC	960	9.090	1680	21.739
Reference	1526	9.567	1380	-40.5172

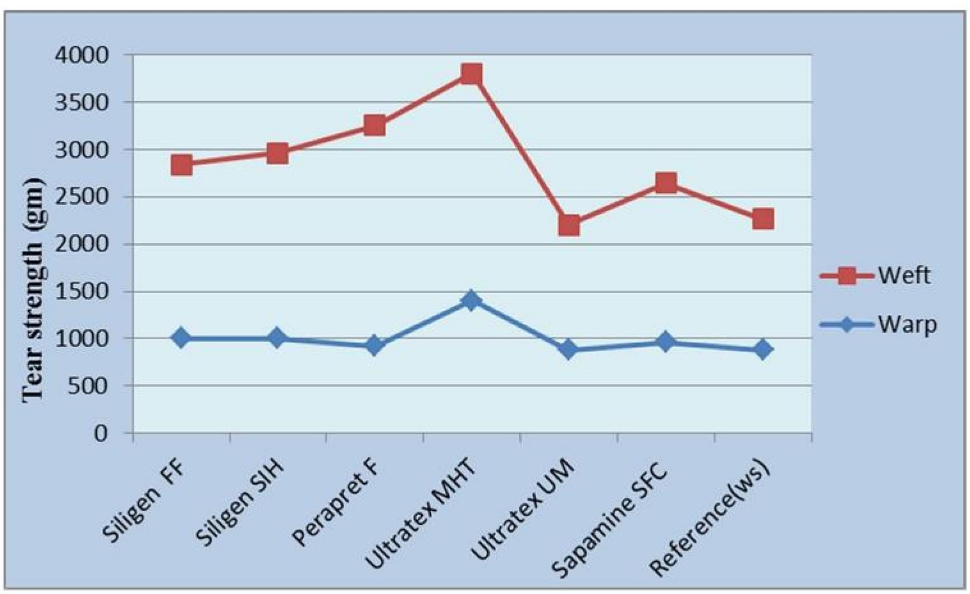

Figure 2. Effect of softeners on the tear strength of Cotton/Polyester fabrics dyed with resin bonded pigment colouration system

Table 4. Percent Change in Tensile Strength of P/C Fabrics Dyed with Resin Bonded Pigment Colouration System

Type of Softener	Tensile Strength (lb)				Elongation (%)	
	Warp	%Change T.S	Weft	%Change T.S	Warp	Weft
Siligen softener FF-SI	157.52	4.7653	72.44	22.6757	1.65	1.90
Siligen SIH Nano	138.01	-23.4533	30.01	-49.1787	1.29	1.38
Perapret F-PEB NEW	144	-14.7654	65.1	10.24555	1.50	1.28
Ultratex MHT CONC	138.01	0.460137	82.5	39.71211	1.25	1.97
Ultratex UM New	168.4	19.17995	93.2	57.83235	1.28	2.08
Sapamine SFC	137	-4.738	50.04	-15.2583	1.50	2.08
Reference	160	0	59.05	25.6383	1.32	1.49

