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A Review on Plasma and Resin Treatment for Textile Materials

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Abstract

The garment industry has gone through several improvisations in the area of finishing. Several finishing techniques have been developed and researched upon and it is never-ending. Among this plasma and resin, treatments are one of the majorly known finishing techniques. Plasma treatment is majorly used for improving the surface characteristics of textile materials. The properties and effects of the textile substances that are increased through this treatment embody adhesion, wettability, protection, biocompatibility, chemical affinity/inertness, anti-wear, and sterilization. Whereas resin (wrinkle-free finishing) is broadly used in the textile materials such as cotton to impart a wrinkle-resistance to the fabrics as well as the garments. But there is a major concern involving the resin finishing technique that is there could be a considerable amount of decrease in the abrasion resistance and strength of the finished fabric. In this study, various types of plasma and resin treatments and their effects on textile material are discussed.

Keywords: Plasma treatment; Resin treatment; Finishing; Textile

Introduction

In the textile industry, finishing can be referred to as a process by which a fabric can be converted into woven or knitted into a more usable material, more precisely improving the look, feel (hand), performance, etc of the final textile material. Fabric treatment, on the other hand, is used to improve the durability of the fabric, properties such as flame retardant, water repellent, crease-resistant, etc. Plasma treatment and resin treatments are hence used for improving the surface quality of the fabrics in the textile industry. Plasma treatment is said to help enhance the fabric's hydrophilic properties, and improve the surface energy of the textile material. These changes observed in the surface energy can be majorly due to developments of polar functional groups on the fabric surface when it is exposed to plasma reactions. The resin treatment gives the fabric property of crease recovery, improves the smoothness, and also gives it a better bending length as there is a higher crosslinking of the cellulose.

The incorporation of plasma within the space of textile modification represents an excellent chance for improvement of the old, strenuously challenging, setting polluting, as well as slow treatments. The appliance of plasma is supposed to be eco-friendly and additionally reduces the assembly prices. Plasma treatment bids a great chance to attain finishes while not inflicting any changes in the key textile properties [1].

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The textile industry is in a very constant search for new and innovative production methods to boost the quality of its products, and conjointly the society needs newer and improved finishing techniques operating in the honor of the environment. These improvised methods show various benefits, such as modifying or changing the surface structure of inert materials such as chemical or other, rarely with environment-friendly devices. The surface modifications done to the textile fibers with the assistance of atmospheric plasma treatment gives out particular desired properties such as adhesion promotion, surface energy, wettability to the fiber to own a pre-barrier impact that may not solely enable the correct bond of all the particle loaded fluids to the surface of the fibers, however, it will also facilitate in retentive excellent air porosity [2].

Resin treatment that is given for cotton fabric mainly improves its physical properties, like dimensional stability, abrasion resistance, or crease recovery. From all the known varieties of resin finishes, melamine-formaldehyde resin delivers the most outstanding formaldehyde matter; furthermore, it gives an improved angle for crease recovery, bending length, and a larger scale of smoothness. The greater mass of the resin molecules improves the construction of most of the intricate cross linked structures with the cellulose molecules; this crease imparts a better crease recovery angle [3].

Resin washing or crinkling is among the main techniques used for dry processing that are applied to almost all the denim products like jeans/trousers. Usually, crinkling can be defined as the formation of wrinkles on a specific area of the product by applying the resin, and then followed by the formation of wrinkles, and then, at last, it is exposed to curing. Resin application leads to changes in surface characteristics such as flexibility, strength and weight loss etc. [4].

Plasma Basics: Plasma has been known by the human in nature since a very long time before. It is said that most of our universe is composed of plasma and not solid, gas, or liquid [5]. The word 'plasma' came from a Greek word which states "something that is modeled or fabricated. Plasma has a different definition in different fields. Plasma in the blood is the clear, somewhat straw-colored portion of the blood that is remained when red blood cells, platelets, and other blood components are separated [6]. Plasma can be also defined as ionized gas, it is also considered to be the 4th state of matter [7]. A portion of plasma gas and its components are having ionized molecules and atoms [8]. When gaseous substances are subjected to very high energy, the energy that is absorbed results in the ejection of the outermost electron from the atom. The escaped electron thus becomes negatively charged and the atom gets a positive charge. The chemical status thus achieved by the substance is called plasma [9]. Plasma gas has an equal density of positively and negatively charged ions, it can exist in extreme ranges of temperatures and pressures.

