COMFORT AND FUNCTION: CURRENT TRENDS IN COTTON FINISHING

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Cotton is traditionally the most important natural fibre in the apparel industry because of the comfortable wearing comfort and durability of cotton textiles. The chemical finishing of cotton aims to further improve the quality of the cotton fibre, either to overcome some disadvantages of the apparel or to establish additional desirable properties. This paper highlights some current trends in cotton finishing with the focus on anti-wrinkle (easy-care) and antimicrobial finishes.

The utilization of cotton as a fabric for clothing dates back to ancient times and is still the most important use for this natural fibre. Since cotton can readily absorb moisture, cotton-made apparel provides a very comfortable feeling on the skin. Despite its many advantages, there have been numerous efforts to overcome some limitations of cotton fabric by applying chemical finishes to provide superior products. The most prominent disadvantage of cotton is the easy wrinkling of the fabric, especially after washing. To solve this problem, a variety of easy-care finishes have been developed, which will be discussed in the first part of the paper.

A major recent trend in the textile industry has been the development of high-value fabrics for apparel and technical textiles with improved functions such as UV resistance, antimicrobial activity, and flame-retardant, antistatic or anti-repellent properties. Here, the use of known fabric types (cotton, polyester, nylon) in combination with specially developed chemical finishes has proven to be the method of choice to generate technical textiles for a variety of applications (medical, automotive, geotextiles, domestic, etc.). The second part of the paper will focus on current approaches that use chemical finishes to achieve antimicrobial and anti-fouling properties.

Anti-wrinkle (easy-care) finishes for cotton fabrics

The most advantageous property of cotton - the good absorption of moisture - is also the molecular basis for its most negative quality: the easy formation of wrinkles, especially after washing. Cotton fibres consist of strands of the polysaccharide cellulose that are stabilised by intramolecular hydrogen bonds (Figure 1). In the wet state, water molecules insert in between the individual strands, thereby allowing them to move relative to each other. Upon drying, the water molecules are removed, and the cellulose strands are fixed in the new orientation, i.e. wrinkle formation has occurred.

The basic principle of current anti-wrinkle finishes is also shown in Figure 1 (bottom). A chemical cross-linker is used as a finish to connect different cellulose strands permanently. Water molecules can still insert in between two strands, but strand movement is prohibited because of the stable chemical linkage. As a result, the formation of wrinkles is reduced.

