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Impact Of Concurrent Pigment-Dyeing & Resin Treatments On The Abrasion And Pilling Resistance Of Polyester/Cotton Fabrics

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Abstract:

Polyester/Cotton (PES/CO) blended fabrics were subjected to one stage pigment dyeing and resin treatments on common laboratory padding mangle at 70 percent wet pick-up and constant thermo-fixing conditions. Formaldehyde resin treatment on fabrics is usually associated with lowered abrasion resistance and pilling propensity, therefore, the main objective of pigment dyeing in conjunction with resin finishing was not only to retain these characteristics of PES/CO fabrics but at the same time save energy. The simultaneously dyed/treated fabrics with modified di-hydroxyethyleneurea (DHEU) were abraded at maximum number of cycles and displayed also the highest pilling grade i.e.5. As regards the performance of different binders, the effect of acrylate co-polymer binder on the abrasion and pilling resistance seemed to be better as compared to simple acrylic dispersion. Hence, the combination of acrylate copolymer binder(200g/L) along with pigment red (50 g/L) and a low formaldehyde cross-linker (DUEH),100g/L recommended to be a compatible formulation for dyeing PES/CO fabric in terms of maintaining the desirable abrasion and pilling resistance. Further. single phase dyeing-crosslinking system for PES/CO fabrics relatively found more economical and feasible regarding minimal pollution creation in the absence of post wash treatment

Key words: Resin treatment, abrasion resistance, pilling, pigment colouration, acrylic copolymer binder, formaldehyde free cross linker.

Introducton

Polyester/cotton (PES/CO) blended textiles can be graded as well-recognized textiles both as home furnishings and apparel products among the customers. Despite its numerous advantages the colouration of this blend renders some problems due to their different chemical characters i.e. the hydrophobic and hydrophillic nature of polyester and cotton respectively (Arslan, 2001). The Imperial Chemical Industries (ICI) has developed fast single-bath method for dyeing polyester/cotton blended fabrics using a combination of disperse with reactive dyes in parallel (Lee *et al.*, 2003). Pigment dyeing of PES/CO blended fabrics can be a satisfactory replacement of single-stage colouration method with disperse/reactive dyes or disperse/vat dyes (Hussain *et al.*, 2013). Pigment colouration has currently evoked immense interest for polyester blended fabrics due to its environment friendly nature. The colouration system with pigment is modifiable for different textile products in terms of formulating with various auxiliaries Uddin & Lomas, 2005). The incorporation of cross-linking agent to pigment padding system allows the single stage dyeing and finishing with a compatible ingredients (Hussain & Rashid, 2009). Amino resins react with cellulosic fibers and change their physical properties by crosslinikg with adjacent molecules. The formaldehyde adducts of urea are the most productive crosslinking agents for durable press finishing of cellulosic materials but with a limitation of its formaldehyde omission during use in clothing treatments.

Low or formaldehyde free-content in durable press finisher and other auxiliary reagents are constantly being developed. (Voncina *et al.*, 2000, Chakarborty, 2010). Dimethylol dihydroxyethylene urea (DMDHEU) compounds, both conventional and modified contain N-methylol and generally N-alkoxymethyl groups (figure 1) which are applied as durable press finishing (Yang *et al.*, 2001, Shiqi, 2008).

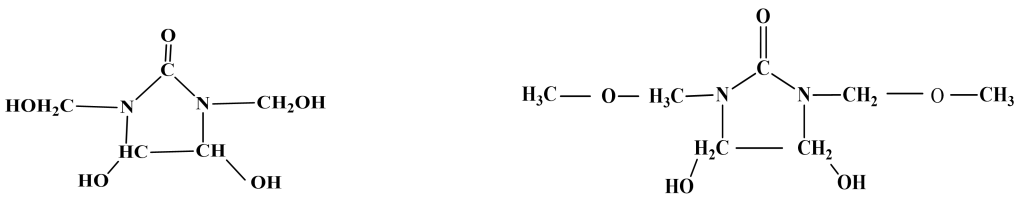

Figure 1: Structure of durable press finishes

The application of resin finishing on cotton with enhanced dimensional stability has been correlated with reduced abrasion resistance and tensile strength properties (Welch, 1995). Durable press (DP) finishing is a method that is extensively used by the textile industry to yield the wrinkle-resistance in cotton fabrics, however it is found to causes substantial loss of abrasion resistance (Yang *et.al*., 2001).

