CHAPTER I

INTRODUCTION

Cotton and polyester are important textile fibers. Both are extensively used individually and in varying blends for the manufacture of apparel fabrics. The popularity of the polyester/cotton blend fabrics is due to their light weight, good crease recovery property and easy washability. However these fabrics alone have certain drawbacks; cotton fabrics have poor resistance to creasing during wear and shrinkage during washing, whereas polyester fabrics get easily soiled during wear, they have low moisture absorbancy and are susceptible to pill formation. Several of these properties of cotton and its blends are improved by finishing, depending on their end uses. According to Fortess (11) and Marsh (28) the objectives of finishing are:

1. to improve aesthetic qualities.
2. to impart specific functional properties not inherent in fiber or fabric.
3. to improve easy care characteristics.
4. to improve durability by improving certain service qualities.

Finishing in General

The first commercially successful resin treatment of textile goods was introduced around 1925 by Tootal, Broadhurst and Lee in England. Using urea formaldehyde as a thermosetting composition, they obtained substantial improvement in the ability of cellulosic fabrics to resist creasing. Since then many other resins have been tried and eventually used to ameliorate the behavior of textile fabrics.

The main objectives of resin finishing are to impart crease recovery and sharp crease retention to the fabric. This finish is largely applied to cotton and its blends with synthetic fibers. The wash and wear property is the important property imparted to cellulosic materials with the use of the resins. It has also been referred as anticrease, crease resistant, self smoothing, drip dry, min-iron, all being synonymous. Barach et al. (5) have referred the ease of care properties as including dimensional stability, wrinkle resistance, crease retention or pleatability, ease of laundering and drying, ease of ironing, retention of appearance after washing and drying. To obtain a truly wash-and-wear garment the fabric from which the garment is made must have excellent smooth drying properties and should not crease to any substantial degree when worn or used or if creased should recover from the creases soon.

As stated by Nanavati (31) there are mainly three types of finishing treatments with resins, namely anticrease finishing, wash and wear finishing and durable press finishing.

Though the method of imparting anti-crease finish or wash and wear finish is essentially the same, the difference is only in the type and level of the crease recovery. In the anti-crease finish, one is satisfied if the treated fabric has a dry crease recovery of about 230° (warp + weft). However, in wash and wear fabrics, it is not only the crease recovery which is important but also the wet crease recovery. Dry crease recovery is responsible to a large extent for the wrinkle resistance during wearing whereas wet crease recovery is most important in the smooth drying property after washing. A dry and wet crease recovery of about 240° each can be considered as satisfactory for wash and wear fabrics.

Anti-crease or crease resistance means that a fabric resists bending, twisting, and other deformation. Wrinkle recovery means that the fabric can bend and twist and then recover from this deformation. Wash and wear fabrics are well suited for saries, dhoties, ladies blouses and children's garments where pressed in creases are not required. In durable press finishing, fabrics are treated with high concentrations of resin i.e. about 8 to 10 percent. The losses in mechanical properties are higher with durable press finishing than those with easy-care finishing.

Chemicals and Processes Used

Chemical finishing involves the application of certain synthetic polymers on the fibers, which may be located on the surface, or may penetrate into the fiber interior.

The conventional process of the application of finishing these finishes consists of impregnating, drying, curing to bring about resinification, and washing to remove any uncombined reagents which may give rise to unwelcome effects later.

These synthetic polymers are of two main types—thermoplastic polymers and thermosetting polymers. Thermoplastic finishes include the compounds formed by addition polymerization. Thermosetting finishes include condensation products of aminoplasts. Both of these are used as interfiber finishes and may be applied from a solution or as an emulsion. (46)

An outstanding advantage of synthetic polymers over starch finishes is the clarity and transparency of the resin film, which does not dull the colour and lustre of the fabrics, nor obscure the texture. Furthermore, unlike the natural polymer finishes, they have good adhesion to synthetic fibers as well as to their blends. (46)

Thermoplastic Finishes

Thermoplastics are those polymers which consist of long linear molecules accompanied by some branching but not interconnected, i.e. cross linked from molecule to molecule. These plastics, rapidly soften and melt with heat and reharden to rigid materials upon cooling. Generally there is no appreciable change in the physical properties of the thermoplastics through repeated heating and cooling cycles. They may be remelted and reshaped as often as is practical and as long as the procedure does not introduce charring or degradation to the reworked material (17).

