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STRENGTH ANALYSIS OF ONE-STEP PIGMENT DYEING AND DURABLE PRESS FINISHING OF POLYESTER/COTTON BLENDED SHEETING FABRICS WITH VARIOUS CROSSLINKING AGENTS

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Abstract: Pigment dyeing of Polyester/Cotton (P/C) blended fabrics was carried out by a conventional padding method, incorporated with various crosslinkers and two different binders at 70 %wet pick-up and constant thermo-fixation temperature. The aim of pigment dyeing in conjuction with resin finishing was not only to save time, cost of production and energy, but maintaining the durability of the fabric too. In the current study, the tensile and tear strength properties of treated specimens were evaluated, based on the effect of different types of binders and crosslinkers. The results clearly reveals a non-significant decreasing trend in the tensile strength of fabrics with the cross-linkers, however one of them i.e. modified dihydroxyethylene urea (DHEU) provoked excellent tensile strength in fabrics. According to the findings, CL5, a highly etherified melamine compound remained beneficial in augmenting the tear strength of pigment dyed fabrics, while the minimum tear strength was acquired by the CL1 (Dimethylol dihydroxyethylene urea) treated fabric. In general, the alliance of acrylate copolymer binder with pigment colourant, and the modified DHEU cross-linker showed a compatibility with each other in persisting the desirable tensile and tear strength of P/C fabrics.

Keywords: Dihydroxyethylene urea, resin finishing, tear strength, pigment colourant, acrylic copolymer binder.

Introduction

Polyester/cotton (P/C) blended fabrics, which often presents difficulty while dyeing by conventional systems, can now be more conveniently dyed with pigments (Smith, 2011). Pigment dyeing can be an acceptable replacement of one step dyeing with disperse/reactive or disperse/vat dyes (Hussain *et al.*, 2013). As pigments have no affinity for any type of fibers they can be adhered to the substrate with a film forming resinous material called, binder. The functionality of binders is associated with crosslinking ability, hence the acrylic binders with carboxylic acid component, provides reacting sites for crosslinking with other polymers (Kawath *et al.,* 2004). In case the binder molecules are deficient of self-crosslinking groups, some additional cross-linking monomers such as resins can be incorporated for enhancement of desirable characteristics in the textile products. When dyeing is carried out in conjunction with resin finishing, the time, cost of production as well

as energy consumption can be saved (Raheel, 1998).

The pre-condensates viz melamine formaldehyde and urea formaldehyde can be applied as crosslinking as well as binding agents (Chakarborty, 2010, Iqbal *et al*., 2012). The most effective crosslinking reagents for durable press finishing of cellulose fibres are formaldehyde adducts of urea, which unfortunately release formaldehyde during production and use in clothing (Voncina *et al*., 2000). Dimethylol dihydroxyethylene urea (DMDHEU) and modified DMDHEU are the compounds which contain N-methylol (and mainly N-alkoxymethyl groups and used as durable press finishing (Yang *et al*., 2001, Shiqi, 2008). The chemical structures of both conventional and modified forms (with low formaldehyde) are exhibited in Figure 1.

Fig. 1: Chemical structure of DMDHEU & modified DMDHEU.

The loss in tensile, tear strength and abrasion resistance in 100% cotton are directly related to cross-linking quality. In a study performed with 15 % commercial DMDHEU (7 % bath solids) in the bath, the upgrading in durable press properties was observed while on the other hand, the strength and abrasion resistance losses exceeded 30 to 60 % of the original fabric values. Another commercially important cross-linkers, i.e. Melamine resins are characterized by their multipurpose finishing ability which form a three dimensional network by crosslinking with other polymers. One of the commonly applied melamine resin used for fabric modification technique is trimethylol melamine which has a tendency to self-polymerize (Tomassino, 1992).

