Chapter II
CHAPTER II

VARIOUS APPROACHES TO IMPART CLOTHING COMFORT TO POLYESTER

INTRODUCTION

As pointed out in the preceding chapter, in spite of various benefits offered by polyester due to its certain desirable properties, its properties like lack of moisture sorption and wicking, generation of static electric charge and oleophilicity have kept the polyester away from enjoying a reputation for comfort. Even after a decade of research and development works, only a few products are commercialized. Suchecki believes\(^1\) that "the concept of polyester with increased comfort potential is an idea whose time is coming".

SCOPE OF MODIFICATION

Polyester can be modified either physically or chemically. Modification done to improve one property, generally affects other properties. Hence, a balance must be optimised before attempting to modify any property.

Physical modification\(^2\) involves mainly changes in orientation, crystallinity and thermosetting pattern of the fibre producing certain effects in the molecular configuration of the fibres. Extensive research and development work has been carried out
on chemical modification of polyester to impart comfort characteristics to polyester. Ghose discusses in general terms how the comfort of hydrophobic fibre garments can be made equal to that of natural fibre ones and deals with both structure and finishing factors. Vaidya and Nigam in their review cover the developments in methods to impart hydrophilic properties to polyester fibres. The various chemical approaches followed to impart hydrophilicity to polyester can be broadly classified into the following three categories:

1. Manufacture of modified polyester by incorporation of hydrophilic compounds into the polyester backbone;

2. Grafting of hydrophilic monomers onto polyester; and

3. Topical finishing treatments with chemicals which impart hydrophilic character to polyester.

(1) **Incorporation of Hydrophilic Compounds in the Polymer Backbone**

Various attempts have been made to improve hydrophilic, soil-release and antistatic characteristics of polyester by incorporating certain hydrophilic chemicals either during the course of polymerization or in the polymer melt, but most of the work is patented. Some of the important developments are summarised below. These hydrophilic compounds, can be classified into the following three groups:
(a) Compounds having anionic groups;
(b) Compounds having cationic groups; and
(c) Miscellaneous compounds.

(a) **Compounds Having Anionic Groups**

In order to dye with basic dyes, copolyester with strong acid groups, which are anionic in nature, were produced. Polyester fibres were modified by anionic components containing sulphonic acid groups, sulphonated benzene compounds or with phosphonic compounds. Cationic dyeable polyester fibres are the most popular variety amongst all the modified polyesters. Various patents based on the addition of sulphonic acid or sulphonate containing compounds during or after the polycondensation process, have appeared in the past few years, claiming the development of improved hydrophilic, antistatic and basic dyeable polyester. The antistatic components used during polymerisation, are aromatic sulphonate compounds like 5-sulpho isophthalic acid. These increase the dye affinity of polyester fibres. ICI have suggested a method of preparation of polyester of improved moisture regain by the addition of 5-10% by weight of sodium sulphate of particle size less than 3 microns to a slurry in ethylene glycol during polymerization. Also the ICI claims the preparation of an improved linear polyester having better affinity for basic dyes by carrying out the polycondensation
process in the presence of diphenyl sulphonic acids or their salts. Toray industry\textsuperscript{5} has disclosed a process for producing a hydrophilic polymer with an affinity for basic dyes by the addition of alkali metal salts of phenosulphonic acids to the polyester forming reaction mixture. Bykov et.al.\textsuperscript{14} and others\textsuperscript{7-8} have recommended the addition of metal phthalocyanines containing sulphonyl acid groups, bifunctional alkylene-arylene-diphosphonic acid during the course of synthesis for getting modified polyester. Modified types of polyester filaments - Slotera\textsuperscript{15} produced in Czechoslovakia and newer types of polyester staple\textsuperscript{16} produced in Japan are cationic dyeable. Polyester dyeable with azo dyes can be produced by adding heat resistant nickel compounds such as nickel stearate, nickel di-octyl phosphate just before spinning.