Resin Basics: We must have heard about non-iron garments. These garments retain their original shapes even after several washes. There is no need for ironing them. There are mainly two categories of resin types which are decomposition type and cross-linking type. Resin comes to play here, they act as cross-linking mediators that react with O-H groups which are in the materials to form covalent bonds. Mainly used on cotton fabrics as cotton fabrics tend to easily wrinkle. The nitrogen atoms present in the individual resin molecules react with the O-H group present in the cotton fabric (cellulose). The resins are let to be a cure in an acidic pH under certain heat and temperature (293-320 F), as advised by the Resin tech bulletin. But there are problems associated with this process too, unfortunately, it leads to loss of the shade changes and loss of strength of the fabric, depending on the construction, composition, and weight of the fabric. In the decomposition type of resin, the resin is deposited on the surface of the fabric. But there is no reaction taking place between the fibre and the resin.

Treatment of Plasma

It is shown through studies that the fabric made of polyester and cotton wettability can be increased when it is treated with plasma under low temperatures. But the surface resistance of these fabrics has been observed to dramatically reduce after they are subjected to plasma treatment. Low-temperature plasma treatment disregards the usage of the chemical substances for technological requirements and gains the treatment of the unbleached/undyed cotton fabric inside the air plasma glow discharge which is then accompanied by a hot water bath.

Low temperature has been proved to be useful to increase the fabric surface properties of the sample fabrics and also polymers with the proper use of ions, electrons, excited, and radical molecules that are produced by electric discharge. Though cotton fabric possesses several positive characteristics, the performance and property of cotton can be altered to be better with plasma treatment [10]. When fabrics like cotton or wool are exposed to low-temperature plasma treatment it seemingly triggered alterations in the geometrical irregularity of its surface. A smooth fabric, as well as a rough surface fabric, could be formed using the plasma treatment. It correspondingly has been seen to have caused alterations in the chemical configuration of the surface that is treated. Fabrics that have a uniform surface can be taken for antibacterial treatment as well. Whereas fabric with a more uneven surface could be used as a padding fabric and is also is quite significant in the traditional aqueous textile dyeing and finishing because it has a greater rate of liquid acceptance [11]. The low-temperature plasma method likely proposes a more flexible, versatile, eco-friendly, and clean, finishing method for divulging the chosen efficient properties to textile materials and to also encounter certain requirements, with much lesser environmental hazards. Plasma treatment is aiding to avoid harmful chemicals, thus it can be considered as a form of sustainable treatment that is at the same time able to compete against the traditional chemical finishing techniques in the textile industry [12].

The most widely used repellent agents are achieved by fluorochemical finishes in the textile treatments, both synthetic well as natural fibers are treated using this method. Fluorocarbons are unique; it is because how it is easily able to repel the water molecules and any oils due to their less surface energy. An assuring way to improve the resilience of fluorocarbon finishes can be characterized by pre-treatment of plasma. Though the repellence rate is not entirely affected in an instant after the chemical treatment is given, it is observed that the durability is improved if used for a long time. Once the processed samples are artificially aged through frequent washing cycles, the plasma pre-treated samples showed a decrease in their performance slower than the untreated samples [13].

Biocidal fabrics are more important these days; it provides avoidance and safety against several microorganisms such as viruses and bacteria. Antimicrobial fabrics are manufactured in such how that it's able to destroy or hinder the expansion of any types of microorganisms similar to mold, bacteria, fungi, or perhaps insects. The technique of adding biocidal agents to the fibres during melt spinning is also provided lesser fastness. Through a research study, it was observed that when atmospheric plasma is employed for pre-treatment of a nonwoven Polypropylene fabric, a substance glycidyl methacrylate (GMA-monomer) that has an extreme reactivity towards its epoxide group got ingrained onto the Polypropylene fabric sample. Cyclodextrin (CD) by products once connected to the GMA embedded fabric sample did not have much impact on the mechanical properties of the material. More testing of the material samples disclosed that insect repelling and antimicrobial actions and additionally antistatic properties were observed [14].