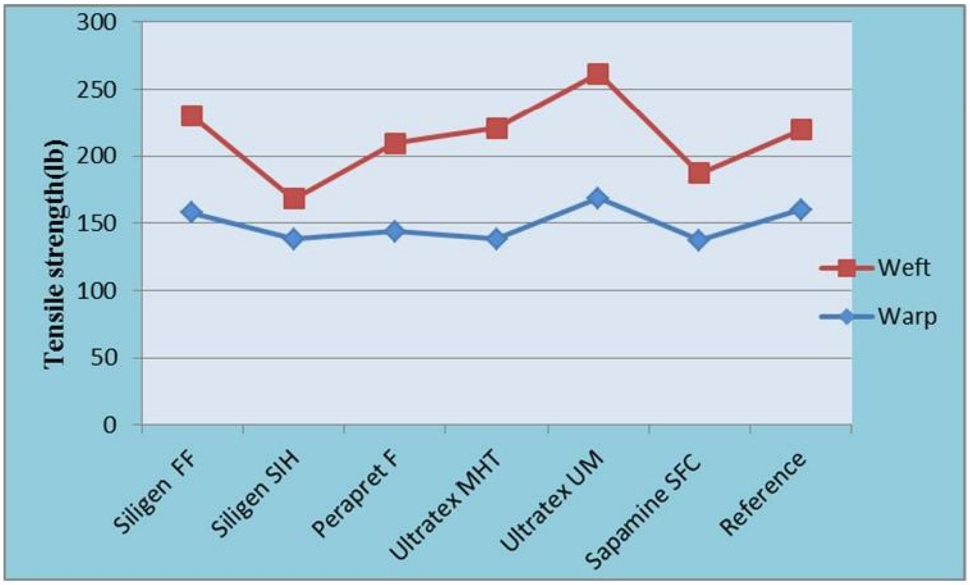

Figure 3. Effect of softeners on the Tensile Strength of Cotton/Polyester fabrics dyed with resin bonded pigment colouration system.

Table 5.Percent Change in Flexural Rigidity & Abrasion resistance of P/C Fabrics Dyed with Resin Bonded Pigment Colouration System

Type of Softeners	Flexural rigidity(µ Joule/M)				**Abrasion resistance (no. of cycles)**	
	Warp		**Weft**			
	Actual	**%Change**	**Actual**	**%Change**	**Actual reading**	**%Change**
Siligen FF-SI	21.87	2.9176	17.53	60.384	70,000	113.544
Siligen SIH Nano	22.25	4.70588	11.89	8.783	27,900	-14.887
Perapret F-PEB NEW	23.12	8.8	8.39	-23.238	48,800	48.871
Ultratex MHT CONC	21.25	0	7.72	-29.368	66,600	103.172
Ultratex UM New	22.5	5.8823	7.61	-30.375	27,750	-15.344
Sapamine SFC	17.25	-18.8235	5.99	-45.196	22350	-31.818
Reference	21.25	105.11583	10.93	173.934	32,780	–

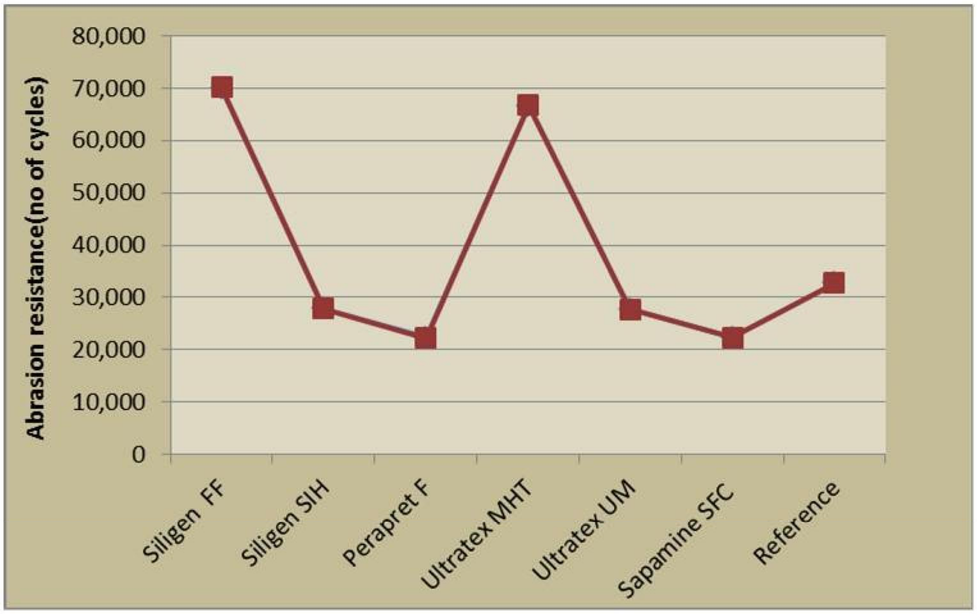

Figure 4. Effect of softeners on the abrasion resistance of Cotton/Polyester fabrics dyed with resin bonded pigment colouration system