(b) **Compounds Having Cationic Groups**

Attempts have been made to incorporate aliphatic and aromatic amine groups or amide groups such as Nylon-6, Nylon-66 in the polyester backbone. However, when these polyesters are melt spun above 270°C, they darken due to oxidative degradation. Hence an antioxidant is added as a stabiliser. Duddey\textsuperscript{6} has suggested the use of ammonium or amine salts of alkoxybenzene sulphonylic acids. Spanninger\textsuperscript{17} claims a process for preparing modified polyester by the addition of about 1-15 mole percent of a monohydroxy or dihydroxy amines
to the reaction mixture. The antistatic component diamines are also used during polymerisation. It increases the dye affinity of anionic dyes with polyester.

Thus by introduction of some specific groups into the polymer chain for linking up with dyes, the affinity of dyeing with cationic and anionic dyes increases.

(c) Miscellaneous Compounds

Fibres with enhanced dye affinity can be produced\textsuperscript{18} from block copolymers made from PEG or polypropylene glycols of high molecular weight (1000-3000) with PET. Though the dye affinity is satisfactory, the greatest disadvantage of these fibres are poor resistance to degradations, particularly hydrochloric, thermal and photochemical. Other formulae which have been disclosed for the production of improved polyester include the addition of 3-12\% by weight of sodium paraffin sulphonate\textsuperscript{19}, 1-7\% of a sulphonated polyoxy alkylene\textsuperscript{14}, polyester urethanes\textsuperscript{20} and surfactants\textsuperscript{21} insoluble but stable in polyester polycondensation process, either in the polymer melt before spinning or in the reaction mixture. Hydrophilic polyester fibres were spun\textsuperscript{22} from a bis (hydroxy-ethyl)-5-sulphoisophthalic acid sodium salt/ethylene glycol/dimethyl terephthalate copolymer containing 5-20\% sulphoisophthalate units. The fibre absorbs more moisture, retains less static electric charge and has a lower oil affinity.
(2) Grafting of Hydrophilic Monomers

The graft copolymerization of hydrophilic monomers onto polyester textiles to impart comfort characteristics has received considerable attention and the technique has already been successfully employed in the USA and Japan. Various attempts have been made to copolymerise hydrophilic monomers like acrylic acid, methacrylic acid, acrylamide, acrylonitrile, vinyl acetate, the mixture of 4-vinyl pyridine/ acrylic acid, poly vinyl alcohol, styrene and other derivatives either by:

(a) High Energy Irradiation or,
(b) By Chemical Initiation.

The graft copolymerized chains lie flat on the surface of fibre resulting in protection to the fibre. On putting in water, these side chains spread away from fibre being mobile and thus assist in soil removal. Graft copolymerization of polyester with certain vinyl monomers employing a suitable initiation technique has been found to impart good dyeability and improve comfort characteristics. Grafting with acrylic acid monomer has been studied extensively.

(a) High Energy Irradiation

Ionizing radiations like γ-rays from a Cobalt-60 source or, high energy electrons from accelerators; an Argon glow
discharge (cold plasma) and direct fluorination in liquid or vapour phase, interact with the polyester fibre and produce free radicals. The free radicals thus formed are responsible for the grafting\textsuperscript{23} and the reaction always takes place in the absence of oxygen. These radical sites permit the attachment of monomer molecules which may grow into short chains.

Hall\textsuperscript{24} has reviewed the irradiation polymer grafting with nine references. Lee et al.\textsuperscript{25} have increased the hydrophilicity by conversion of the acrylic acid grafts to corresponding metal salts. Use of a 90:10 4-vinyl pyridine/acrylic acid mixture at pH 7 to 8 effectively increased the percentage of grafting and reduced water contact angles. They have also grafted acrylic acid by exposing impregnated drawn crystalline polyester fibre to gamma radiation in a nitrogen atmosphere and found that the resulting fibre has good water sorption and tensile properties and affinity for basic dyes\textsuperscript{26}.

