EVALUATION OF FLEXURAL RIGIDITY AND ABRASION RESISTANCE OF POST AND META-FINISHED PIGMENT DYED P/C FABRICS

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ABSTRACT

The present study was conducted to explore the pigment colouration system in conjunction with functional finishing treatments for polyester/cotton (P/C) blended fabrics; further to assess its effect on flexural rigidity and abrasion resistance. The simultaneous finishing and pigment dyeing is more economical than conventional method, since, more energy can be conserved by using same machinery for dyeing, finishing, drying and curing. Furthermore, elimination of post wash treatment in this method caused little or no contamination. Despite its manifold advantages, the rubbing fastness and fabric stiffness of pigment dyed fabrics in deeper shades is doubtful, hence needed further exploration. The effect of various parameters i.e. finish type and concentration were taken in to consideration along different modes of application on the abrasion resistance and flexural rigidity of fabrics. As regards the type of finish, the effect of U-V absorber and Pekoflam OP flame retardant (organic phosphorous compound) on fabric stiffness was found to be advantageous, providing it a soft texture. The post-application of fluorine based liquid water repellent finish (NUVA-FD) at high concentration well resisted the abrasion rubs. The optimized formulation, 50g/L of polyurethane had improved the abrasion resistance of fabrics. Generally, the finishing of polyester/cotton fabrics with Pekoflam OP flame retardant and water repellent chemicals induced resistance against heavy brunt of abrasive action and a desirable flexural rigidity in fabrics. As regards the meta-treatment of soft polyurethane (hand building) finish, the dyed fabric showed an inversely proportional relation i.e. decrease in abrasion resistance with increase in finish concentration.

KEYWORDS: *flexural rigidity, abrasion resistance, meta-finishing, polyurethane, water repellent, UV absorber*

INTRODUCTION

The traditional method of exhaust dyeing for Polyester/Cotton (P/C) blends is to dye each constituent separately under its optimum conditions, i.e. in a two-phase process. Previously, several attempts have been made to reduce this to a single-phase procedure with the purpose of confronting the issues of productivity and environment hazards. The Imperial Chemical Industries (ICI) has established a quick one-bath method using assorted combination of disperse and reactive dyes[1,2]. Though numerous conventional and innovative approaches have been used for dyeing P/C blended fabrics, with its satisfactory and adverse colouring effects, yet, it poses a challenge for the textile industrialists to improve its dye-ability and performance

properties. The challenges can be met with pigment dyeing, in which the affinity to various substrates for this colouration system is adaptable. As pigments are not fibre specific, these are applicable to a wide range of textiles even with different characters and un-identical physico-chemical characteristics like P/C blends[3].

Pigment dyeing of P/C blended fabrics can be a satisfactory substitution of single step dyeing with disperse/reactive or disperse/vat dyes[4].The colouring process incorporated cross-linkers and binders, attaches the pigment to the substrate. But, on the other hand it has been observed that, it increases the stiffness level of particularly deeper shades of fabrics[5]. To overcome these deficiencies, the fabric may need a specific treatment with pigmentation other than conventional methods, such as application of functional finishes. Functional finishing technology is presently considered as an explicit technology that allows the textiles a high-grade functions by contributing value to a particular characteristic, function or effect. Recently, the techniques of functional finishing are employed in textile treatments by combining the chemicals contemporarily with the dyeing formulations. These reagents with modified functionalities include fire retardants, antimicrobial agents, U-V blockers, hand builders and water repellents, etc.[6].

Textile flame retardancy is generally needed in work clothes, protective clothing, military uniforms and various furnishings items. The flame retardant treatment is one

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of the most applicable methods, which increase thermal resistance of cotton to ignition, reduces flame propagation rate, raises ignition temperature and inhibits continuous burning[7]. The physical properties like surface texture and durability of fabric can be least affected if the proper selection of the flame retardant be carried out[8].

