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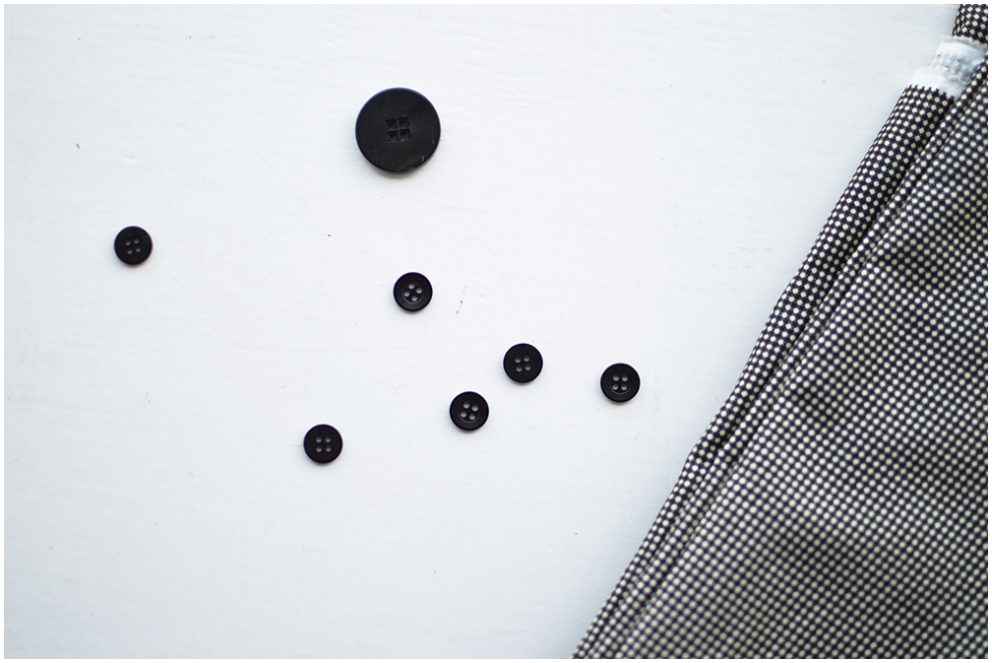
Soiling and soil-release finishing of textiles

by Silvia Pavlidou



Introduction

The problem of textiles soiling is not a new one. Natural and synthetic textiles all get soiled during use by various mechanisms, including mechanical adhesion, adhesion by electrical forces or redeposition of soil during washing. However, the most important factor that raised the issue of soil-release properties was the introduction of synthetic hydrophobic fibres into garments [1-3].

Until the 1960s most garments were made of cotton, which absorbs water quite well and is consequently easily cleaned during washing. In addition, at that time washing temperatures were quite high relatively to today s low temperature washing cycles, while the detergent systems contained phosphates and the laundry cycles included in most cases a bleaching step, since there were little environmental concerns for these processes. All this was to change dramatically with the introduction of synthetic fibres along with the application of milder washing conditions [3].

Being hydrophobic, synthetic fibres and in particular polyester, do not allow penetration of the aqueous washing solution and are thus much more difficult to clean. Considering this, the trend towards fabricating textiles from blends of cotton or wool with polyester has aggravated the situation, because such blends are easily soiled and the absorbed soil is difficult to remove [1]. In such cases, whatever soil is removed from the natural fibres

during washing, gets redeposited on the synthetic fibres, which attract oily matter from the dirty wash waters [4].

At the same time durable press finishes appeared in the market and were widely accepted by the consumers. However, it quickly became clear that durable press garments are much more difficult to clean than untreated ones [5].

In order to overcome the above performance deficiencies and facilitate the removal of soils during household laundering even from fabrics containing hydrophobic fibres or durable press finished, much research has focused on the problem of soil-release and different approaches have been proposed [5].

For example, aiming to increase the surface energy and hence the hydrophilicity of polyester, its chemical structure has been modified by chemical finishing or grafting, chemical treatment with NaOH, superficial physical treatment using plasma or biochemical treatment with enzymes [6]. Herein, after a short discussion of soiling mechanisms, only the approach of soil-release finishing will be discussed.

