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Effects of Soil-repellent and Smolder-resistant Finishes, Types of Soils and Cleaning Methods on Soiling Characteristics of Upholstery Fabrics

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ABSTRAK

Kebanyakan fabrik upholsteri sekarang diberi kemasan florokarbon untuk kemudahan penjagaan Selain daripada itu, terdapat minat yang kian mendalam terhadap ciri kebakaran pada perabut upholsteri. Fabrik upholsteri jenis 100% kapas koduroy yang diberikan kemasan mencegah kekotoran berbes florokarbon dan kemasan rintangan api berbes boraks, telah digunakan untuk mengkaji kesan kemasan-kemasan ini ke atas ciri-ciri pengotoran pada fabrik. Fabrik yang diberi kemasan ini telah dikotorkan dan kemudian dibersihkan untuk menyerupai keadaan biasa dalam penggunaan fabrik upholsteri. Kekotoran yang digunakan ialah minyak galian, keliat hitam bandy dan keliat hitam bandy berliput minyak. Cara pembersihan termasuk penyedutan, memedap dengan perkloroetilena dan penggunaan bahan pencuci (bahan pencuci komersial yang berdebu kering). Pengotoran dan pengeluaran kekotoran dinilai dengan mengguna kaedah pantulan cahaya. Analisis varian telah digunakan untuk menentukan kesan angkubah-angkubah ini. Keputusan menunjukkan kemasan mencegah kekotoran, dapat mengurangkan pengotoran oleh partikel kerana salutan kemasan melicinkan permukaan gentian. Boraks merosakkan fabrik dan dengan ini akan menyebabkan kotoran terperangkap di celah-celah permukaan gentian yang rosak itu. Walau bagaimanapun kesan boraks ke atas darjah pengotoran tiduk begitu ketara disebabkan kesan tindak balas boraks yang dapat melunturkan fabrık. Kekotoran yang terdapat sangat sedikit/kecil jika dibandingkan dengan saiz gentian. Keliat hitam bandy berliput minyak lebih susah dikeluarkan kerana lekatannyc lebih kuat melalui cantuman minyak.

ABSTRACT

Many upholstered fabrics are treated with fluorocarbon finishes for ease of maintenance. Moreover, there is a widespread interest in the flammability characteristics of upholstered furniture. For this study, 100% cotton corduroy upholstery fabric finished with fluorocarbon based soil-repellent finish and borax based smolder-resistant finish, was studied for the effects of these finishes on the soiling characteristics of the fabric. The finished fabrics were soiled and cleaned to simulate normal conditions of the upholstery fabrics in use. Soils used were mineral oil, bandy black clay, and oil-bound bandy black. Cleaning methods used included vacuuming, sponging with perchloroethylene and use of a cleaning aid (a commercial dry powdery cleaning agent). Soiling and soil-removal were evaluated using the reflectance methods. Analysis of variance was used to determine the effects of the variables. Results showed that soil repellent finish reduced particulate soiling by smoothing fiber surface with a finish coating. Borax had a tendering effect on fabrics which generally caused more soils to be entrapped in the cracks of the damaged fiber surface. However, the effects of borax on the degree of soiling was not extensive because the borax finish made the fabric whiter. The traces of soils were relatively small in relation to the fiber size. Oil-bound bandy black soils were more difficult to remove due to their greater attachment to the fabric via oil-bonding.

INTRODUCTION

Soiling, soil resistance, and soil release are complex phenomena involving the interrelationship of the nature of the fiber surface, fiber-fabric structure, soil, chemical finishes and removal agents. Soiling occurs when the soil comes into contact with the fabric and is retained as a more or less stable unit. A fabric becomes soiled either by contact with air-borne or liquid-borne substances or by direct contact with another soiled surface. Soil particles floating in the atmosphere settle down on the fabrics due to the forces of gravity and interception of the particles by the fabric. Liquid-borne soils that come into contact with the fabric may evaporate or filter off leaving the undissolved or suspended particles on the fabric surface. Soiling through direct contact involves simple mechanical forces in the transfer of the soil to the fabric (Compton and Hart, 1953a, 1953b, 1954).