Another type, hexamethoxymethyl melamine (HMMM) is its highly etherified version, facilitating in complete crosslinking under proper curing conditions due to more reacting sites.HMMM can react with hydroxyl carboxyl and amide groups, providing stability to coloured materials (Yorstan,1995).Melamine resins which exceeds urea formaldehyde in resistance, toughness and strength are applied for pigment printing to achieve enhanced crock fastness and wash fastness Mlynar, 2003). The performance criteria which assure that, the pigment within the matrix of crosslinked binder film is fast to wear and cleaning is measured by elasticity, cohesion and bond to the substrate and resistance to hydrolysis (Miles, 2003). N-methylol cross-linkers are broadly used in textile industry as durable press finisher, however, the process is considered to be notorious for its deteriorating effect on strength (Ramachandran *et al.,* 2009). Dimethyloldihydroxy ethylene urea and pigment colourant has been applied simultaneously on cotton to assess the colour-fastness, crease recovery and strength properties the printed fabrics (Uddin and Lomas, 2005). Keeping this in mind, a concurrent pigment dyeing and finishing approach was followed for polyester/cotton blended sheeting fabrics using some commercial cross-linkers and two optimized binder systems. The fabrics were further evaluated to optimize the tensile and tear strength properties with respect to the effect of applied resin treatments.

Experimental Fabric

The medium-weight; 65/35 polyester/cotton; plain woven blended fabric with a thread count of 83ends, 54 picks per inch and weight per unit area (GSM) of 108g/m^2 was used in the present study. The grey fabric was de-sized by industrial pad batch method, while scoured and bleached by pad-steam method before any treatments.

Pigment with auxiliaries and crosslinking agents

Helizarin Pigment Red, Helizarin binder CFF (acrylic dispersion), Helizarin binder ET ECO (acrylate co-polymer) and the Setamol-BL dispersing agent (sodium salt of a condensation product of naphthalene sulphonic acid and formaldehyde) were provided by BASF chemical company, Pakistan, while, magnesium chloride. 6H_2O of commercial grade was obtained from the company of its origin. The type of crosslinking agents (resins) used with pigment formulations are given in Table-1.

Table 1 Type of crosslinking agents

S. No	Commercial Name/Source	Chemical Nature
CL1	Fixapret CPF (BASF)	Methylolation product based on Glyoxal monourein
CL2	Fixapret F-ECO (BASF)	Modified Dimethyloldihydroxyethylene urea (DMDHEU) (Formaldehyde free)
CL3	Knittex RCT (Huntsman)	Modified dihydroxyethylene urea
CL4	Arkofix NZF (Clariant International Ltd)	Modified Dihydroxyethylene urea (DHEU)
CL5	Printofix Fixative WB liquid (Clariant International Ltd)	Highly Etherified Methylol melamine compound (Very low Formaldehyde)

Preparation of formulations, with incorporated cross-linkers in the optimized pigment/binder

For dyeing and resin treatment, 1000ml of stock solution was prepared by 50g/L pigment, 200gm/L binder, 1g/L dispersing agent, 100g/L of cross linker and 20 gm/L of magnesium chloride. 6H_2O.The formulations were applied with both of the binders at constant parameters with the only difference being in the type of cross linker.

Fabric Dyeing

Application of Pigment and cross-linkers was carried out on laboratory padder model VPM-250, from Nippon-bashi, Japan. The drying and curing of the treated specimens was done on an over feed pin tenter from Tsuji dyeing machine manufacturers. All the fabric specimens were concurrently dyed and cros-slinked on padding mangle, using double-dip, double-nip technique with a wet pick up of 70%, dried at150ºC for 3 minutes and ultimately cured at 170ºC for 2 minutes.

Fabric Testing

The tensile strength and elongation of treated fabric samples was determined on Testometric 220 D electronic testing machine in accordance with the ASTM standard, D 6035-06. As regards the resistance of fabric to tear strength, it was evaluated on Elmendorf Apparatus according to the standard, ASTM. D 1424-96. The results were statistically analyzed by using Minitab 17 software package.

Results and Discussion

Effect of different crosslinking agents on tensile strength with optimized binders

The results regarding the effect of crosslinking agents and binders on the tensile strength and elongation (%) of pigment coloured P/C fabrics is given in Table 2. The analysis of variance (ANOVA) of the results is given in Table 3, which clearly represents a statistically non-significant effect of the crosslinking agents and the binders on the mean tensile strength of dyed P/C fabrics. The main effects plot of treated fabrics displayed in Figure 2. Indicates a slight decreasing trend in the tensile strength with application of cross-linker, however, one of the crosslinking agent imparted excellent tensile strength in fabrics. The overall performance of acrylic binder B2 was slightly better than B1. The individual performance of P/C fabrics in Figure 3 showed, that one of the crosslinking agent (CL2) had adversely affected the strength, while the treatment of fabrics with CL4 was comparatively better than others.