Hand builders are the chemicals which impart desirable draping quality to the substrate. As a finishing agent the film of latex can be used to engineer the fabric's hand, as the polymers with a very high glass transition temperature (Tg) contribute stiffness properties without adding weight. The poly methyl methacrylate latexes converted into very stiff films after dying so it does not take much add-on to stiffen a fabric. On the contrary, ethyl or butyl acrylate polymers converted into softer, flexible films after drying. Another class of finishes i.e. water and oil repellents, are generally available as fluoro-chemical repellents are fluorine-containing vinyl or acrylic polymers[9]. The effect of fluorocarbon finishing chemical on the pigment dyed fabrics had an advantageous effect on the crock and wash fastness properties of cotton fabrics whereas, at higher ratio the dry rubbing fastness was slightly reduced[10]. The application of aqueous fluorocarbon agents imparted the enhanced water and oil repellent characteristics and fabric handle to the cotton fabric in conjunction with dyeing or post treated with exhaustion and pad-dry-cure system[11].

Application of finishes and its effect on various characteristics

The performance of textile fabrics is influenced by their physico-chemical characteristics which are modifiable by the treatment of some finishes. Pigment printed fabrics have some intrinsic properties which assure their multiple application in various fields, however the treatment may originate the problems of deteriorated fabric handle. The pigments are deposited on the surface of the substrate in dispersion form with the assistance of some binding chemical that may cause an increased stiffness level, particularly in deeper shades[12].Flexural rigidity of a fabric can be judged in terms of stiffness of a fabric, which is a simple determination of bending length and weight per unit area in combination and is highly reliant on its thickness[13].. One of the several factors which are responsible for rendering the textile material un-serviceable is its abrasion resistance. The fabric is generally abraded out by the wearing, cleaning or washing procedures which may alter the fabric's appearance, cause fibres or yarns to be pulled out or removes from the surface[14]. Abrasion not only resulted in reduced tensile strength but it also affects the physical appearance of the fabric[15,16].

Keeping in view the afore mentioned textural problems of pigment dyeing, i.e. the harsh handle, the undertaken research focused on the application of pigment dye and functional finishing reagents on the P/C blended fabrics with respect to their minimal adverse effects on flexural rigidity and abrasion resistance.

EXPERIMENTAL

Materials

Medium weight P/C fabric having 65/35 blend ratio and areal density of 108 g/m2 was used for dyeing and finishing. The gray fabric was de-sized by industrial pad

Table 1: Finishing reagents used in this study.

S.No.	Trade name/Code	Description/Chemical Constitution	Origin
1	Pekoflam HSD Liquid (F1)	Flame Retardant /An-organic salts	Clariant International Ltd
2	Pekoflam OP liquid (F2)	Flame Retardant/ Organic Phosphorous compound	Clariant International Ltd
3	NUVA F D Liquid (F3)	Water Repellent Finish/ Dispersion of a fluorine compound	Clariant International Ltd
4	NUVA 3585 (F4)	Oil & Water Repellent Finish/ Dispersion of a fluorine compound	Clariant International Ltd
5	NUVA HPU Liquid (F5)	Durable Water & Oil Repellent Finish/ Dispersion of a fluorine compound	Clariant International Ltd
6	UV SUN CEL LIQ (F6)	UV Absorber/ Oxalanilide	Huntsman chemicals
7	Dicrylan BSRN (F7)	Handle Modifier & Stain / soft polyurethane emulsion finish	Huntsman chemicals
8	Hand building finish (F8)	---	BASF chemicals

batch method, while scoured and bleached by pad-steam method before dyeing or any other treatments.

Pigment and auxiliaries

The Pigment Orange, Helizarin binder CFF (an acrylic dispersion) and the Setamol-BL dispersing agent were utilized in the current study. The details of the finishing reagents are displayed in Table 1.

Application of Pigment Dyeing and Finishing

Pigment colouration and application of functional finishing chemicals was conducted on a thermosol laboratory padder, model VPM-250, from Nippon-bashi, Japan. The fabric was dried and cured on an over feed pin tenter of model number OPT-1 from Tsuji dyeing machine manufacturing company, Ltd.