Soiling mechanisms

Textiles soiling includes not only specific spot soil, but also the greying that is the result of deposition of soil over the entire garment and occurs through three main mechanisms [3]. First is the mechanical adhesion of soil to the fabric by direct contact with a soiled surface or by picking up dirt from liquids or from the air. Second is the adhesion by electrical forces due to the attraction of dust particles from the air by electrically charged fibre surface. Last, is the redeposition of soils during washing [1].

Evidently, the mechanical adhesion of soils is largely influenced by the particle size of the soil (the smaller it is, the greater the soil retention by the fabric), as well as by the construction of the fabric itself. In particular, yarn count, twist and the cross section of the fibre all influence soiling. The smaller the denier and the higher the twist in the yarn, the greater is the tendency to soil, while circular cross-sectional fibres retain less soil than those with an irregular cross section. Loosely woven and open knitted fabrics are more prone to soiling than tightly woven ones, but removal of soil from loosely woven fabrics is easier. Finally, fabrics made of filament yarns are not as easily soiled as those made of spun yarns [4].

On the other hand, adhesion of soils by electrical forces occurs mainly with synthetic fibres, which exhibit low moisture regain and accumulate static charge during manufacture and during wear. Charged fibres attract soil from the air, with positively charged fabrics attracting more soil than negatively charged ones [4].

Similarly, redeposition of soils during washing is an issue mainly with synthetics because of their oleophilic nature [4].

In all cases, the time lag between soiling and washing is an important parameter, since when a soiled fabric is allowed to lie unwashed for long the soil diffuses inside the fibres and becomes more difficult to remove [1].

Soil-release finishes and mechanisms

Soil-release is the term used to describe the cleanability of a fabric by the laundering process [4]. Accordingly, a soil-release finish is a finish that permits relatively easy removal of soils with ordinary laundering by making the fibres more absorbent, thus permitting better wettability for improved soil removal. It is emphasized that, in contrast to soil-repellent finishes, a soil-release finish does not prevent initial soiling, but merely enables deposited dirt to be removed in laundering [1].

In order to understand the action of soil-release finishes, the mechanisms of soil-release should first be explained.

For the removal of particulate soil, a thin layer of washing liquid is penetrated between the particle and the fibre, enabling surfactants to absorb onto the particle surface and carry it away from the fibre, into the bulk of the washing liquid by mechanical action (Figure 1). In this case the soil-release finish should facilitate the penetration of the washing liquid in the interface between the soil and the fibre. Accordingly, hydrophilic finishes with low adhesion to soil under washing conditions improve particulate soil-release [1].

On the other hand, oily soils are generally removed by a roll-up mechanism, provided that the difference among the interfacial energy between the fibre and the oil and the interfacial energy between the fibre and the washing liquid is greater than the interfacial energy between the oil and the washing liquid. Therefore, a low fibre-washing liquid interfacial energy is required, i.e. a hydrophilic finish is needed for spontaneous roll-up, Also, a high fibre-oil interfacial tension is desired, so the finish should also be oleophobic [1].

Finishes that leave the surface of the textile during washing, carrying along the soil are called ablative or sacrificial finishes and are effective for the removal of both particulate and oily soils. Finally, other finishes act by swelling to reduce the inter-fibre spacing and push out entrapped soils.

Chemistry and application of soil-release finishes

Various kinds of soil-release finishes have been developed with different chemical structures. An early method used to improve the soil-release and prevent soil redeposition was the treatment of polyester textiles with polyglycols. Sodium polyglycolate is capable of reacting with poly(ethylene terephthalate) through an ester interchange reaction. However, since this reaction is very sensitive to time, temperature and moisture, this approach was

abandoned [7].

Soil-release finishes used today include carboxy-, hydroxy-, ethoxy- and fluorine-based finishes. Carboxy-based finishes are based on acrylic and methacrylic copolymers, which are usually applied by padding along with crosslinking agents and act by a swelling mechanism. Hydroxy-based finishes are mainly cellulose-based, e.g. methyl cellulose, ethyl cellulose or hydrolysed cellulose acetates, again applied along with a crosslinker to improve their durability. Ethoxy-based finishes may contain polyethylene blocks or ethylene oxide reaction products with acids, alcohols, amines, etc [1].