Soils are retained in the fabric by a) adhesion of particles to fabric surfaces by oil bonding, b) mechanical entrapment in the inter-fiber and inter-yarn spaces (macro-occlusion), c) the fiber crevices and pores (micro-occulusion) and d) by electrostatic forces (Compton and Hart, 1953a, 1953b, 1954; Snell *et al.*, 1950).

Soil-repellent finishes have been used to increase consumer satisfaction with the appearance of upholstery fabrics. These finishes are popular due to the problems associated with in-place cleaning of upholstery fabrics and the care needed in maintaining the cleanliness of the fabrics (Hardin *et al.*, 1977). The soil-repellent finishes withstand penetration by liquid soils under static conditions if liquid soils are not forced into the fabric by external forces other than the capillary forces of the weight of the liquid. Fluorochemical finishing agents used as soil repellent finishes lower the energy of the fabric surface and thus eliminate wicking. However, as dynamic forces are introduced, such as those encountered in a spill or pushing of the liquid into the fabric, the low surface energy oil stains may be held out from significant penetration. With particulate soils, the extent of repellency by the fluorocarbon finishes has not been studied to a great depth.

A fluorochemical is defined as an organic compound in which a high percentage of the hydrogens attached to carbon have been replaced with fluorine (Grajek and Peterson, 1962). To obtain soil repellency, the compound must have a fluorinated carbon chain of at least four carbons terminated by a-CF_3 group. Goldstein (1961) has suggested that commercial finishes are a polymer or copolymer of vinyl perfluoro-acid ester and/or perfluoroester of acrylic acid with the perfluoro groups.

Liquid soils that do not penetrate the fluorocarbon finished fabric are easily removed by blotting the excess soil. In cases where the liquid soil has penetrated the fabric, removal is difficult due to the hydrophobic nature of the fabric surface. In the case of particulate soils, the loosely held soils can be removed by vacuuming. However, the deeply embedded soils would require some cleaning procedures such as washing with detergent. Again the hydrophobic nature of the fabric surface would make the soil removal process difficult. In velvets, the cleaning procedure is made more difficult due to the high tendency for pile fiber distortion. Professional dry cleaning is usually recommended for velvets. Today, however, some dry powdery cleaning aids are available for cleaning velvet upholstery fabrics by the consumers.

The degree of soil pick up and soil removal are important textile properties. The presence of soils affect appearance, durability, and perhaps the smoldering of textile fabrics. Methods to evaluate the ease of soil removal on fabrics include visual comparisons with standards, chemical analysis, and photometric measurement of changes in reflectance (AATCC, 1956; Berch and Peper, 1963; Berch *et al.*, 1967; Beninate *et al.*, 1963 and Bubl, 1970). The photometric measurement method is most often used for soil removal evaluations since it is easy to perform and gives less variable results than does the visual comparison ranking method (AATC, 1956; Berch and Peper, 1963; Berch *et al.*, 1967 and Beninate *et al.*, 1963).

Besides the need for upholstery fabrics today being treated with fluorocarbon based soil-repellent finishes, there is also an increasing need for upholstered fabrics to be made smolder-resistant. The smolder resistant-finish that has been found to be the most effective is borax.

Since the problems associated with upholstered furniture fires have long been recognized (US Dept. of Commerce, 1972), there has been an increase in research activity in the aspects of flammability and smolder resistance of upholstered furniture. The emphasis for most of the research has been on the evaluation of individual materials used in the upholstered furniture fabric, cushioning material, finishes and testing methods.

There has not been much research on the effect of variables such as soil repellent finishes and smolder resistant finishes on soiling behaviour. However, soil repellent finishes are widely used on upholstery fabrics and the types of soils, available cleaning methods, and types of flame or smolder resistant finishes so far developed also vary widely. Therefore this study was designed to gain a greater understanding of the combined effect of soiling, soil-repellent, and smolder-resistant finishes in the soiling characteristics of upholstery fabrics.