According to Shapirao (41) although these thermoplastic finishes are dispersion of solid resin particles, in most cases these particles merge on drying to form a continuous film, which do not alter the shade of dyed and printed fabrics, but enhance their brilliance. The properties of thermoplastic compositions as stated by Shapirao are:

1. Complete mixibility with water.
2. Sets to form insoluble film on drying.
3. Compatibility with anionic and nonionic softeners, surface active agents, starches and gums.
4. Excellent adhesion to natural and synthetic fibers.
5. Improved hand, tensile strength, abrasion resistance.
6. Odourless, tasteless, nonyellowing on exposure to heat, ultraviolet rays or aging.
7. Resistant to removal by laundering or drycleaning.
8. Resistant to acids, alkalies, grease and solvents.
9. Freedom from tendering and chlorine absorption on laundering.

He has further stated that in the acrylic ester series, film properties can be varied very widely by copolymerization of various acrylic and methacrylic esters, as well as by copolymerization with other emulsions. Their mechanical stability, particle size etc. depend on the emulsifying agent, type and intensity of agitation etc.

Thermoplastic finishes are inherently more flexible and durable and do not require curing, as the resinous constituents are present in the fully polymerized form.

According to Nuessle (35), polymers range from methyl methacrylate - hardest, to 2 - ethyl hexyl acrylate, the softest. Homopolymers of acrylic acid or acrylamide which are water soluble, will form hard, but continuous films. Most acrylics used for textile processing are designed to form a continuous film at 100°F (38°C), but for durability it is preferred that the fabric reaches 250°F (120°C) for a few seconds. It will then have better cohesion and adhesion.

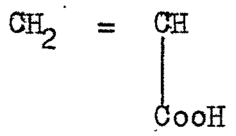
He has further mentioned that the common acrylic esters are non-reactive. A reactive acrylic is a copolymer composed predominantly of acrylic monomers and containing functional groups that enables it to crosslink during or after application to textiles. The reactive acrylic products are useful for crease recovery and wash-wear, bonding of nonwovens, foam laminating, flock bonding, fabric coating and pigment drying and printing.

According to Taylor and Hurwitz (48) acrylic monomers can be polymerized by an anionic or from radical catalyst system in bulk, emulsion, suspension or solution. Acrylic resins have been used as the sole fabric finish or as additives with thermosetting resins. Acrylic resins have been utilised:

i. to improve tear strength of cellulose fabrics.
ii. to improve the crease recovery of resinated fabrics.
iii. to improve abrasion resistance.
iv. to improve "wash-wear" behaviour.
v. to control shrinkage.

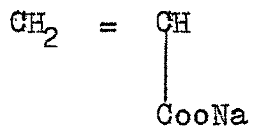
Nuessle and Kine (34) described acrylics as subdivision of unsymetrically substituting ethylene class, obtained by polymerization of monomer containing $CH_2 = C$ = Vinyl groups. In properties and uses, the ordinary acrylic resins are more closely related to vinyl monomers than to the condesation resins such as the urea formaldehyde.

More specially, the acrylic monomers include acrylic and methacrylic acids and their salts, like esters, amides and nitriles. Any of these alone or in combination, will undergo addition polymerization to form linear polymers.



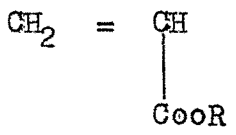
$$CH_2 = \underset{\underset{\displaystyle CooH}{|}}{CH}$$

Acrylic acid



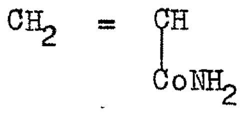
$$CH_2 = \underset{\underset{\displaystyle CooNa}{|}}{CH}$$

Acrylate salt



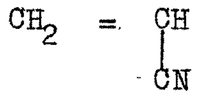
$$CH_2 = \underset{\underset{\displaystyle CooR}{|}}{CH}$$

Acrylic ester



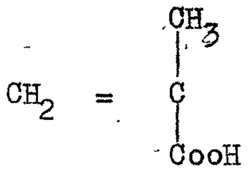
$$CH_2 = \underset{\underset{\displaystyle CoNH_2}{|}}{CH}$$

Acrylamide



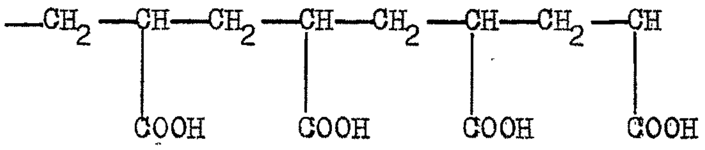
$$CH_2 = \underset{\underset{\displaystyle CN}{|}}{CH}$$

Acrylonitrile



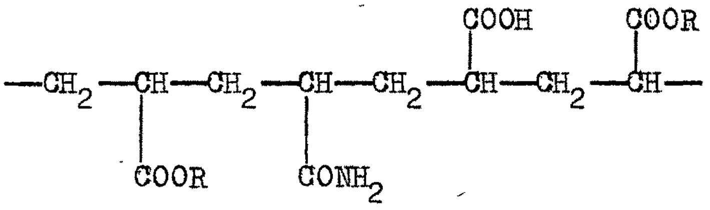
$$CH_2 = \overset{\overset{\displaystyle CH_3}{|}}{\underset{\underset{\displaystyle CooH}{|}}{C}}$$

