Emulsifier Choice in Design of Spin Finishes for Man-Made Fibers[1]

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ABSTRACT

Spin finishes for diverse, polymeric textiles are necessary for efficient processability and maximum conversion to functional fiber. Such finishes should provide lubricity, cohesion and increased resistance to static development on the fiber. The emulsifiers, lubricants and antistats used in fiber processing differ in reactivity with such polymers. Finish components rely extensively upon derivatives of fats and oils, particularly the numerous emulsifiers used. Certain deficiencies of these finish components, with particular emphasis upon their reactivity with process equipment having polyurethane surfacing, are discussed. Susceptibility of polypropylene to degradation in the presence of conventional finish components is examined. Unique properties of polyglycerol esters and glycerido-ester ethoxylates, which overcome these processing difficulties, are considered. The relationship of chemical structure to plasticising activity appears as the key to polymeric fiber resistance to loss of breaking strength.

INTRODUCTION

"Spin finishes" are applied to melt spun man-made fibers to facilitate their manufacture. Selected fatty acid derivatives are the active ingredients in many such processing aids. These are applied to freshly extruded filament to give a uniform deposit of both lubricating and static retarding compositions which help maintain predetermined fiber properties (1).

Such finishes represent a 30,000,000 lb annual market. Traditional fat and oil technologies thus contribute importantly to textiles designed for fashion and industrial use.

A spin finish is a material uniformly deposited upon freshly extruded fiber to facilitate textile machinery processing of such fiber into yarn and fabric. The term, spin finish, usually used in conjunction with synthetic polymeric fibers, also has analogies in nature. Pure silk is extruded by the silkworm with a protective lubricating covering of sericin, then continuously wound into the cocoon with minimum change in denier or silk diameter. Wool is extruded from the follicle in the skin of the sheep with its accompanying deposit of wool grease sterols. Raw cotton is coated with an invaluable spinning assistant, about 0.3-0.5% cotton wax. Regenerated cellulose immediately absorbs 11% moisture from the ambient air, imparting ease of processability to cellulosic fibers. Cotton wax is never removed from raw cotton before carding and spinning, nor is raw wool scoured to less than 0.4% grease content. If such solvent soluble libricants were removed entirely, it would be impossible to card and process both of these natural fibers in a commercially acceptable manner. Generally, synthetic polymeric fibers are of little commercial value until a satisfactory spin finish is applied.

Choice of a satisfactory finish, enabling full realization of the market potential for a fiber, may require lengthy trials. This is costly and traditionally confidential research. Effective spin finishes require performance properties within the composition which frequently seem contradictory. Newer fatty acid derivatives have frequently proved helpful here.

The finish must impart fiber cohesion sufficient to resist "sluff off" from the pirn, the cone, or the package on which fibers are wound. The fiber must unwind freely, yet demonstrate the property of sliding easily over metal, alsimag, varnished wood or other fabricated textile equipment surfaces. The fiber may be subsequently heated, and the spin finish required to offer effective fiber-to-fiber and fiber-to-metal lubricity, yet, upon cooling, require the opposite property of maximum fiber-fiber cohesion while maintaining tolerable fiber-metal lubricity. In other cases the spin finish must impart the properties of antistatic protection and good lubricity at both low and high temperatures and varying yarn speeds. Ease of finish removal is necessary for products to be dyed, but not for twines and ropes. Good resistance to both fatigue and oxidation can be built into a finish with further experimental study. Viscosity changes in the finish emulsion on the fiber must be understood and often counteracted. Compatibility may be needed with warp sizes or with latex compositions.

The traditional trial and error method is being replaced by sophisticated instrumentation, operated under known conditions of relative humidity and temperature, to accelerate finish evaluation studies.

Spin finishes are chiefly composed of lubricants, emulsifiers and antistatic agents of many available types. It is apparent that their physical properties are often more important than their chemical properties. Such studies of lubricants, antistatic agents and emulsifiers represent an ever expanding search, often carried out in the absence of useful basic information.

We have experimentally examined two particularly difficult problems, aware that the answers in turn serve to introduce new avenues of investigation.