MATERIALS AND METHODS

The fabric used in this study was a 100% cotton, undyed, upholstery fabric with a horizontal rib-corduroy construction. A 4 × 4 × 2 factorial design (four finish treatments, 4 soils, 2 cleaning methods) was used. Three replicates of the specimens were used per soiling/cleaning treatment.

Finishes

A total of 4 finishes were used to study the effects of finishes on soil-uptake. The finishes were the untreated, the soil-repellent finish (Scotchgard FC-214); the borax-H_3PO_4-methylated trimethylolmelamine; and the borax-H_3PO_4-methylated trimethylolmelamine and soil-repellent (Scotchgard FC-214) finish.

Soils and their Application

The soils selected represent those that may be present on upholstered furniture. The soils were mineral oil, bandy black clay and oil-bound bandy black clay. The dry soil chosen was bandy black clay since chemical and particle size analysis has shown that this soil gives a very good correlation with natural soil (Spinks Co. Inc., Laboratory). The oil-bound bandy black clay was prepared by treating the clay with mineral oil. The mineral oil of 8.5 g was dissolved in 200 mm of Stoddard solvent. Bandy black clay (91.5 g) was then added to the solvent by slurrying into the solution. The slurry was spread out thinly in a porcelain tray. The tray was then left under an operating hood to allow the solvent to evaporate. The soil was mixed well after drying (Hardin *et al.*, 1977).

The particulate soil of bandy black or oil-bound bandy black clay (5% of weight of fabric) was then added to the fabric. To allow for better uniformity in the distribution of soils on fabric, 10 balls (ping-pong balls) were placed in a large round plastic container. The cover was then placed on the container and cellophane tape was used around the cover to ensure that the cover was held tight despite the tumbling actions. Two containers were placed in an automatic clothes dryer per run. One container held a sample with the oil-bound bandy black clay and another contained fabric with the bandy black clay. These were tumbled on the fluff air setting for 30 minutes.

The mineral oil was applied by immersing the samples in the oily soil prepared by stirring 10 g of mineral oil into 40 ml of perchloroethylene. The fabric swatches were immersed in this oil/perchlorethylene mixture for ten seconds and then placed in a dry porcelain container and dried under a fume hood for 24 – 72 hours. Oily soil uptake by Bubl (1970) using this method was found to be around 3% on weight of fabric.

Cleaning Procedure

For each soil treatment, two cleaning methods were used. On fabrics soiled with particulate soils of bandy black clay and oil-bound bandy black clay, one method used was the removal of excessive or loosely held soil by vacuuming, and the other was the removal of excessive soil by vacuuming first, followed by application of a dry powdery cleaning agent (this commercial cleaning agent was used because it is a home product that is quite easily available and it is a suitable cleaning agent for removal of soils on velvet upholstery fabrics). The cleaning agent was left on the fabric for 3 hours before further vacuuming to remove the soils and the cleaning agent.

One method of cleaning fabrics soiled with mineral oil, was sponging off excess oils on both surfaces of the sample with perchloroethylene. Another method of removal was applying the dry powdery cleaning agent and leaving it on for 3 hours before vacuuming.

For the unsoiled fabrics, one method was control (no cleaning); the second method was the application of the dry powdery cleaning product, and leaving it for 3 hours before vacuuming for removal.

Evaluation of Soil Pick-up and Removal

The unsoiled, soiled and cleaned fabrics were evaluated for degree of soiling and soil removal using the Hunter-Lab-D-40 Reflectometer without fluorescence. The reflectometer was standardized with the off-white plate that was closest to the color of the untreated (control) fabric. Two readings were taken for each blue and green reflectance value. Readings were taken with the pile direction downwards and only on the face of fabric. The photometric method was used because of the ease of operation and also for the purpose of reducing inherent operator variability. The blue and green relectance readings are a measure of fabric whiteness. Whiteness is an entity measured by reflectance of light in the blue portion of the spectrum. The concept of brightness is an entity measured by reflectance of light in the green portion of the spectrum.