Methacrylic acid



$$-CH_2-\underset{\underset{\displaystyle COOH}{|}}{CH}-CH_2-\underset{\underset{\displaystyle COOH}{|}}{CH}-CH_2-\underset{\underset{\displaystyle COOH}{|}}{CH}-CH_2-\underset{\underset{\displaystyle COOH}{|}}{CH}$$

Polymer of acrylic acid



$$-CH_2-\underset{\underset{\displaystyle COOR}{|}}{CH}-CH_2-\underset{\underset{\displaystyle CONH_2}{|}}{CH}-CH_2-\overset{\overset{\displaystyle COOH}{|}}{CH}-CH_2-\overset{\overset{\displaystyle COOR}{|}}{CH}-$$

Acrylic Copolymer

Thermosetting Finishes

Thermosetting resins generally are liquids or low melting solids which under the influence of heat, pressure, ultra-violet light, radio frequency excitation, catalysts and accelerators are transformed into rigid products that are relatively infusible and insoluble. They cannot be reshaped or remelted after they have been cured to their final state. Thermosets are cured, set or hardened into a permanent shape. This curing is an irreversible chemical reaction also known as crosslinking, which usually occurs under heat. For some thermosetting materials, however, curing is initiated or completed at room temperature.

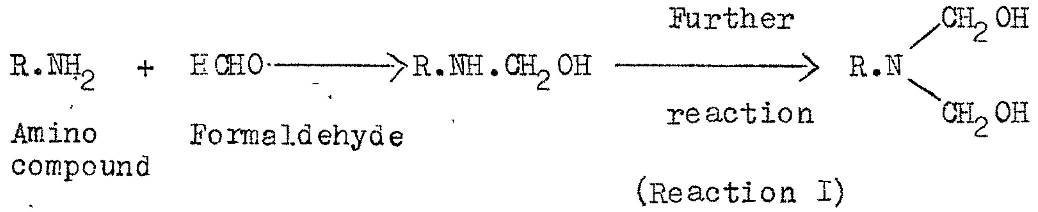
The crosslinking that occurs in the curing reaction is brought about by the linking of atoms between or across two linear polymers, making a three dimensional rigid chemical structure.

Marsh (28) has summarized the chief advantages of the fabrics treated with thermosetting compositions. The important ones are given below:

a. Improved resistance to and recovery from creasing.
b. Smooth-drying properties after laundering and reduced laundry shrinkage.
c. Increased dry tensile strength.
d. Improved handle and drape of fabrics.
e. Increased resistance to distortion of fabric and improved retention of garment shape and freshness.
f. Increased resistance to weathering and photodegradation and rotting.

As reviewed by Marsh (27) and Smith (44) the thermosetting resin finishes can be divided into two groups nitrogenous compounds and non-nitrogenous compounds. The former consists of methylol urea, methylol melamine, methylol cyclic ethyleneurea and methylol triazone and the latter comprises of formaldehyde, epoxy resins, chloroalkyl compounds and divinylsulfone derivatives.

Nitrogenous compounds are obtained by the reaction between an amino compound and formaldehyde, forming a mono-, di-, or poly-methylol compounds as shown in reaction I.