Bonnefis and Coworkers\textsuperscript{27}, on the basis of their study on grafting by direct irradiation of polyester fibres in contact with aqueous solutions of acrylic acid, have shown that grafted fibres containing up to 40% polyacrylic acid have interesting properties with respect to moisture uptake, static electrification, and affinity with basic dyes while mechanical properties are unaffected. The most useful grafting ratio has been found to be between 15 and 20\%.
The direct radiochemical grafting of the fibres with acrylic acid in vapour phase, gave grafted fibres with good hydrophilic characteristics and improved antistatic property. In order to improve the antistatic and dyeing properties of polyester, further attempts have been made to graft vinyl monomers with polar functional groups such as 4-vinyl pyridine and acrylic acid and polyvinyl alcohol utilising ionizing radiation. The mechanism of grafting polyester fibres with vinyl monomers has been studied. Polyester fibres grafted with vinyl monomers were shown to have very low resistance to alkaline hydrolysis.

Okada et al. have carried out extensive studies on the radiation-induced grafting of various types of monomers on to polyester and have examined the properties of the grafted fibres. Impregnation-graft copolymerisation of acrylic acid on polyester textiles initiated by electron bombardment proceeded smoothly at 60-100°C and gave 25% add-on at 100°C in 2 sec. An add-on as low as 4% was found to give improved hydrophilicity, static electric charge dissipation in air, oily stain release and dyeing ability with basic dyes. A degree of grafting of 15-20% of polyacrylic acid onto PET fibres was obtained by the radiation-induced grafting of fibres, impregnated with a mixture of acrylic acid, H₂O and 1,2-dichloroethane. Fe(NH₄)₂SO₄ was used as an inhibitor in the solution. They have also studied the grafting of
high density PET filaments with acrylic acid to increase the fibre softening temperature and to impart flame retardance and hydrophilic properties. Polyester fabric grafted with a mixture of sodium styrene sulphonate and \( \text{CH}_2\text{CMeCO}_2(\text{CH}_2\text{CH}_2\text{O})_n \text{COCMe} = \text{CH}_2 \) (where, \( n = 1,3,4,14 \) or 23) from aqueous solution by means of electron beam radiation showed improved anti-static properties with greater wash-fastness than fabrics grafted with acrylic acid or sodium acrylate. Accelerated \( \bar{e} \) beams at high dose rates were used in acrylic acid grafting. The grafted fibre showed considerable improvements in moisture regain. Electron beam induced in situ polymerisation of several hydrophilic monomers on polyester is reported to give cross-linked finishes with various polar groups.

Swelling characteristics of the grafted polyester were compared with those obtained using a commercial, non-swelling surface finish. It was found that the grafted polyester produced fabrics which wicked faster than those with swelling finish, but whose moisture holding capacity was not greater than that of the control. While the swelling finish gave more water holding capacity, without feeling damp, in several instances without significant restrictions on wicking. Lightly cross-linked, highly swelling finished fabrics, however, absorbed too much water, blocking the capillaries and completely stopping wicking in some cases. Anionic groups attracted wet soil much less than cationic groups, which soiled significantly more than the control.
Polyester fibres, films and fabrics were grafted with acrylamide and with mixtures of acrylamide and styrene using $\gamma$-irradiation from a Co-60 source. The graft copolymers showed 25% increase in tensile strength, 80% in elongation and improved dyeability and moisture retention. Grafting of polyethylene-glycol dimethacrylate and diacrylates onto polyester fabric was inhibited at room temperature by the presence of air but went smoothly at 65°C. Both grafts were found to have good frictional, electrical and hydrophilic properties, but the diacrylate graft was more effective.

The resistance to soiling of polyester fabric is very markedly improved by activating the surface of the fabric by an Argon-glow discharge (cold plasma) whereby polar carboxyl groups are created. The treatment does not change the bulk properties of textiles. The plasma of inert gases can be used to initiate the grafting of selected vinyl compounds to textile fabrics. The following are the commercial products of the above type of grafting:

<table>
<thead>
<tr>
<th>Product</th>
<th>Chemical Nature of Finish</th>
<th>Method of Application</th>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refresca (Spring Mills, USA)</td>
<td>Copolymerisation of poly acrylic acid on to polyester fibre surface</td>
<td>Treatment with Argon (cold plasma) in the presence of acrylic acid vapour</td>
<td>Excellent performance and durable</td>
</tr>
</tbody>
</table>
Recently, fluorination of polyester has been shown to improve its moisture transport, soil-release and anti-soil redeposition properties. Incorporation of fluorine as low as 0.03-0.04% gives excellent hydrophilic character to polyester. The effect is unaffected by dyeing and heat setting operations and therefore, can be conducted either before or after dyeing of the fabric. The improvements are attributed to an increase in acidity and to the addition of fluorine to the polymer backbone which occurs at both the ring and ethylene glycol positions.

