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Colour Fastness Properties of Polyester/Cotton Fabrics Treated with Pigment Orange and Various Functional Finishes

SHABANA RAFIQUE[1], SHAHNAZ PARVEEN KHATTAK[1], TANVEER HUSSAIN[2], BASHIR AHMAD[3,*] and IMRANA SEEMI[1]

[1]College of Home Economics, University of Peshawar, Khyber Pakhtunkhwa, Pakistan
[2]National Textile University, Faisalabad, Pakistan
[3]Centre of Biotechnology & Microbiology, University of Peshawar, Khyber Pakhtunkhwa, Pakistan

*Corresponding author: E-mail: bashirdr2015@yahoo.com

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This study was conducted to develop an eco-friendly pigment colouration method in combination with functional finishing treatment for polyester/cotton blended fabrics. The advantages of pigment dyeing are manifold, however the rubbing fastness of colours in deeper shades is doubtful, hence it requires further exploration. The undertaken research focused on the assessment of colour fastness characteristics of polyester/cotton fabrics treated with pigment colourants and common functional finishes. The effect of finish type and concentration along with two different approaches of finish application were considered. As regards the effect of finishing techniques, the meta finishing treatments of dyed polyester/cotton fabrics with pigments, provided maximum dry rubbing fastness at both high and low concentrations of finish, while wet rubbing and wash fastness (staining) were found to be better in performance than post finishing method only at low concentration. The most favourable results regarding wet rubbing fastness of fabrics were attained by the treatment of durable water and oil repellent finish. The responses of soft polyurethane, water repellent (NUVA FD) and water/oil repellent (NUVA 3585) on dyed polyester/cotton fabrics were maintained at a good level of wash fastness (shade change). Moreover, desirable wet crocking and washing fastness of fabrics was achieved by incorporating fluorine dispersion (water repellent finish) directly in to the pigment formulations.

Keywords: Functional finishes, Water repellents, Acrylic binder, Organo phosphorous compounds, Wet rubbing fastness.

INTRODUCTION

The blends of cotton/polyester can be ranked among the well recognized textiles by the consumers, both as home furnishings and apparel products. Polyester contributes tensile strength, abrasion resistance and dimensional stability whereas cotton induces good pilling resistance, absorbency and comfort during use. Numerous possibilities of colouring polyester/cellulose fabrics batch wise, continuously or semi continuously have been determined. These contain the combined formulations of disperse dyes with azoic, direct, sulphur, vat and particularly reactive dyes[1]. Two chemically different classes of dyes are currently in use namely disperse for polyester and reactive for cotton, in two bath processes. However, the method is comparatively lengthy and complex. On the other hand, single bath, two-step dyeing process is short, but produces a product with reduced dye ability and undesirable reproducibility[2]. As pigments are not fiber specific, these are applicable to a wide variety of textiles even with different natures and unidentical physico-chemical characteristics like cotton/polyester blends[3].

Pigment dyeing of polyester/cotton blended fabrics can be an acceptable replacement of single-phase dyeing process with disperses/reactive dyes or disperse/vat dyes[4]. One bath pigment dyeing offers considerable savings in cost, equipment and also in time, energy and water. Another advantage offered by this process is the possibility of obtaining solid shades on all types of fibrous blends with one class of dye, in one operation[5].

Pigment dyeing is more beneficial, as compared to other conventional dyeing systems since the former can incorporate various finishes in the same formulation without any ecological hazards[6]. This attribute of pigment dyeing can be used to attain important functional characteristics in the substrate with the co-application of various finishing chemicals. The functional finishing technology is based on textile treatments by directly incorporating chemicals to textiles, such as flame retardants, water repellents, oil repellents, antimicrobial agents, UV absorbers, soil and stain removals and handle modifiers *etc.*[7]. Though, the chemical finishing comprises all the processes after dyeing/printing that induce acceptable properties to the

textile substrate, yet, the most important responsibility of dyers is the enhanced colour fastness properties along with many other requirements of the customers[8]. The American Association of Textile Chemists and Colourists have developed nearly thirty test procedures to assess the fastness of a coloured item of which the commonly used tests consist of wash, light, perspiration, dry cleaning, abrasion and heat[9,10].