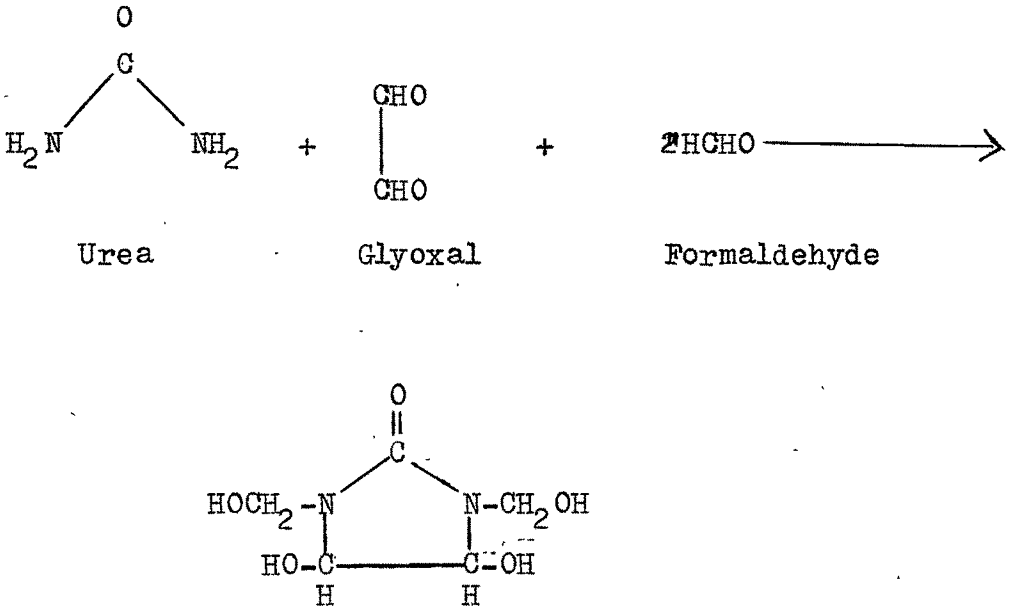


$$\underset{\text{Amino compound}}{R.NH_2} + \underset{\text{Formaldehyde}}{HCHO} \longrightarrow R.NH.CH_2OH \xrightarrow[\text{reaction}]{\text{Further}} R.N\begin{matrix} \diagup CH_2OH \\ \diagdown CH_2OH \end{matrix}$$

(Reaction I)

With the exception of formaldehyde, the non-nitrogenous compounds are of recent origin. Because of the absence of the nitrogen they do not have the disadvantage of absorption of chlorine from hypochlorite solutions and subsequent damage with hot ironing. The conditions of treatment vary with individual substances.

The preparation of the dimethylol derivative consists of reacting urea, glyoxal, and formaldehyde as shown in reaction II. One of the advantages of dimethyloldihydroxyethyleneurea (DMDHEU) is that they are simple to make. They are also chlorine resistant and further fabrics treated with this reactant will remain in the uncured state for a few months.



Dimethyloldihydroxyethyleneurea

(Reaction II)

Theoritical Considerations

Wrinkle resistance of fabrics is the result of a complex mixture of chemical and physical effects. It is generally accepted that cross-linking is an important factor in producing wrinkle resistance in cellulosic fibers. For good crease recovery, the formation of the resin should be essentially inside the fiber, that is, in the amorphous portion of cellulose. Dye staining techniques used for the location of the resin confirm this (8, 23). Differing views have been given by different workers to explain the mechanism of crease-recovery. These views generally fall into three groups:

a. Hydrogen bonding mechanism,

b. Complex formation and molecular entanglement, and

c. Cross-linkages between cellulose chains.

Reid and Reinhardt (38) have explained the term "cross link" as a chemical bond resulting from the reaction of a finishing agent with the hydroxyl groups of the anhydroglucose units of cellulose chains of which the cotton fiber is composed. They further stated that by the formation of a three dimensional network the cellulose molecules are bound in place and prevent, or reduce their slippage over each other during deformation of the fabric. After deformation the cellulose molecules tend to return to the position held when the fabric was cured. When the force is strong, the cotton fabric dries smoothly and is said to be wash-and-wear.

On the possible mechanism of crease recovery, Nuessle, Fineman and Heige (33) have pointed out that it is most difficult to distinguish between hydrogen bonding and the co-valent cross-link in crease resistant fabrics. Inter-molecular bonding could take place through hydrogen bonds and there is no need to postulate the co-valent cross-link. There is a possibility of cross-linkages because of the presence of formaldehyde during the reaction. Marsh (26) has pointed out that the crease recovery of even untreated fabric increases on drying, which is probably due to hydrogen bonding at the junction points in the amorphous network of cellulose, and which disappears when the bonds are broken again on the absorption of moisture. Crease recovery by resin formation, however, is not believed to be due to a form of permanent dehydration. The recovery varies with humidity in the case of resin - treated rayon as well as cotton, as pointed out by Marsh (26) and Landells (23). The co-operating hydrogen bonds contribute to the crease recovery of the treated fabric, more so during the drying of fabric. The hydrogen bonding in a sense is similar to molecular entanglement.

The broad idea of molecular entanglement as a general explanation of crease resisting effect was suggested by Marsh (26), alongwith a useful hypothesis, that a swollen fiber is as lively and resilient as a canvas hosepipe distended with water in comparison with the same material empty, flat and lifeless.

Improvement in resilience of cotton textiles was ascribed to either simple polymer deposition or to covalent crosslinking. The idea of covalent crosslinking to improve the resilience in cotton was revived by Cameron and Morton (7) and also supported by Linken, Davis and Jorgensen (24). Gagliardi and Nuessel (12) and Nuessle et al. (33). Cameron and Morton concluded that the modification of the fiber involves an increase in elasticity and a decrease in plasticity, and this is the basis of the crease recovery of the treated fabric. While summarizing the mechanism of wet crease resistance and crease retention, Ryan (40) has stated that covalent-bond crosslinking in the wet state, or highly swollen state if swelling is due to media other than water, will result in wet crease recovery and crease retention, but little dry crease resistance and crease retention. Whereas covalent-bond crosslinking by dry curing at elevated temperature will result in dry crease recovery and crease retention as well as substantial degree of wet crease resistance and crease retention.