(b) Chemical Initiation Method

In the chemical method, the active site is created by oxidizing the polymer to hydroperoxide at several points along the chain in a random manner and then allowing it to decompose into the active form in presence of the monomer either by heat or redox system. In a recent paper, Hebeish et al. have reported the properties of P/C blended fabric after grafting with 2-methyl 5-vinyl pyridine (MVP) using benzoyl peroxide as an initiator. Fabric properties such as tensile strength, elongation at break and moisture regain have been found to increase with increasing degree of grafting whereas crease-recovery-angle and electrical resistivity show a decreasing trend. Authors believe that the mechanism of polymerisation is "grafting by vinyl addition to the
polyester macro-radicals, formed under the influence of benzoyl peroxide, because cotton did not show any increase in weight under similar conditions.

Two-step grafting of acrylic acid and methacrylic acid has been reported55. In the first-step, an emulsion of peroxide initiator was applied and subsequently grafting of acrylic acid or methacrylic acid to polyester was carried out. The maximum grafting percent produced a modified polyester fibre with 8% moisture regain. Poly(ethylene-terephthalate) fibres were grafted56 with hydrophilic monomers such as acrylic acid, methacrylic acid and mixtures of the two monomers for improvement in the hydrophilic property. The grafting reactivity of the polyester fibre was improved by swelling with 1,1,2,2-tetrachloroethane. Dibenzoyl peroxide was used as the initiator for the two-step grafting. The first-step was pretreatment of the fibre with an aqueous emulsion of dibenzoyl peroxide and the second-step involved the grafting of pretreated fibre with an aqueous solution of monomer containing CuSO4 as homopolymerization inhibitor. It was found that mixture of monomers gave a higher grafting yield than each monomer alone. Grafting was also found to improve the dyeability and moisture retention of the fibre. Wang57 has also studied the grafting of acrylic acid and acrylonitrile, on to polyester using the technique of initiation.
by gamma irradiation and dibenzoyl peroxide. Studies on grafting of acrylic acid and acrylonitrile, carried out by Kale and Lokhande\textsuperscript{58} onto polyester using the technique of initiation by $\gamma$-radiation as well as benzoyl peroxide in chemical method, have shown that the degree of grafting and length of the chain are dependent upon the time of treatment, concentration of the initiator, and the monomer, irradiation dose, conditions of swelling and temperature. These parameters can be controlled very easily in radiation grafting but the nature of the grafted fibre substance remains the same irrespective of the grafting technique. Increase in moisture regain of polyester from 0.4 to 1.22 and 4.6\% could be achieved by grafting with acrylonitrile and acrylic acid respectively. Dye uptake was found to increase with increasing amount of acrylic acid in polyester.

Hygroscopic property and antistatic property were improved by converting the acid graft into the corresponding metal or sodium salt\textsuperscript{25-26, 59}. The Na-salt of the grafted fibres was compared with the acid form with regard to hygroscopicity, water absorbency, mechanical properties and melting behaviour. Almost all the physical, chemical and dyeing properties of grafted polyester with acrylic acid were evaluated\textsuperscript{60}. The fibres can be dyed with disperse and cationic dyes below 100°C. The resistance of the fabric to washing, perspiration,
dry heat and rubbing was investigated and compared with unmodified polyester. Controlled wear trials with grafted and ungrafted fabrics revealed that the former were more comfortable.

