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Clean Trends in Textile Wet Processing

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Textile industries are facing a challenging condition in the field of quality and productivity, due to the globalization of the world market. The highly competitive atmosphere and as the ecological parameters becoming more stringent, it becomes the prime concern of the textile processor to be conscious about quality and ecology. Again the guidelines for the textile processing industries by the pollution control boards create concern over the environment-friendliness of the processes, making it essential for innovations and changes in the processes [1]. Textile wet processing, is consider as a big and important sector in textile industry, with a wide range of procedures, which affect the final product appearance and quality. Wet processing occurs at various stages in the creation of textiles, as shown in Figure 1.

This is the most widely used wet processing flow-chart on the contemporary textile industry. As textile industry is searching for innovative production techniques to improve the product quality, as well as society requires new finishing techniques working in environmental respect [2].

Through this review article, we focus on the most innovated trends applied in textile wet processing, in addition to applying eco-friendly procedures and technologies:

Ultrasonic

In recent decades ultrasound has established an important place in different industrial processes and has started to revolutionize environmental protection Figure 2.

The use of ultrasound in textile wet processing offers many potential advantages including energy savings, process enhancement and reduced processing times. Ultrasonic represents a special branch of general acoustics, the science of mechanical oscillations of solids, liquids and gaseous media. With reference to the properties of human ear, high frequency inaudible oscillations are ultrasonic or supersonic. In other words, while the normal range of human hearing is in between 16 Hz and 16 kHz, ultrasonic frequencies lie between 20 kHz and 500 MHz.

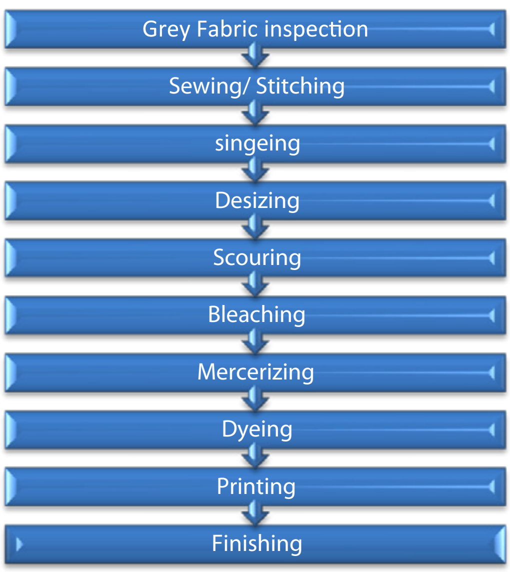

Figure 1

Figure 2

Wet processing of textiles uses large quantities of water, electrical and thermal energy. Most of these processes involve the use of chemicals for assisting, accelerating or retarding their rates and are carried out at elevated temperatures to transfer mass from processing liquid medium across the surface of the textile material in a reasonable time. Nowadays the ultrasound technique had been applied in the different areas of textile wet processing including: **Desizing**: It was found that the use of degraded starch followed by ultrasonic desizing could lead to considerably energy saving as compared to conventional starch sizing and desizing. Fiber degradation is also reduced and final whiteness and wet ability of the fabric are same as those of without ultrasonic. **Scouring and Bleaching**: The scouring of wool in neutral and very light alkaline bath reduces the fiber damage and enhance rate of processing by using 20 KHz frequency for peroxide bleaching of cotton fabric and observed an increase in bleaching rate in required time the degree of whiteness also increases as compared to that of conventionally bleached sample. **Dyeing**: The possibility of dyeing textile using ultrasound was started in 1941. The dyeing of cotton with direct dyes, wool with acid dyes, polyamide and acetate fiber with disperse dyes can be used. The significant increases in rate of dyeing with disperse dyes on polyamide and acetate was obtained. Ultrasound is more beneficial to the application of water insoluble dyes to the hydrophobic fibers. Effects dispersion and degassing are

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promoted by the mechanical action of cavitations, while diffusion due to medical action and heating of surface. Ultrasound irradiation also produces a greater evenness in color. The dyeing results are affected by frequency of ultrasound used. Frequency of 50 or 100 c/s produces no effect while frequency of 22 to 175 Kc/s has been found to be most effective. **Cavitation:** Ultrasound energy of 20 KHz frequencies is suitable for inducing cavitations. It is known which causes formation and collapse of micro bubble is most effective for better dye uptake. The micro bubbles that are unstable solely grow in the process of oscillation that implodes violently thereby generating momentary localized high temperature and pressure. This active stage causes chemical reaction between fiber and dye, this result in better dye uptake. Enzymatic treatments supplemented with ultrasonic energy resulted in shorter processing times, less consumption of expensive enzymes, less fiber damage, and better uniformity treatment to the fabric [3,4].