The mechanism of increased resilience of resin treated material has been investigated by Miksys and Alaune (30), who found the curing of samples, which were washed with warm water after impregnation developed the maximum crease recovery almost instantly; while cured and washed samples reached the maximum values after a prolonged period. This indicates the existance of hydrogen bonds between OH and NH groups in cellulose and resin. As pointed out by Ryan (40) the precise nature of crosslinks may differ with different finishing agents and may involve not only covalent linkages but also hydrogen bonds and Van der waals forces.

During normal service a fabric is subjected to tensile forces. In the case of untreated cellulosic fabric the tensile forces readily displace the cellulose molecules in the amorphous areas and the cellulose molecules do not suffer much strain. When the cellulose chains are crosslinked, displacement of the cellulose molecules results in the creation of considerable restoring forces and for a given displacement a much higher strain arises in the cellulose chain. The stresses arising in the cellulose molecule breaks the cellulose chain. Breakage of the cellulose chains results in the breakage of the fibers, which in turn results in failure of the fabric. The greater the number of crosslinks, the greater the degradation of fabric properties (40).

As stated by Hall (15) the loss in wear resistance and tear strength can be minimized by adding to the pre-condensate liquor a compatible softening agent. Bullock and Welch (6) suggest that in the case of silicones, the mechanism of crease recovery involves the formation of a resilient film tightly surrounding the fibers, which not only contributes directly to recovery properties, but decreases the accessibility of the cellulose to moisture, thus rendering hydrogen bonding more effective as a type of cellulose crosslinking. Gonzales _et_ _al_. (14) have also indicated the absence of cellulose cross-links in the case of synthetic polymers, such as, polyvinyl acetate - stearate, etc. Acrylates are considered as reactive polymers by Skelly (43).

On the basis of infra-red-measurements, Cooke _et_ _al_. (8) also suggest the similar type of mechanism, namely, that the elastomeric type of thermoplastic resins impart wrinkle recovery property by an elastic type of bridging of yarn to yarn. Long, flexible chains, without too much of netting or branch chains, are necessary for an elastic material was also indicated by Mark (25).

Properties Introduced by Thermoplastic and Thermosetting Finishing

Polymer additives have been used extensively to improve wrinkle recovery and strength characteristics of fabrics. Walsh, Siahkolah and Rutherford (50) studied the changes in properties of cotton fabrics by application of series of acrylic copolymers having glass transition temperature ranging from -47°C to 33°C. Acrylic copolymers were padded on the fabric for 100 percent wet pick up to give a solid add-on of ten percent.

They have concluded that fabric stiffness is changed very little by polymers with glass transition temperature below room temperature, but the glossy polymers produced a large increase in stiffness. Dry crease recovery angle increased smoothly with decreasing glass transition temperature of applied polymers. Glossy polymers (glass transition temperature above room temperature) decreased the crease recovery angle (W + F) by as much as 100° and the softest polymer increased it by about 50°. The tear strength and flex abrasion were also related to the glass transition temperature of polymer. No significant difference in properties was observed when the cross-linking was carried out before, during or after polymer application.

Changes in crease recovery angle produced by these polymers were not due to lubrication but were related to the elastomeric properties of the added polymer. Changes in tear strength and abrasion resistance were a function of inter-yarn mobility by measuring yarn withdrawal forces of the fabrics.

Rawls, Klein and Eyer (37) examined a number of polymer treated fabrics and concluded that the polymer characteristics necessary for improved wrinkle recovery are high elastic recovery, low glass transition temperature and low permanent set.

Harper, Lofton and Coworkers (20) applied polymers with various glass transition temperature to yarn prior to weaving and to fabrics after weaving. To achieve smooth drying characteristics required in durable press fabrics, combinations of polymer additives and a lower than normal amount of cross-linking agent was used. The various polymers used were polyacrylates, polybutadine, butadiene-styrene, butadiene-acrylonitrile copolymers, polyurethanes and polyethylene. The cross-linking agent used was dimethyloldihydroxyethyleneurea (DMDHEU).

The fabrics or yarns for polymer treatments were padded with a solution containing 12 percent polymer (solids), dried and cured. The cross-linking treatment was applied after the polymer treatment, the cross-linking formulation containing 7.2 percent DMDHEU and 0.6 percent zinc nitrate hexahydrate catalyst.