In both the methods of grafting, homopolymers of vinyl monomer are to be expected but often can be suppressed by suitable additives. In grafting by chemical initiation the homopolymer formation is more pronounced. During the course of grafting, monomers, in the liquid state, either pure or in aqueous solutions, undergo simultaneous homopolymerisation leading to a sticky product as well as the loss of monomer and therefore, it is necessary to add a retarder in the grafting solution to avoid this parasitic homopolymerization. Bonnefis and Puig have suggested the addition of Mohr salt and cupric chloride to prevent homopolymerization of aqueous acrylic acid solution. Rao and co-workers, on the basis of their study on grafting of acrylic acid and methacrylic acid onto polyester, have shown that ferrous ammonium sulphate in the case of acrylic acid, and copper sulphate in the case of methacrylic acid are the best additives capable of inhibiting homopolymerization without affecting the grafting process.
(3) Chemical Finishing Treatments

Various finishing treatments have been developed in the recent past to improve hydrophilicity, antistatic, soil-release and anti-soil re-deposition properties of polyester but only a few of them were found durable to laundering. The main reason for the poor wash-fastness is the lack of accessible reactive centres in polyester which can hold applied chemicals through covalent bonds. Chemical finishing processes which impart durable hydrophilic character to polyester can broadly be classified into the following two categories.

(a) Fibre surface coating, and

(b) Chemical reaction.

Numerous topical finishing chemicals, based on nonionic ethylene oxide adducts, aromatic sulphonate acid derivatives, dialkyl ammonium derivatives of fatty acid and acrylic acid condensation products etc., are claimed to offer comfort properties to polyester textiles⁴⁷, ⁶¹-⁶⁸. Most of the soil-release finishes increase the hydrophilic characteristics of synthetic fibres. They impart antistatic property, increase moisture absorbency and improve water transport, soil-release and wicking properties to synthetic fabrics⁶⁹. The soil-release finishes act as "fabric conditioners". Some of these products have been commercialised in foreign countries⁷⁰-⁷¹ and Suchecki has reviewed products which have brought increased comfort to the wearer.
Fibre surface coating is carried out by the curing method. It gives mainly durable soil-release property and antistatic property to polyester. Epoxides, polyalkylene oxides, quaternary ammonium compounds and silicones with polar side chains have been applied as polymer coating to fabrics. Sorption of amphiphilic compounds at a temperature above 200°C is reported to increase hydrophilicity and oily soil removal characteristics of polyester textiles, the extent of which depends on the structure of the sorbed compound. Compounds having HLB values between 13 and 16 were found to be most effective. Thus a reported method of modifying polyester fibre materials for comfort properties consists of applying to the fabric a liquor containing a polyester/polyether block copolymer stabilized by a specified surface active agent. Okada and co-workers have claimed to impart durable antistatic and hygroscopic properties to polyester. Caldwell has claimed that coating the fabric with an aqueous solution of an inorganic acid at 0.5-5% solid acid add-on and heating the dry acid coated fibres at 80-200°C (to form polar groups on the fibre surface without significant alteration of the physical structure) increases the hydrophilicity of polyester fibre materials. Soil-release property can be imparted to polyester fabrics by coating them with a treating composition comprising of polyalkylene groups and ethylene
terephthalate units and heating the coated fibres at a temperature of at least 80°C\textsuperscript{76}. For improved and durable\textsuperscript{77} soil-release characteristics, polyester fabrics are padded with an aqueous emulsion of synthetic acid polymer, which comprises acrylic acid and a water-soluble salt of Mg\textsuperscript{2+}, Ba\textsuperscript{2+} or Ca\textsuperscript{2+} with a halogen as an organic acid.

