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The Impact of Plasma Treatment As A Sustainable and Green Technology on The Supply Chain Management of The Spinning Mills

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Abstract

This paper discusses the application of green, sustainable technology of plasma treatment as an aid to improve the supply chain management in spinning with a number of advantages. Suitable suggestions have been given to incorporate this treatment in the processing of yarn and to take advantage of it. The advantages of plasma treatment applied to yarns in terms of better absorbency, wettability and improved dyeability have been discussed in depth.

Keywords: Plasma treatment, yarn, wickability, dyeability, anti bacterial effect.

Introduction

A considerable amount of work has been done on the application of plasma treatment to textiles with a view to improving their moisture absorbency, wettability and dyeability. Plasma treatment given to cotton yarns has improved the wickability and dyeability. It is a well known fact that the terms sustainable, greener and cleaner have assumed lot of importance in textile manufacturing processes. The supply chain of textiles includes fibre production, yarn spinning, fabric manufacturing, textile wet processing, final products distribution (Retailing, Marketing and merchandising) and disposal. Among the different steps in the supply chain, the yarn production is the most important area which caters to the requirements of weavers, knitters, yarn dyers, sewing thread manufacturers, food industry, embroidery threads and medical textiles. If some treatments are given to the yarn following spinning, it will enable the yarn dyers to reduce the number of pre-treatments and to get a better dye up take of the yarn. This paper discusses the role of plasma treatment on the supply chain management of yarn and the benefits that accrue of it.

Plasma Treatment

Plasma means the excited gaseous state consisting of atoms, molecules, ions, metestables, and excited state of these as well as electrons such that the concentration of positively and negatively charged species is roughly the same. Theoretically, plasma is referred to as a "fourth state of matter" and is characterised by average electron temperature and charge density of the system. (Chen [1], Heinlin et al. [2])

Application of Plasma Treatment of Yarns

Plasma technology has received a great deal of attention as a solution for environmental problem in textiles. Traditional textiles wet processing methods for dyeing and for various finishes require the use of large amount of chemicals, water and energy. With the increasing importance of ecological and economical restrictions imposed on the textile industry, it is imperative to use environmentally friendly and economical process developments. Plasma treatment is a dry process and does not require water or wet chemicals. Also, plasma is able to change subtract surface properties such as micro roughness without affecting the bulk properties.

It has been reported that the plasma treatment also lead to shorter dyeing time and improve dye uptake. Also, the wickability of the yarns has improved following plasma treatment. Many workers have demonstrated that the materials become hydrophilic after plasma treatment and their tensile properties have not been affected.

Prakash et al. [3] have reported on the effect of plasma treatment on air and water-vapour permeability of bamboo-knitted fabric. They have found that oxygen and atmospheric plasma treatments have increased water-vapour permeability and decreased air permeability. SEM showed that the plasma modified the fibre surface outwardly. Wong et al. [4] have conducted studies on linen using plasma treatment. Abidi and Hequet [5] have carried out work on cotton fabrics using plasma treatment and have found that it led to excellent water repellency of fabrics. Rashidi et al. [6] found that the surface resistivity of cotton and polyester have reduced following plasma treatment. Yasuda et al. [7] investigated the effect of air plasma treatment on fibre and fabrics, using non-polymerisable gases and found that weight loss increased with an increase of exposure time. Kale et al. [8] found that plasma process parameters play a key role in determining properties of the plasma- treated fabrics. Yu et al. [9] have found that plasma treatment had led to a drop in strength and elongation of polypropylene. Kwon et al. [10] have found that surface modification of polypropylene film by atmospheric pressure plasma is more lucrative in a relatively short plasma treatment time. That exposure of polyamide 6 fabrics to low temperature oxygen plasma had led to changes in the surface roughness, density and crystallinity has been pointed out by Raslan et al. [11]. Yaman et al. [12] have found that wearability and comfort properties of polyamide fabrics improved following plasma treatment. Wettability and wickability of cotton fabrics were found to improve by atmospheric air plasma treatment. Karahan et al. [13] have looked at the thermal resistance, water vapour permeability, air permeability and surface friction coefficient of cotton fabrics following plasma treatment and have found an improvement. Naebe et al. [14] have found that plasma treatment had effectively removed the covalently bonded lipid layers from the wool surface. The plasma- treated fabric showed increased wettability and the fibres showed greater roughness. X-ray photoeletron spectroscopy (XPS) analysis showed a much more hydrophilic surface with significant increase in oxygen and nitrogen concentrations and decrease in carbon concentrations. Adhesion had shown an increase. Aging of fibres was determined over a period of 28 days and it was found that while there were no physical changes, the chemical nature of the surface changed significantly. XPS showed decrease in the hydrophilic rupture of the surface with time, consistent with the measured decrease in wettability. The change is proposed to be due to the reorientation of proteo lipid change. Scanning probe microscopy (SPM) adhesion studies also showed the surface to be changing with time. After aging for 28 days, the plasma-treated surface was relatively stable and still dramatically drifting from the untreated fibre, suggesting that the oxidation of the surface and modification or removal of the lipid layer were predominant.

