Textile Finishes

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Abstract

The dynamic course of textile technology in the last two decades has brought to the market-place fabrics manufactured from many fibers and combinations of fibers as well as fabrics chemically treated or "finished" to acquire specific functional properties and maintain them through multiple washing-cycles. The most important classes of durable textile finishes are reviewed with reference to the chemical types, to the functions performed by the finish, and to the fabric substrates on which finish is generally used.

Some of the problems associated with the washing of chemically treated fabrics are discussed, including impairment of fabric appearance or strength and impairment of performance through gradual removal of the finish. These problems can be minimized by adequate quality-control programs in the textile industry, but truly optimum behavior of fabrics in washing would also require coordinated efforts on the part of those who manufacture consumer products and the cooperation of consumers as well.

Introduction and Definitions

DURING THE LAST TWO DECADES the textile industry has become increasingly aware of the importance of innovation. Many new products have reached the market-place as a result of a rapidly advancing technology. Fabrics manufactured from new fibers or new combinations of fibers and fabrics chemically treated or "finished" to acquire specific functional properties have been developed and are found today in every household. This review will outline the most important facts pertaining to chemical finishes for textile fabrics, to the evaluation of their effectiveness, and to their usefulness to consumers.

Substrate. The textile material to which a chemical finish is applied is defined as the substrate. This is generally a fabric, which may be woven or knitted from one or more types of yarns and fibers. Natural fibers (cotton, wool, linen, silk), synthetic fibers (polyesters, polyamide, polyacrylonitrile, polyolefin), and regenerated cellulose fibers (rayon, acetate) are employed alone or in blends to manufacture the yarn from which the fabric substrate is made.

Finish. The chemical treatment applied to the substrate in the textile mill to impart a specific property or combination of properties is defined as the finish. Dyes are excluded from this definition. Composite structures such as coated fabrics, foam-backed fabrics, and bonded fabrics will not be considered. In the chemical finishing process, the fibers in the substrate may be modified by chemical reaction (fiber modification) or chemicals may be deposited on fiber surfaces without reaction with the substrate (additive finish). Finishes based on fiber modification are generally not removed by washing; their resistance to removal depends on the chemical stability of the bonds formed between fiber and substrate. For additive finishes, the rate of removal in washing is primarily a function of their solubility or dispersibility in the washing solution. In many finishing processes, insolubilization of additive finishes is achieved by *in-situ* polymerization of the chemicals applied.

Effectiveness. The extent to which a finish imparts the desired property to the substrate is defined as its effectiveness. The evaluation of finish effectiveness and the development of valid laboratory testing procedures for this purpose are essential factors in the objective selection of finishes for commercialization. Standardized industry-wide test methods for measuring effectiveness provide the basis for the quality control of finished fabrics in the textile mill.

Durability. The life-span of the finish in normal use, relative to the life-span of the fabric substrate, is defined as its durability. For washable fabrics, resistance of the finish to removal in washing is the most important aspect of durability. Although this can be evaluated by testing effectiveness after multiple laundering cycles, an exact definition of the durability of a given finish is difficult because of the broad range of washing conditions which are encountered by finished fabrics in the household. Standardized wash tests and accelerated wash tests are used to provide valid, though relative, measures of the effect of laundering on the effectiveness of a finish. The durability of commercial finishes varies greatly, and acceptable limits for each type of finish are determined by a complex set of factors including end-use requirements and by consumer demand.

Durable Finishes

Large volumes of chemicals are used in the textile industry for nondurable finishes, which are generally removed completely in the first laundering. These are employed either to improve the processability of fabrics in the mill and in garment-cutting plants (e.g., fugitive antistatic agents) or to enhance the "store" appearance of the end-product (e.g., softeners, hand builders). However the present review will be limited to durable finishes, which present more complex chemical problems to textile chemists and are of greater concern to consumers.

