Adhesion Studies of Atmospheric Pressure Plasma Treated Nylon66 Fabrics with Polyurethane

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Abstract

Plasma treatment of nylon fabric was carried out with aim of improving the adhesion properties with polyurethane polymer. The effect of the plasma parameters vis. treatment time and power on adhesion improvement were examined. The force required to separate the coating from the fabric was measured as a peel-off strength of the coated fabric. Significant improvement in the adhesion of the plasma-treated sample was observed as compared to the untreated sample. Surface wettability after plasma treatment was studied by wicking measurements. A change in surface morphology was analysed using a scanning electron microscope (SEM). SEM results reveal the surface roughening after plasma exposure. The mechanical property was also studied by tensile strength measurements.

Keywords

Adhesion, Coating, Plasma treatment, Nylon 66, Polyurethane

1.0 Introduction:

Synthetic fibres are widely used in technical textiles and home furnishings due to their good physical and chemical properties. However, these fibres are hydrophobic due to the lack of polar functional groups. The hydrophobic nature of such fabrics limits their applications. Textile coatings are widely used in everyday life in different areas. The purpose of the coating is to provide its carrier material with specific functional properties for suitable application. The surface of the synthetic fibre is generally inert, making the fibre difficult to wet and hard to chemically bond to coating material, as a result, the adhesion between the fibre and coating material is inferior [1-4].

Adhesion is the tendency of dissimilar particles or surfaces to cling to one another. To ensure the maximum adhesion between polymeric material and coating; they must be compatible with each other in terms of hydrophilic and hydrophobic nature. An incompatibility between the polymeric material and the coating substance leads to poor interphase or adhesion which may limit its application. To improve adhesion to coatings, fibres are usually subjected to controlled surface treatments by wet chemical methods. However, chemical modifications have some disadvantages. For example, conventional methods are time-consuming and in most cases, are accompanied by a decrease in fibre strength. Moreover, these conventional treatments can also lead to environmental pollution. Therefore, we propose to explore plasma techniques. Surface modification of textile fibres by cold plasma is simple and cost-effective. It produces no pollution and is becoming increasingly popular [5-11].

In this work, we have modified nylon 66 fabric using atmospheric pressure plasma generated from helium and helium mixed oxygen gases. The effect of plasma surface modification on the adhesion with polyurethane is reported in this paper.

2.0 Experimental

2.1. Materials and methods

A plain woven nylon 66 fabric with an area weight of 90 g/m^2, warp and weft density 70 and with 150 denier yarn fabric was plasma treated on an atmospheric pressure plasma reactor. Optimisation of the plasma process parameters was carried out by varying the plasma power and treatment time. Three different levels of plasma power and three different plasma exposure times were studied at a fixed distance between the electrodes at 0.5mm. Helium gas was used for the generation of plasma. Plasma treated fabrics were coated with polyurethane (commercial name: TUBICOAT MP SP) with a knife over roller coating method using a hand coating

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machine. The distance between the knife and roller was set at 3mm to apply the uniform coating. Drying and curing of the coated sample were carried out at 80°C for 10min and 140°C for 10 min respectively.

3.0 Characterization techniques

3.1 Uniformity of the coating

The uniformity of applied coating was studied by the thickness of and GSM of the coated fabric. The thickness of the uncoated and PU coated samples were tested as per ASTM D-1777-96 (2015) standard test method at 20 kPa pressure. Ten readings were taken randomly all over the fabric as directed in the test method and considered as the final thickness of the fabric. Similarly, Weight per square meter was measured as per ASTM D 3776-2013 standard. An average of five readings is considered as GSM of the fabric.

3.2 Wettability of plasma-treated samples

Change in hydrophilic and hydrophobic nature of nylon 66 fabric after plasma treatment was studied by the wicking height measurement. The rate of vertical capillary rise on plasma-treated samples was measured using the method described in ISO 9073-6; 2000 (E). Test specimens were suspended vertically in the liquid and checked for the increase in the capillary height at predetermined time intervals up to 20 min.

3.3 Adhesion strength test

T-peel off test was employed to measure the adhesion strength of coated fabrics according to the IS 7016 part 5-2011 test standard. Tinius Olsen, peel bond tester was used to masseur the peel-off strength. Five different measurements were performed and the average value is considered as the bonding strength of the coated fabric.