Digital Printing

Digital printing is so far one of the most exciting developments in the textile industry. Not only does it open up endless opportunities for customization, small run printing, prototyping and experimentation but it also puts textile printing within the budget of your average illustrator. Digital textile printing can reproduce unlimited colors and shades but as with most forms of printing what you see on screen is not necessarily what you get back. In fact inkjet direct printing on textiles has become quite significant in recent years in both the large format and the tape segment, taking market share from the previously dominant screen- and transfer-printing technologies [5,6].

The inks used in digital printing are formulated specifically for each type of fiber [cotton, silk, polyester, nylon, etc]. In theory, inkjet technology is simple a print head ejects a pattern of tiny drops of ink onto a substrate without actually touching it. Dots using different colored inks are combined together to create photo-quality images. There are no screens, no cleanup of print paste, little or no wastage. During the printing process, the fabric is fed through the printer using rollers. The chemicals required for fixation of the dyes have to be applied by padding or coating application prior to ink jet printing. However, even with the application of the conventional print chemicals color yield is still not comparable to that achieved by conventional printing processes. This is the main due to the very much smaller amount of ink formulation applied by the print head where, ink is applied to the surface in the form of thousands of tiny droplets. Actual amounts applied by the various print technologies differ depending on the actual print head principle, nozzle size [drop volume], frequency rate [which determines the number of drops /second].

The fabric is then finished using heat and/or steam to cure the ink [some inks also require washing and drying]. Digitally printed fabric will wash and wear the same as any other fabric, although with some types of ink you may see some initial fading in the first wash [7] Figure 3.

For textile ink jet application to be successful, the dye or textile chemists and the media must work in a close relationship with the systems integrator [and the print head developer] [8].

Biotechnology

Textile processing has benefited greatly in both environmental impact and product quality through the use of enzymes. As using of enzymes in textile processing and after-care is already the best established example of the application of biotechnology too. From

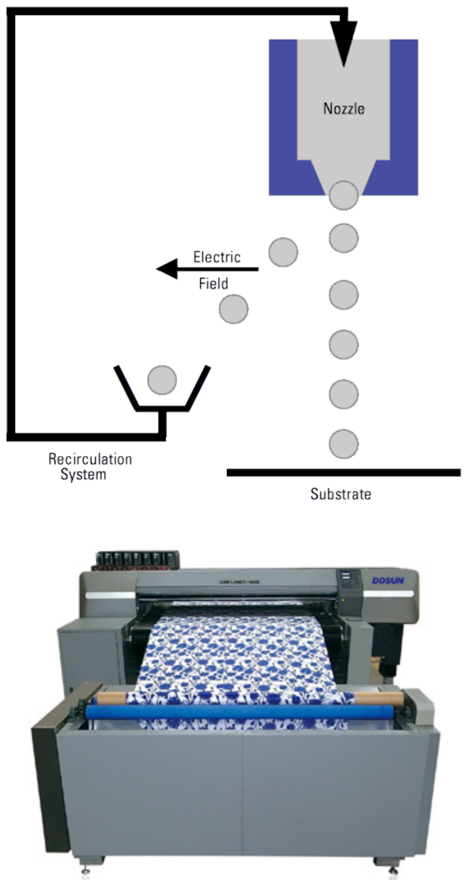

Figure 3

the 7000 enzymes known, only about 75 are commonly used in textile industry processes. The principal enzymes applied in textile industry are hydrolases and oxidoreductases. The group of hydrolases includes amylases, cellulases, proteases, pectinases and lipases/esterases. Amylases were the only enzymes applied in textile processing until the 1980s. These enzymes are still used to remove starch-based sizes from fabrics after weaving. Cellulases have been employed to enzymatically remove fibrils and fuzz fibers, and have also successfully been introduced to the cotton textile industry.