The antistatic effect is increased by the presence of double bonds, benzene nuclei and a higher number of polarizable bonds in a surface active molecule\textsuperscript{78}. Permanent antistatic finishes were obtained\textsuperscript{79} on PET fibre by application at a temperature of 20° to 120°C, of a preparation containing a water-soluble or water dispersible polycondensation product of a poly glycol ether of a polyol and a water-soluble amine, an organic solvent or solvent mixture and an organosoluble dispersing agent. A survey of currently available antistatic agents has been made\textsuperscript{83} by BASF, Hoechst, Sandoz, Francolor, Ciba and DuPont. Their composition and method of application were reviewed\textsuperscript{80}. The fibre surface coating chemicals can be broadly classified into the following three groups:

(i) Acrylic polymer finishes.
(ii) Oxyethylation products of polymers.
(iii) Fluoropolymer finishes.
(i) **Acrylic Polymer Finishes**

Acrylic polymers are surface active and therefore tend to concentrate on the fabric/air interface. These finishes are based on acrylic acid, substituted acrylic acids, acrylic esters, substituted acrylic esters and methylolated acrylamide. Copolymers of acrylic acids and acrylic esters are good SR agents. Copolymers containing methacrylic acid have better SR performance than those containing acrylic acid. Copolymer of 70% methacrylic acid and 30% ethyl acrylate have been widely used as effective SR agents. Commercial products based on these compounds are included in the following table:

<table>
<thead>
<tr>
<th>Products</th>
<th>Chemical Nature of Finish</th>
<th>Method of Application</th>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>PerapretD (BASF) W. Germany</td>
<td>Dispersion of reactive polyacrylates and acrylic polymers</td>
<td>-</td>
<td>Hydrophilic and antistatic effect to the fibres</td>
</tr>
<tr>
<td>Rhoplex528 (Rhom &amp; Haas) USA</td>
<td>Dispersion of reactive polyacrylates and acrylic polymers</td>
<td>-</td>
<td>Hydrophilic and antistatic effect to the fibres</td>
</tr>
<tr>
<td>Rhoplex SR 488 (Rhom &amp; Haas), USA</td>
<td>Dispersion of reactive polyacrylates and acrylic polymers</td>
<td>Simple coating</td>
<td>Hydrophilic and antistatic effect to the fibres</td>
</tr>
<tr>
<td>Tival SR 251 (Geigy)</td>
<td>Dispersion of reactive polyacrylates and acrylic polymers</td>
<td>-</td>
<td>Softening effect on the handle of the fabric</td>
</tr>
</tbody>
</table>
Perapret D cannot be used for 100% synthetics while Rhoplex SR 488 can be used for 100% polyester also. These finishes have a swelling tendency in aqueous solutions and thereby help to mechanically force the soil out of the fibre surface and interstices. Dorset has discussed the recently published literature and patents on acrylic SR agents.

(ii) Oxyethylation Products of Polymers

The H-bonding ability of ethylene oxide backbone provides water attraction sites and therefore its derivatives have been successfully employed commercially in SR finishing. On the basis of oily SR ability, the carboxyl moiety and ethylene oxide moiety are equally effective. The ability of such products depends on the availability of the oxygen in the polyether structure at the fabric coating/air interface. Molecules containing both hydrophobic and hydrophilic groups similar to chemical constitution of the fibrous polymers are fixed onto polyester so that the hydrophobic portion of the molecules forms a co-solution with the fibre and the hydrophilic groups remain protruding on the fibre surface. Compounds of the type Permalose T, work on this principle. Condensation products of ethylene oxide of the following types have been found quite interesting and are gaining considerable popularity.
- Ethoxylated aromatic carboxylic acids, e.g., terephthalic acid-oxyethylated product,
- Ethoxylated polyamide derivatives,
- Fatty acid-alkoxylated products containing ethylene/propylene oxide, and
- Polyglycol ether derivatives with different chain lengths.

The following are a few commercial products based on these compounds.