Durable finishes are generally obtained by insolubilization of the chemicals applied, either by reaction with the fibers or by polymerization *in situ*. The steps involved in a typical finishing sequence in the textile mill are a) impregnation of the fabric with a solution of the chemicals by padding, b) drying, c) heating (curing) to induce or accelerate chemical reaction, and d) washing to remove residual unreacted chemicals. Chemical finishing needs and approaches for specific fabrics are usually related to the chemical properties of the substrates.

Washable fabric substrates can be grouped according to chemical type, as shown in Table I. Fabrics made from hydrophilic fibers, such as cotton, rayon, and wool, require chemical finishing to acquire the desired degree of dimensional stability or resilience. But fabrics made from hydrophobic fibers, which are inherently resilient and dimensionally stable, require finishing to prevent the accumulation of static charges or to aid in the removal of oily soils. The functional groups in cellulosic and protein fibers provide sites for fiber modification; additive finishes are more important for synthetic fibers which do not contain reactive groups.

Durable finishes can be classified in several ways, according to chemical type, or to the property they impart, or to the substrate to which they are com-

TABLE I

Washable Fabric Substrates

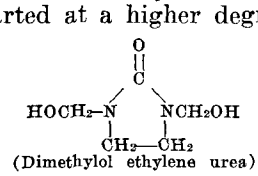
Cellulosic	Cotton
Hydrophilic	Regenerated cellulose
[OH] reactive groups	(rayon, modified rayon)
	Linen
Protein	Wool
Hydrophilic	Silk
Many reactive groups	
[NH_2, SS, SH, etc.]	
Synthetic	Polyester
Hydrophobic	Polyamide
Thermoplastic	Polyacrylonitrile
No reactive groups	Polyolefin
Blends	Polyester/Cotton
	Polyester/Rayon
	Polyester/Wool
	Polyacrylonitrile/Wool
	Wool/Rayon

monly applied. Some durable finishes are used to impart a specific property (primary function), others are needed to compensate for side effects which result from the use of a finish that is performing the primary function. The most important durable finishes are grouped according to the type of property they impart in Table II. Minimum-care finishes for cellulosics and for wool, water-repellents, stain-release finishes, and flame-retardants are discussed to illustrate some durable finishes currently well known to the consumer and others that are on the threshold of acquiring commercial significance.

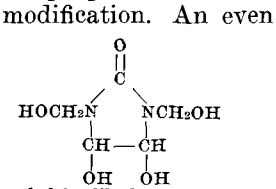
Finishes for Cellulosic Fabrics

In the course of the last 20 years, finishes to impart dimensional stability, improve wrinkle recovery, and obtain "wash-wear" and "durable-press" properties on cellulosic fabrics, primarily cotton and rayon, have assumed increasing importance and reached new levels of effectiveness. The underlying principle common to these finishes is the cross-linking of cellulose chains in the fiber by the reaction of polyfunctional reactive compounds with cellulose hydroxyl groups. Hundreds of cross-linking reagents have been evaluated, and at least four classes of polyfunctional compounds have been used in commercial finishing processes: formaldehyde, polyfunctional N-hydroxymethyl amides, polyepoxides, and activated vinyl compounds. Among these, polyfunctional N-hydroxymethyl amides have been of major importance for many years. The structure of some widely used reagents in this class is shown below with the "common" chemical name.

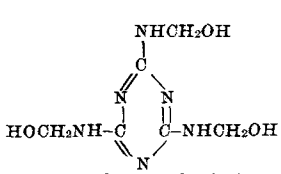
In the finishing process, the cross-linking agent reacts with cellulose, yielding a three-dimensional polymer network under relatively mild conditions. The cross-linking reaction generally results in extensive changes in fiber and fabric properties, and the magnitude of the changes is primarily governed by the extent of cross-linking. Low levels of cross-linking are sufficient to attain dimensional stability; good wrinkle-recovery and wash-wear properties are imparted at a higher degree of modification. An even



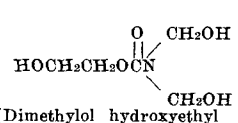
(Dimethylol ethylene urea)



(Dimethylol dihydroxy ethylene urea)



(Trimethylol melamine)



(Dimethylol hydroxyethyl carbamate)