The fabrics were padded twice to achieve the wet pick up of 70% with an aqueous formulation containing, orange pigment (200g/L), Helizarin binder (50 g/L), and Setamol dispersing agent (1-2 ml/L). Two approaches for dyeing, finishing and thermos-fixation were followed according to the sequence given in Figure 1 and 2

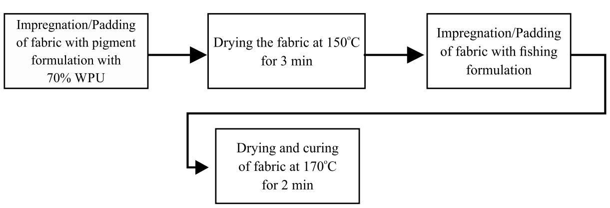

Figure 1.Conventional pigment dyeing & finishing

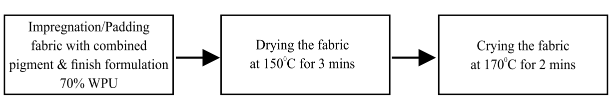

Figure 1.Conventional pigment dyeing & finishing

Physical Testing

All the pigment dyed fabrics treated with post and meta-finishing modes were subjected to the following tests.

(a). Flexural Rigidity

Flexural rigidity was tested on Shirley Stiffness Tester in accordance with the procedure described by ASTM17. A narrow fabric strip (25 mm x 200 mm) was allowed to bend to a fixed angle (41.5o) under its own weight called the bending length, based on cantilever bending fabric principle. After taking the mean bending length, the flexural rigidity (G) was calculated as following:

$G = (1.241 \times W \times C^3 \times (10^{-5})$ in μ joule/m

W= Fabric mass per unit area (g/cm^2).

C = Bending length (mm)

(b). Abrasion resistance

Abrasion behavior of fabric specimens was evaluated on Martindale abrasion tester (Abrasion machine mark II) in accordance with standard test method described by ASTM[18]. The circular specimens of fabric, 38 mm in diameter were subjected to rubbing action under pressure of 14 ounces against a standard cross-bred worsted fabric. The visual examination of specimens was carried out at regular intervals till abrasion (breakdown of two or more threads). The total number of movements required to break the threads in the form of Lissajous figure (a geometrical shape as in Figure 3) was observed and average calculated.

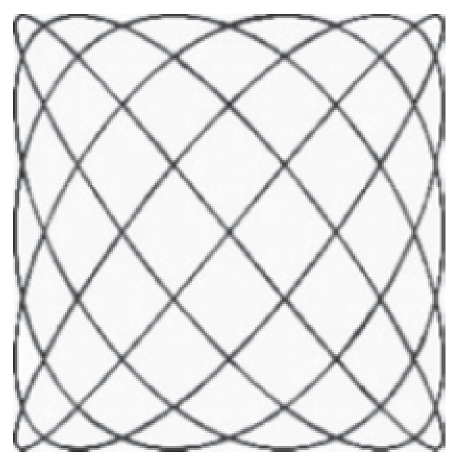

Figure 3. Lissajous figure.

The effect of various finishing reagents, different concentrations and application modes on the abrasion resistance and flexural rigidity was statistically analyzed by the general linear model using Minitab 17 software package.

RESULTS

Effect of functional finishes on the flexural rigidity

The effect of process parameters i.e. various types of functional finishes, their concentration and different application methods on the flexural rigidity of dyed/finished fabrics was determined and the results presented in Table 2. As regards the statistical computation, Table 3 comprises the analysis of variance of the dyed/finished fabrics which shows a non- significant (P-value > 0.05) effect of the finish type, concentrations and application methods on the flexural rigidity of the fabrics. Figure 4displays the main effects plot for the results of flexural rigidity results in that the rate of stiffness was higher with post method at high finish concentration.

Table 2. Effect of types, concentrations and application methods of different functional finishes on the flexural rigidity and abrasion resistance of dyed/finished fabrics.