The present study aims at finding a compatible pigment colouration system, incorporated with various functional finishing reagents for cotton/polyester blended fabrics with desirable colour fastness properties (stability to laundering and rubbing action). The washing and rubbing fastness results were compared with post application of functional finishes on the conventionally pigment dyed polyester/cotton blended fabrics. The feasibility of mode of applications and the other parameters was checked by the minitab statistical software using general linear model.

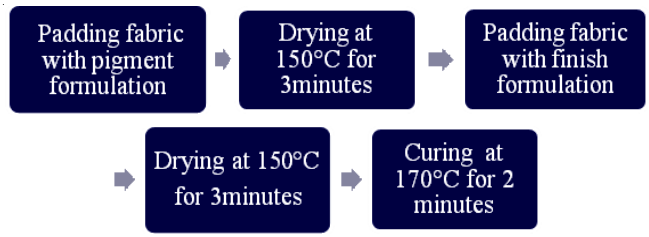
EXPERIMENTAL

Fabric: The medium weight polyester/cotton fabric, comprising 65/35 blend, woven in 83 ends and 53 picks per inch ratio with areal density of 108 g/m^2 was used in the current research project. The greige fabric was de-sized by industrial pad batch method, while scoured and bleached by pad-steam method before dyeing and finishing.

Pigment and auxiliaries: The pigment orange, helizarine binder CFF (an acrylic dispersion) 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.

The detail of the finishing reagents is given in Table-1.

Mode of application for pigment dyeing/finishing: Pigment colouration and application of functional finishing chemicals was carried out on laboratory padder model VPM-250, from Nippon-bashi, Japan. The drying and curing was done on an over feed pin tenter of model number OPT-1 from Tsuji dyeing machine manufacturing company, Ltd. The fabrics were padded by double-dip-double-nip-technique with a wet pick up of 70 % with an aqueous formulation including, pigment colourant (50 g/L), Helizarin binder CFF (200 g/L) and setamol dispersing agent (1-2 mL/L).The two modes of application for dyeing and finishing were followed according to the sequence 'a' and 'b' respectively.



(a) Post finishing pigment dyeing

(b) Simultaneous pigment dyeing and finishing

Testing (colour fastness)

Washing fastness (shade change and staining): Colour fastness to washing was tested on Launder-o-meter in accordance with the AATCC-TM 61[11] standard method. The specimens were evaluated for shade change of dyed fabric and staining against untreated fabric using standard grey scale.

Rubbing fastness (wet and dry): Colour fastness to wet and dry rubbing was assessed on crockmeter according to the standard test method, AATCC-08[12].

The effect of various finishes, concentrations and application method on colour fastness characteristics was statistically analyzed by the general linear model using Minitab 17 software package.

RESULTS AND DISCUSSION

The colour fastness properties of the reference *i.e.* dyed fabric without treatment is given in Table-2. The summary of the results of post and meta finished polyester/cotton fabrics is given in Table-3.

TABLE-1
TYPE OF FINISHES

S. No.	Commercial name/Source	Type of finish	Chemical nature
F1	Pekoflame HSD (Clariant)	Flame retardant	Inorganic salts
F2	Pekoflame OP (Clariant)	Flame retardant	Organic phosphorous compound
F3	Nuva F D liquid (Clariant)	Water repellent finish	Dispersion of a fluorine compound
F4	Nuva 3585 (Clariant)	Oil and water repellent finish	Dispersion of a fluoro compound
F5	Nuva HPU liquid (Clariant)	Durable water & oil repellent	Dispersion of a fluorine compound
F6	UV SUN CEL LIQ (Huntsman chemicals)	UV absorber	Oxalanilide
F7	Dicrylan BSRN (Huntsman chemicals)	Handle modifier & stain release finish	Soft polyurethane emulsion
F8	Hand building (BASF chemicals)	–	Polyurethane

TABLE-2
COLOUR FASTNESS PROPERTIES OF REFERENCE FABRIC

Reference*	Pigment/Binder conc. (g/L)	Colour fastness			
		Dry rubbing fastness	Wet rubbing fastness	Washing fastness (SC)	Washing fastness (ST)
1	50/200	3	2.5	4.5	4

*Dyed sample without treatments.