3.4 Surface morphology by SEM

Surface topographical modifications in the nylon 66 samples before and after plasma treatment were investigated by scanning electron microscopy (SEM) on the JEOL SEM model JSM 5400 (Tokyo, Japan).

3.5 Mechanical properties

Tensile strength of the untreated and plasma-treated samples was carried out on pyramid tensile testing machine model Tinius Olsen H50KL Aimil. ASTM D 5035 -2015 standard test method was used. The average of the five test specimen was considered as the tensile strength of the fabric.

4.0 Results and Discussions

4.1 Uniformity of the coating

Table 1 gives the results of thickness and GSM of untreated and plasma-treated coated nylon 66 samples.

After coating thickness was increased by 0.29±0.01 mm and GSM was increased by 376±1 GSM. As per the standards0.2mm and 5% variation in thickness and GSM is

Table 1: Thickness and GSM of plasma treated and coated nylon 66 fabric

Sr. No.	Sample name	Thickness in mm	GSM
1	Nylon fabric without coating	0.28	90
2	Untreated coated	0.57	467
3	Plasma treated 1.5kW/ 15 Sec	0.59	466
4	Plasma treated 1.5kW/ 30 Sec	0.59	466
5	Plasma treated 1.5kW/ 45 Sec	0.57	465
6	Plasma treated 2.5kW/ 15 Sec	0.58	465
7	Plasma treated 2.5kW/ 30 Sec	0.57	465
8	Plasma treated 2.5kW/ 45 Sec	0.59	467
9	Plasma treated 3.5kW/ 15 Sec	0.59	466
10	Plasma treated 3.5kW/ 30 Sec	0.58	467
11	Plasma treated 3.5kW/ 45 Sec	0.59	466

allowed respectively. In our case, the variation in thickness and GSM is well within the limits. Therefore, it can be said that the coating applied on the fabric is uniform all over the surface of nylon fabric.

4.2 Wettability studies on plasma-treated nylon fabric

Measurement of wicking height gives a good idea about the hydrophilic and hydrophobic nature of the textile fabric. The height of capillary rise was recorded for different wicking durations up to 20 min for plasma-treated and untreated nylon fabrics. The value of capillary height recorded for a predetermined time for both untreated and plasma-treated samples is plotted against the wicking time in figure 1.

It can be seen from figure 1, that all plasma-treated samples exhibit more wicking height as compared to untreated nylon sample. Further, as the plasma power increased from 1.5kW to 2.5kW wicking of the fabric improved. However, after 2.5kW of plasma power, there was no improvement in the wicking property of the plasma-treated samples. Hence it can be inferred that plasma power of 2.5kW is optimum to get maximum wettability. Similarly, the effect of plasma treatment time was also studied and it was found that the plasma exposure time of 30sec gives the maximum increase in wicking height. The increase in wicking height after plasma treatment can be attributed to a change in surface morphology which leads to an increase in the surface area and results in an increase in effective pore size and reduces the capillary pressure [12,13].