Sample	Factors			Flexural Rigidity (µ Joule/M)			Abrasion Resistance (no .of rubs)
	Application Method	Type of Finish	Concentra-tion of Finish (g/L)	Warp	Weft	Cumulative (Warp + Weft)	
1	Post Finish Technique	F1	500	23.02	12.38	35.4	42,200
2			300	21.07	11.69	32.76	40,390
3		F2	300	26.71	12.81	39.52	41,000
4			200	20.39	12.09	32.48	40,350
5		F3	50	20.4	3.08	23.48	39,040
6			20	19.74	7.19	26.93	21,080
7		F4	50	26.23	13.14	39.37	45,285
8			30	40.13	13.14	53.27	21,770
9		F5	50	18.78	11.89	30.67	24,080
10			30	16.95	12.45	29.40	16,425
11		F6	50	21.22	9.19	30.41	32,570
12			15	30.59	11.62	42.21	49,320
13		F7	40	25.79	11.42	37.21	17,710
14			20	25.42	11.96	37.38	36,900
15		F8	40	23.03	11.27	34.30	31,265
16			20	27.38	23.38	50.76	41,085
17	Meta Finish Technique	F1	500	23.02	14.2	37.22	23,500
18			300	10.14	13.38	23.52	22,500
19		F2	300	17.38	11.79	29.17	26,000
20			200	23.38	14.01	37.39	68,300
21		F3	50	20.04	10.88	30.90	55,335
22			20	32.91	10.66	43.57	42,400
23		F4	50	18.16	11.79	30.03	42,400
24			30	18.20	12.39	35.83	56,440
25		F5	50	18.47	11.72	37.51	49,950
26			30	18.15	10.19	28.34	31,650
27		F6	50	18.47	12.43	30.50	50,000
28			15	19.41	10.62	30.03	28,600
29		F7	40	23.19	12.64	35.83	41,500
30			20	24.66	12.85	37.51	50,000
31		F8	40	19.09	14.98	34.07	52,690
32				31.27	13.64	44.91	52,200

The same trend was observed with the meta-finishing method also, but in this case the degree of change was not so prominent. As regards the overall effect of finish concentrations, the flexural rigidity was found to be increased at higher range. The data plotted in Figure 5 revealed the individual performance of fabrics for the flexural rigidity of pre-dyed fabrics verses simultaneously dyed and finished P/C fabrics. An inversely proportional relation among the finishes (F1, F3, and F5) and the flexural rigidity of P/C fabric was found.

Table 3. Analysis of variance for flexural rigidity of dyed/finished fabrics

Source	DF	Adj SS.	Adj MS.	F-Value	P-Value
Model	11	685.33	62.30	1.61	0.171
Finishing Method	3	209.58	69.86	1.81	0.179
Finish Type	7	269.00	38.43	0.99	0.464
Finish Concentration	1	28.84	28.84	0.75	0.398
Error	20	773.55	38.68	-	-
Total	31	1458.88	238.11	-	-

*Statistically significant at P value 0.05

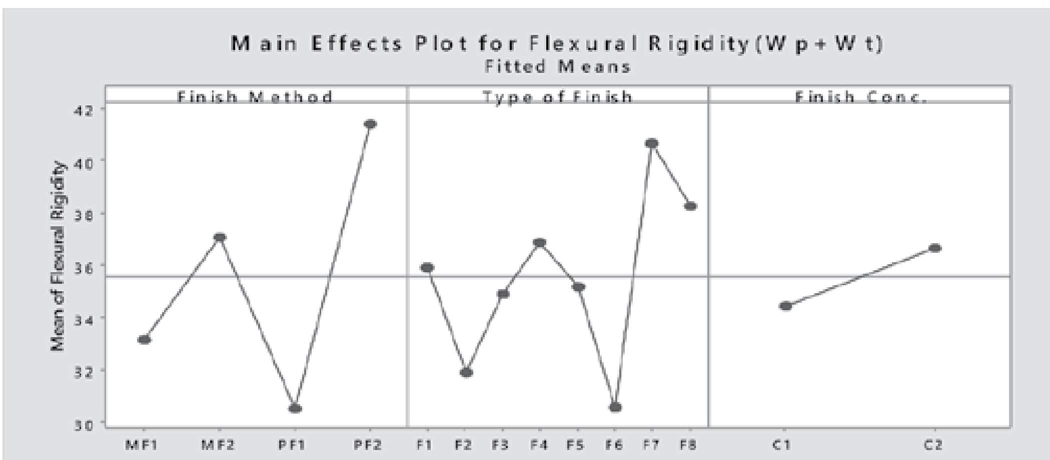

Figure 4: Main effects plot for flexural rigidity of fabrics.

*MF1& MF2: Meta finishing at high & low conc. PF1& PF: Post finishing at high & low conc.

The results displayed that, by increasing the finish concentration, the flexural rigidity of fabrics tended to decrease particularly with the post treatment of NUVA 3585, oil and water repellent finish (F4) and hence, a softer texture achieved.