A study showed that once plasma and antimicrobial treatment on water repellent material Sontara was observed to have a reduction in its breaking load and conjointly amendment within the stiffness features. Plasma treatment can block water and blood, and can also act as a barrier in contradiction of many micro-organisms, therefore making it a way suitable for the surgical and medical robes than the commercially accessible materials [15].

In a study conducted, It was observed that there is an improvement of hydrophilic property of grey cotton due to the usage of dc glows discharge air plasma under low pressure. It was also observed that there was an increase in both surface energy as well as surface hydrophilicity. This can be explained as it was caused because on the surface of the fabrics there was a creation of polar. It's been observed that there was an increase in the roughness and surface energy of the fabric sample which could have been due to the plasma treatment. The treatment seemed to be also responsible for the improvement in the dying properties of the fabrics [16].

A study was done on a hydrophobic cotton fabric sample which was coated with a very thin film of nanoparticle plasma. In a short time, they were able to impart super-hydrophobicity to the surface of cotton materials by way of thin-film coating given on the fabric surface. The roughness present on the fabric also influenced super-hydrophobicity. The permeability, abrasion resistance, softness, color, water retention, and fraction coefficient had also improved much better than the controlled samples. It had been concluded by the study that plasma nanoparticulate film coating is extremely helpful when treating oil or water-repellent cotton fabrics [17].

A study was done for improvising the wool fabric surface characteristics such as hydrophilicity and better dyeing rate when it is treated under low-temperature plasma and it is also observed that there was no effect on the fabric luster. Observing through a scanning electron microscope showed that there is the presence of some groove-like structures on the fiber samples that might act as the trail for achieving a much higher dyeing rate [18].

Flame retardant agent(FR), organic phosphorus compound that once combined with a cross-linking(CL) agent melanin resin, catalyst(PA) element acid, and a co-catalyst flowers of zinc imparted a sturdy and effective flame resistance(/retardant) property. When pre-treatment gave a boost to the post-finishing i.e. flame retardant finishing on cotton materials. The study was centered on the surface structure, combustibility, chemical morphological analysis, and also the mechanical properties of samples of cotton fabric which is first subjected to plasma pre-treated and then to incombustible treatment. The surface morphology of the treated samples displayed a chapped still and also wrinkled surface with an elevated rate of deposition of the finishing agent for flame retardance, instigated by the plasma etching impact and also the acidic flame retardant.

According to FTIR-ATR spectra, it was understood that there are changes in the chemical structures of the treated cotton samples. Furthermore, specimens that were treated using FR-CL-PA- showed a rather exceptional incombustible property, which was in addition improved with the assistance of pre-treatment of plasma. But there have been few downfalls too, the cotton samples given flame-retardant treatment showed weak mechanical strength in contrast with the control sample, ensuing from the aspect effects of the cross-linking agent that was used, whereas plasma pre-treatment might recompense for the drop within the tensile and tearing strength caused by the incombustible agents[19].

Dying can be harmful to the environment; therefore sustainable new improved techniques are required for textile dying that will exploit the uptake of dyes and also improve the characteristics and performance of the fabric. These kinds of improvements in the technology will further help decrease the concentration of dye molecules present in the waste-water effluents that come from the textile processing sector and eventually become more energy-efficient as well as a cost-effective method. Plasma treatment technology has been able to prove to impart an enhanced dye penetration, dye exhaustion, and also help to dye in a shorter amount of time with minimum chemical auxiliaries, and less energy usage. Plasma treatment is a clean and dry technique that is operated under an optimal temperature, which will then facilitate the enhancement of the coloration and also develop better functional characteristics on the surface of the textile material minus having any alterations to the performance of the bulk fiber. Moreover, plasma treatment can be combined with other forms of natural treatment techniques that can additionally improve the overall performance of the sample. This causes a trivial reduction of any toxic chemical wastes and auxiliaries that can be present in the effluent load that will diminish the usage of energy cost, and ecological effect [20].

Resin Treatment: In earlier days in the area of application of synthetic resins to textile materials, there were two major classes of products that emerged: emulsions of vinyl type of resins, its production was mainly handled by plastic industries; the other one was pre-condensates' of urea-formaldehyde type resin which was inspired from the Total Broad Hurst Le crease resist process. These set the basis for further development in the area of resin finishing.