To minimize the significant loss in mechanical strength and abrasion resistance of the fabrics with durable press finishing have been a major concern for the industry (Lickfield *et al.*, 2001)

Abrasion is the physical damage of fibers, yarns and fabrics, initiating from the rubbing action of a surface over another textile surface (Abdullah, 2006). Various parameters, affecting the abrasion resistance of the textiles is the type of finishing reagent, concentration and its mode of application. Concurrent dyeing and of finishing tend to adhere the fibers on the fabric surface, thus restricting the movement of fibers within the yarn and impede abrasion loss. (Manich *et al.,* 2001). Abrasion causes loose fibers to pull from the surface of textile fabric and convert into a fuzzy structure or minute pills.

Generally, the pilling affects the fabric aesthetics and does not provoke any functional problem but it is imperative to minimize or preclude pilling for consumer's satisfaction. (Kurlageri, 2009). One approach to control the pill formation is to reduce friction with the help of lubricating agents and tough, film forming polymers such as acrylic co-polymers.(Schindler & Hausar, 2004)

The present research work demonstrates the impact of resin bonded pigment dyeing on the abrasion and pilling resistance of PES/CO fabrics. The study aims at investigating the said properties of meta phase dyed/crosslinked system for PES/CO fabrics with minimal energy loss and waste material, as occurs in conventional dyeing methods

Experimental

Materials

Medium weight fabric, comprising of 65/35 polyester/cotton blend ratio with an areal density of 108g/m.^{2} was used for pigment dyeing and resin finishing. The gray fabric was de-sized by industrial pad batch method, while scoured and bleached by pad-steam process prior to dyeing and crosslinking.

Pigments, binders and crosslinking agents

The Pigment red, Helizarin binder ET-ECO (acrylate copolymer), Helizarin binder CFF (an acrylic dispersion) and the Setamol-BL dispersing agent (sodium salt of a condensation product of naphthalene sulphonic acid and formaldehyde) were supplied by BASF chemical company, Pakistan. The catalyst, magnesium chloride. $6H_2O$ of commercial grade was acquired from the company of its origin. Various crosslinking chemicals for combine resin treatments are given in Table 1.

Table 1: Types of crosslinking agents

S. No	Commercial Name/Source	Chemical Constitution
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 systems

The stock formulation (1000ml) was prepared by 50:200g/L pigment/binder, 1g/L dispersing agent, 100g/L of cross linker and 20 gm/L of magnesium chloride. $6H_2O$. All the treatments were applied on fabric specimens, containing two different binder systems at constant process parameters with variant cross linkers.

Fabric Dyeing

The samples were concurrently Pigment dyed/cross-linked on laboratory padding mangle, model VPM-250, from Nippon-bashi, Japan. The drying and curing was done on an over feed pin tenter from Tsuji dyeing machine manufacturers. The mode of application was followed according to the given scheme:

Scheme 1: for Simultaneous Pigment dyeing and crosslinking treatments

Fabric testing

The treated fabric specimens were subjected to various physical tests.

Abrasion resistance

The abrasion resistance of treated fabrics was assessed on Martindale abrasion tester (Abrasion machine mark II) according to the standard test method, ASTM D4966-98. The circular specimens were subjected to rubbing action against a standard cross-bred worsted fabric in the form of Lissajous figure (a geometrical shape, Figure 2).

