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Garima Anand
Associate Professor, Knitwear Design Department, National Institute of Fashion Technology, New Delhi, India

Dr. Ananya Mitra Pramanik
Associate Professor, Textile Design Department, National Institute of Fashion Technology, New Delhi, India

Corresponding Author:
Garima Anand
Associate Professor, Knitwear Design Department, National Institute of Fashion Technology, New Delhi, India

An introduction to sustainable finishing techniques of textiles

Garima Anand and Dr. Ananya Mitra Pramanik

Abstract
Textile finishing plays a crucial role in imparting value addition to textiles. The conventional functional finishes used on textiles during processing involve application of hazardous chemicals and auxiliaries. These processes are also disadvantageous in terms of energy consumption, cost and industrial effluents which ultimately lead to environmental pollution. The advent of sustainable finishing processes related to UV Protection Finish, Anti-microbial finish, Flame retardant finish, Irradiation Technologies, Nanotechnology and Plasma treatment helps to overcome the hazardous effects of chemicals and auxiliaries used in the conventional finishing processes. This paper uses secondary research methods from various books, publications, as well as electronic sources to conduct the study of the prominent recent developments in Sustainable finishing techniques used for natural and man-made fibers.

Keywords: UV protection finish, anti-microbial finish, flame retardant finish, irradiation technologies, nanotechnology, plasma treatment

Introduction

Cotton, wool, viscose, linen and silk are the most preferred fibres in the textile industry which are used in various applications. Cotton is the most prevalent material out of all the fibre varieties. It is used in preparation of various stain-resistant and water-resistant garments due to its super hydrophobic finish. Fibers with unique features such as shrink resistance, crease resistance, stain resistance, UV protection and water resistance are becoming very important from a customer's perspective. To fulfil these requirements, a number of innovations have been made to increase the quality of the garment. In recent times, a lot of chemicals have been successfully used for preparation of garments with antimicrobial characteristics like N-Halamine siloxanes, polyhexamethylene biguanide, triclosan and biopolymers.

With the objective of enhancing the finishing properties of textiles, many new nano particles like silver, titanium dioxide and zinc oxide are being used effectively. In the finishing process, improper binding of chemical and other aides, results in contamination of natural resources like air, water and soil.

For the purpose of reducing toxic and unwanted textile contaminants from the environment, a number of techniques which treat wastewater are used. Techniques like ion exchange, membrane separation, adsorption, coagulation, biological degradation and advanced oxidation process are generally used in the textile industry.

Utilizing traditional techniques has proved to be difficult, inadequate and extremely costly. This deficiency in waste water treatment due to industrial effluents has led to development of new sustainable practices in the finishing section. With the advancement in material research, new research areas like geo-materials, fire-retardant materials, aromatic materials, nano-textile materials, medical textiles and insect-resistant materials are becoming popular. Numerous licenses have been accounted for various regions of textile finishing, as across the world researchers are committing to leverage these interesting areas of material research (Islam S, *et al*, 2015) [15].

Sustainable Finishing Techniques

UV Protection Finish

Ultraviolet rays have a lot of effect on all living organisms on the earth though it's percentage in the solar spectrum is low. Moderate and apt amount of sun exposure helps in blood

circulation, stimulates metabolism, and increases resistance to different pathogens. In case the UV rays penetrate the top layer of skin, it leads to damage in the lower layer. This results in early aging of skin along with blotches and wrinkles. These are reported by Palacin F (1997) [23], Perkin SW (2000) [27] and Srinivasan M *et al*. (2000) [33].

About 175 nm above the stratosphere is absorbed in solar spectrum and radiation up to 280 nm is intercepted in the ozone layer. Stratospheric ozone greatly lessens the UV ray transmissions. UVC rays around 100-280 nm are harmful for the skin and eyes and the rays in the range of 310-300 nm are the most harmful. These are reported by Dayal A *et al*. (1998) [8], Rupp J *et al*. (2001) [29], Holme I (2003) [14], Menter JM *et al*. (2004) [19], Pailthorpe MT *et al*. (1995) [22], Bajaj P *et al*. (2000) [4], Gerber B *et al*. (2007) [11] and Desai AA (2003) [9].

Textiles partially reflect, transmit and absorb the UV rays through the gaps between warp & weft yarns and also through fibres (Lal RA, 1998) [17]. The optical permeability of a fabric restricts the potential to enable protection against UV rays. Fabrics with low UV protection values provide less protection than expected. Using various dope additions and topical applications, many commercial products and processes have been developed to produce fibres with high level of ultraviolet protection factor. These are reported by Rupp J *et al*. (2001) [29], Holme I (2003) [14], Bajaj P *et al*. (2000) [4], Australian Guide for UV Protective products (2003) [3] and Rosinskaya C *et al*. (2003) [28]. Majority of these products are compatible with dyes and other finishing agents used for fabrics. Different methods such as simple padding, exhaust method, pad-thermofix and pad-dry-cure methods are used for applying these agents These are reported by Achwal WB (2000) [1], Gantz GM *et al*. (1957) [10], Hanke D *et al*. (1997) [13], Haerri HP *et al*. (2001) [12] and Anon (2000) [2].