The degree of soil pick-up and soil removal and effect of the cleaning procedure on unsoiled fabrics were calculated using the following equations (Rees, 1954).

$$\%\text{ soil pick-up} = \frac{Ruu - Rsu}{Ruu} \times 100$$

$$\%\text{ soil removal} = \frac{(Rsc - Rsu) - (Ruc - Ruu)}{Ruu - Rsu} \times 100$$

Ruu is reflectance value of unsoiled and uncleaned specimen.
Rsu is reflectance value of soiled and uncleaned specimen.
Ruc is reflectance value of unsoiled and cleaned specimen.
Rsu is reflectance value of soiled and uncleaned specimen.

The reflectance measurement calculation was used as it is a measurement of appearance/color of fabric. This can be correlated to consumer perception of the degree of soiling and soil removal of fabrics (Warfield and Hardin, 1981).

RESULTS AND DISCUSSION

Soiling and Soil Removal

The effects of all types of soils on the degree of soiling and soil removal were analyzed, but the results of the mineral soil were so inconsistent that analysis of variance was carried out only with the particulate soils.

The significance of effects of the finish treatments, types of soils, and the cleaning methods on degree of soiling are listed in Table 1. The combined effects of finish treatments, soil types and cleaning methods was significant on degree of soiling and soil removal.

Finishes

The effect of finish treatment was significant on the degree of soiling and the degree of soil removal using the blue reflectance measurement, but not significant when using the green

TABLE 1
Significance levels of analysis of variance for degree of soiling and soil removal using both the blue and green reflectance measurements*

Source of variations	DSB	DSRB	DSG	DSRG
Finish Trt.	0.0002*	0.0094*	0.0637	0.0601
Soils	0.0001*	0.0010*	0.0003*	0.0007*
Finish Trt. *Soils	0.1422	0.4770	0.2847	0.5620
Cleaning Methods	0.0352*	0.0095*	0.1980	0.0003*
Finish Trt. *Cleaning Method	0.0001*	0.0001*	0.0009*	0.0001*
Soil × Cleaning Methods	0.2035	0.0266*	0.2811	0.0185*
Finish Trt. *Soil *Cleaning Method	0.0235*	0.0059*	0.0321*	0.0114*

DSB = Degree of soiling using blue reflectance measurement

DSRB = Degree of soil removal using blue reflectance meausurements

DSG = Degree of soiling using green reflenctance measurements

DSRG = Degree of soil removal using green reflectance measurements

* = Indicates significance level at or beyond 0.05 probability level.

reflectance measurement (Table 1). This was due to evaluations on fabric whiteness being based on fabric color (which was yellowish) rather than fabric brightness. Blue reflectance is a measure of fabric whiteness while green reflectance is a measure of fabric brightness. The significant effect of finish treatments was due to the untreated fabric used being an off-white color while borax treated fabrics seemed to be bleached out by borax and hence appeared whiter than the non-borax treated fabrics (Table 2).

Duncan's Multiple Range Test on degree of soiling using the blue reflectance measurement shows that the untreated fabric and the borax treated fabric are not significantly different (Table 3). The bleaching effect of borax made up for the dullness effect from the presence of bandy black soils entrapped in the cracks of the borax treated fabrics. The borax finish treatment seemed to be tender and impart a rough texture to the fabric. The untreated was significantly poorer than the soil repellent treated fabrics in terms of soiling tendency. The soil repellent finish smoothed the fiber-surface and gave the fibres a lower surface energy hence reducing soil attachment to the fibres. The borax with soil repellent finish treated fabrics was significantly lower in degree of soiling than the other fabrics. The bleaching effect of borax finish reduced the soiled appearance of the fabric while the soil-repellent finish contributed by smoothing the fiber surface and lowering the surface energy of the fibers, hence reducing tendency for soil attachment to the fabric.