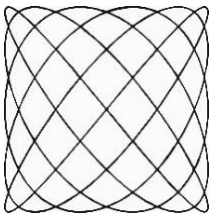

Figure2. Lissajous figure (ASTM, D4996-8)

Pilling assessment

The pilling resistance was determined on I.C.I. Pilling-Box tester according to the method described in British Standard -5811. The degree of pilling of the samples was evaluated by comparing their visual appearance against standard photographs of pilled fabrics or ASTM light box as a subjective grading (1-5 indicating severe to no pills respectively).

Statistical Analysis

The effect of various binders and crosslinking reagents on the abrasion resistance and pilling behavior was statistically analyzed by the general linear model (main effect plots) using Minitab 17 software package.

Results and Discussions

Effect of resin bonded pigment dyeing on abrasion resistance of fabrics

The treatment of various cross-linkers with pigment colouration system on PES/CO fabrics was evaluated for their effect on abrasion and pilling resistance, and the results are summarized in Table 2.

Table 2: Effect of different crosslinking agents and binders on abrasion and pilling resistance of the pigment dyed samples

Samples	Factors		Responses	
	Type of Cross linker	Type of Binder	Abrasion res. (no. of cycles)	Pilling
1	CL1	B1	14,600	3
2		B2	42,710	5
3	CL2	B1	16,220	4
4		B2	27,635	5
5	CL3	B1	23,160	3
;6		B2	17,270	4
7	CL4	B1	24,000	3
8		B2	37,160	4
9	CL5	B1	28,000	3

10		B2	18,275	3

CL.1. Fixapret CPF CL.2. Fixapret F-ECO CL.3.Knittex RCT CL.4 .Arkofix NZF

CL.5. Printofx Fixative WB Liquid B1: Helizarin Binder ET ECO B2: Helizarin Binder CFF

The analysis of variance for the results of the abrasion resistance of fabrics is given in Table 3, according to which the type of cross-linkers and binders had a non-significant effect on the abrasion resistance of fabrics. Figure 3 clearly represents the main effects plot for the abrasion resistance of fabrics, attained by the application of different crosslinking agents and binders. The figure shows that majority of fabrics were found to be adversely affected by resin finishing, with the exception of CL4**.** As regards the type of binders, the effect of B2 appeared to be less intense than B1. Figure 4 illustrates the individual abrasion behavior of all the fabrics of dyed and treated with various crosslinking agents and the binders as well.

Table 3. Analysis of variance for abrasion resistance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	5	190910025	38182005	0.54	0.744
Type of Crosslinkers	4	128059535	32014884	0.45	0.770
Type of Binders	1	62850490	62850490	0.89	0.400
Error	4	283293335	70823334		
Total	9	474203360	665113855		