TABLE II

Durable Finishes

Minimum Care	Dimensional stability
	Wrinkle recovery
	Crease and pleat retention
Comfort	Antistatic properties
	Stretch
New Dimension	Water repellency
	Stain repellency
	Flame-retardant properties
	Bacteriostatic properties
	Rot, mildew resistance
	Moth resistance
Secondary Function	Fiber mechanical properties
	Color-fastness
	Hand modification
	Stain-release properties

higher extent of cross-linking is required for durable-press properties. If the cross-linking reaction takes place while the fabric is held flat, the fabric tends to return to the flat state after deformation (wrinkle-recovery and flat-drying properties). If the cross-linking reaction occurs while the fabric is pleated or creased, the fabric tends to resume the pleated or creased configuration (crease and pleat retention). The primary function of the finish is thus to impart dimensional stability, wrinkle recovery, and shape retention.

The mechanical properties of the fibers (strength and abrasion resistance) are generally impaired as a result of the cross-linking reaction, and the wear life of the fabric would be severely decreased without the judicious use of finishes to perform a secondary function. Additional components are also used in the finishing formulation to overcome the effect of the cross-linking reaction on the hand of the fabric and on the color-fastness of the dyes. Durability requirements for minimum-care finishes for cellulosics are high. In finished fabrics which are currently available commercially, the effectiveness of the finish is essentially unchanged after 50 laundering cycles.

Finishes for Wool and Wool Blends

Traditionally wool fabrics have not been exposed to washing. However washable wool fabrics have been developed and have become important in recent years. Dimensionally stable, wool-containing fabrics that can be machine-washed and tumble-dried with minimal shrinkage are a commercial reality, and developments in progress suggest that washable, crease-retentive (durable-press) wool garments will soon be available. The chemical and morphological complexity of the wool fiber is such that the mechanism in the dimensional stabilization of wool cannot be explained concisely or with certainty. Effective finishes for minimizing shrinkage in woven or knitted wool fabrics usually modify the scale surface of the wool fiber by deposition of a flexible polymer coating and/or by chemical reaction of the functional groups in the wool molecule.

The approaches of major importance have been oxidative treatments, deposition of polymer coatings on the fibers by interfacial polymerization techniques, and the application of reactive polymers which are anchored to the fiber by chemical bonds. With polymer coatings, good dimensional stability is obtained without impairment of fiber mechanical properties, and the most important side-effects are the harshening of fabric hand and loss of loft owing to fiber-to-fiber bonding. Side effects are minimized by the use of suitable softeners and by mechanical treatment of the fabric after finishing. In view of the end-uses for which wool fabrics are commonly employed, durability requirements for minimum-care finishes are less

stringent than in the case of cotton.

Water-Repellent Finishes. Durable water-repellency is an important property for outer wear in civilian and military end-uses. Water-repellent finishes are applied to several types of substrates. The underlying principle is the formation of a non-wettable fiber surface by introducing hydrophobic substituents in the fiber or by coating the fiber surface with a hydrophobic polymer. Several chemical approaches have been used for the development of effective durable water-repellent finishes. Compounds containing saturated aliphatic hydrocarbon chains of 16–20 carbon atoms, silicone polymers ($-\overset{|}{\underset{|}{Si}}-[O-\overset{|}{\underset{|}{Si}}]_n$), and polymers containing perfluoroalkyl chains ($CF_3-[CF_2]_n-$), yield effective water-repellent finishes on several substrates without impairing appearance, fabric properties, or air permeability.

The durability of these finishes in laundering and/or dry cleaning is limited, but the need for and commercial acceptance of water-repellent finishes have been considerable nevertheless. Further progress in the development of more durable finishes is certain. The polymers containing perfluoroalkyl chains (fluorochemicals), which are used in durable water-repellent finishes, can perform a dual function since they impart oleophobic as well as hydrophobic properties to the fiber surface and thus render the fabric stain-repellent and water-repellent in a single finishing process.