<table>
<thead>
<tr>
<th>Product</th>
<th>Chemical Nature of Finish</th>
<th>Method of Application</th>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pormalose T</td>
<td>Non-ionic polymer contains add-on level hydrophilic properties and softening effect</td>
<td>1-3% solid process</td>
<td>Hydrophilic properties and softening effect while Permalose TG gives stiffening effect on handle and both give antistatic effect. Durable to washing</td>
</tr>
<tr>
<td>(ICI Ltd.) &amp;</td>
<td>poly-glycol ether by the conventional groups, as hydrophilic groups and it is an aqueous process</td>
<td>solid Non-ionic poly-1-mer contains poly-glycol ether by the groups, as hydrophilic groups and it is an aqueous process</td>
<td></td>
</tr>
<tr>
<td>Permalose TG</td>
<td></td>
<td>pad-cure emulsion</td>
<td></td>
</tr>
<tr>
<td>or Cirrasol PT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cassapret SR</td>
<td>An ethylene oxide adduct applied in combination with high finishing resins by pad-dry-cure method</td>
<td>Increased in hydrophilic properties, partially antistatic effect and softening effect on handle</td>
<td></td>
</tr>
<tr>
<td>(Cassella Hoechst, Germany)</td>
<td>with terophthalic acid or fatty acid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zeleon USA</td>
<td>A highly hydrated polyether containing non-swelling aromatic groups polymeric hydrophilic</td>
<td>Continuously curing at a 300°F</td>
<td>Improvement in moisture uptake and transport properties</td>
</tr>
</tbody>
</table>
ICI®-86-87 developed a product under the label Cirrasol®PT in the USA and Permalose T in other countries. The SR product has two free electron pairs due to the presence of ether-linked oxygen. These electron pairs can bind water molecules. The mechanism is similar to the solubilization of fatty chain ethylene oxide condensates in water. The Permalose finishes have been shown to confer the following technical improvements not only on 100% polyester, but also on polyester blend fabrics, including polyester/cellulosic and polyester/wool blends.

- They minimize the gradual greying of fabrics resulting from the redeposition of soil during repeated household washing;
- They assist in the removal of oils and greases during washing particularly from 100% polyester fabrics;
- They improve the moisture absorbency of fabrics thus leading to greater comfort of garments during wear. (So the garment treated with Permalose have increased comfort in wear, improved antistatic effect, lower soil redeposition and enhanced stain removal); and
- They minimize the build-up of electrostatic charges, a property of particular importance on 100% polyester fabrics.
'Cassapret SR' also meets the requirements of a soil-release finish. The above mentioned soil-release compounds can be applied to textiles using a number of techniques. These techniques of application depend on the type of fibre and the type of SR compound. Treatment of polyester textiles to improve soil-release and wettability properties has been patented by Latta et al. and one review article covers modification of specific properties e.g., static load, soiling, soil removal, etc., of PET fibre.

(iii) Fluoropolymer Finishes

Fluoro chemicals have very low surface energy and because of this, have very good oily soil-repellency. These finishes are better than acrylic-based finishes for SR finishing of polyester/cotton blends. Despite their good performance, the fluoro-chemical treatments are rather expensive. In the dual action, (stain repellency and soil-release) the fluoro-chemical SR finishes work in the following manner. In air, the fluoro-chemical segment of the finish becomes oriented so as to impart soil repellency to the fabric surface. In an aqueous environment (i.e., during laundering) the surface molecules reorient so that the hydrophilic segment becomes effective and the surface exhibits good soil-release properties. But the conventional fluoro-carbon oil repellent finishes provide low energy surfaces in water.
during fabric laundering. As a result, the finished fabric tends to become contaminated by hydrophobic soils in the aqueous wash medium. The chemical composition and performance of a range of fluorine compounds for the combined water-repellent and soil-repellent finishing of fabrics has been investigated. A number of polymeric siloxanes were examined as possible soil-release agents. With a proper ratio of fluorocalkylesilane/hydrophilic silane, the copolymers are effective in providing stain release and oil stain repellency.