Examination of the polymer-treated yarns indicated that polymers of low glass transition temperature increased immediate recovery and decreased the permanent set of the yarns relative to untreated yarn. Polymer treatment of yarns improved yarn breaking strength significantly, but the overall strength improvement is decreased when these yarns are put into fabrics and are crosslinked. Polymer treatments, either by the yarn or fabric route improved fabric resiliency more than fabric durable-press ratings.

The effect of polymeric latices, in mixtures with various urea-formaldehyde and melamine formaldehyde resins on cotton cambray was studied by Abrams and Sherwood (1). Finish was applied by single step method and two step method. The study revealed that the crease recovery angle and abrasion resistance remains the same as for the one-bath treatment, when the latex and urea-formaldehyde resins were padded in separate operations. A ratio of 70:30 of the latice to the resin resulted in the fabric acquiring good crease resistance with good physical characteristics. Fabrics treated with butadiene-acrylonitrile latex (70 percent) and urea-formaldehyde (30 percent) had very good resistance to creases as well as good strength and excellent resistance to abrasion. The polyacrylate ester treated fabric had only slightly lower strength than the former. Moreover, the tendency of urea-formaldehyde treated fabrics to retain chlorine during laundering was markedly reduced.

The improvement in the properties, due to the use of latex resin formulation is not brought about just by the reduction in concentration of the urea formaldehyde but because polymeric latex plays a definite part in the improvement in breaking strength, abrasion resistance, bursting strength and hand.

Kottes, Andrews and Harper (21) explored to produce durable crease in the 50/50 cotton/polyester fabric, by inclusion of polymeric additives in the cross-linking formulations. As any two step process incurs additional cost for additional processing, the investigation was limited to one-step processes.

The fabric used was a double knit swiss pique, knitted from 50/50 cotton/polyester yarn. Cross-linking agents used were dimethyloldihydroxyethyleneurea (DMDHEU) and trimethylolmelamine (TMM) and polymer additives included an ethylene-vinylacetate copolymer, two polyethylene emulsions, two polyacrylate emulsions and polyvinyl alcohol.

The data revealed that although durable press ratings, strength, and dimensional change on laundering were too similar for significant comparisons, response of the finished fabric to creasing did differ among the treatments. They have further stated that the combination of a self-crosslinking reactant with a predominantly cellulose-crosslinking reactant catalyzed by magnesium chloride hexahydrate served as another way to produce fully-cured cresable knitted fabrics.

Andrews and Frick (3) treated knitted fabric samples with baths containing dimethyloldihydroxyethyleneurea (DMDHEU) and a series of polyacrylates or polyurethanes as additives. It was indicated from the data that these polymer additives could reduce the amount of crosslinking required, therefore, the effect of polyacrylate additives at a lower level of cross-linking agent were investigated. Properties were examined after five home launderings. The improvements obtained this way were small on knitted cotton fabrics. The polymer additives at the optimum treatment levels (3 percent) contribute the same amount of dimensional stability to the fabric, regardless of the level of cross-linking.

Recovery from a monoaxial stress, a measure of the tendency of a garment to retain its shape, decreases with increasing glass transition temperature. The long term recovery from such deformation, however, is improved by increasing the elastomeric qualities of a polymer of given glass transition temperature. With the polyacrylate series, the resistance to flat abrasion and bending stiffness increased with increasing glass transition temperature. Durable-press ratings are decreased by polymers of glass transition temperature approaching or greater than ambient temperature, glass transition temperature lower than that seems to have little effect on appearance of the finished fabrics. They have stated that dimensional stability and strength of the finished fabrics are independent of polymer glass transitions.

Cotton and cotton-polyester blend fabrics treated with formaldehyde-free finishing agents and additives were studied by Harper and Frick (19). They concluded that the use of polymer additives in conjunction with the formaldehyde-free cross-linking agent gave conditioned wrinkle recovery angles of 285 - 300° (W + F) on cotton and cotton/polyester blend fabrics. These fabrics had durable press rating of 3.3 - 4.0 on cotton fabrics and 3.7 - 4.8 on blend fabrics.

The lower concentration of polyacrylate did not increase durable press ratings noticeably, but did increase wrinkle recovery angle. The other additives, polyethylene and polysiloxane with polyacrylate did not increase the effect of polyacrylate on wrinkle recovery, but in many instances did lead to further improvement in durable press rating.

They have further stated that the polyacrylate supplemented the cross-linking agent but, had little or no effect by itself on durable press rating. However, it did tend to increase wrinkle recovery both on cotton and on blend fabric. The additives increased the tear resistance of the fabric that was not cross-linked with formaldehyde free finishing agent.