We have determined the extent of polymer swelling in polyurethane by measuring the percentage of dimensional distortion found for measured strips of belting immersed in various surfactants for one week at 70 C. Such data can be related to fiber texturizing operations where the yarn finish may cause deterioration of polyurethane transport belting during yarn movement to and from the heater station.

We have assigned qualitative degrees of polypropylene resistivity to breaking strength decline. This was done by immersing skeins in test finish materials, squeezing them to remove excess finish, and storing at 110 C by the day. The accelerated aging of the fiber is then related directly to contact with various finishes, causing strength loss by thermal degradation.

Biaxially oriented polyproplyene film, about 0.5 mils thick, was "spotted" with 25-30 mg of finish. Resistance to blister formation after one week at 70 F was considered necessary for a useful, nonpenetrating finish.

The finish effect upon polypropylene relates to the difficulty in formulating polyolefin fiber finishes that are not reactive with the fiber. Condition of coning and

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TABLE I

Effect of Emulsifiers on Viscosity of 10%
Emulsions of Solid Spin Finishes for Staple Fibers

		Parts by weight					
Chemical type	State	A	B	C	D	E	F
Lubricant							
Self-emulsifiable							
Glycerol mono stearate	Solid	45	45	45	45	45	40
Antistatic agent							
Phosphated alcohol	Solid	25	25	25	25	25	25
Decaglycerol decaoleate	Liquid	10	---	15	20	---	5
Decaglycerol monolaurate	Liquid	20	---	15	10	---	10
Lauryl alcohol + 23 moles ETO	Solid	---	15	---	---	---	---
Lauryl alcohol + 4 moles ETO	Liquid	---	15	---	---	---	---
Myristyl alcohol + 8 moles ETO	Liquid	---	---	---	---	15	---
Myristyl alcohol + 4 moles ETO	Liquid	---	---	---	---	15	---
pH of 10% emulsion		4.85	4.4	4.65	4.85	4.8	8.2
Centipoises (10% emulsions - LVF Brookfield at room temperature)		10	45	77	110	200	1150

winding generate heats of friction which, with a reactive finish, cause serious variations in yarn breaking strength.

These two forms of processing failure may be largely controlled by usage of polyglycerol esters, glycerido-ester ethoxylates, or both, as alternatives to more familiar fiber finish materials.

The limited objective of this paper is to examine the effect of emulsifiers on polyurethane and the effect of emulsifiers on polypropylene. An approach is offered to examine the physical effect upon these two polymers; but first, the general types of ingredients used in spin finishes are reviewed.

Lubricants are one type of ingredient, they include: mineral oils, alkyl esters, glycerides, silicone oils, waxes, paraffinic, naphthenic and polyolefinic types, polyalkylene glycols, polyoxyalkylene glycols, hindered glycol esters (including "neo"-structured types), and polyglycol esters. Emulsifiers, the second type of ingredient, includes the following: alkali, alkaline earth, and amine soaps, glycerol mono-di-fatty acid esters, sorbitan and polyoxyethylene sorbitan esters, polyglycerol esters, polyoxyethylene esters, polyoxyethylene ethers, polyoxyethylene polyol ether esters, polyoxyethylene amines and amides, partial polyol ester ethoxylates, sulfated vegetable oils, and sulfonated aromatic petroleum hydrocarbons. Antistatic agents are the third type of ingredient: cationic agents (quaternary ammonium, pyridinium, imidazolinium, or quinolinium function), phosphated alcohols, phosphated ethoxylates of fatty acids and fatty alcohols, amines, organic sulfates and sulfonates, amides (including ethoxylated types), and amines (including ethoxylated types).

The physical properties of the emulsifiers must also be measured and known for the emulsion form of the spin finish as it exists on the fiber.