Effect of different functional finishes on abrasion resistance

The results regarding effect of various finishes in different concentrations and application methods on the abrasion resistance of P/C fabrics are presented in Table 1. The Analysis of variance of the results is displayed in Table 4. It is evident that, the effect of types and concentrations of finishes and different modes of application were found to be statistically insignificant on the abrasion resistance. The main effect plot is displayed in Figure. 6 which indicates the better performance of combined dyed and finished fabrics with various chemicals. As far as the type of finishes is concerned, F3 (NUVA FD water repellent) rendered the highest abrasion resistant to the fabrics while the lowest mean value corresponded to F5 (durable oil and water repellent finish). A little difference in abrasion values was observed among the high and low concentrations of the finishing chemicals used on the sample fabrics. Again the application of Pekoe flame OP liquid (flame retardant finish) on P/C fabric, showed an increase in the number of rubs as compared to the untreated fabric.

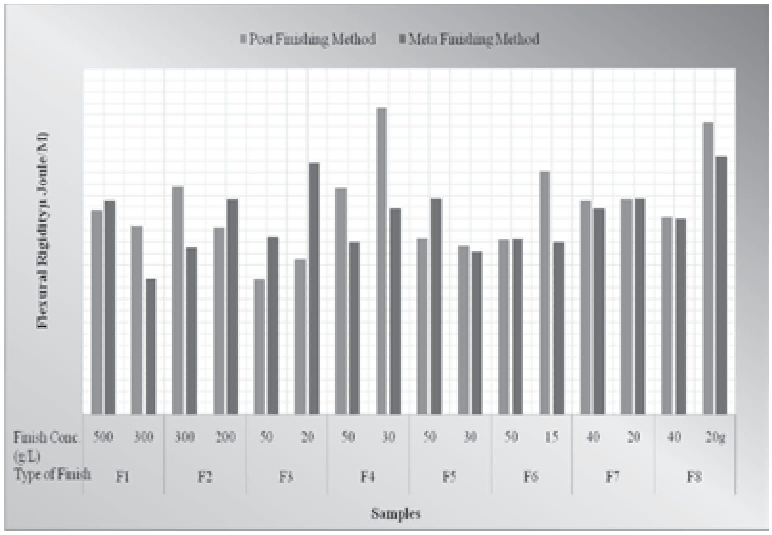

Figure 5: Effect of functional finishes in different concentrations and application methods on the flexural Rigidity of P/C fabrics

Table 4. Analysis of variance for abrasion resistance of dyed/finished fabrics.

Source	DF	Adj SS.	Adj MS.	F-Value	P-Value
Model	11	1965564535	178687685	0.86	0.590
Finishing Method	3	1172863498	390954499	1.88	0.166
Finish Type	7	139102167	19871738	0.10	0.998
Finish Concentration	1	139102167	99344635	0.48	0.498
Error	20	4162612738	208130637	-	-
Total	31	6128177273	896989194	-	-