Table 6: Paired Sample T Test for Comparing the difference of Mean Abrasion resistance of Softener Treated and untreated P/C fabrics

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Softener. T - Untreated	1.1120E4	20984.4466	8566.8645	-10901.8262	33141.8262	1.298	5	.251

Difference is non significant at $\alpha = 0.05$

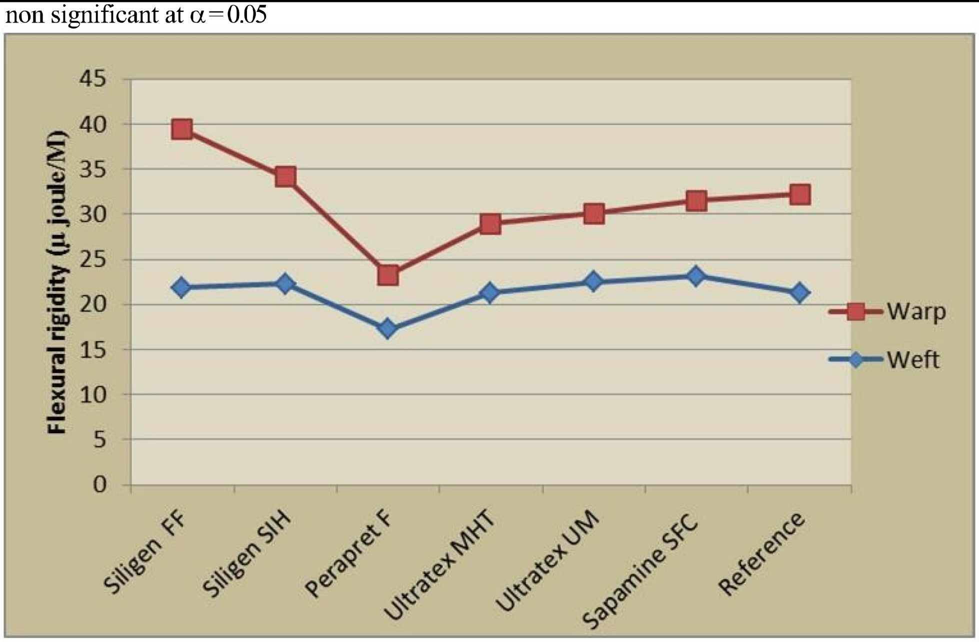

Figure 5. Effect of softeners on the Flexural rigidity of Cotton/Polyester fabrics dyed with resin bonded pigment colouration system

Flexural rigidity:

It was expected that the softener treatment Influenced the flexural rigidity positively, giving a softer handle to all Pigment dyed fabrics but with one fabric the observation turned to be reversed. In this case the application of amino functional polysiloxane product along with modified DHEU contributed a stiffer handle to the P/C fabric with a higher percentage increase in flexural rigidity (Figure X). These results almost compare able with a study conducted by Beal *et al* 1990 in which the 100 % polyester and 50/50 cotton/polyester fabric treated with and without certain functional finishes in respect of softening effect. The fabrics treated with dimmethyldihydroxy ethylene urea durable press finish were found to be less soft as compared to unfinished fabric. The stiffness was increased by the application of acrylic finish even a large amount of softener did not decrease stiffness. The softening capacity of Siligen SIH Nano modified polysiloxane too reduced the percentage of fabric stiffness but not to a greater extent.

Conclusions

The color fastness of combined dyed and finished P/C fabrics with modified DHEU and fatty acid amide constituted softener was found to be very good, however the tear strength reduced with a small percentage. The abrasion resistance and flexural rigidity of P/C fabrics has been enhanced by most of softeners. Pigment colouration system for combined dyeing and softener treatment with different chemical natures is a feasible option for P/C blends.

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