TABLE-3
EFFECT OF DIFFERENT FUNCTIONAL FINISHES (TYPES, CONCENTRATIONS AND APPLICATION METHODS) ON THE COLOUR FASTNESS PROPERTIES

Sample	Factors			Responses			
	Application technique	Type of finish	Finish conc. (g/L)	Dry rubbing fastness	Wet rubbing fastness	Washing fastness SC	Washing fastness ST
1	Post Finish Method	F1	500	3/4	2.0	4.0	4.0
2			300	3.0	2.0	4.0	4.0
3		F2	300	4.0	2.0	4.0	4.0
4			200	3/4	2.0	3/4	4.0
5		F3	50	3.0	2/3	4.0	4/5
6			20	3.0	2/3	4/5	4.0
7		F4	50	3/4	2/3	3/4	4/5
8			30	3.0	2/3	4.0	4/5
9		F5	50	3.0	3.0	4.0	4.0
10			30	3.0	2/3	4/5	4/5
11		F6	50	3/4	2.0	3/4	4/5
12			15	2.0	3.0	3/4	4/5
13		F7	40	3/4	2/3	4.0	4/5
14			20	3/4	3.0	4.0	4.0
15		F8	40	3/4	2.0	4.0	4.0
16			20	3/4	2.0	4.0	4.0
17	Meta Finish Method	F1	500	3.0	2/3	4.0	4.0
18			300	3/4	2/3	4.0	4.0
19		F2	300	3/4	2/3	4.0	4.0
20			200	3/4	2.0	4.0	4.0
21		F3	50	3/4	2.0	4/5	4/5
22			20	3/4	2/3	4.0	4.0
23		F4	50	3/4	2/3	3/4	4.0
24			30	3/4	2/3	3/4	4/5
25		F5	50	3/4	2/3	4.0	4.0
26			30	3/4	3/4	3/4	4.0
27		F6	50	3 /4	2.0	3/4	4/5
28			15	3/4	2.0	3/4	4/5
29		F7	40	3/4	2/3	4.0	4.0
30			20	3.5	2.0	4.0	4/5
31		F8	40	4.0	2.0	4.0	4.0
32			20	3.5	2.5	4.0	4/5

Effect of different functional finishes on dry rubbing fastness: The analysis of variance (ANOVA) for results of dry rubbing fastness of finished fabrics is given in Table-4, which shows that the effect of application methods of finishes on the dry rubbing grades of treated fabric was found to be statistically non significant. As far as the finish types and their concentrations are concerned, yet again the effect was not found statistically significant on the dry rubbing fastness of treated fabrics.

The main effects plot for dry rubbing fastness is given in Fig. 1 which represents an increasing trend in dry rubbing fastness of meta finished, dyed polyester/cotton fabrics. As far as the type of functional finishes is concerned, an increasing and decreasing trend in fastness rating was observed. Overall, Pekoflam OP liquid flame retardant (F2) and a hand building finish, poyrethane (F8) produced the highest rubbing grades. The effect of concentration of finishes showed a highly significant effect on the dry rubbing fastness of treated fabrics. Fig. 2 shows dry rubbing fastness of the individual samples, treated with different types and concentration of finishes and different methods of application. In a study conducted by Khattak *et al.*[13], the post treatment of polyurethane finish on cotton fabrics dyed with natural colourants (marigold flower extracts) produced desirable wash and dry rubbing fastness. However, the fastness of the treated fabric was found to be fair regarding wet rubbing performance.