Commercial fluorine containing polymers for textile finishing became available in the 1950's. Commercial products based on these compounds are included in the following table:

<table>
<thead>
<tr>
<th>Product</th>
<th>Chemical Nature</th>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zepel</td>
<td>Fluorocarbon polymer</td>
<td>Stain-release and oily soil repellency</td>
</tr>
<tr>
<td>(DuPont, USA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scotchgard</td>
<td>Polymerization product of 1,1, dihydrofluoroalkyl acrylate</td>
<td>Stain-release and oily soil repellency</td>
</tr>
<tr>
<td>(3M Co. USA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quarpel</td>
<td>Large proportion of the water repellent agent with the fluorocarbon in a synergistic combination</td>
<td>Stain-release and oily soil repellency</td>
</tr>
<tr>
<td>(Quarter-master)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Other stain-repellent as well as soil-release finishing agents have been prepared by incorporating within a single hybrid molecule both fluorochemical and hydrophilic segments. The
examples of such finishes are the reaction product\textsuperscript{25} of ethyl perfluoro-octanoate and polyethyleneimine (EPO-EL-finish) produced by copolymerization in tetrahydrofuran. These can be incorporated in resin-finishing baths for P/C fabrics. The soil and stain repellency of extruded filaments of a synthetic resin is improved\textsuperscript{96} by incorporation in the resin of a small amount (about 1\%) of an amphiphatic compound having 1 to 4 fluoroalkyl groups.

(b) Chemical Reaction

Hydrophilic character of polyester textiles can also be improved by hydrolyzing some of its ester linkages and thereby creating carboxylic and hydroxyl groups at the fibre surface. This has been carried out in both the acidic\textsuperscript{97-100} and alkaline conditions. The effects of dilute and concentrated solutions of acid (H\textsubscript{2}SO\textsubscript{4}) on hydrolytic degradation of polyester fibres were investigated by determination of their molecular weight by viscometry and end group method. A reaction mechanism was established for the degradation of PET films in aqueous solution of H\textsubscript{2}SO\textsubscript{4} and an equation is obtained which facilitates quantitative prediction of the chemical stability of PET over wide intervals of temperature, acid concentration and treatment time. The alkaline hydrolysis has been considered in greater detail\textsuperscript{101-105}. It has been observed that alkaline hydrolysis of polyester fibre surface with about 10\% sodium hydroxide solution at 60°C for
10 minutes, results in good soil-release properties of the fibre. Stevens developed a finish named 'Fantessa' which provides improved comfort properties to polyester. The treated fabrics were claimed to be cooler, faster to dry and more comfortable. The treatment essentially involves hydrolytic degradation of polyester surface by aqueous sodium hydroxide solution of saponification strength. Hydrophilic properties and handle of polyester fabrics have also been claimed to improve by treating the fibre with an aqueous alkali solution followed by heat treatment in ethylalcohol for 0.5-4 minutes at 80-170°C. All these hydrolytic processes are dependent on reactant concentration, treatment time and temperature. Therefore, a satisfactory compromise has to be made between the increase in hydrophilicity and fibre weight loss during the course of the finishing operation. The catalytic action of different quaternary alkyl ammonium halides on the alkyline hydrolysis of PET has been studied. It is reported that these compounds accelerate the process, control percentage fabric weight loss by limiting the amount of hydroxyl ion and in addition produce more silk-like polyester than it is produced by only alkali.

Soil resistance of polyester is improved by impregnating the fibre with an aqueous solution containing a rare earth metal halide compound. Modification of fibre surface, done
by an ester exchange reaction on polyester with sodium salt of polyethylene oxide, imparts good soil-release properties to the fibre, without changing the inherent fibre structure and it was confirmed by wear trials\textsuperscript{115}. But this process was unsuitable for commercial use.

Thus, alkaline hydrolysis is one of the easiest, practicable and inexpensive way of modifying polyester which has received considerable attention in the recent past. A survey of the pertinent literature indicates that alkaline hydrolysis has been extensively studied to impart silk-like properties to polyester textiles, with a view to giving aesthetic comfort\textsuperscript{105,108-111,116-118}. Also the studies dealing with basic and other aspects of the alkali reaction are relatively few and in some cases conflicting viewes have been expressed\textsuperscript{102,104,111-112,116,119-120}. It was, therefore, thought worthwhile to carry out a systematic study on alkaline hydrolysis of PET in the absence and in the presence of catalysts and to characterise and correlate its various physical, mechanical and physicochemical properties.

Ester exchange reactions of PET with sodium salts of different glycols namely, EG, DEG, TEG have also been carried out.
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