Emulsifier characteristics are: emulsifying power, viscosity, pH, volatility, wettability, hygroscopicity, chemical stability, tixicity hazards and corrosion resistance. Good emulsifier performance includes: lubricity, cohesiveness, static protection and alleviation of fiber breakage, as well as minimum finish deposits on equipment. Table I illustrates how the viscosity of the emulsion may be changed by varying the proportions of the emulsifier blend or using different emulsifiers. Indication of fiber cohesion is thus given of emulsion viscosity effect, which for some staple fibers may be transplanted into per cent "fly" in the air or "drop out" of fiber under the carding engine. Lapping of the staple fiber on spinning frame rolls, in some cases, is a function of emulsion viscosity on the fiber.

We have studied finish "pick up" by certain elastomer components widely used in man-made fiber processing equipment. Polyurethane has gained widespread acceptance because it wears better and abrades less under these conditions than SBR, nitrile and other rubbers. Polyester types of polyurethane give better service than polyether types of polyurethane. The polyurethane belt inevitably becomes wetted with the spin finish on the yarn. The proximity to the heated plate raises the temperature of the polyurethane belt. Heat and pressure accentuates the spin finish effect upon the belting.

In some cases the thermally treated yarn passes over polyurethane rollers after heat-setting of the desired spiral configuration in the year. The spin finish must thus have a degree of thermal stability at these elevated temperatures. The polyurethane susceptibility to chemical attack is, in any event, much greater.

This property of thermal stability largely determines lubricant, emulsifier and antistatic agent acceptability at various process temperatures. Table II illustrates differences in heat resistance (or volatility) under frequently employed, significant test conditions.

Compatibility difficulties in spin finish formulation have often occurred with many conventional ethylene oxide-

TABLE II

Thermal Stability Comparison of
Mineral Oil With Vegetable Oils and Esters

	Per cent weight loss	
Oils and esters	20 min 160 C	10 min 265 C
Mineral oil		
60 SUS[b]	5.8	33.3
85 SUS	2.1	27.2
100 SUS	1.2	26.1
Triglycerides		
FD-0655	0.2	2.0
FD-0700	0.6	3.0
FD-0728	0.4	2.7
Polyglycerol esters		
10-12-0	0.2	0.4
6-6-0	0.05	0.1
6-6-L	0.1	0.2
Esters		
FD-0670	0.6	2.7
FD-1219	0.3	2.9
Butyl stearate	1.3	25.5

[a] Thin film test on hot plate at time and temperature indicated.

[b] Abbreviations:

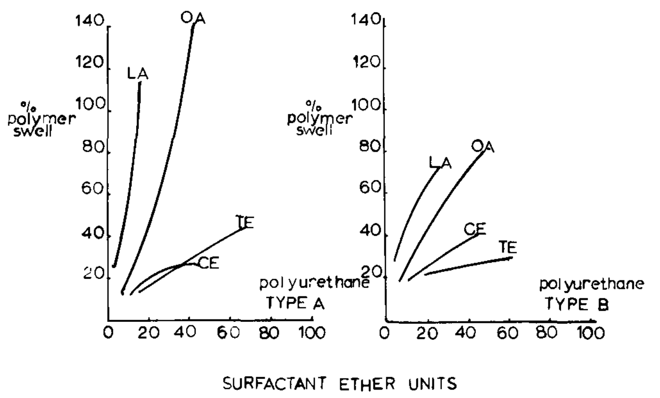

FIG. 1. Influence of ethylene oxide burden upon polyurethane swelling properties of various surfactants. Ethoxylates; LA, lauryl alcohol; OA, oleyl alcohol; TE, tallow diglyceride; CE, coconut diglyceride.

derived emulsifiers. These cause polyurethane surfaces described earlier to swell or disintegrate to an intolerable degree.

The presence of both carbamate group and polyether chain renders polyurethane sensitive to various chemicals. The carbamate linkage is susceptible to hydrolysis by acids and alkalies. Ethylene oxide adduct-type emulsifiers show solvating and swelling effect.

The choice of a proper emulsifier system is now limited if we are to retain the structural integrity of the polyurethane.

LABORATORY TEST

The laboratory test is carried out by cutting measured strips of polyurethane belting, determining the volume of each piece by measurement of length, breadth and thickness, and immersing the polyurethane in the liquid for 168 hr at 70 C. The sections are then remeasured and the per cent gain in swelling reported.