TABLE-4
ANALYSIS OF VARIANCE FOR DRY RUBBING FASTNESS OF DYED & FINISHED POLYESTER/COTTON FABRICS

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	11	1.7917	0.1629	1.48	0.217
Finishing method	3	0.5104	0.1701	1.54	0.235
Finish type	7	0.8917	0.1274	1.15	0.371
Finish concentration	1	0.2604	0.2604	2.36	0.140
Error	20	2.2083	0.1104	–	–
Total	31	4.0000	0.8312	–	–

*Statistically significant at P value, 0.05

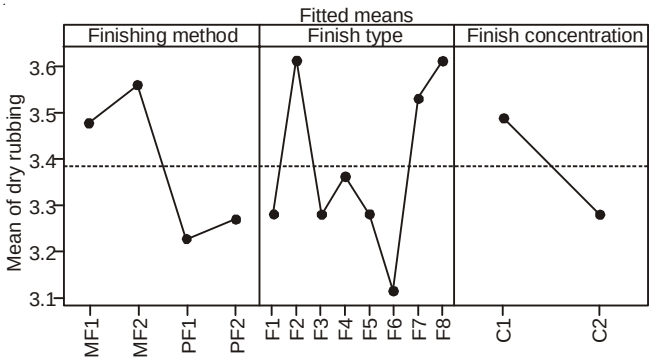


Fig. 1. Main effects plot for dry rubbing fastness of finished polyester/cotton fabric. MF1 & MF2: Meta finishing at high& low conc. PF1 & PF2: Post finishing at high & low conc.

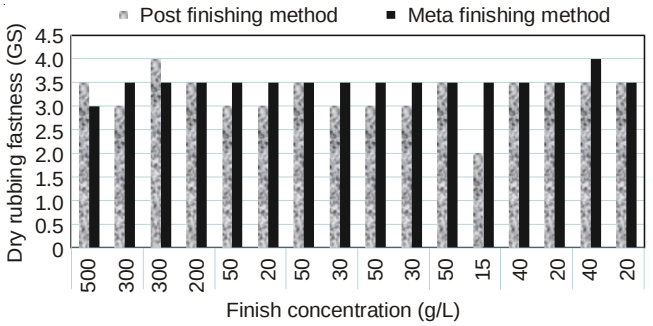


Fig. 2. Effect of functional finishes in different concentrations and application methods on the dry rubbing fastness of polyester/cotton fabrics

The meta finishing treatment of dyed polyester/cotton fabrics with flame retardants, rendered a slight reduction in the colour fastness grades at high concentration. Pekoflam HSD and Pekoflam OP liquid flame retardant had a beneficial effect on the dry rubbing fastness amazingly, at high concentration. Probably, the finishing reagent in combination with acrylic binder and pigment formed a network of protective layer on the substrate and provided the resistance against rubbing.

Effect of different functional finishes on the wet rubbing fastness: The data with respect to wet rubbing fastness was statistically analyzed by (ANOVA) and the results are displayed in Table-5. The results indicated that the effect of different methods, types and concentrations of finishes, used for polyester/cotton fabrics was found to be statistically insignificant on wet rubbing fastness.

The main effects plot for wet rubbing fastness of polyester/cotton fabrics is shown in Fig. 3, according to which the simultaneously dyed and finished polyester/cotton fabrics had better fastness grades than post finishing method at high concentration. However, at low concentration an adverse effect on rubbing fastness was observed. The wet rubbing fastness of pre dyed fabrics was found to be slightly better compared to the meta finished fabrics. The effect of concentration on wet rubbing fastness was statistically significant at lower range. As far as the individual assessment is concerned, the most favourable results with respect to wet rubbing was attained by the simultaneously dyed and finished fabric with NUVA HPU durable oil and water repellent liquid (Fig. 4). The wet rubbing fastness of UV treated (F6) fabrics upgraded from 2 to 3 G S with meta and post finishing method respectively at low concentration. Similarly, the combined application of polyurethane finish (F7) with pigment dyeing on polyester/cotton fabric was rated at the maximum fastness level. As regards the wet rubbing fastness, the simultaneously dyed and finished/meta finished polyester/cotton fabric gave better response than post finishing treatment of flame retardants on fabrics.