Further applications have been found for these enzymes to produce the aged look of denim and other garments. The potential of proteolytic enzymes was assessed for the removal of wool fiber scales, resulting in improved anti-felting behavior. However, an industrial process has yet to be realized. Esterases have been successfully studied for the partial hydrolysis of synthetic fiber surfaces, improving their hydrophobicity and aiding further finishing steps. Besides hydrolytic enzymes, oxido reductases have also been used as powerful tools in various textile-processing steps. Catalases have been used to remove H_2O_2 after bleaching, reducing water consumption. Enzymes have also been widely used in domestic laundering detergents since the 1960s [9] such as proteases which used for removing grass, blood, egg, sweat stains and Lipases used for Lipstick, butter, salad oil, sauces etc. Future developments in the field of textile after-care also include treatments to reverse wool shrinkage as well as alternatives to dry cleaning. On the other hand, Natural and enhanced microbial processes have been used for many years to treat waste materials and effluent streams from

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the textile industry. Conventional activated sludge and other systems are generally well able to meet BOD and related discharge limits on most cases. However, the industry does face some specific problems which are both pressing and intractable. They include color removal from dyestuff effluent and the handling of toxic wastes including PCPs, insecticides and heavy metals. These are not only difficult to remove by conventional biological or chemical treatment but they are also prone to 'poison' the very systems used to treat them.

Reactive dyes are particularly difficult to treat by conventional methods because they are not readily adsorbed onto the activated sludge biomass where they could be degraded. Currently one approach to this problem is direct microbial attack on the azo linkage of organic dyestuffs, leading to their complete degradation in solution. Alternative approaches being evaluated in the UK include the use of biologically active materials such as chitin to absorb color. Researchers in some developing countries are experimenting with more readily available and cheaper local sources of biomass such as straw pulp and even residues from biogas reactors [10].

Plasma Treatment

The plasma technology is considered to be very interesting future oriented process owing to its environmental acceptability and wide range of applications. Plasma is the fourth state of matter besides solid, liquid and gas which contains ionized gas comprising of ions, electrons, atoms and molecules. Presence of free electrons and other charged particles converts plasma as electrically conducting and responsive to electricity. For fabrics, cold plasma treatments require the development of reliable and large systems. Such systems now exist and the use of plasma physics in industrial problems is rapidly increasing. The plasma modifies the fabric surface by the bombardment with high energy electrons and ions. The classification systems of plasmas is often based on temperature, pressure, type of current used, and the types of gaseous matters used in the plasma processes, types of substrates used and the results appear to vary depending upon the effects targeted. Plasma surface treatments show distinct advantages, because they are able to modify the surface properties of inert materials, sometimes with environment friendly devices [11,12] Figure 4.

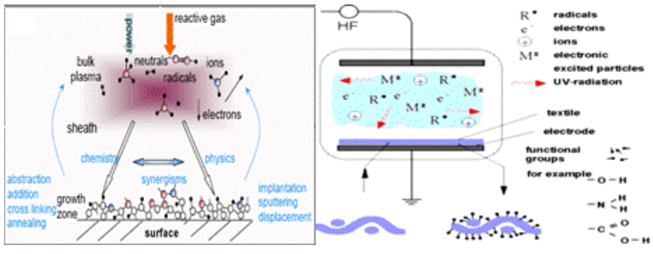

Figure 4

On textile surfaces, three main effects can be obtained depending on the treatment conditions: the cleaning effect, the increase of micro roughness [anti pilling finishing of wool] and the production of radicals to obtain hydrophilic surfaces. Plasma polymerization, that is the deposition of solid polymeric materials with desired properties on textile substrates, is under development. The advantage of such plasma treatments is that the modification turns out to be restricted in the uppermost layers of the substrate, thus not affecting the overall desirable bulk properties. Both the surface chemistry and the surface topography may be influenced to result in improved adhesion or repellency properties as well as in the confinement of functional groups to the surface. Plasma treatment has to be controlled carefully to avoid detrimental action of the plasma onto the substrate [13,14].