Sharma and Daruwalla (42) grafted fabric samples with binary and ternary mixture of selected vinyl monomers alongwith acrylamide onto cotton using ceric ammonium nitrate as catalyst from aqueous solution or emulsion, and subsequently polyacrylamide grafts were methyloated in situ and crosslinked. Except in the case of acrylamideacrylanitrile treatment, finished fabrics showed good wrinkle recovery properties accompanied by satisfactory retention of breaking and tear strength, and also very much improved resistance to abrasion.

Richards and White (39) studied the effect of graft polymerization on crease resistance of cellulosic fabrics. Methyl acrylate and styrene monomers were polymerized on cotton and viscose fabric by graft polymerization technique. They found that the rate of polymerization increases markedly with increasing concentration of monomer. The crease recovery of methyl methacrylate grafted cotton in the wet state showed a continuous rise with increasing graft level, whereas under ambient conditions the crease recovery went through a slight maximum followed by a decrease with increasing graft level. The decrease in crease recovery with increasing graft level may indicate that the polymethyl methacrylate component can participate in such hydrogen bonding with the cellulose, thus increasing the tendency to permanent set.

The effect on crease recovery of grafting styrene was a continuous slight increase in wet crease recovery. They state that this behaviour is again attributed to the effect of the hydrophobic graft in causing a stiffening of the wet fabric and reduced water imbibition. The air dry crease recovery showed a slight but significant maximum between 0 and 9 percent add on.

They recommended the process as suitable for the deferred cure process with minimum evolution of formaldehyde. They have stated that when the above mentioned uncross-linked samples are cross-linked with N-methylol cross-linking agents, improvement in wrinkle-recovery properties are accompanied by usual losses in strength and abrasion resistance. However, when ternary mixtures containing ethylacrylate acrylamide, and acrylonitrile are grafted at higher polymer add-ons, and fabric is cross-linked through conventional cross-linking agents, very good strength retention is achieved. Whereas in the reverse process where samples are first cross-linked through polyacrylamide grafts and then further grafted with ethylacrylate alone or in combination with other monomers abrasion properties are markedly improved, while wrinkle recovery properties are only moderate.

Garvey (13) studied the changes in the physical properties of resin-treated fabrics resulting from the addition of elastomers, thermoplastic resins, repellents and softners to a normal thermosetting resin finishing bath. The general formulation used in the application of all the additives was 9 percent resin solids (a modified urea-formaldehyde) with 4 percent catalyst and 5, 10 and 20 percent additive based on the resin solids. Spun-Viscose fabric was used for the investigation.

Analysis of the results showed that the additives have certain optimum concentration, which varied with each compound used. Smaller percentage of resin gave a larger increase in wrinkle recovery. Merlon KR-4 (an aqueous dispersion of polyvinyl acetate) produced a greater increase in wrinkle recovery than did the Hycar 1562 (a latex containing acrylonitrile and butadiene with an antioxidant added) probably because it forms a tougher, more pliable film on the surface of the fibers.

The addition of the thermoplastic resins increased the tear strength, but the tear strength did not exceed the original tear strength of the untreated fabric. The thermoplastic resins coat the fibers and the abrasion resistance is thus increased.

Hamalainen et al. (16) examined the physical properties and performance properties of fabrics treated by the poly-set process. The poly-set process involved two pad-dry-cure treatments. In the first step N-methylol resin reactant and a polymerization catalyst were applied by padding on fabric and then heat cured to deposit the resin on fabric and within the fibers. In step two, a strong latent acid catalyst was used to cause more extensive cross-linking to obtain the desired smooth drying performance.

The process was responsive to lubricant and softener additives in both steps. A polyethylene-polypropylene softener used, greatly enhanced the wrinkle recovery when it was used in either or both steps. These effects were durable to laundering. The results were compared with the conventionally treated fabric. They have found this process suitable for both pre- and post-curing operations.

Breaking and tearing strengths of the poly-set processed fabrics were somewhat greater than the conventionally treated fabric. The greatest improvement was noted in abrasion resistance which was several times more than that of the conventionally processed sample.

Varghese and co-workers (49) studied the influence of finishing techniques and additives on the overall performance of 5 percent dimethyloldihydroxyethyleneurea (DMDHEU) finished cotton poplin. They concluded that moist cure treatment is highly deleterious probably due to the high sensitivity of the technique to the conditions employed, while the combined wet-fix catalyst treatment is on par with the standard pad-dry-cure technique. The use of 20g/1 polyethylene emulsion and 10g/1 silicone emulsion in the bath showed significant improvement in properties for moist-cure technique than either for pad-dry-cure or for the combined wet-fix catalyst treatment. The use of 20g/1 acrylic emulsion showed its high beneficial effect in both pad-dry-cure and the combined wet-fix catalyst treatments as against its low value for moist-cure technique. Acrylic emulsion in general is able to improve not only the resilence property but also the strength and abrasion properties of fabrics.