*Statistically significant at P value 0.05

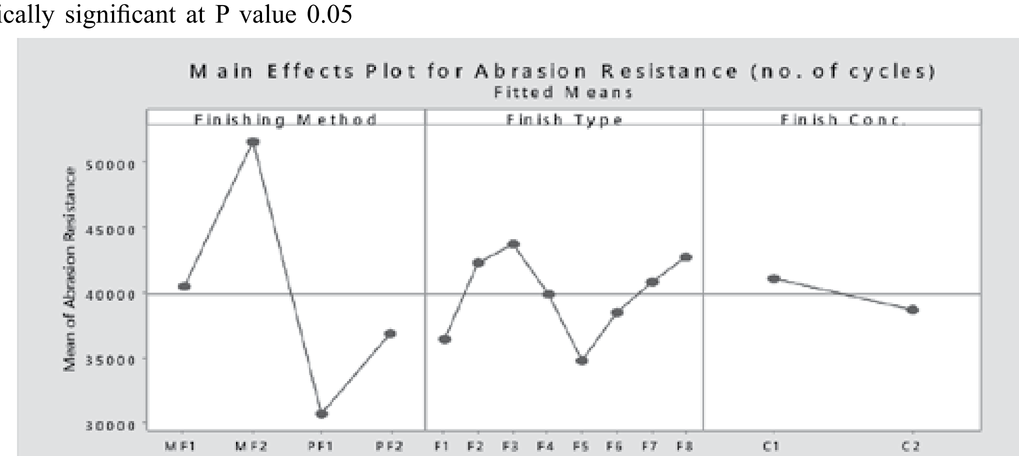

Figure 6: Main effects plot for abrasion resistance of fabrics

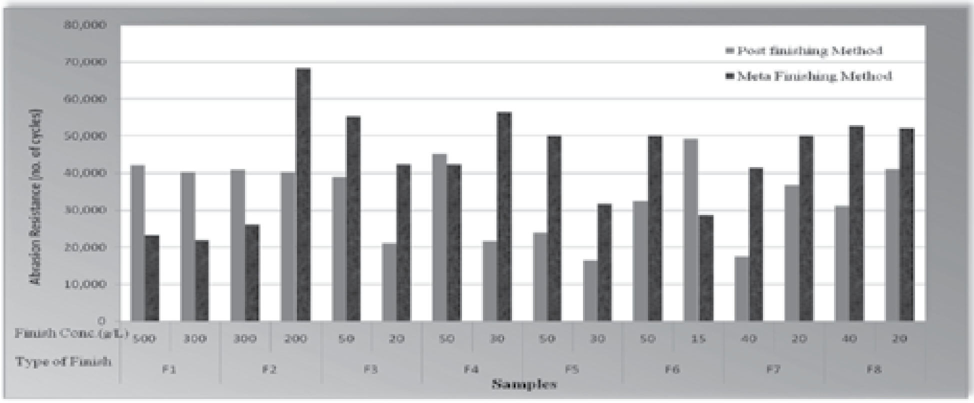

Figure 7: Effect of Functional Finishes in different concentrations and applications method on the abrasions resistance of finished fabrics

Figure 7 presents the individual performance of treated P/C fabrics with respect to abrasion resistance. According to the plotted data the after treatment of pekoflam HSD liquid (F1) brought about positive change in fabrics in the increasing order of abrasion cycles at 300 and 500g/L concentration in the finishing bah. Conversely, the abrasion resistance of meta-finished pigment dyed fabric with the same flame retardant was adversely affected irrespective of the concentration of finish. The fabric wore off at an initial stage of rubbing action. The post application of Peko flam OP liquid flame retardant finish on fabric showed an increase in the number of rubs as compared to the meta- treatment. The post treated pigment dyed fabrics with water repellent finish exhibited the improved performance of fabrics at high concentration of NUVA FD water repellent liquid (F2). However, at low ratio i.e. 20 g/L it was adversely effected by the devaluation in the number of abrasion cycles. As regards the meta- finishing method of application the same reagent had shown a beneficial effect on abrasion resistance as compared to the pre dyed fabric. The low concentration of finish had provoked excellent abrasion resistance and the fabric bore the brunt of abrasive motion with a remarkable increase. The post treatment with durable oil and water repellent finish showed that it had significantly boosted the abrasion resistance of fabric at high concentration. On the other hand the effect of post treatment of UV absorber (F6) displayed the low resistance of fabric by wearing off at an early stage of abrading operation at high concentration of finishing agent. As regards the application of soft polyurethane and another hand building finish by meta-finishing method, the dyed fabric showed a similarity in their results i.e. an increased finish concentration tended to lower down the abrasion resistance.

DISCUSSION

The previously mentioned results indicated that meta-finished P/C blended fabrics with Pekoflam liquid flame retardant and UV absorber were found to be comparatively flexible than the other finishing reagents. It might happened that combined dispersion of the finishes and pigment formulations probably decreased the friction between fibre and yarn, thus lowering the flexural rigidity of substrate to a desirable level. The results concur with the report of Talebpour & Holme[19], according to which when a certain type of silicon finish was deposited on the surface of cotton fabric, had reduced the inter-fibre friction and further led to lowered bending length. The same phenomena might worked here and is partially concur with the current findings in which the flexural rigidity (stiffness) of fabric was outwardly reduced by the low friction of the applied finishing reagents.