Swelling changes the diameter of the rolls or belts and causes uneven tensions throughout the length of the yarn or between yarns running on different spinning heads. Past experience associates dissimilar tensions with different dyeing affinities.

The laboratory test is an accelerated one, using 100% active emulsifiers. In an actual formulation, the amount of emulsifiers may be less than 50% of the total composition. Textile mills strive to operate false-twist texturizing equipment for as long as two to three months before changing polyurethane belts and cleaning the hot metal plates and guides. Hence the laboratory test is not excessively severe.

Further check of an apparently successful formulation suggests exposure up to one month.

Ethylene Oxide Adducts

Ethylene oxide adducts of many descriptions imperil the life of polyurethane. The extent of effect, however, depends upon the type of hydrophobic segment R, the number of ethylene oxide units -(n), and the type of polyurethane.

It is apparent from Figure 1 that the higher the ethylene oxide content (n) of the emulsifier, the greater the swelling. This behavior can be understood in terms of more efficient solvating by higher ethylene oxide analogs of polyurethane, which generally contains the same sort of long chain polyether.

A sharp increase in degree of polyurethane swelling was noted for many emulsifiers containing more than 30 moles of ethylene oxide.

Recently developed modified ethylene oxide adducts of tallow and coconut show a pronounced decrease in swelling effect compared with conventional ethylene oxide adducts of lauryl and oleyl alcohols. This finding, illustrated in Figure 1, and other favorable data such as low volatility and good lubricity performance (which is little affected by temperature variation), prompted an investigation to determine the usefulness of these as potential emulsifiers in texturizing finish. Experimental work and commercial acceptance have confirmed their utility. They will be discussed later.

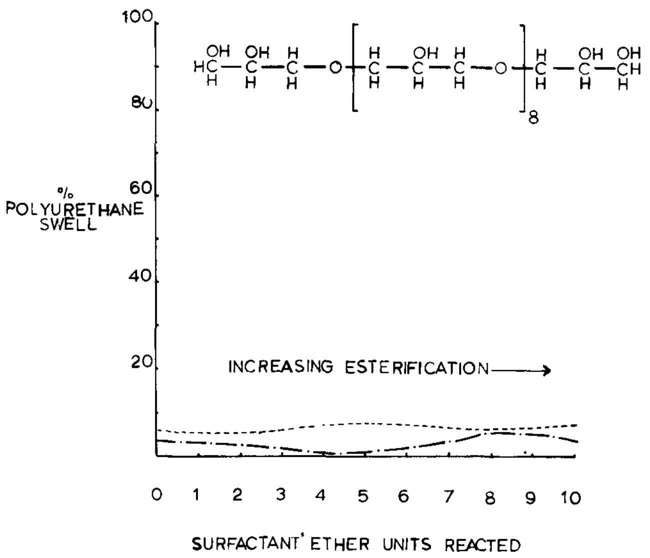

FIG. 2. Influence of 2-hydroxy-propylene oxide burden upon polyurethane swelling properties of various decaglycerol ester surfactants. Polyurethanes; -•-•-; type A; —; Type B.

Polyglycerol Esters

Polyglycerol esters, by virtue of low functional group reactivity and structural dissimilarities with polyurethane, do not cause physical deterioration of polyurethane through plasticizing activity. Figure 2, although specific for decaglycerol oleate esters, is representative of polyglycerol esters generally in showing their low capacity to produce polyurethane swelling.

The data relating to the effect of other polyglycerol esters on polyurethane are summarized in Table III. They establish polyurethane inertness to polyglycerol esters of both low and high water dispersibility.

Alkanolamides and Their Ethylene Oxide Adducts

Table IV shows that the degree of swelling caused by diethanolamides of fatty acids is dependent upon the chain length of fatty acid and amount of free amine in the product. The paucity of experimental data currently precludes comprehensive analysis. The data available, however, suggests that higher molecular weight fatty acid in amide derivatives cause less swelling, but they are known to be poorer emulsifiers.