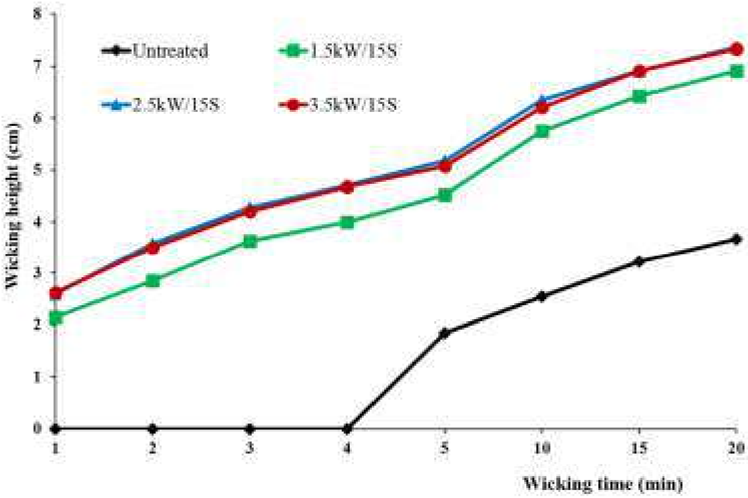

Figure 1: Wettability of plasma-treated nylon fabric, the effect of power

4.3 Adhesion studies of PU coated nylon fabric

Adhesion is the force required to separate the coating layer from the fabric. Adhesion force was measured as peel-off strength of the untreated and plasma-treated nylon coated samples and is given in Figure 2. The adhesion bond strength of plasma-treated coated samples showed a 20 -50 % increase compared to the untreated coated sample. It can be seen that with an increase in plasma power there is a gradual increase in adhesion strength. The highest peel bond strength value was obtained at a plasma power of 3.5kW. This suggests that by increasing the plasma power, the efficiency of plasma improves. Similarly, it was seen that with increasing the plasma exposure duration the adhesion strength was also improved. A similar trend concerning plasma exposure duration and power has also been reported by other researchers [14-16]. Improvement in adhesion strength after plasma treatment can be attributed to improved wicking which results in better spreading of the coating chemical and wetting of the nylon fabric which removed the week boundary layer. Also, improved surface roughness proved better mechanical interlocking and improves the adhesion strength [17-19].

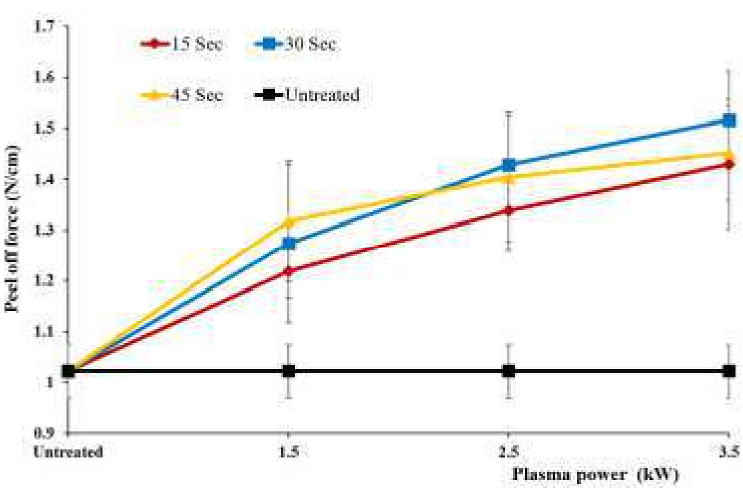

Figure 2: Peel off the strength of plasma-treated coated nylon samples

4.4 Surface morphology by SEM

Figure3 shows SEM images of untreated and plasma-treated nylon samples. Morphological changes on the surface after helium plasma treatment can be observed(figure 3-B). The untreated (figure 3-A) nylon has a smooth and clean surface, while plasma-treated fabric shows a rougher surface. Helium plasma treatment etched the surfaces. Morphological alteration of the surface might lead to improved adhesion by providing better mechanical interlocking due to the roughening effect [20-22].