Lamprinakes and Sookman (22) have studied the influence of reactive vinyl pyrrolidone polymers on various fabrics. The properties studied were crease recovery angle, tensile strength, abrasion resistance, tearing strength and appearance ratings.

The results of these tests indicated that the abrasion resistance of the fabrics treated with vinyl pyrrolidone acrylate emulsion having functional groups is much better than that of the normal acrylic treatment. Because of its excellent adhesion to polyester it gives greater durability of hand than do most acrylics. This finish also improve the tear strength and hand of durable press fabrics. They have stated that 7.5 percent level of resin would also afford maximum durability although good results were obtained at 25 percent level of durable press resin and 6 percent level of vinyl pyrrolidone polymers.

Olson, Langston and Rainey (36) studied the effects of rubber and resin latices on chemically modified and unmodified cotton fabrics. The various physical characteristics studied were the stability to ultraviolet light, crease recovery, resistance to abrasion, tear resistance, breaking strength, resistance to microbiological attack and dimensional stability.

Latices having the best ability to improve crease recovery were diepoxides and certain selected silicones. The polyvinyl acetate resin in combination with either latex showed improved crease-recovery characteristics when applied to the chemically modified cotton fabrics. The diepoxide and the silicone diepoxide showed ability to impart dimensional stability to cotton fabrics. This ability was reduced somewhat when the silicone was applied.

With the increased lubrication properties of the applied latex or resin the breaking strength decreased. Those latices which possessed well-known lubricating properties from linear polymers, that is polyethylene or silicone emulsions did yield lowest breaking strength qualities. The copolymers, which produced non-lubricating linear and plan~~n~~er systems that is butadienestyrene, acrylonitrile-butadiene and polystyrene, improved the breaking strength of cotton fabric. This improvement was supplemented by adhesive properties which reduced the slippage factor. Hard polymers lacking internal pliability and those applied so as to crosslink with cellulose tended to reduce tear strength. Polymers containing linear connecting groups and those known to plasticize and otherwise induce pliability, increased tear strength. Latices possessing the ability to form continuous films resist abrasion more than those forming discontinuous films. Large particle size yielded increased abrasion resistance. Significant improvement in resistance to microbiological attack was noted when selected latices were applied to cotton fabrics during resin treatment.

Steele (47) treated fabrics with various levels of two synthetic polymer latices, Rhoplex S-1 and Rhoplex WN-77. The first of these forms very soft, extensible films on drying, while the second is much harder and stiffer. The concentrations of resin solids used were 0, 0.5, 1.0, 1.5, 2.0, 3.0, 4.0 and 5.0 percent. He has found that Rhoplex S-1 increases tear strength while Rhoplex WN-77 decreases it. He has stated that these surface resins affect tear resistance by the changes they produce in fiber-to-fiber interactions in the filler assembly.

Nuessle (32) found out that crease recovery of cotton fabrics may be greately enhanced by treatment with thermoplastic (polyvinyl alcohol and polyacrylate) and thermosetting (urea formaldehyde etc.) resin formers and reactants. Improved recovery is always accompanied by a loss in tear strength; and in order to obtain high crease recovery value with maximum tear strength, it is necessary to select a fabric and to include a softener in the treatment.

Soignet and Coworkers (45) applied epoxides from aqueous and nonaqueous solvent systems under different cure conditions to impart optimum fabric properties to blends of high percentages of cotton. A typical formulation contained 5 to 10 percent epoxide and 1.1 percent ZN $(BF_4)_2$. The various textile tests performed were breaking strength, wrinkle recovery, abrasion resistance and wash and wear appearance ratings.

The study revealed that fabrics containing as much as 80 percent cotton and 20 percent polyester can be treated effectively with difunctional epoxides capable of improving both wet and conditioned recoveries without losing an excessive amount of tensile strength. They have suggested that in high cotton blends, there should be an intimate mixture of cotton and polyester in both warp and fill direction.

Harper and Bruno (18) treated cotton and polyester-cotton blended fabrics of various proportion with dimethylol-dihydroxyethyleneurea (DMDHEU) using a conventional pad-dry-cure technique to know if any reactions occur between the polyester and the cross-linking agent and whether cotton fibers in the blends are over cross-linked.

They have concluded that, a treatment from 6.8 percent to 9 percent DMDHEU is adequate to produce acceptable durable press performance in the all cotton fabric. In order to achieve an equivalent level of add-on on the cotton fibers in the blended fabrics treatment with 4.5 percent DHDHEU is sufficient.. They further state that treatment with higher levels of cross-linking agent failed to generate additional improvements in durable press ratings. Excessive cross-linking did not significantly improve the resiliency of the cotton fibers and lowered certain strength characteristics particularly abrasion resistance.