High free amine content in the product tends to degrade polyurethane. Coconut diethanolamides of 2:1 type containing 30% free amine, compared with 7% in the 1:1 diethanolamide series, completely disintegrates polyurethane.

Alkanolamide ethoxylates are conspicuously detrimental to polyurethane, causing total disintegration of polymer structure. This may be viewed as a possible synergism occurring with a combination of low level free amine with a polyether chain, polyether glycol ester, and polyether glycol homologs.

Phosphate Esters

Phosphate ester acids, as shown in Table V, severely attack the carbamate bond, although their salts apparently

TABLE III

Nonionic Surfactant Contact Effect Upon Polyurethane

	Per cent swelling	
	Type A	Type B
Decaglycerol	2	5
Decaglycerol monolaurate	9	9
Triglycerol monostearate	19	17
Hexaglycerol distearate	12	7
PEG 400 Monolaurate	57	54
POE (20) Sorbitan Monooleate	43	31

do not. Swelling exhibited by the amine salt of phosphated oleyl alcohol ethoxylate is of the same order as that conferred by corresponding oleyl alcohol ethoxylate; consequently, the swelling effect seems to depend upon polyether presence, rather than phosphate ester.

Sulfates (Salts of Sulfuric Acid Esters)

Sulfates of triglycerides and fatty esters normally contain 20-30% of water. The latter carries a small amount of mineral acid liberated by dissociation of sulfate esters. With prolonged heat, scission of carbamate linkage and rupture of polyurethane occurs at the interface of sulfated product and air.

Table VI records the extent of polyurethane swelling caused by a variety of surfactants having various HLBs. Extent of swell obviously relates more closely to molecular structural considerations than to HLB number. It is shown here that hydrophilic or lipophilic surfactant nature is not indicative of potential polyurethane attack. Low to high HLB polyglycerol esters, for example, show no progressive increase of contact deteriorative action. Fatty alcohol ethoxylates of increasing polyether chain length, on the other hand, will heighten this effect, as shown in Table VII.

RESISTANCE OF POLYPROPYLENE TO THERMAL DEGRADATION

Polypropylene was chosen for study of finish-and-fiber interaction because of the many unexpected and disastrous processing failures encountered with conventional finish materials.

This fiber is susceptible to degradation by oxidation mechanisms unless properly stabilized. The stabilizers are principally compounds containing functional groups such as keto-, phenolic and aromatic sulfonate that will deactivate the radicals propagating oxidative chain reactions. It is difficult to stabilize the fiber because a wide variety of chemicals, on extended exposure to high temperature, tend to remove polypropylene polymer stabilizers by extraction. The fiber is thereby rendered vulnerable to attack by oxidation. Selection of proper finish components, which do not act as preferential solvents for polymer stabilizers, are vitally important to assure reasonable polymer life span under realistic service conditions.

TABLE IV

Alkylolamide Surfactant Contact Effect Upon Polyurethane

		Per cent swelling	
	Free amine, %	Type A	Type B
C_{12} DEA[a]	7	15	15
C_{12} C_{14} DEA	7	14	10
C_{14} DEA	7	8	5
C_{12} DEA	30	D	D
C_{12} C_{14} MEA	30	D	D
C_{12} C_{18} MEA (3-18 moles ETO)		D	D

[a] Abbreviations: D, polymer degradation or decomposition; MEA, monoethanolamide; DEA, diethanolamide.

TABLE V

Phosphate, Sulfate Ester Surfactant Contact Effect Upon Polyurethane

	Per cent swelling	
	Type A	Type B
Alkyl alcohol phosphate	D[a]	D
Alkyl alcohol phosphate, amine salt	nil	nil
Fatty alcohol ethoxylate phosphate	D	D
Fatty alcohol ethoxylate phosphate, amine salt	17	19
Sulfated glycerol trioleate	D	D

[a] D, polymer degradation or decomposition.