El Khatib et al. [15] have reported on the effect of low temperature plasma treatment on the properties of wool / polyester blended fabrics. Changes in the whiteness index, wettability, surface roughness, tensile strength, elangation, surface morphology, dyeability and fastness properties were investigated. It was found that colour intensity and wettability had shown an improvement.

As stated by Malek Reza and Holme [16], plasma treatment is a first solvent free technique. The operation procedure is simple and well controlled. It is also easy to create any ambient of oxidation for reductive or inactive reasons by changing the feed gas. Today, with changing awareness of environmental concerns, a significant amount of ecological legislation has been introduced regarding fibre treatment that use huge amounts of chemicals, water and release toxic effluents. According to Hwang et al. [17], plasma treatment is considered a dry process since it does not require the use of water or chemicals. Plasma is able to change the fibre surface properties and consequently, its dyeability (Poll et al. [18]). One of the typical plasma discharges that operate at atmospheric pressure is the dielectric barrier discharge (DBD) (Kim et al. [19]). Yip et al. [20] used DBD to modify the surface properties of natural and synthetic fibres, and thereby improve their hydrophilicity, adhesive properties and wettability. Polyester is considered as one of the leading synthetic fibres due to its good tensile strength, abrasion resistance, resiliency and other properties. Plasma treatment does not involve handling of hazardous chemicals and thus there are no problems of treatments of effluents. Environmentally friendly surface modifications of polyester fabric by plasma to improve its wettability and dyeability are reported by Bhat et al. [21]. Also, improvements in felting, shrinkage, wettability and dyeability of plasma treated wool substrates have been reported by Wakadia et al. [22]. A comparative study on the effect of the treatment with different plasma gases (oxygen, nitrogen and air) on wool polyester blend has been investigated by evaluating the induced changes in the treated fibre properties, such as wettability, whiteness index, surface morphology, mechanical properties, dyeability, and fastness properties.

Although wet processing is a well-established method in textile industries to carry out desizing, bleaching, dyeing/printing and finishing, all these wet processing procedures require water as a medium. The wet processing of textiles materials includes highly energy consuming operation, approximately to 80% of total energy requirement of all the operations. Out of this, about 66% of energy is consumed in heating and evaporation of water from the fibers and fabrics. Plasma surface treatment does not involve the use of fresh water and chemicals and hence it is regarded as an environmentally friendly textile process. The surface materials of textile exhibit great potential for their structurisation and functionalisation. There are many procedures for structurisation and functionalisation of fibre surface and their selection on the purpose of the change. The functionalisation of the fibre surface material assumes that the material maintains its original properties. The functionalisation of the fibre surface of a material is directly affected by surface structurisation. The process of plasma modification is characterized by an interaction between the plasma and thin outer layer of the fibres. It causes changes to a limited depth, modifies the uppermost atomic layers of a material surface and leaves the bulk characteristics unaffcted, even in the most delicate materials.

Yip et al. [23] have highlighted on recent developments in the plasma treatment of textile materials and conclude that it has an enormous potential as an alternative technology for the textile processing in terms of cost saving, water saving and ecofriendliness. Low temperature low pressure plasma treatment has been shown to be useful and suitable technique to modify a polymer surface, especially natural polymers like cellulose in a dry and pollution free system as pure water is becoming scarce and expensive.

Plasma treatment is a dry textile processing technique and is a surface-sensitive method that allows selective modification for imparting product specific functionality in textiles and apparel. The plasma reaction involves the interaction of atoms, free radicals and metastable particles, electrons and ions. The effect and efficiency of the plasma treatment depend on the pressure, power, duration of treatment and the choice of working gas. Plasma treatment improves wettability, hydrophobic finishing, adhesion functionality and product quality in cellulosic fabric. The use of oxygen plasma can modify the wettability of cotton and other cellulosic materials. Argon gas is used to increase surface roughness and modify the texture. It also alters the tensile properties and functional behaviour of the fabric. It improves air permeability and drape properties. Optimization of surface properties of textile materials without altering the inherent properties of the textile materials can be achieved by air, argon and oxygen gas plasma treatments. Plasma treatment can be a viable substitute to conventional processes and very often it can provide the advantageous effect that cannot be obtained by wet processing of textile material as stated by Samanta et al. [24] in their research.