Table 2 Effect of different crosslinking agents on tensile strength of the dyed samples

Sampl e No.	Factors		Responses				
	Cross Linkers	Type of Binder	Tensile Strength (Warp,lb)	Tensile Strength (Weft, lb)	Tensile Strength (Wp+Wt)	Elongatio n %(warp)	Elongatio n %(weft)
1	CL1	B1	137.3	35.61	172.91	1.32	1.23
2		B2	142.8	35.2	178	1.53	1.59
3	CL2	B1	139.41	43.61	183.02	1.52	1.6
4		B2	123.5	21.5	145	2.61	2.69
5	CL3	B1	160.0	72.05	232 .05	2.0	1.95
6		B2	160.6	91.01	251.61	2.0	1.98
7	CL4	B1	153.01	37.61	190.2	1.55	1.3
8		B2	168.8	27.71	196.51	1.8	2.0
9	CL5	B1	123.2	36.5	159.7	1.4	1.9
10		B2	150.71	54.25	204.96	1.8	1.9

Table 3 Analysis of variance for tensile strength

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	5	7408.7	1481.7	3.25	0.139
Type of Cross linkers	4	7262.4	1815.6	3.98	0.105
Type of Binders	1	146.3	146.3	0.32	0.602
Error	4	1825.8	456.5		
Total	9	9234.5	3900.1		

*Statistically significant at P value 0.05

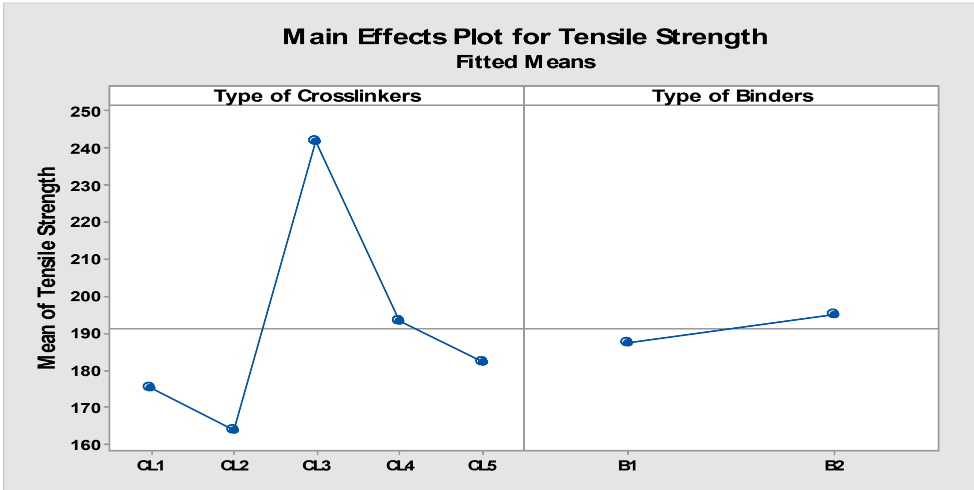

Fig. 2:Main effects plot for tensile strength, warp and weft way

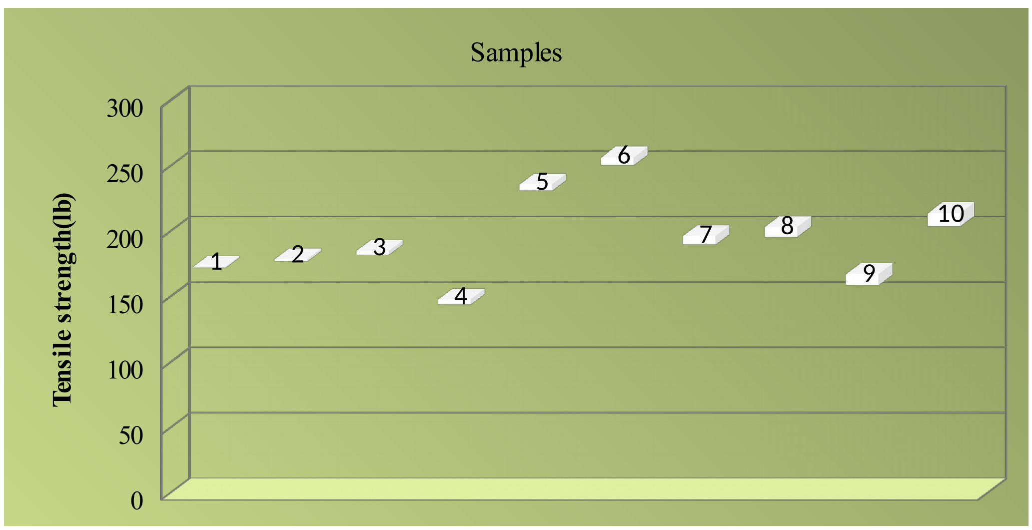

Fig. 3: Effect of binder types and cross linkers on the tensile strength, warp and weft way