TABLE VI

Effect of HLB on Polyurethane

		Per cent swelling	
	HLB	Type A	Type B
Hexaglycerol distearate	13	12	7
9 Moles ETO on lauryl alcohol	13	54	55
9 Moles ETO on nonylphenol	13	63	51
11 Moles ETO on glycerido ester	6.6	13	20
Decaglycerol tetraoleate	6	None	7

Data in Table VIII show that sulfated products, soaps of fatty acids and cationics do not encourage oxidative degradation while most ethylene oxide adducts, phosphate esters and various polyol esters accelerate this condition.

In practice, it has been found that a suitable combination of oxidation resistors and accelerators can be successfully utilized in spin finish for polypropylene. Mixtures of polyethylene glycol esters and alkanolamides (or ethylene oxide adducts of the latter) are being used as spin finishes. The usage of polyethylene glycol esters improves fiber-fiber cohesiveness and other physical characteristics which facilitate mechanical processing of the yarn.

Plasticity

Emulsifiers, in general, showed little or no deleterious plasticizing effect on polypropylene film.

Straight chain esters and mineral oils all cause severe plasticization. The extent of plasticization should be attributed to the solvating effect imparted by individual products. Such differential solvating effect can be related to the product's susceptibility to penetration, with the compound's mobility in polypropylene film then causing a

TABLE VII

Effect of Nonionic Emulsifiers on Polypropylene

Nonionic emulsifiers	Resistance to thermal degradation, fiber[a]	Plasticizing resistance, film[b]
Ethoxylates of		
fatty alcohols	Poor	Excellent
fatty acid	Poor	Excellent
alkylphenols	Poor	Excellent
alkanolamides	Good	Excellent
sorbitan esters	Poor	Excellent
C_{12} C_{18} Diethanolamide	Excellent	Excellent
PEG's and PEG ester	Poor	Excellent
Polyglycerol esters	Fair	Excellent
Glycerol mono-di-esters	Poor	Excellent
Propylene glycol mono-di-esters	Fair	Good
Sorbitan esters	Fair	Excellent

[a] Skein of fiber, immersed in finish, lightly squeezed, and hung in dryer at 110 C. Strength test made each day. One-day resistance is poor, 30-days, good.

[b] Biaxially oriented film spotted with drop of finish. No blister after one week is rated good.

TABLE VIII

Effect of Anionic and Cationic Emulsifier on Polypropylene Polymer

Emulsifier	Resistance to thermal degradation, fiber[a]	Resistance to plasticization, film[b]
Anionics		
Fatty acid soaps	Excellent	Excellent
Sulfate esters of		
fatty acids	Excellent	Good
fatty alcohols	Excellent	Good
fatty alcohol ethoxylates	Excellent	Good
fatty amides	Excellent	Good
triglycerides	Excellent	Good
Phosphates of		
fatty alcohols	Good	Fair
fatty alcohol ethoxylates	Poor	Good
alkylphenol ethoxylates	Poor	Good
Olefin sulfonate salts	Good	Good
Cationics		
Quaternary alkylamides	Excellent	Good
Quaternary alkylimidazolines	Excellent	Good

[a] Skein of fiber, immersed in finish, lightly squeezed and hung in dryer at 110 C. Strength test made each day. One-day resistance is poor, six-day resistance is satisfactory, 30-day, excellent.

[b] Biaxially oriented film, spotted with drop of finish; no blister after one week is rated good.

blister-like appearance.

The application of products causing plasticization must be avoided in order to avert failure of various intermolecular forces which lead to a polymer with poor tensile characteristics.

Basis for Further Surfactant-Emulsifier Evaluation

It is typical of any rapidly advancing technology that older, more familiar tools, in this case, traditional surfactants, may have significant deficiencies. The distinction between lubrication, lubrication with high lubricant-polymer affinity, and plasticizing potential is, at times, very narrow.

Effective bridging materials that will overcome complex problems of fiber-polymer compatibility must be found. We will briefly discuss two new such classes of surfactant here.

POLYGLYCEROL ESTERS

We have lately seen commercial introduction of polyglycerol esters. These materials have unique properties that often complement fiber production demands beyond the capability of conventional ethoxylates or polyglycol ester-derived surfactants.