The extracts of various natural products have been reported to show protection against UV rays. Some examples include green tea, black tea, curcumin, silymarin, soy, pongamiapinnata, tomato, nuts, carrot, grapes and papaya as stated by Shenekar PN *et al*. (2014) [32], Patil S *et al*. (2015) [25], Buso P *et al*. (2019) [6] and Mizrahi (1997) [20]. Leaf extracts of Aloe vera, neem (Azadirachtaindica), holy basil (Ocimum sanctum) and peppermint (Menthapiperita) show marginal protection against UV rays within the range 290–320 nm (Buso P, *et al*, 2019) [6].

Anti-microbial finish

Traditionally, antimicrobial fabrics have found acceptance as baby clothing, surgical clothes, undergarments, etc. However, recently the antimicrobial finishing treatment is also applicable for traditional clothing and home textiles. The anti-microbial agents hinder or kill the growth of pathogens and reduce their effect. Cotton and other natural fibres are prone to attack by pathogens as these fibres have carbohydrates. Fabrics with antimicrobial finishes have different variety of applications in areas likes intimate apparels, sportswear, medical textiles, automotive textiles, etc. Microorganisms in fabrics causes staining, unpleasant odour and can also lead to health issues. Garments which are worn next to the skin require antimicrobial finish as microbial infections cause allergies, skin diseases and inflammation. According to US and European standards, many antimicrobial agents are banned and as a result there is an increase in demand for eco-friendly antimicrobial textiles based on natural antimicrobial agents like chitosan, which are good for the skin even on long-term usage. Neem, banana, papaya, aloe vera and hemp extracts can be used for the purpose of providing antimicrobial finish to the fabrics. Compounds such as tannin, flavonoids and terpenoids which are present in many plants are responsible for antimicrobial activity and have potential to kill (bacteriocide) as well as inhibit the micro-organism growth (bacteriostatic) (M. Gobalakrishnan, *et al*) [18].

Flame-Retardant Finish

Flame- retardant finishes play an important role for saving the life of humans (Wang X, *et al*, 2014) [36]. Though synthetic fibers show poor bio-degradability, they are widely used in flame-retardant fabrics. Natural fibers are used as renewable materials for flame-retardant fabrics as these fibers are partially or fully recyclable. Examples include jute, hemp, cotton, flax and sisal. Natural fiber composites are now replacing man-made fibers like carbon, glass etc. and a lot of work has been done on cotton fabric to increase its efficiency with respect to flame retardancy. These are reported by Basak S *et al*. (2015) [5], Patil VM *et al*. (2012) [26] and Parikh DV *et al*. (2003) [24].

The probability of flame retardants in the environment is rising due to the development and implementation of polymers in the field of military, transport, furnishing, clothing, etc. Around 465,000 tons of flame retardants were utilised in Europe by the end of 2006 according to the reports of de Boer and Van der Veen. Several compounds that are found in traditional flame retardants are found to be toxic and have a bad effect on human beings and environment. Some examples include urea, phosphorus, melamine- formaldehyde, antimony- halogen, THPC, etc. Functional finishing techniques like Plasma technology, nanomaterials, layer deposition and Sol-gel process are found to be less water consuming. Search for sustainable and environment friendly raw materials which are obtained from biological sources is taking place so as to counter the negative effects of chemicals utilised in finishing process. Application of proteins, nucleic acid, DNA, hydrophobins and caseins is considered as a replacement for the traditional finishing materials. Such materials help in making of flame retardants with increased thermal stability (Samanta KK, *et al*, 2017) [30].

Irradiation Technologies

Researchers are in search of substitutes for producing textiles in a sustainable way as the finishing process consumes a huge amount of water and results in huge volume of water as harmful textile effluent. One of the biggest substitutes to textile wet processing is irradiation technology, which is eco-friendl**y,** consumes less energy, is efficient, simple to use and does not use any chemicals. For managing sustainable dyeing and finishing, the use of ultrasound, gamma, ultraviolent and plasma radiation for alteration of fibre surface to improve the uptake of dyes and finishing enzymes is gaining lot of importance (Islam S, *et al*, 2015) [15].