In current investigation the simultaneous pigment dyeing and crosslinking with dimethylol dihydroxy ethyleneurea rendered low tensile strength in P/C fabrics regardless of the binder type. The reason for this decline may be the cross linking mechanism of DMDHEU with adjacent molecules. According to (Schindler & Hausar, 2004) in DMDHEU finishing chemical the cross linking of adjacent molecules impede the movement of fibres under stress, which leads to reduced tensile and tear strength. Without resin treatment cellulose chains are not cross linked and stress can be distributed over adjacent molecules, minimizing strength loss. Contrary to these results the incorporation of modified DHEU with pigment stock formulation, rendered very good tensile strength to P/C fabric. The degree of improvement in the earlier mentioned parameters was determined by the type of binder and the cross linker used for finishing. The meta-treatment of knitted RCT (modified DHEU) with two optimized binder systems (acrylic dispersions) imparted a positive impact on the tensile strength of P/C fabric.

According to the results (Table 2) there was moderate increase in percentage extension values in weft (crosswise direction) as compared to warp of fabric which might facilitated the enhanced strength. For such a mechanism the analysis of (Lickfield et al., 2000) on various crosslinkers which were applied on cotton fabric ca be quoted here. According to the investigation the cross link chains formed by DHEU treatment were mutually displaced in order to resist the applied load uniformly, thus strengthening the fabric.

Effect of different crosslinking agents on tear strength with optimized binders

The summary of tear strength results are given in Table 4, representing the effect of cross linking agents on the warp and weft way tear strength of fabrics. Table 5 contains the statistical analysis of results for the tear strength of simultaneously dyed and crosslinked P/C fabrics. The effect of crossliking agents as well as the type of binders were found to be highly significant on the tear strength of fabrics. Figure 4 illustrates the main effects plot for the results with an overall decreasing trend in the tear strength of fabrics. As regards the binder types, B2 has proved to be better than B1, with respect to the effect of crosslinking agents on tear strength. The individual results of simultaneously pigment dyed and finished P/C fabrics with various cross linkers have been displayed in Figure 5. According to the findings, CL5 remained beneficial in augmenting the tear strength of treated fabrics, while the minimum tear strength was acquired by the CL1 treated fabric

Table 4 Effect of different cross linking agents on tear strength of the dyed samples

Sample No.	Factors		Responses		
	Type of Cross linker	Type of Binder	Tear Strength, Warp (lb)	Tear Strength, Weft (lb)	Tear Strength (Wp + Wt), lb
1	CL1	B1	680	1480	2160
2		B2	960	1400	2360
3	CL2	B1	720	1440	2160
4		B2	800	1780	2580
5	CL3	B1	740	1200	1940
6		B2	840	1480	2320
7	CL4	B1	800	1320	2120
8		B2	1000	1600	2600
9	CL5	B1	1000	1840	2840
10		B2	1120	1960	3080

Table 5 Analysis of variance for tear strength

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	5	110480	222096	31.11	0.003
Type of Crosslinkers	4	814640	203660	28.52	0.003*
Type of Binders	1	295840	295840	41.43	0.003*
Error	4	28560	7140		
Total	9	1139040	728736		

