Effect of Atmospheric Pressure Plasma on Pilling Propensity of Acrylic Fabrics
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Abstract— Plasma is the 4th state of matter and a gas becomes plasma when the kinetic energy of the gas particles equals the ionisation energy of the gas. When gas molecules reaches excited state, molecule breakdown takes place and collision between excited species takes place. In this state it behaves as a chemically very active environment and the surface interaction with organic substrates takes place[1]. Pilling is the ball like structures on the surface of the fabrics that are formed due to repeated abrasion. Synthetic fabrics especially knitted are likely to pill more because of smooth surface and higher tensile strength. This paper focuses on application of plasma treatment and its effect on various types of acrylic fabrics. The treated and untreated fabrics viewed under SEM and pilling tests and tensile strength test were carried out. It was observed that plasma treatment makes the fibre surface rough and decreases tensile strength of fibre; thus reducing the formation of pills on the fabrics by increasing inter fibre friction and detaching the pills from the fabric surface.

Key words: Acrylic Fabrics, Atmospheric Pressure, Plasma

I. INTRODUCTION
Plasma treatment of textiles is attractive because it is clean, dry, environment friendly, waste free technology and much less energy is consumed than conventional treatments. They do not affect the bulk properties of the textile fibres since only surface interactions are carried out. Plasma can be generated by applying electric fields at low frequency, radio frequency or micro frequency, depending on the surface alteration required. The extent and nature of the modification of a textile surface by plasma treatments is governed by / depends upon several parameters such as, working pressure, power, distance between two electrodes, time of treatment, type of gas / monomer, the type of textile, used etc[3]. There are basically two kinds of plasmas: first is low temperature plasma which is an ionic gas whose components and characteristics are different

From normal gas, LTP is an ionic gas whose components and characteristics are different from normal gas. With the help of electrical discharges, various plasma of different ionisation extents can be produced [2]. Second is atmospheric plasma that can be generated under atmospheric conditions and requires no vacuum systems with continuous and open perimeter fabric flow [3]. There are three different forms of atmospheric plasma viz. Corona discharge , Dielectric barrier discharge(DBD) and Atmospheric pressure glow discharge(APGD)[3].

Atmospheric plasmas have been successfully used to alter various properties of synthetic as well as natural fibres. Plasma treatment, due to bombardment of reactive species with textile substrate [3], makes the fibre surface rough. This rough surface can bring out many physical changes in textile material such as cotton[4], anti-pilling of wool[5-8]. There are various reasons for pilling on fabrics such as smooth surface, higher tensile strength , high breaking elongation, lower coefficient of friction etc. Angora fibres were treated with atmospheric plasma to improve spinnability and coefficient of friction[9].

Acrylic fibers, like other fibers used in staple fabrics pills more as a result of abrasive action on the fabric surface. The required changes in fiber properties include reducing the fiber strength, introduction of defects in the fiber, brittleness, and lack of shear strength. All of these properties are easy to impart to the fibers, but increases in antipilling properties generally lead to corresponding decreases in the spinnability or ability to process the fibers. Thus, commercial antipilling processes depend on a balance between these factors[10]. But plasma treatment does not involve any chemical or wet processing to apply anti pill finish on fibres. It just makes the fibre surface rough due to ion bombardment resulting in increase coefficient of friction between fibres and sliding of fibres is prevented. It also decreases tensile strength of fibres which breaks off pill before it is formed.

II. EXPERIMENTAL SET UP

A. Samples
3 different fabrics with different properties (Table 1) have been used in this experiment. The purpose of taking different types of fabrics was there structure and parameters. Sample A was woven on handloom and samples B and C were knitted on weft knitting machine.

<table>
<thead>
<tr>
<th>P</th>
<th>WOVEN</th>
<th>KNITTED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gsm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warp</td>
<td>2/24</td>
<td>2/24</td>
</tr>
<tr>
<td>Weft</td>
<td>2/40</td>
<td>4/60</td>
</tr>
<tr>
<td>EPI</td>
<td>56</td>
<td>14</td>
</tr>
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<td>Warp</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Weft</td>
<td>26</td>
<td>Double</td>
</tr>
</tbody>
</table>

Table 1: Construction Parameters of Fabrics (Here, P-Parameters)

B. Atmospheric Pressure Plasma Treatment
The plasma treatment was given on atmospheric plasma reactor situated at FCIPt (Facilitation Centre for Industrial plasma treatment, IPR Gandhinagar). In this study two different types of dielectric barrier discharge (DBD) atmosphere pressure plasma reactors are used In one system the flat electrodes with dimensions L:B = 300mm*400mm , separated by 1.5 mm apart from each other using Teflon
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spacers(300x20x3mm) and covered by dielectric layer of PET with thickness 0.125 microns is used. The dielectric layer prevents the formation of a spark or an arc discharge. The system is operated at 50 Hz, 10 kV; the voltage being changed according to requirement. The top electrode is connected to power supply and bottom to the ground. 99.99% pure helium gas was introduced in the chamber. Plasma treatment was given to all the 3 fabrics at 5 kV for 1, 5, 10 and 15 minutes. (Figure 1 depicts the plasma system at FCIPT and figure 2 depicts the electrodes under the plasma chamber). [NOTE: For simplicity these samples has been connoted as helium plasma samples.]