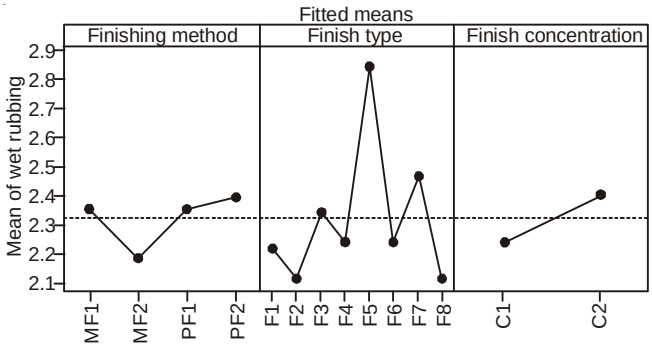


Fig. 3. Main effects plot for wet rubbing fastness of finished polyester/cotton fabric

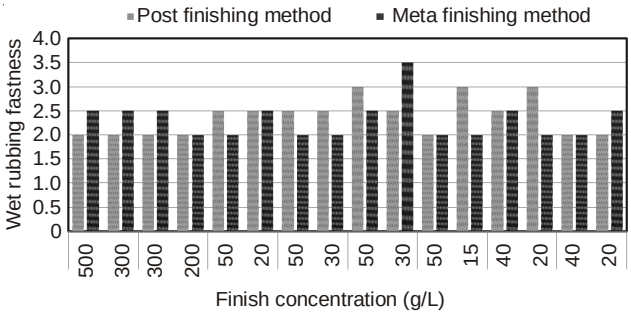


Fig. 4. Effect of functional finishes in different concentrations and application methods on the wet rubbing fastness of polyester/cotton fabrics

It seemed that increasing the concentration of finish in combined formulation could not develop an appropriate binder film on the finished polyester/cotton fabric. In the current study, a commercially desirable crocking fastness was achieved by

TABLE-5
ANALYSIS OF VARIANCE FOR WET RUBBING FASTNESS OF DYED/FINISHED FABRICS

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	11	1.9479	0.17708	1.28	0.305
Finishing method	3	0.1042	0.03472	0.25	0.860
Finish type	7	1.1417	0.16310	1.18	0.359
Finish concentration	1	0.1667	0.16667	1.20	0.286
Error	20	2.7708	0.13854	–	–
Total	31	4.7188	0.68011	–	–

*Statistically significant at P value 0.05.

incorporating fluorine dispersion with extremely durable water repellent quality in pigment dyeing formulation at high concentration. The improvement occurred probably due to better orientation of fluorine dispersion, coupled with pigment colourant on the fabric surface. The same beneficial effects of combine pigment dyeing and finishing were observed by Cao[14].

The dry rubbing fastness of polyurethane treated fabric was found to be improved irrespective of the concentration as compared to the reference fabric. However, at low concentration, the level of wet rubbing fastness was better which is an evidence of the fact that the degree of improvement from any of the finishing technique is strongly dependent on the appropriate amount of the finishing chemical in particular formulation. The maximum value of polyurethane treated polyester/cotton fabrics suggests that it had developed good pad/liquor stability in the formulation, yielding an increased resistance in fabric against wash and rubbing fastness tests. A consistent and uniform film formation tended to strengthen the binding force between polyurethane dispersion and pigment/fabric matrix. The results are supported by the report given by Mike[15] according to which polyurethane dispersions have excellent chemical and scrubbing resistance as coating materials in several products.

Effect of different functional finishes on the wash fastness (shade change): Table-6 comprises results, regarding the analysis of variance of wash fastness results (change in colour). The data reveals that only the effect of finish type was found statistically significant, while the finishing methods and different concentrations had no effect on the shade change after washing treatment. The main effects plot for wash fastness (shade change) of finished polyester/cotton fabrics is shown in Fig. 5. The post finishing of fabrics produced better results at high concentration than meta finishing method, whereas, the remaining observations were found to be consistent with an acceptable performance of wash fastness level. As regards the effect of assorted functional finishes on colour change of treated fabrics, the minimum shade change occurred with Pekoflam OP liquid flame retardant (F2) and maximum by polyurethane finish. The level of wash fastness remained the same irrespective of the different concentration of finishes. The individual effect of functional finishing reagents with pigment colourants on the wash fastness (shade change) properties of polyester/cotton fabrics is given in Fig. 6. The fastness was decreased at high concentration, while at lesser concentration it was found to be increased with post treatment of F3, water repellent finish.