Comfort Properties and Dyebility of Fabrics

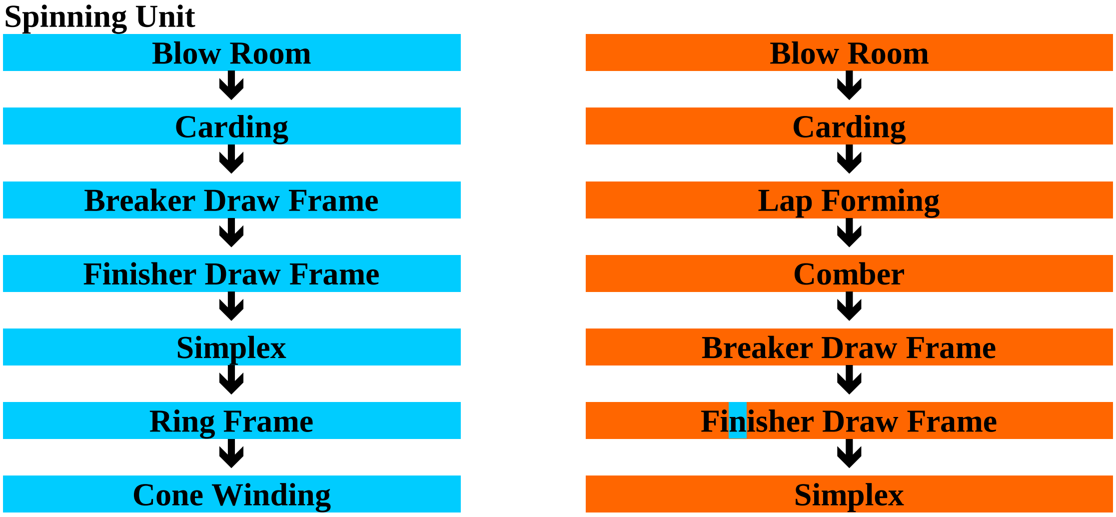
The fabric texture and the movement of air, moisture and heat through the fabric are extremely important for designing of garments for imparting good comfort. Kan et al. [25] and Kan [26] have shown in a number of papers the advantages of plasma treatment on wool fabrics. They have reported that plasma treatment results in the reduction of air permeability and q_{max} (warm cool feeling). Plasma treatment leads greater moisture absorption, better dye uptake and eco-friendly environment. They have also looked at the low stress mechanical properties of wool fabrics following plasma treatment and have provided extensive data. The dyeing rate, dyebath exhaustion and dyeing uniformity are highly improved by plasma treatment. The published works reported by Alfredo Calvimontes et al. on polyester [27], Kan Chi-wai et al. [28], Andrea Oravcova et al. on polyethylene [29], have show an enhancement of dyeability by plasma treatment. Functional finishes could be imparted by plasma treatment, which include, antimicrobial, soil repellency, stain resistance, soft handle and improved dyeing by Zhuang et al. [30]

Olga Troynikov et al. [31] have stated in their research that knitted fabrics are used because of their excellent mechanical and comfort properties. The attributes of plain knit structures on flammability and air permeability has been discussed by Daiva Mikucioniene [32]. They possess high extensibility under low load, allowing comfortable fit on any part pulled. The dimensional stability of cotton weft knitted fabrics is further explored by Daiva Mikucioniene and Ginta laureckiene [33].The advantages of using knitted fabrics, as opposed to conventional fabrics, lie in their low cost, improved barrier properties, adequate strength and comfort properties as stated by Onofrei Elena et al. [34] in their research.

Thus a number of research workers have taken projects on plasma treatments, particularly their effect on moisture absorbency, dyeability and improved fabric products such as higher thermal resistance, higher air-permeability. Another great benefit that is conferred to yarn or fabric is the anti-microbial effect. This may be particularly preferred for the yarns which are meant for medical application such as gauze and surgical bandages. Also sewing threads, which are developed from the plasma treated yarns will be preferred for less fly in the sewing department of the garment unit.

A flow chart which is given below will aid to have a better supply chain management in the spinning unit (Figures 1 & 2).

Spinning Unit



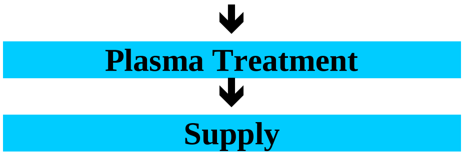


Figure 1: Flowchart – Carded Yarn

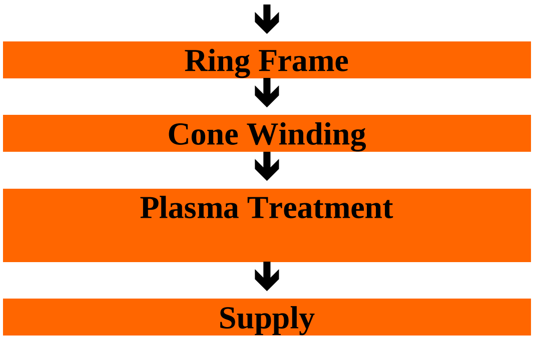


Figure 2: Flowchart – Combed Yarn

A scheme for utilizing plasma technology in the production of carded and combed yarn which is given above will involve fabrication of plasma chambers in the mills. After this treatment is given, the yarns can be tested for the usual properties and in particular absorbency and dyeability for the benefit of consumers. This also will aid the denim manufacturers to take advantage of plasma treatments. The supply of plasma treated cotton yarn will assist the yarn dyers to consume less quantity of chemicals and dyes. And to avoid pretreatments which consume more water. This will also enable them to have environmentally cleaner plant.

Conclusion

The advantages of plasma treatment applied to yarns include better wickability, wettabillity and dyeability. A scheme for introducing plasma technology in the spinning mills as an aid to improve the supply chain performance is given.

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