Nanotechnology

The concept of Nanotechnology is not new; it was started over forty years ago. Nanotechnology is defined as the utilization of structures with at least one dimension of Nanometer size for the construction of materials, devices or systems with novel or significantly improved properties due to their nanosize. Nanotechnology not only produces small structures, but also an anticipated manufacturing technology which can give thorough, inexpensive control of the structure of matter. Nanotechnology can best be described as activities at the level of atoms and molecules that have applications in the real world. Nanotechnology also has real commercial potential for the textile industry. This is mainly due to the fact that conventional methods used to impart different properties to fabrics often do not lead to permanent effects, and will lose their functions after laundering or wearing. Nanotechnology can provide high durability for fabrics, because nanoparticles have a large surface area to volume ratio and high surface energy, thus presenting better affinity for fabrics and leading to an increase in durability of the function. In addition, a coating of nanoparticles on fabrics will not affect their breathability or hand feel [15]. So Coating is a common technique used to apply nanoparticles onto textiles. The coating compositions that can modify the surface of textiles are usually composed of nanoparticles, a surfactant, ingredients and a carrier medium. Several methods can apply coating onto fabrics, including spraying, transfer printing, washing, rinsing and padding of these methods, padding is the most commonly used. The nanoparticles are attached to the fabrics with the use of a padder adjusted to suitable pressure and speed, followed by drying and curing Figure 5.

The properties imparted to textiles using Nanotechnology include **Water repellence**: as nano tex improves the water-repellent property of fabric by creating nano whiskers, which are hydrocarbons and 1/1000 of the size of a typical cotton fiber, that are added to the fabric to create a Peach fuzz effect without lowering the strength of cotton. The spaces between the whiskers on the fabric are smaller than the typical drop of water, but still larger than water molecules; water thus remains on the top of the whiskers and above the surface of the fabric. However, liquid can still pass through the fabric, if pressure is applied. About using nanotech in **UV protection:** it was found that inorganic UV blockers are more preferable to organic UV blockers as they are non-toxic and chemically stable under exposure to both high temperatures and UV. Inorganic UV blockers are usually certain semiconductor oxides such as TiO_2, ZnO, SiO_2 and Al_2O_3. It was determined that nano sized titanium dioxide and zinc oxide were more efficient at absorbing and scattering UV radiation than the conventional size, and were thus better able to block UV. For imparting **Anti-bacterial** properties, nano-sized silver, titanium dioxide and zinc oxide are used. Metallic ions and metallic compounds display a certain degree of sterilizing effect. Nano silver particles have an extremely large relative surface area, thus increasing their contact with bacteria or fungi, and vastly improving their bactericidal and fungicidal effectiveness.

Concerning antistatic: Static charge usually builds up in synthetic fibers such as nylon and polyester because they absorb little water. Cellulosic fibers have higher moisture content to carry away static charges, so that no static charge will accumulate. As synthetic fibers

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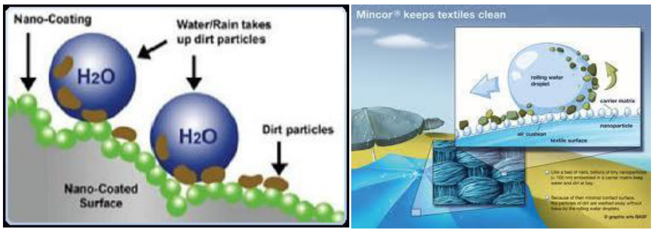

Figure 5

provide poor anti-static properties, research work concerning the improvement of the anti-static properties of textiles by using nanotechnology were conducted. It was determined that nano sized titanium dioxide, zinc oxide whiskers, nano Antimony-Doped Tin Oxide [ATO] and silane nano sol could impart anti-static properties to synthetic fibers. TiO_2, ZnO and ATO provide anti-static effects because they are electrically conductive materials. Such material helps to effectively dissipate the static charge which is accumulated on the fabric. On the other hand, silane nanosol improves anti-static properties, as the silane gel particles on fiber absorb water and moisture in the air by amino and hydroxyl groups and bound water. In addition to impart **Wrinkle resistance:** to fabric, resin is commonly used in conventional methods. However, there are limitations to applying resin, including a decrease in the tensile strength of fiber, abrasion resistance, water absorbency and dye ability, as well as breathability. To overcome the limitations of using resin, some researchers employed nano titanium dioxide and nano silica to improve the wrinkle resistance of cotton and silk respectively. nano titanium dioxide was employed with carboxylic acid as a catalyst under UV irradiation to catalyze the cross-linking reaction between the cellulose molecule and the acid. On the other hand, nano silica was applied with maleic anhydride as a catalyst, the results showed that the application of nano-silica with maleic anhydride could successfully improve the wrinkle resistance of silk [16].

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