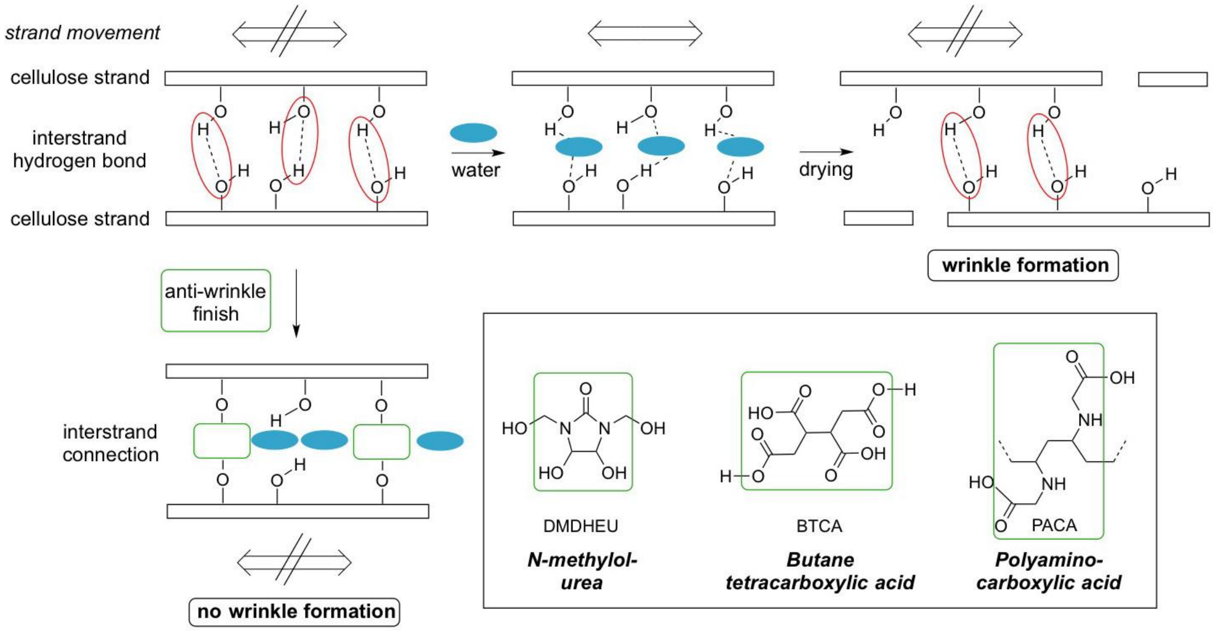

Figure 1. Mechanism of wrinkle formation (top), effect of anti-wrinkle finishes (bottom), and structure of chemicals that act as anti-wrinkle finishes (inset).

The most widely used anti-wrinkle finishes (Schindler and Hauser 2004; Ameri Dehabadi et al. in print) are the so-called *N*-methylol derivatives, e.g the urea derivative DMDHEU (Figure 1, inset). Using such reagents, good results can be achieved, which are judged by determining the wrinkle recovery angle (WRA). An unavoidable side effect of all cellulose crosslinking finishes is a reduction of the flexibility of the cellulose fibres. In addition, a reduction of the whiteness is also often observed, especially in the case of the *N*-methylol derivatives. The most severe drawback of these finishing agents, however, is the slow release of formaldehyde from textiles treated with *N*-methylol derivatives, which has prompted the search for alternatives. This has led to the development of the polycarboxylic acid-type finishing agents, e.g. citric acid or BTCA (Figure 1, inset). Upon addition of a catalyst, the cross-linking of the cellulose strands is achieved by formation of ester bonds. BTCA is currently the most promising alternative for the *N*-methylol agents, as it provides a similar anti-wrinkle effect and a less severe greying. Nevertheless, the high price of the polycarboxylic acid finishes has prevented a wider use.

In recent years, a number of research projects at the Deutsches Textilforschungs-zentrum Nord-West (DTNW) in Krefeld have examined the use of commercially available polyamines, e.g. polyvinylamine (PVAm) and polyethylene-imine (PEIm), for the modification of different textile fibres. In the context of easy-care properties, we have developed polycarboxylic acids based on polyamines, e.g. the PVAm-derived polyaminocarboxylic acid (PACA) shown in Figure 1 (Ameri Dehabadi et al. 2012). These compounds are easily synthesized by reaction of an aqueous solution of the technical grade polyamine with bromoacetic acid. Different degrees of substitution can be achieved depending on the amount of reagent used. As anticipated, the chemical cross-linking of cellulose fibres with such PACAs in the presence of sodium hypophosphite as a catalyst led to fabrics with very good anti-wrinkle properties. While an increase of the WRA by 50% was maintained even after 5 washing cycles, we also observed an acceptable loss of tear strength and reduction of whiteness superior to many of the currently used finishing agents. In further studies, we could also show that the finishing of cotton with PACAs improves the dyeability in a salt-free reactive dyeing process (Ameri Dehabadi et al. 2013) and procures improved flame-retardant properties. As a consequence, PACAs are promising finishing agents for a variety of applications.

Antimicrobial finishes for cotton fabrics

The production of textiles with antimicrobial properties is one of the fastest growing markets in the textile industry (Gao and Cranston 2008). In addition to apparel and activewear, where the growth of microbes leads to unwanted effects such as unpleasant odour, stains and discolouration, emerging markets include protective clothing and medical textiles, outdoor and automotive textiles, air filters, etc.

Antimicrobial textiles should be effective against a broad range of bacterial and fungal species and at the same time be safe to use for the consumer. In addition, the effect should be long lasting and the appearance and quality of the textile should be similar to regular products. There are a number of approaches that try to fulfil these requirements (Figure 2), and numerous products have been launched so far.