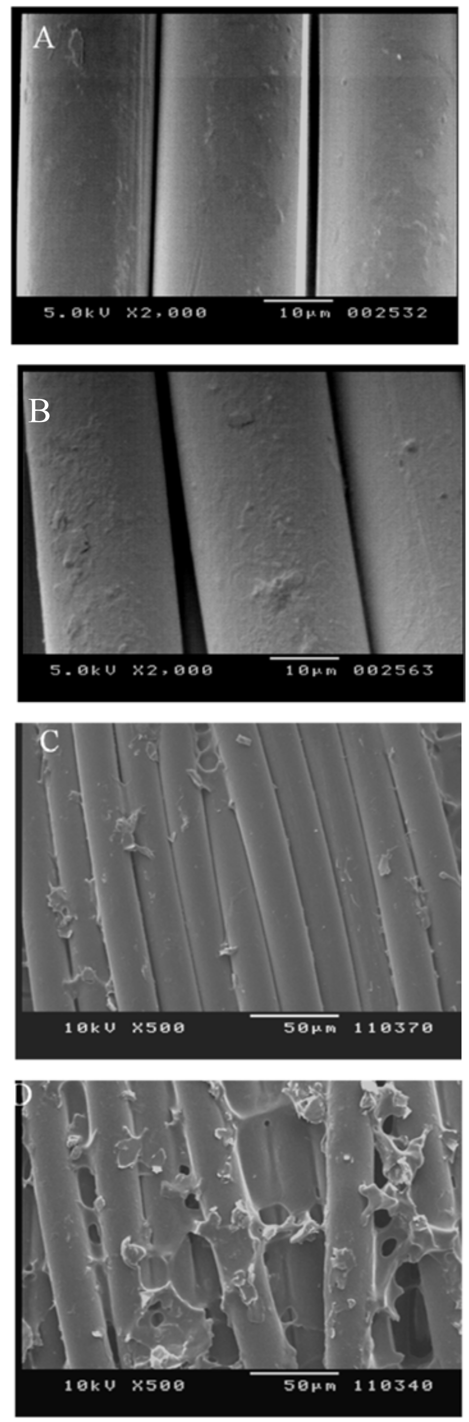

Figure 3: SEM photographs of nylon samples A- Untreated nylon, B- Plasma treated nylon, C- untreated after peel off and D- plasma-treated after peel off.

Figure 3-C, shows that for untreated samples after peel off testing, no coating material is left on the surface of fabric and coating is removed smoothly. The smooth surface after removal of coating may be due to no adhesion of the coating with fabric and hence the coating is removed smoothly. The bond failure occurs at the interface between the adhesive and nylon fabric. On the other, (figure 3-D) plasma-treated coated sample after peel off shows a considerable amount of PU film is left on the fabric surface this shows that there is better mechanical adhesion between the fabric and PU coating after plasma treatment. Hence adhesion strength is more after plasma treatment as shown in the above section. In this case, the adhesive itself breaks and particles of adhesive remain on the nylon surface. This type of bond failure is known as a cohesive failure.

4.5 Tensile properties of plasma-treated nylon fabrics

The tensile strength values of untreated nylon fabrics and after treatment with plasma are shown in Figure 4. The tensile strength of the untreated nylon(in warp direction) was 27.9N/mm. The tensile strength values after plasma treatment at power =1.5, 2.5 and 3.5 for 15 sec treatment time were 29.04, 29.01 and 29.11N/mm, respectively. Figure 4 shows hardly any effect on the tensile properties after plasma treatment. Even, the percentage change in fabric tensile strength after plasma treatment is very small (up to 4%) in comparison with untreated nylon. Therefore, it may be inferred that the given plasma process parameters result in only a slight increase in the fabric tensile strength. During plasma, treatment etching occurs. The etching kind of the interaction may cause an increase in tensile strength by increasing cohesive force between the fibres [13].

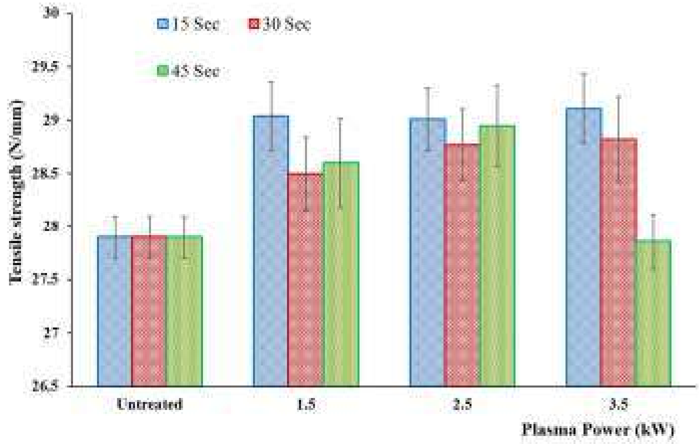

Figure 4: Tensile strength of plasma-treated nylon fabric

Conclusions:

Plasma treatment of nylon 66 fabric was carried out in atmospheric pressure plasma using helium gas. It was found that after plasma treatment the wettability was improved and adhesion with the coating is also improved. Further, it was noticed that the change in wettability and adhesion strength are highly dependent on plasma processing parameters. The plasma exposure time of 30sec and 2.5kW plasma power was found to optimum for maximum improvement in adhesion strength. No adverse effect on tensile properties was seen after plasma treatment.

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