Finally, hybrid fluorocarbons may present the unusual property of being hydrophobic/ oleophobic in air and become hydrophilic/oil-releasing in water and aqueous media. This "dual action" mechanism is achieved because such finishes form films that possess low surface energy in air and low interfacial energy in water. It has been postulated that the fluorinated segments lie on the fabric surface in air and the hydrophilic ones lie on the surface in water. Typically, these modified fluoropolymers are pad applied in combination with durable press crosslinking agents to increase the durability of the finish [1,4,7].

Table 1 gives an overview of the mechanisms of soil-release for finishes based on specific chemical structures, while Table 2 summarizes the methods available for the assessment of soil-release properties.

Table 1. Mechanisms of soil-release finishes and relevant chemicals [5]

Chemical mechanism	Examples of structure types involved
Increasing hydrophilicity, swelling of fibre and finish	Polyvinyl alcohol, carboxymethyl cellulose, caprolactam oligomers, ethoxylated products, sulfonates, polyacrylic acid or adipic acid copolymers
Some hydrophobicity (HLB value about 15)	Hybrid fluorocarbons (dual action block copolymers) or polyacrylic acid esters or polyethylene terephthalate block copolymers
Electrostatic repulsion	Anionic polymers such as polyacrylates and CMC in alkaline washing liquors or sulfonates repulse partly negatively charged soil particles or micelles, including dispersed soil particles
Protective coating with ablative or sacrificial finishes	Polyvinyl alcohol, carboxymethyl cellulose, starch
Alkali treatment of polyester	New carboxylic and hydroxyl groups on the fibre surface by hydrolysis of ester structures
Plasma treatment	New carboxylic and hydroxyl groups on the fibre surface by carbon radical formation and oxidation

Table 2. Test methods to evaluate soil-release finishes [2]

Soil redeposition	AATCC Test Method 151

The fabrics that are to be tested are exposed to a soiling medium during a laundering simulation with a standard detergent. The change in reflectance of the fabric before and after the testing is an indication of the redeposition potential of the fabric.	Used to estimate the degree of soil redeposition likely to occur during laundering.
Oily soil-release testing A measured amount of corn oil is placed on the fabric to be tested and pressed into it with a specific force. The soiled fabric is washed with a standard detergent under specific conditions of water temperature and time in a specified washing machine.	AATCC Test Method 130 Specifies all the parameters that influence soil-release of oily soils. After tumble drying and equilibration, the stained fabric is compared to photographic standards and rated accordingly.

It is worth noting that soil-release polymers, originally developed to be used in textile finishing particularly for polyester-based textiles, are now in common use as so-called washing aids also in detergents and cleaning agents for household laundry [8].

Concluding remarks

As the textiles and apparel industry moves into the twenty-first century, the expectation for performance has been added to the business of fashion, as the industry attempts to meet the consumers more demanding needs [9]. In this context, textile finishing is carried out to increase the attractiveness and/or serviceability. Various finishing treatments are available to get different effects, which add value to the basic textile material. The driving force for change in chemical finishes, such as soil-release, is the need for a competitive strategy by conscious finisher to add value, enhance quality and provide the greater levels of service to customers [2].

In terms of application fields, soil-release finishes were originally applied to men s shirts and tablecloths. Today, fabrics treated with soil-release finishes are used particularly for active wear and leisure wear markets, which are continuously growing in importance.

It is important to note that soil-release finishes have proved to also provide greater comfort in hot weather. It is well known that untreated polyester shirts, for example, do not absorb perspiration, and as such they are not very comfortable when worn in warm climates when compared to cotton shirts. This is because the polyester fibre has little affinity for water. Treatment of polyester with a soil-release polymer, not only improves the fibre s oil resistance but also allows for water wicking. Since soil-release polymers improve the water transport ability of polyester fibres, using them on polyester is often referred to as providing a comfort finish [3].

However, there are some points were attention should be paid during the application of soil-release finishes. First, with some exceptions, soil-release finishes lack the laundering durability desired in a finish expected to last the lifetime of a garment and must be applied in combination with a binder or a crosslinking agent. Too little crosslinking and the soil-

release finish is not durable to multiple launderings; too much crosslinking and the finish cannot swell as much as is needed for adequate soil-release [2].

Also, since the performance of a soil-release finish depends upon its ability to provide a hydrophilic surface during the laundering process, any material deposited on the fibre surface that would reduce this necessary hydrophilicity should be avoided [4].

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