In terms of degree of soil removal using the blue reflectance measurement, the fabric with the soil-repellent finish displayed a significantly higher degree of soil removal than did the other fabrics (Table 3). This may be due to an increase in the smoothness of the fibre surface caused by the finish coating effect which reduced the number of cracks on the fibre surface that could entrap soils and allow for easier soil removal. The low surface energy of the perfluorocarbon soil-repellent finish may have also reduced the extent of force of attachment of oil-bound soils to the fiber surface and hence facilitated in the soil removal process. The untreated, the borax treated, and the borax with the soil repellent finish treated fabrics were not significantly different from each other in terms of soil removal. As has been explained before, the roughening effects of the borax may have caused a lot of surface cracks that resulted in soil entrapment, but the borax whiteness/bleaching effect may have reduced this soiled appearance effect. Result showed that fabrics with borax treatments have less soil removal (15.8%) than the untreated fabrics (20.4%). This may be due to the more

TABLE 2
Reflectance reading of unsoiled fabrics before and after cleaning using vacuuming and a cleaning aid

Finish treatment/no soil	Mean RUUB	Mean RUCB	Mean RUUG	Mean RUCG
Untreated	61.4	58.4	72.1	70.0
Soil-repellent treated	58.0	55.7	70.8	68.6
Borax treated	65.8	63.4	76.6	74.3
Borax and soil-repellent treated	63.5	59.9	76.0	72.5

RUUB = Reflectance reading of unsoiled uncleaned fabric using blue reflectance measurements.
RUCB = Reflectance reading of unsoiled but cleaned fabric using blue reflectance measurements.
RUUG = Reflectance reading of unsoiled uncleaned fabric using green reflectance measurements.
RUCG = Reflectance reading of unsoiled but cleaned fabric using green reflectance measurements.

TABLE 3
Effect of finish treatments, types of soils, and cleaning methods on degree of soiling and soil removal as shown by Duncan's Multiple Range Test

Source of variations	DSB	DSRB	DSG	DSRG
Finish treatment				
Untreated	25.6 [a]	20.4 [b]	21.6 [a]	31.1 [ab]
Soil repellent treated	22.6 [b]	29.7 [a]	19.6 [ab]	34.1 [a]
Borax treated	23.4 [ab]	15.8 [b]	21.0 [a]	25.4 [b]
Borax and soil repellent treated	18.4 [c]	16.3 [b]	18.1 [b]	25.1 [b]
Soil types				
Bandy black	24.6 [a]	25.2 [a]	21.8 [a]	33.3 [a]
Oil-bound bandy black	20.1 [b]	13.9 [b]	18.3 [b]	23.0 [b]
Cleaning methods				
Vacuuming		17.1 [b]		24.1 [b]
Vacuuming and cleaning aid		22.8 [a]		33.1 [a]

DSB = Degree of soiling using blue reflectance measurement.
DSRB = Degree of soil removal using bluc reflectance measurement.
DSG = Degree of soiling using green reflectance measurements.
DSRG = Degree of soil removal using green reflectance measurement.
abc = Superscripts that differ from each other indicate significant differences (at or beyond the 0.05 level) between treatments.

embedded soils in the cracks that are difficult to remove. The fabric with the borax and the soil repellent finish had a higher soil removal than did the fabric treated with the borax finish alone. This may be due to the effects that the soil repellent finish had on the soil removal, as explained above.

The degree of soil removal, using the green reflectance measurements, showed a pattern similar to that for the blue reflectance (Table 3). However, the percentage of soil removal was slightly higher. This could be a more accurate picture of the degree of soil removal, since the particulate soils which are brownish black in color affect the fabric bright/dull appearance more than yellowness.

Soils

The types of soils, previously discussed, had a significant effect on degree of soiling and soil-removal as measured by both the blue and green reflectance readings (Table 1).

Cleaning Aid

Cleaning methods had a significant effect on soil removal. Vacuuming followed by the use of a cleaning aid removed more of the particulate soils than did vacuuming alone. The cleaning agent was a factor that contributed to easier soil removal (Table 1 and 3).

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