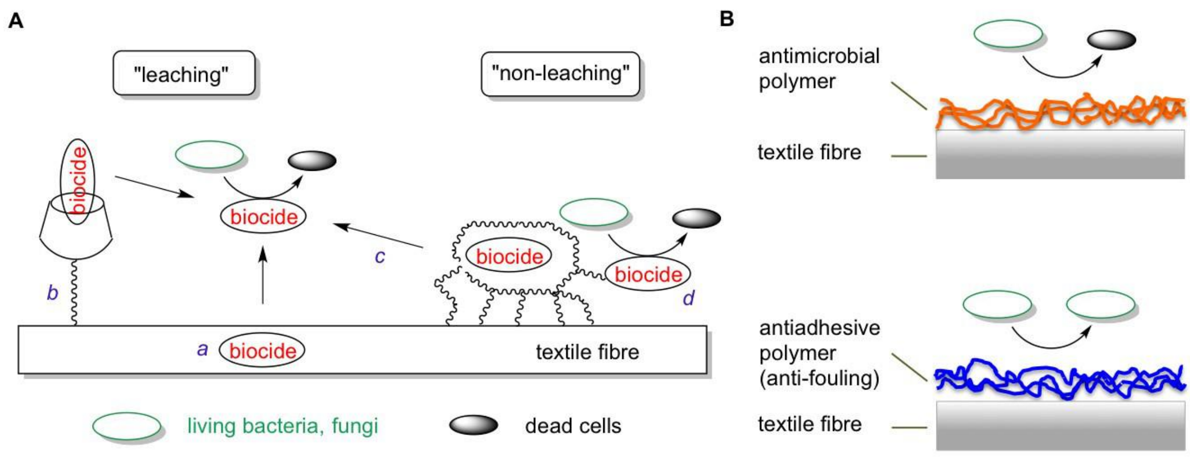

Figure 2. A: Different approaches to attach biocides to textiles using a chemical finishing process. B: Coating of textile fibres with antimicrobial or antiadhesive polymers.

The most common method to obtain antimicrobial textiles is the attachment of a biocide to the fabric, either by means of a chemical finishing process or by the development of new antimicrobial fibres that already contain the biocide. In most cases, the antimicrobial activity of the fabric relies on the release of the biocide from the fabric (“leaching”, Figure 2A, left), e.g. silver ions or antiseptics like triclosan. Some biocides are able to inhibit the growth of microbes by contact, e.g. cationic compounds like quaternary ammonium salts. Here, a “non-leaching” (Figure 2A, right) and thus more permanent coating is possible.

The chemical finishing process to obtain antimicrobial cotton depends on the physical properties of the biocides, and some examples are shown in Figure 2 (Gao and Cranston 2008). Small molecules like triclosan can penetrate the fibre (*a*). Accordingly, a finishing process similar to dyeing is possible. Triclosan and different antibiotics have been attached to fibres by formation of a cyclodextrin inclusion complex (*b*), which requires the initial finishing of cotton with a suitable cyclodextrin derivative. In the case of silver, either silver salts or nanoscalic silver can be immobilised on fibres by various methods, e.g. using zeolithes, alginates or a sol-gel process. Silver ions are then slowly released (*c*). Sol-gel technology has also been used to attach quaternary ammonium derivatives to cotton fibres. This creates a cationic surface, which is able to kill bacteria by destabilisation of the bacterial cell wall via a “non-leaching” mechanism (*d*). A recently developed approach to obtain an antibacterial surface coating of cotton is the use of polyelectrolyte layers that are deposited using the layer-by-layer technology. By using antibacterial polyelectrolytes such as chitosan, bioactive textiles can be obtained (Gomes et al. 2013). Alternatively, the polyelectrolyte films can also act as a reservoir for a biocide.

Finally, it should be noticed that there are two conceptually different approaches to suppress the growth of microorganisms on a textile or on a surface in general. The first approach relies on the active killing or growth suppression of bacteria and fungi by the action of biocides as described above. A newer development takes advantage of the antimicrobial activity of certain polymers (Siedenbiedel 2012) that are attached to a surface (Figure 2B, top). Prominent examples are polycationic compounds, e.g. the natural product chitosan or the synthetic polymer polyvinylamine. The activity of these polyamines can be further increased by quaternisation similar to the monomeric quaternary ammonium salts described above.

In the second approach (Figure 2B, bottom), antimicrobial surfaces are obtained because the cells are not able to attach themselves on the surface. This can be achieved by different surface coatings, e.g. polyethyleneglycol-based films and polymers with a high number of zwitterionic groups (Banerjee et al. 2011), which leads to highly solvated surfaces that prevent fouling by cells and proteins.

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