*Statistically significant at P value 0.05

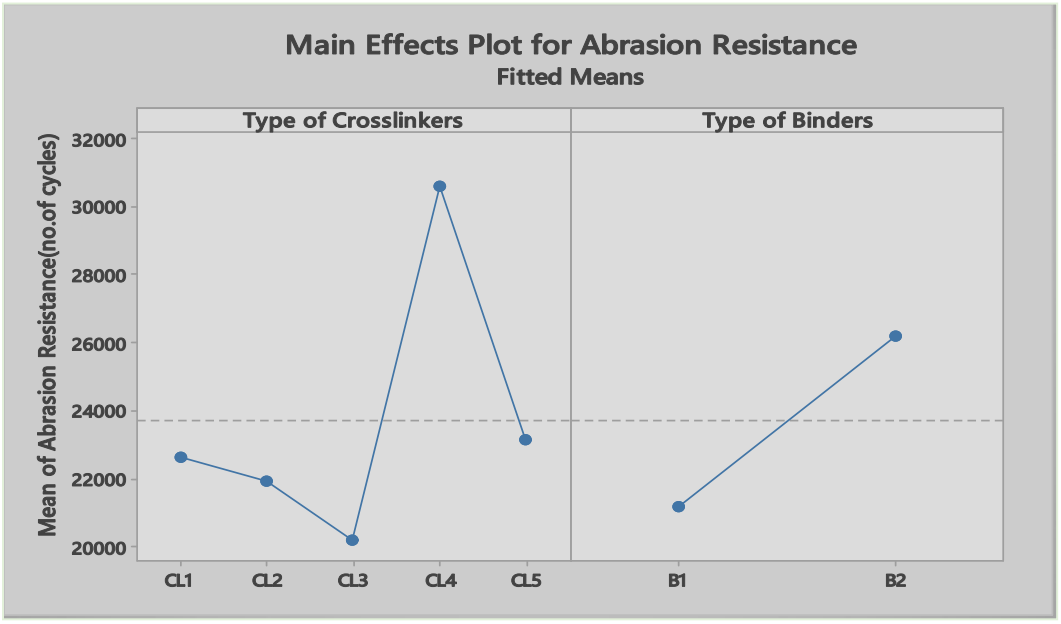

Figure 3 : Main effects plot for abrasion resistance

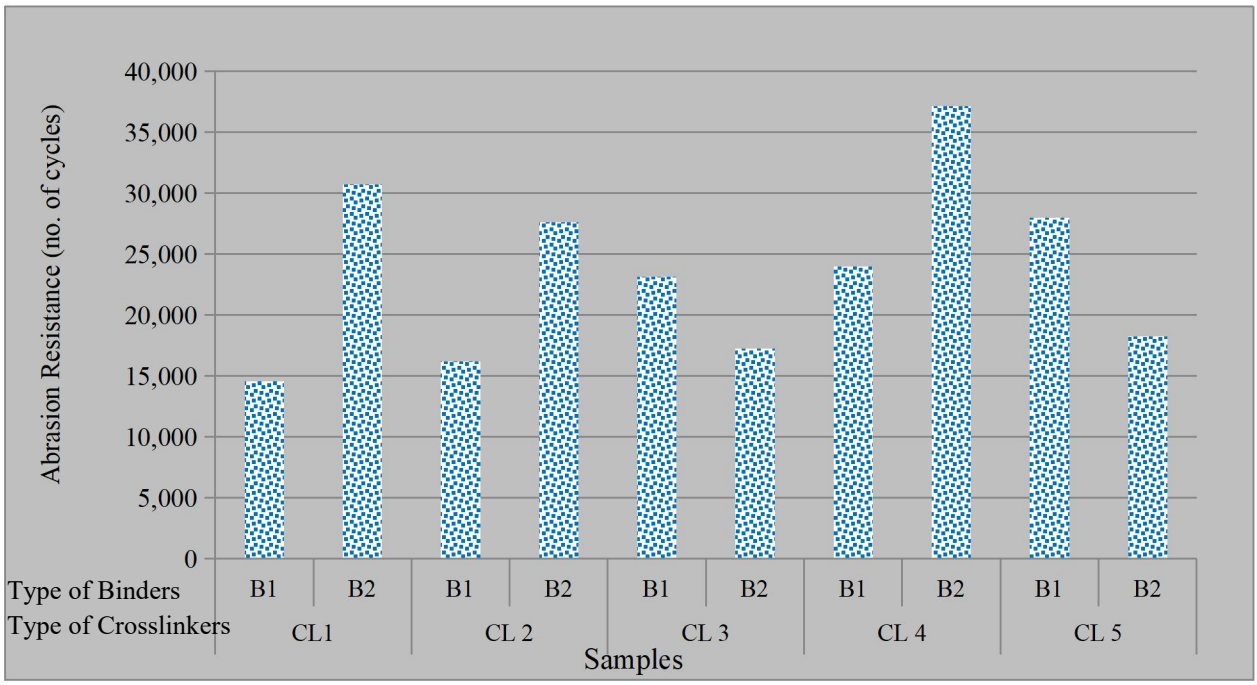

Figure 4: Effect of crosslinking agents on abrasion resistance

In the current study the abrasion resistance of resin treated PES/CO fabrics with pigment colouration though adversely effected by some crosslinkers but few of these showed a very good response irrespective of the binder systems. The fabric treated with Arkofix NZF cross linker (CL4) and acrylic binder 2, abraded at maximum number of cycles. The acrylate copolymer binder forms

a macromolecular network of three dimensional structure which further strengthened with additional crosslinking of a formaldehyde free DHEU. The resinous film formed, thus well resisted the rubbing action of component fibers and provoked significant improvements in abrasion.