Effect of different functional finishes on the wash fastness (staining): The analysis of variance of the data for fastness (staining) to adjacent specimen is mentioned in Table-7 according

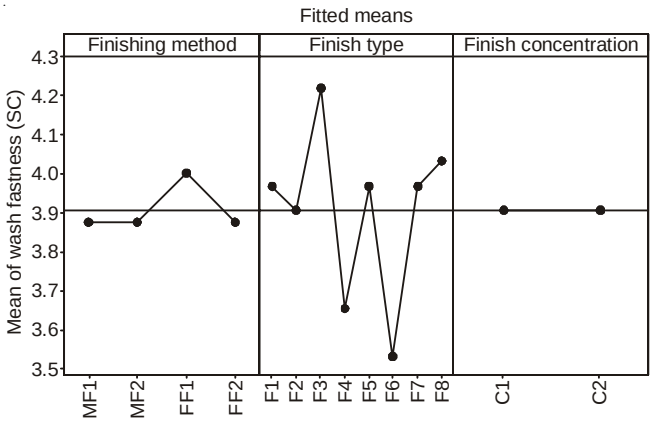


Fig. 5. Main effects plot for washing fastness (SC) of finished polyester/ cottonfabrics

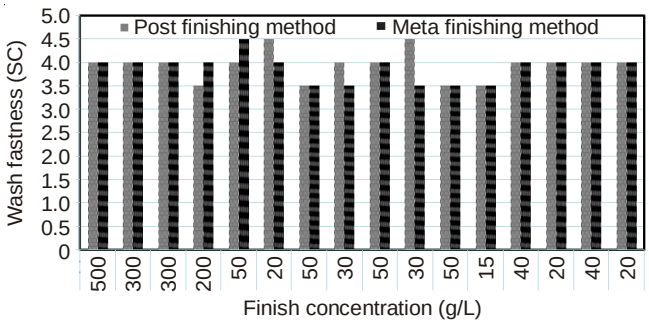


Fig. 6. Effect of functional finishes in different concentrations and application methods fabrics on the wash fastness (shade change) of polyester/cotton

to which there was no clear evidence of statistical significance (p-value 0.05 equals to tabulated value). The post finishing method was found to be better than meta finishing method. As regards the concentration of finishing chemicals no difference was assessed in the fastness grades. Fig. 8 displays individual results with respect to wash fastness (staining) of polyester/ cotton fabric in which a steady GS value (4-4.5) was obtained with post and meta finishing methods at both concentrations. Fig. 7 displayed the main effects plot for the wash fastness (staining) according to which the meta finishing method produced average results. Post finishing method was found to be better than meta finishing method. As regards the concentration of finishing chemicals no difference was assessed in the fastness grades. Fig. 8 displays individual results with respect to wash fastness (staining) results of polyester/cotton fabric in which a steady GS value (4-4.5) was obtained with post and meta finishing methods at both concentrations.

TABLE-6
ANALYSIS OF VARIANCE FOR WASH FASTNESS (SC) OF DYED/FINISHED FABRICS

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	11	1.65625	0.150568	2.83	0.021
Finishing method	3	0.06250	0.020833	0.39	0.760
Finish type	7	0.96250	0.137500	2.59	0.045*
Finish concentration	1	0.00000	0.000000	0.00	1.000
Error	20	1.06250	0.053125	–	–
Total	31	2.71875	–	–	–

*Statistically significant at P value 0.05.

TABLE-7
ANALYSIS OF VARIANCE FOR WASH FASTNESS (ST) OF DYED/FINISHED FABRICS

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	11	1.01823	0.09257	2.03	0.081
Finishing method	3	0.14323	0.04774	1.05	0.393
Finish type	7	0.79792	0.11399	2.50	0.051*
Finish concentration	1	0.01042	0.01042	0.23	0.638
Error	20	0.91146	0.04557	–	–
Total	31	1.92969	0.31029	–	–