Uniquely, polyglycerols are polyethers with potential esterification sites at, rather than terminal to, the polyether functionality. Since esterification may be progressively increased by reaction at all (2-hydroxy) propylene oxy-sites on the polyether chain as well as at 1,2 di hydroxypropoxy sites, polyglycerol esters are inherently dimensionally and thermally stable.

Fatty acid introduction by esterification along the chain enables specific construction of lubricant or near lubricant compounds having low plasticizing potential high molecular weight. Such products have good lubricity.

Low degree of esterification gives polyglycerol esters having noticeable "tackiness" when not dispersed in water. Polyglycerol esters given many conventional surfactant and lubricity responses, but also endow powerful cohesion to fiber assemblies as the anhydrous state is approached during fiber processing.

Finally, polyglycerol esters increase in molecular weight by increments of 200-260, depending upon the choice of fatty acid. Decaglycerol esters, for example, offer 12 hydroxyl sites for potential reaction with monobasic acids. Increasing esterification heightens their oily, lubricating character.

Decaglycerol tetraoleate has an average molecular weight of 1850, while the decaoleate ester has an average molecular weight of 3400. Such progressive esterification is accompanied by increasing fluid character. With the stearate esters, the converse would be true. Decaglycerol decastearate is a hard wax, whereas decaglycerol tristearate has a more mobile, beeswax-like consistency.

It is well known that increasing molecular weight is an index of decreasing penetration or plasticizing power, and indicative of increasing resistance to thermal decomposition in many classes or organic compounds.

The striking resistance of our two polyurethane elastomers to plasticization by decaglycerol tetraoleate, decaglycerol octaoleate, and decaglycerol decaoleate is illustrated by Figure 2. The percentage of swelling approaches 10%, while conventional fatty alcohol ethoxylates (Figure 1) range up to 140% with increasing hydrophilicity.

GLYCERIDO-ESTER ETHOXYLATES

As fiber processing requirements have multiplied, particularly those associated with fine denier continuous filament production, a new category of ethylene oxide-glyceride adducts has been introduced.

The glycerido-ester ethoxylates results from alpha-hydroxy esters voiding of typical triglycerides, followed by introduction of ethylene oxide at the newly opened site.

Certain inherent advantages of such materials include: high molecular weight of both the oil dispersible and water dispersible adducts, with retention of fluid or near fluid character; high formulation affinity for lubricants of triglyceride structure; high affinity for conventional polyoxyethylene esters, polyoxyethylene ethers, sulfated oils, and mono-di glycerides; and moderate cost.

In practice, these expectations have been supported by numerous formulations of practical utility, especially in fine denier, texturizing and carpet yarn applications.

The glycerido-ester ethoxylates can be prepared with reasonably low levels of free hydroxyl and free fatty acid. As a consequence, the tendency of these emulsifiers to act as pro-oxidants may be minimized by use of refining and purification technique not economically applicable to the usual ester and other ethoxylates, or to sorbitan ester derivatives.

Figure 1 demonstrates the dramatic difference in plasticising capability of glycerido-ester ethoxylates (both coconut and tallow) vs. ethoxylated lauryl and oleyl alcohols.

The ethylene oxide moiety obviously plasticizes polyurethane. The high molecular weight of the hydrophobe (diglyceride) makes possible greater additions of ethylene oxide to the hydroxyl site, but with sharply lower plasticizing capability than is shown by the lower levels of ethylene oxide reacted with conventional fatty alcohols.

Table VII shows a universal failing of all ethoxylates hitherto examined. They contribute to increasing breakage incidence in polypropylene filament with increasing HLB. With low HLB-high molecular weight surfactants, such as the glycerido-ester ethoxylates, such failures can be minimized.

REFERENCES

1. Kirk, Othmer, "Encyclopedia of Chemical Technology," Second Edition, Vol. 16, 1968, p. 58-59.
2. Babayan, V.K., T.G. Kaufman, H. Lehman and R.J. Tkaczuk, J. Soc. Cosmet. Chem. 15:473 (1964).
3. Babayan, V.K., H. Lehman and M. Warman, Presented at the American Chemical Society Meeting, Philadelphia, 1964.

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