*Statistically significant at P value 0.05

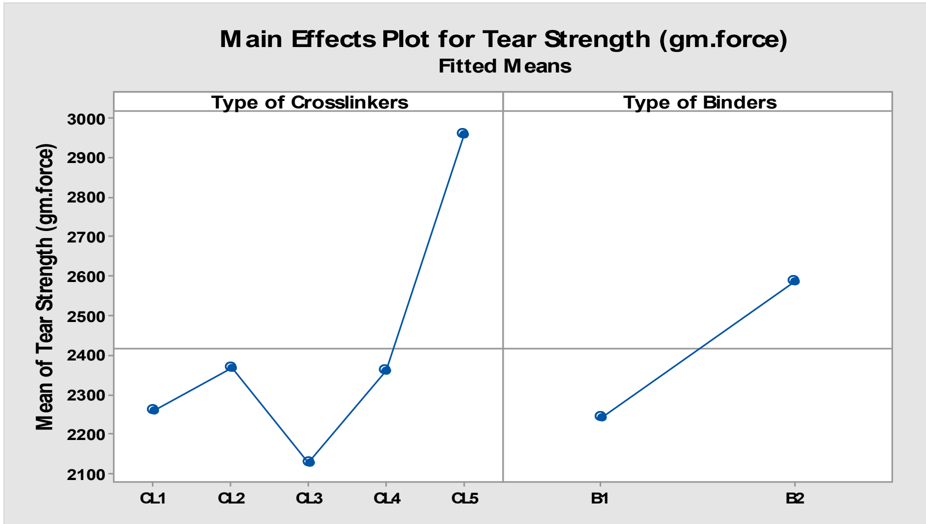

Fig. 4: Main effects plot for tear strength, warp and weft way

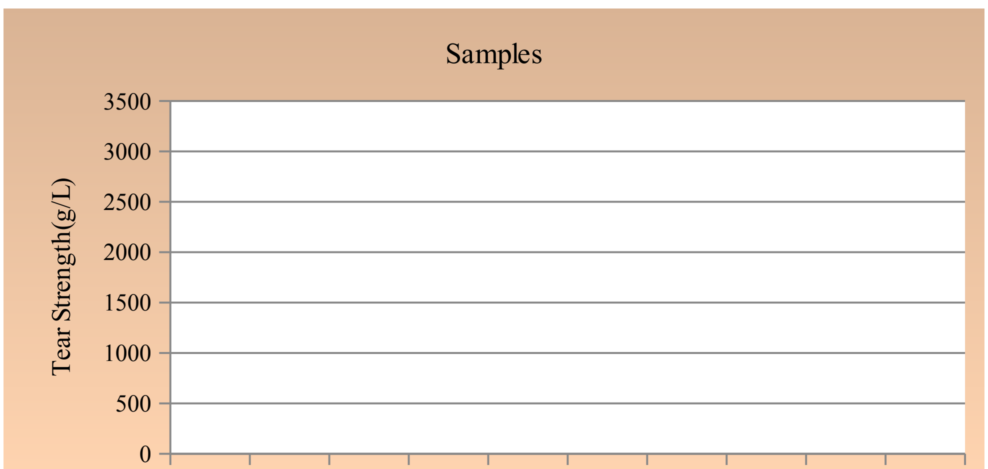

Fig 5: Effect of binder types and cross linkers on the tear strength, warp and weft way

It was observed generally that dyed-only P/C fabrics had shown a decline in tear strength but, when the same formulation was applied with various resin or crosslinking chemicals, it was found to be upgraded. The results concur with the investigation of (Shiqi, 2008) who reported the higher strength (4 to 6% in warp and weft directions respectively of DMDHEU finished fabric, treated with procion- resin method. In the present study, too, the tear strength was found to have increased by the application of Fixapret CPF and Arkofix NZF, both conventional and modified DMDHEU as compared to the control fabric that was dyed only with pigment colourant. The next optimal strength ratio corresponded to Printofix fixative WB liquid treatment, a highly etherified melamine compound. The present findings are in agreement with that of (Yorston, 1995), who observed that since the hexamethoxy melamine creasing agent had more reactive sites, it can cross linked completely with OH groups on cellulose, under appropriate post curing conditions, hence providing stability to fabric.

Conclusion

The treatment of knitted RCT (modified DHEU) induced a positive impact on the tensile strength of P/C fabric with two suitable acrylic binder systems i.e. Helizarin Binder CFF and Helizarin ET ECO respectively. Two of the crosslinking agents i.e. Fixapret CPF and Arkofix NZF (conventional and modified DMDHEU) induced higher tear strength. The P/C fabrics, treated with, a highly etherified melamine compound with a very low formaldehyde content induced minimum loss to the fabric's tear strength. As regards the other parameter i.e. binder types, an acrylate co-polymer binder with additional crosslinking qualities was comparatively found to be better than B1 an acrylic dispersion, in fabrics' tear strength. The overall results specify that the process of cross linking could be used to retain the tensile strength of P/C fabrics by incorporating modified DHEU a formaldehyde free cross linker and an appropriate binder in pigment formulation. It can be a feasible option for imparting crease resistance or durable press finishing to pigment dyed P/C fabrics without interfering their durability.

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