*Statistically significant at P value 0.05

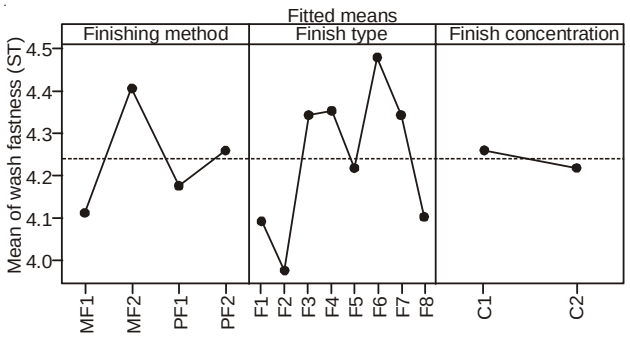


Fig. 7. Main effects plot for washing fastness (staining) of finished polyester/cotton fabric

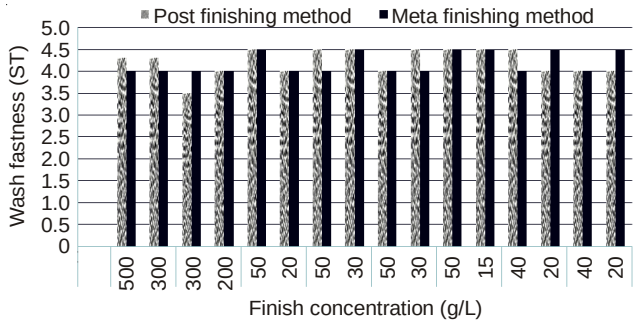


Fig. 8. Effect of functional finishes in different concentrations and application methods on the wash fastness (staining) of polyester/cotton fabrics

The comparative analysis of colour fastness of post and meta treated polyester/cotton fabrics with water repellents were found to be maintained at the same level of performance. Though, the extremely durable water and oil repellent properties had improved the colour fastness grading but, not with a significant difference. In case of wash fastness, a negligible shade change and staining to adjacent cloth was observed with NUVA 3585 water repellent treatment on dyed polyester/cotton fabric.

The results revealed that the colour fastness properties of UV absorber treated fabrics at the recommended range of concentration imparted low fastness grades, particularly the shade change after wash treatment was remarkably effected. It was observed that with both the application techniques *i.e.* post treatment of finish with pigment dyeing or incorporation in the same stock formulation, the results remained consistent.

As far as the staining to adjacent cloth is concerned, the results were found to be very good except in one case. The degradation in fastness probably occurred due to the high quantity of finishing reagent and the binder on the substrate. The colour crocked off due to thick polymer film and caused staining. In another study conducted[16] a novel approach for UV blocking of cotton fabric was developed using sol-gel method. The for-mation of a thin layer of compound of titanium (UV absorber) on the cotton surface enhanced UV protection properties.

Conclusions

Colour fastness to crocking is a complex phenomenon which needs special consideration. Many times, the apparent loss of colour can be attributed to the surface modification in the fabric, resulting from abrasion action during laundering. A commercially desirable crocking fastness can be achieved by incorporating various functional finishes in pigment dyeing formulations in appropriate amount. The fabrics treated with Pekoflam OP liquid flame retardant and polyurethane (hand building finish) showed the best performance regarding dry and wet rubbing fastness. The treatment of soft polyurethane, water repellent (NUVA FD) and the water repellent in combination with oleophillic finish (NUVA 3585) treatment on dyed polyester/cotton fabrics had showed a positive impact on wash fastness by maintaining a good level of fastness for shade change.

The overall effect of finishing reagents on pigment dyed polyester/cotton fabrics showed that best results were obtained with NUVA-HPU liquid, a durable water and oil repellent finish and polyurethane, the handle modifying treatment. The application of organo-phosphorus flame retardant compound on pigment dyed polyester/cotton fabric could not withstand wet treatment, therefore, it is eminently suitable for those products which did not require frequent washing.

The colour fastness evaluation on the basis of modes of applications revealed that generally the meta finishing pigment dyeing of polyester/cotton fabrics, rendered maximum dry rubbing fastness, wet rubbing fastness and negligible staining on the accompanying cloth after wash treatment.

In general the effect of finish concentration indicated that dry rubbing fastness was better at high while, wet rubbing at lower range of concentration. Similarly the finishing reagents responded well at high concentration for wash fastness (shade change).

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