The visual assessment of the fabric's abrasion behavior exhibited the maximum change in decreasing order of abrasion resistance by printofix fixative WB liquid, a methyl melamine compound. The binder film on the surface of the fabric was removed by rubbing action, hence distorting its appearance by exposing the upper layer. The considerable loss in strength and abrasion resistance of cross linked fabrics with multifunctional DMDHEU and DHEU have been found (Lickfield et al., 2000). The higher tendency of abrasion can be attributed to the embrittlement of the surface, resulted by additional crosslinking of the binder film.

Effect of resin bonded pigment dyeing on Pilling resistance of fabrics

The pilling grades that are affected by of crosslinkers and binders are displayed in Table 2. The fabrics treated with CL1 and CL2 attained the maximum value of grade 5, indicating no signs of pilling on the surface of the fabric. The fabrics treated with the cross linkers, CL3 and CL4, both modified DHEU, tended to generate partially formed pills. The analysis of variance for the same property is given in Table 4, according to which a non-significant effect of the crosslinkers was found on pilling resistance. The effect of binder type was highly significant on the plling grdes. Figure 5, represents the main effects plot for rate of pilling.

The results show degrading trend of pills formation induced by some crosslinkers particularly CL5. The overall pilling performance of CL5 showed adverse response on pilling property with a statistically significant change. As regards the performance of binders, again the mean pilling rank of B2 was higher as compare to B1. The individual performance of concurrently dyed and crosslinked PES/CO fabrics regarding pilling grades is clearly evident in Figure 6 in which, the highest grades were gained by crosslinking agent, CL 2.

Table 4. Analysis of variance for pilling resistance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	5	5.100	1.0200	4.08	0.099
Type of Crosslinkers	4	2.600	0.6500	2.60	0.189

Type of Binders	1	2.500	2.5000	10.00	0.034*
Error	4	1.000	0.2500		
Total	9	6.100	3.4		