Nanotechnology

Nowadays in the textile finishing sector, nanotechnology is one of the widely used technologies which uses textile fibres on a nano scale for diameters in the range of 1 to 100 nm. This technology is very useful in improving the breathability of the fabrics as it has shown a positive impact on the enhancement of the surface area of separate fibres. This technology finds applicability in different fields:

- Oil and water repellent features of the fabric can be enhanced.
- Improves the scratch resistance of the fabrics and garments.

- Electrical conductivity of the individual fibers can be improved.
- Provide flame retardancy to the fabric.
- Improves the strength and durability of the clothes and garments.

Implementation of nanotechnology is more helpful in the production of eco-friendly textiles by reducing the usage of harmful and toxic chemicals (Conway R, 2016) [7]. In the work conducted by Vankar and Shukla, they synthesized silver nanoparticles from plant extracts of lemon leaves. Using plant extract as the encapsulating agent of the synthesized silver nanoparticles, the outcome of the exercise was that these particles had a good antifungal and antimicrobial activity. Application of the prepared nanoparticles also enhances the antimicrobial activity resulting in protection against harmful microorganisms (Vankar P, *et al*, 2012) [35].Wound healing properties and resistance to microbes increases due to the application of nano capsules on fabrics. This provides protection against disease causing micro-organisms and also helps in maintaining hygiene. Raw materials having antioxidant and anti-inflammatory properties are chosen as coating materials for preparation of medicinal textiles (Montazer M, *et al*. 2018) [21].

Plasma Treatment

Number of processes have been tried to reduce the pollution load created in the wet processing like water-free processing, low-wet pickup process and solvent assisted processing, but they have met with varied levels of success. Plasma contains ionised gas including electrons, atoms, ions and molecules. It is considered as the 4th state of matter.

Various types of fibres can be subjected to plasma treatment like natural fibres, man-made fibres and fabrics produced from different blends. As compared to the existing wet processing methods, plasma treatment offers environment friendly and in many cases water free processes These are reported by Jhala PB (2005) [16] and Subbulakshmi SM (1998) [34].

Free electrons present in plasma make it electrically conducting making it good sources of radiation as it responds to both electric and magnetic fields. The surface of the fabric gets modified by the plasma due to the bombardment with high energy ions and electrons. For achieving better flexibility and performance in the processing methods, combination of gases is used (Saravanan D, *et al*, 2008) [31].

There are several fabric properties which are enhanced by using plasma technology. Some of these properties are adhesion, strength antistatic properties, dyeing and printing ability, hydrophobicity/ hydrophilicity, functionalized fiber. Helium/ oxygen or helium/ air are the most widely used plasma treatments. In the textile finishing sector, plasma technique finds number of applications:

- Providing antifungal and antibacterial properties to the fabric with the use of silver nano material.
- Enhancing the hydrophobic activity of the fabric for preparation of water repellent fabrics.
- By implementing the surface grass grafting techniques, it improves the final finish of the fabric.
- Improves the adhesion behaviour resulting in strong dyeing and printing ability of the fabric.

These technologies are the most sustainable, innovative and environment friendly technologies as they reduce the consumption of energy and other resources during the finishing process (Samanta KK, *et al*, 2017) [30].

Conclusion

All the finishing techniques discussed in this paper are advantageous in their ways to facilitate sustainable processing. Ultraviolet Protection finish based on extracts of natural products such as green tea, black tea, curcumin, silymarin, soy, Pongamiapinnata, tomato, nuts, carrot, grapes, papaya, etc. have been used on textiles to provide protection against UV rays. Natural antimicrobial agents such as chitosan, neem, banana, papaya, aloe vera and hemp extracts can be used for creating environmentally friendly antimicrobial textiles. Flame retardant finishes based on application of proteins, nucleic acid, DNA, hydrophobins and caseins is considered as a replacement for the traditional finishing materials. These materials help in providing better thermal stability. Irradiation technology uses ultrasound, gamma, ultra-violent and plasma radiation for alteration of fibre surface to improve the uptake of dyes and finishing enzymes. It is an eco-friendly process which consumes less energy and does not involve use of chemicals. Nanotechnology finds varied application in sustainable textile finishing by reducing the usage of harmful and toxic chemicals. Plasma Technology offers environment friendly and in many cases water free processes. It enhances several fabric properties such as adhesion, strength antistatic properties, dyeing and printing ability, hydrophobicity/ hydrophilicity, functionalized fiber.

Research recommends that sustainable finishing processes should be implemented in the textile industry on a large scale to protect the environment from the drawbacks of the conventional finishing methods. The concept of eco-friendly and sustainable clothing is gaining more importance and consumers prefer to buy such clothing. The research also suggests for promoting more awareness with industry & consumer regarding advantages of following sustainable practices.

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