Stain-Release Finishes. The removal of oil-borne stains from polyester/cellulose fabrics by washing has presented a problem for years. The problem has become more acute for fabrics in which the cellulose component is cross-linked to achieve durable-press properties. Diffusion of oily soil into the oleophilic polyester fibers, hydrophobicity of the polyester fiber surface, and reduced penetration of the wash solution because of cellulose cross-linking are probable contributing factors in this problem of difficult washability. To overcome the problem, stain-release finishes have recently been developed. They are obtained from polymers containing polar groups, insolubilized on the fabric to provide a readily wettable hydrophilic coating on the fiber surface. The durability of the newly available stain-release finishes is good, and commercial acceptance has been immediate. Still, much progress can be expected as this new development reaches maturity and stain-release finishes are developed for a broader spectrum of substrates.

Flame-Retardant Finishes. In recent years government and industry have shown increasing concern with the flammability characteristics of textiles. Research and development efforts in the field of flame-retardant finishes have gained momentum, possibly in anticipation of federal legislation that would create an immediate demand for flame-retardant textile products. To date, chemical finishing of fabrics to improve their flame-retardant properties has been investigated primarily on cellulosic substrates. Self-extinguishing properties are imparted to cotton or rayon by inhibiting the formation of flammable organic decomposition products and catalyzing dehydration during the pyrolysis of cellulose. The insolubilization of organophosphorus compounds on cellulosic fabrics has provided a route to the formation of an efficient dehydration catalyst (P_2O_5) during the burning process and made an effective approach to the development of flame-retardant finishes.

TABLE III
Washable Trousers

Development years	Fabric	Important Performance Properties[a]				
		Wrinkle recovery	Crease retention	Wear life	Easy care	
					Wash	Iron
.....	Cotton (untreated)	1	2	4	5	1
1948–1954	Wrinkle-resistant cotton	3	1	3	3	3
1955–1964	Wash-wear cotton	4	1	2	3	4
1964	Durable-press cotton	5	5	1	2	5
.....	Polyester/Cotton (untreated)	4	2	5	2	3
1964–1967	Durable-press polyester/cotton	5	5	4	1	5
1967	Durable-press, stain-releasing polyester/cotton	5	5	4	5	5

[a] Rating—5 = excellent, 4 = good, 3 = fair, 2 = poor, 1 = very poor.

Many problems remain to be solved. The efficiency of available compounds is limited, and large amounts of finish are generally needed. There are concomitant problems such as fabric stiffness, reduced air-permeability, and high cost. The development of more efficient, durable flame-retardant finishes for cellulosic fabrics and the yet-unsolved problem of imparting satisfactory flame-retardant properties to many fabrics which are made from synthetic fibers and their blends with cellulose are important research considerations in the textile industry today.

Problems of Use

It is apparent that the chemical system defined by the substrate and the finish is often complex. Ideally the system should be stable under all conditions of common usage, but, in reality, the chemical stability of the system has definite limitations. The most common problem in use is loss of effectiveness of a finish after repeated laundering or lack of durability. In most cases the loss of effectiveness is attributable to the gradual removal of finish by chemical reaction, solubilization, abrasive forces, or a combination of these factors.

Another problem is the occurrence of a chemical change in the finish, not necessarily causing loss of effectiveness but affecting the properties of the substrate adversely. For example, some of the earlier minimum-care finishes for cotton retained chlorine from bleaching solutions, and the chloramides which were formed could decompose with the formation of hydrochloric acid and cause hydrolytic damage to the cellulose substrate. Other potential problems are related to exaggerated promotional claims and to abusive handling by consumers.

Many problems can be predicted and avoided by good quality-control of fabrics in the textile mill, coupled with realistic labelling of end-products. Other limitations are brought into focus only as new products gain acceptance. All problems, realistically appraised, stimulate the development of improved products and further innovation. The history of a familiar end-product, washable trousers, serves to illustrate some of the important concepts and is summarized in Table III. Washable trousers which exhibit satisfactory performance properties in every respect have been developed in several stages as new technology has become available to solve the major problems indicated by the "very poor" ratings of unity.

From this brief review of textile finishes it is evident that optimum performance of washable fabrics requires the coordinated efforts of the chemical and textile industries.