*Statistically significant at P value 0.05

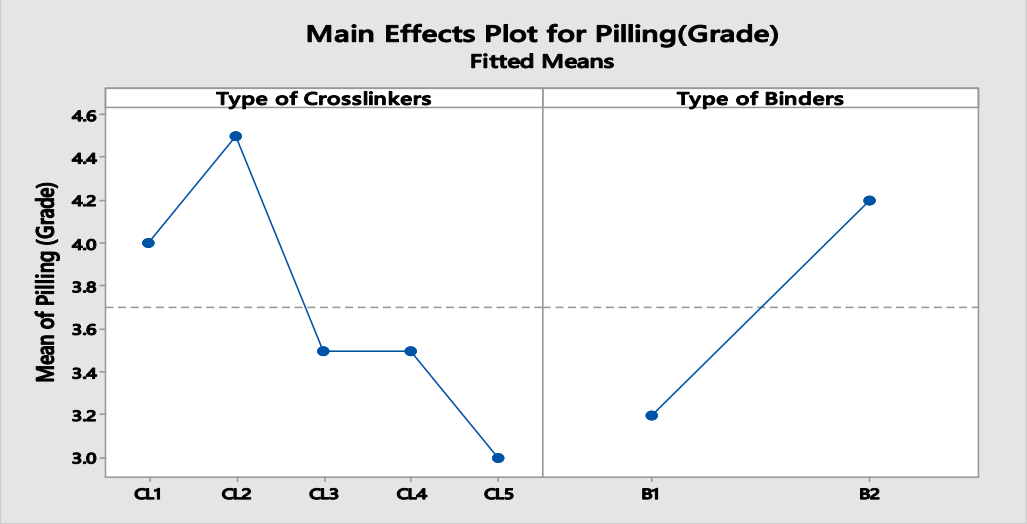

Figure 5 : Main effects plot for Pilling grades

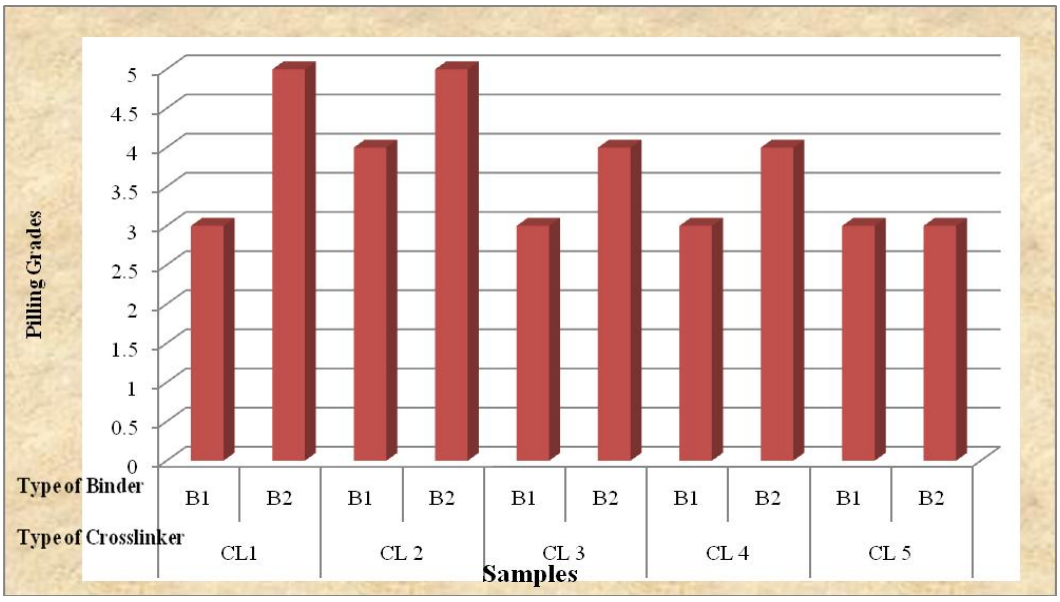

Figure 6: Effect of crosslinking agents on pilling performance

In general the pilling behavior showed a decreased resistance of PES/CO fabrics with the resin bonded dyeing and acrylic binder B1. Contrary to that, the incorporation of cross linking agents (DMDHEU and modified DHEU) with acrylate copolymer binder no.2 in pigment dyeing formulations resulted in an excellent pilling resistance properties to PES/CO fabric. This binder with two of the crosslinking agents developed only a partially formed pills or no pilling at all. The reason might be the strong cross linking effects of these chemicals which resisted the protruding fibers to cling on the surface of the substrate by strong polyester filaments and resin coating. The results concur with those of Schindler & Hausar (2004) according to which, some durable press finishes and polymeric coatings can be applied to fabrics for reducing the pilling tendency.

Conclusions

- The incorporation of cross linking agent (modified DHEU) and acrylate copolymer binder in pigment colouration system provoked an excellent pilling resistance to PES/CO fabric.
- The visual assessment of the fabrics' abrasion and pilling behavior revealed a prominent reduction order of resistance by one of a very low formaldehyde crosslinker (composed of a highly etherified methyl melamine compound).
- The process of cross linking could retained the desirable abrasion resistance and pilling grades of PES/CO fabrics by the application of formaldehyde free cross linker (DHEU) in an optimum ratio of 100g/L, magnesium chloride 20g/L, pigment/ binder 50: 200g/L along with a small quantity of dispersing agent.
- The treatment with modified dihydroxy methylene urea (100g/L) and acrylate co-polymer binder at 50/200 g/L ratio induced a desirable abrasion resistance in P/C fabrics.

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