Studies have shown by giving a resin finishing to the material it can help even out the changes in the dimensions of knitted fabrics. It was believed from the studies done that the residual shrinkage observed on the surface of knitted fabrics was mostly due to the change in the structure of the yarn which was making up the entirety of the fabric. If the original profile of the yarn is the same as the structure of the original loop, then there will be a negligible difference observed in the shape of the loop when it is relaxed, therefore, there will not be a significant variation in its dimension. So the larger the differences between them, the higher the dimensional variation observed [21].

In cotton denim fabrics, the most commonly used resin types are Resinol AM and Resacryl M, mostly consumed for permanent wrinkle treatments as well also to obtain 3Dimentional effects on denim materials. Through studies, several conclusions were made. When the concentration of the finishing agent increases, an increase in fabric thickness is observed. But the thickness does reduce after washing. SMD is used to measure the geometrical roughness of the fabric surface, i.e., characteristics of fabric surface evenness. It was seen that when the SMD value was lower, the fabric had a more even surface. Seemingly, when the values were higher, the roughness also increased. When using Resinol AM at different curing temperatures, SMD values are seen to increase when resin concentration is reduced. While using Rescacryl M, at allow curing temperature, before it is washed, the values are observed to be stable, but SDM decreases when the resin concentration is increased. When the curing temperature is increased a bit, there is a decrease in SDM values when the concentration of resin is increased before it is washed. Similarly, other observations were also made such as, Resinol AM influences the mechanical properties such as strength, extension, etc. of the materials at high intensity and high temperatures. After it is washed, we can see a significant improvement increase recovery, but breaking strength lowers while comparing to the untreated fabric. Before washing, Resacryl M can improve the crease recovery for a small amount and also can preserve its mechanical properties at optimized settings. Finishing conditions are observed to be independent of the resin types used or the composition of the fabrics tested [22].

There is another finishing which lyocell resin is finishing. In a study conducted lyocell fabric tasters were pre-treated with KOH and NaOH and then resin finishing was applied. The study was done to test the significant influence of these alkali pre-treatments on the mechanical properties such as abrasion resistance, tenacity, and the crease recovery of the resin finished lyocell. It was concluded from the study that resin finishing done on alkali pre-treated fabric samples showed a greater concentration of regent present on the surface of the fabric compared to that done on control samples, where there was a more even distribution of regent. Among all the resin finished samples that were tested, alkali pre-treated samples resulted in having a lower rate of crease recovery, tensile strength, and resistance to abrasion [23].

Results of a study show improvement in fabric resiliency, softness, and also decrease in the fabric strength when using silicone along with the resin. Using a combination of amino-modified polysiloxane, low amino modified polysiloxane, and hydroxy-terminated polysiloxane as an additive is shown to minimize the loss of strength of the cotton fabric. It also showed enhancement in fabric softness due to the treatment of cotton fabric with catalyst as well as resin, without producing any negative effects on the fabric wrinkle resistance [24].

For the production of interlining fabric, several varieties of chemicals can be employed like cross-linking agents, relaxing agents, rigidifying, and water-repelling agents. In the study conducted, a blend of polyvinyl acetate (PVAc), dimethylol dihydroxy ethylene urea (DMDHEU), and few additional kinds of resins were inspected by giving a unique finishing to the cotton samples. The main cross-linking agents that were used in the study were DMDHEU based on having a low formaldehyde level. The concentration of the DMDHEU and PVAc were increased to get the clarification in the fabric physical properties modifications. It was observed that bending lengths, wettability time, and thickness of the cotton fabric samples rose when PVAs and DMDHEU concentrations were also increased. But, the angle of crease recovery decreased when the PVAc concentration was increased while on the opposite when DMDHEU concentration was increased the crease recovery angle improved [25].

Conclusion

The area for garment finishes is vast and among this, we have covered a small portion of plasma treatment and resin finish in the textile industry. Through this review paper, we have been able to learn about the background of plasma technology and resin finishing and also how it's being used in the textile industry for ages. We also came across different variants of these finishes and how they are used with other chemicals to provide different properties and how their property is changed with the use of additional chemicals or substrates used, the concerns involved while using these finishes and techniques. We have also learned about the importance of these finishes through this paper.

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