The second system consisted of cylindrical electrodes, operated at frequency of 3 MHz and voltage 3 kV. Fabric was passed from between these electrodes. Atmospheric air was used to generate plasma. (Figure 3 depicts the cylindrical electrodes system). Because of very high frequency, treatment time was only for 5, 10, 12 and 15 seconds.

[NOTE: For simplicity these samples has been connoted as air plasma samples.]

The purpose of taking two different types of system was to compare the effect of two main parameters of plasma treatment viz time and frequency. At higher frequencies i.e. MHz range plasma is generated at low voltage and less time is required.

C. Characterization of Samples

Due to the interaction between air and other activated surface, plasma treated samples were conditioned for 24 hours at room temperature and humidity.

Surface roughness of fibers was observed under Carl Zeiss microscope, having resolution up to 0.8 nm.

Tensile strength of individual fibres was carried out using Fafegraph M tensile tester according to standard ASTM D 3822-01/ ISO 5079-1995.

Pilling tests were carried out using ICI Pill Box tester according to standards IS 10971. The results were graded by numbers from 1(sever pilling) to 5(abscence of pilling).

III. RESULTS AND DISCUSSION

A. Surface observation

The surface observations are shown in fig 4. From the SEM images it is clearly evident that plasma species has made the fibre surface rough. The treated fibres has uneven surface with microcraters and voids formed due to ion bombardment. Helium gas has more free electrons in its outermost orbit, which when ionized releases more active species and hence more collision takes place. Thus it etches fibre more as compared to air.

B. Tensile strength

The pilling formation in synthetic fibres depends on many factors such as surface smoothness, high flex life, high tensile strength, fibre denier, staple length, fabric constructional parameters etc. The table below shows decrease in breaking strength, and tenacity of individual fibres after plasma treatment. Thus fibres might have broken off before they are transformed into pills. This can be attributed to micro craters and micro voids formed due to ion collision in plasma treatment. The reduction in breaking extension indicates that the fibres will break off before being extended. The results of tensile strength test are shown in table 2.
Table 2: Tensile Strength Test Of Fibres

<table>
<thead>
<tr>
<th>Sr no</th>
<th>Particulars</th>
<th>Breaking strength (CN)</th>
<th>Breaking extension (%)</th>
<th>Tenacity (cN/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Untreated</td>
<td>5.43</td>
<td>45.24</td>
<td>3.02</td>
</tr>
<tr>
<td>2</td>
<td>Helium 50 Hz 5 kV 1 min</td>
<td>5.12</td>
<td>43.58</td>
<td>2.19</td>
</tr>
<tr>
<td>3</td>
<td>Air 3MHz 6 kV 15 sec</td>
<td>5.09</td>
<td>42.30</td>
<td>2.48</td>
</tr>
</tbody>
</table>

C. Pilling tests

Pills are the small spherical balls that are formed on fabric surface; especially knitted. The formation of pills is due to the migration of fibers from the constituent yarns inside the fabric. The plasma treatment thus reduces the migration tendency of fibers by making the fibre surface rough due to ion bombardment; thus improving the pilling resistance. The results of pilling tests are tabulated in table 2. Pills have been judged quantitatively using high resolution camera. Treated fabrics shows increase in pilling grades both in air plasma as well as helium plasma as shown in table 2. Hence it can be said that surface alterations after plasma treatment depends on gas used, time of exposure and voltage and frequency used.

Because of rough surface, the inter-fibre friction has increased and prevented the movement of fibres during the abrasion. Thus resulting in less abrasion. Also plasma treatment makes the rate of pill detachment faster than rate of pill formation; as less strength will break the fibres. Both the types of plasma reduce pilling formation. Effect of helium plasma is less on sample B as it has low twisted yarn. Fig 5 shows the photographs of fabrics tested for pilling.

IV. CONCLUSION

The above study has confirmed the positive effects of plasma treatment on acrylic fibres. It alters surface roughness without affecting bulk and voluminousity of fabrics. The pilling grades have improved significantly in treated fabrics in both the types of treatment. Pilling is reduced due to rough surface, reduced tensile strength and breaking elongation of fibres. Thus it can be said that low frequency requires higher time and high frequency requires less time of treatment. Using plasma treatment other functional properties such as thermal conductivity, dimension stability etc can be improved. Also applying plasma treatment on fibre stage can have better effect on all the functional properties of acrylic fabrics, considering the cost of equipment of plasma reactor.

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REFERENCES