As regards the effect of concentration of various auxiliaries, it has previously been found by Hussain et.al[20], that an increase in binder concentration had increased the stiffness level, while, the increase in fixer concentration had slightly a reverse effect i.e. it tended to reduce the stiffness or flexural rigidity. The findings are moderately consistent with the current findings since here, instead of crosslinking agent (fixing agent), various functional finishes like organo-phosphorous flame retardant compounds (F3) dispersion of fluorine compound (F-5), UV absorber and polyurethane handle modifier (F6 & F7) were co-applied with pigment formulations.

Though the performance of meta-finished fabrics was found to be better regarding abrasion resistance, however, some finishing reagents with pigment stock formulation showed adverse response. According to the earlier mentioned results, Pekoflam OP flame retardant at low concentration well resisted abrasion damage. The coating of organo-phosphorus polymer-matrix on the cellulose component of fabric blend protected it from the rubbing. The statement given by Zurich [21] in his study on flame redundancy of cellulose fabrics partially In line with our findings. According to him the cotton fibre-ends protrude from spun yarn and are not firmly incorporated in the fabric as filament yarns hence the polymer film (of finish/binder) which cover the surface of fibres and the yarns, provide protection to the treated fabrics against abrasion.

The high concentration of the similar finish decreased the abrasion resistance indicating that fabric was being damaged by the removal of over layered hard and stiffer film. The results are supported by the investigation of Alaee & Wenning[22], in which they determined some adverse effects on the mechanical properties of cotton fabrics with the application of these chemicals flame retardant finishes. The decrease in tensile and tear strength, harsh handle and particularly loss in abrasion cycles are few of the draw backs induced by flame retardants.

As regards two the application methods, the after finishing of UV absorber provoked excellent abrasion resistance at low concentration. The pre-dyed fabric after finishing treatment, being prevented by the polymer coating over -layer. It seemed that the utilization of acrylic binder for pigment colouration of fabric, assisted to retain the treatment of UV absorber resisted the rubbing action successfully. Thiagaraj & Nankalli[23]reported that acrylate based binder helped to retain the applied chemical on the surface of the .The coating of UV absorber was firm enough to resist the fibres being pulled out from substrate, leading to yarn breakage or abrasion. In case of combined application also, the solution well penetrated in the fabric structure, reduced friction and enabled it to develop an outstanding performance regarding abrasion behavior. The results are in agreement with Manich, et al[24] who, reported that finishing reagents, types of finishes and the concentration are important parameters which affects the abrasion performance of the fabrics. Similarly, single phase dyeing and application of finishes tend to cling the fibres on the fabric surface and restrict the movement of fibres within the yarn.

CONCLUSIONS

It can be clearly inferred from the earlier mentioned results that, the effect of UV absorber and Pekoflam OP flame retardant (organic phosphorous compound) on the flexural rigidity was found to be beneficial. The fabric stiffness with these finishes was remarkably reduced, inducing a soft textural quality as compared to other finishes. The results conformed to one of the initial objectives which were formulated to achieve the desirable softness with minimal adverse effects on pigment coloured fabrics.

The application of fluorine based liquid water repellent finish (NUVA FD) after dyeing at high concentration well resisted the abrasion rubs. The performance was found to be gradually improved when the concentration of finishing reagent increased from 20 to 50 g/L. The same composition with oil repellent NUVA HPU finish occurred to be non-beneficial while simultaneous dyeing and finishing provided good response.

The simultaneous application of UV absorber and soft polyurethane finish in appropriate ratio with the pigment colourants could induce a desirable rubbing resistance in the dyed P/C fabrics, but, when it exceeded beyond a certain limit couldn't take the brunt of abrasive action and reduced the number of cycles. The optimized concentration for polyurethane was found to be 50g/L. Generally, the finishing of P/C fabrics with Pekoflam OP flame retardant and water repellent chemicals induced resistance against heavy brunt of abrasive action and a desirable flexural rigidity in fabrics.

The functional finishing technology is specifically considered as a technical link for achieving the 21st century's textile requirements. On the other hand, the technique of pigment dyeing has prospects for providing an environmentally friendly dyeing system with no problem of effluents disposal as found in conventional dyeing system. So, the overall investigation specifies that simultaneous finishing and pigment colouration with assorted functional finishes could be a feasible option for achieving an acceptable abrasion resistance and stiffness in P/C blended fabrics.

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