Effect of hydrolytic action of NaOH in presence of methanol on aesthetic and comfort properties of polyester fabric

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Polyester fabric has been treated with 5\% NaOH (w/v) with and without 20\% methanol (v/v) for 60 min at 60°C and its aesthetic and comfort related properties investigated. It is observed that the feel, handle and comfort related properties of polyester fabric improves significantly without much deterioration in its mechanical properties on using methanol as an accelerator. The total hand value, vertical wicking height, air permeability and thermal insulation properties are found to be much improved for the fabric treated with NaOH and methanol.

Keywords: Air permeability, Comfort properties, Hand value, Polyester, Water absorbency, Wicking

1 Introduction

Synthetic fibres like polyester are characterized by high strength, superior abrasion resistance, very good crease recovery, excellent biological resistance and low density\textsuperscript{1,4}. Due to the hydrophobic and oleophilic nature, the moisture transporting behaviour of polyester is very poor\textsuperscript{1}. It also has unnatural hand, unfamiliar skin contact sensations, unpleasant thermal sensations, lack of moisture absorbency and clamminess of fabric in contact with skin.

Sufficient literature\textsuperscript{1,3,5} pertaining to the improvement in hydrophilicity of polyester fabric is available. Most of these studies reveal that the desired comfort in polyester fabric can be achieved by using sodium hydroxide as a hydrolytic agent provided the weight loss of the fabric is significant. The higher weight loss in hydrolysis process of polyester may deteriorate most of its mechanical and chemical properties and at the same time will waste polyester unnecessarily. In the present study, an attempt has been made to improve the feel, handle and comfort related properties of polyester fabric by treating it with minimum amount of sodium hydroxide in presence of methanol as an accelerator. Minimum quantity of sodium hydroxide (5\% w/v) was used mainly to keep the weight loss at a desired level (below 5\%) and to reduce the effluent load as the higher concentration of sodium hydroxide increases the total dissolved solids (TDS) in the effluent.

2 Materials and Methods

2.1 Materials

2.1.1 Substrate

100\% polyester grey fabric having the following specifications was used: ends/in., 86; picks/in., 63; and weight, 57g/m\textsuperscript{2}.

2.1.2 Chemicals

Commercial grade sodium hydroxide, methanol (B.P., 64°-66°C), benzyl alcohol, acetic acid, bromophenol blue indicator, phenol, chloroform, tetrachloroethylene, potassium hydroxide and Auxipon NP (non-ionic wetting agent) were used. Reverse osmosis water was used throughout the study.

2.2 Methods

2.2.1 Pretreatment of Fabric

Polyester fabric was mild scoured using 2 gpl sodium carbonate and 0.5 gpl non-ionic wetting agent (Auxipon NP) at 80°C for 3h. The treated sample was then thoroughly washed with reverse osmosis water and dried in open air.
2.2.2 Fabric Treatment with Sodium Hydroxide and Methanol

The scoured fabric samples were treated separately with different concentrations of sodium hydroxide (5%, 10%, 15% and 20% w/v) for different intervals of time (10 min, 20 min, 30 min, 40 min, 50 min and 60 min) at different temperatures (30°C, 45°C and 60°C). After optimizing the treatment conditions, similar experiments were also carried out using methanol as an accelerator in the presence of 5% sodium hydroxide. The concentration of methanol was varied from 20% to 100% (v/v) at 10 units interval. After the treatment, samples were thoroughly washed with cold and hot water for 15 min each to remove adhered oligomers completely from the polyester fabric, neutralized with 2 gpl acetic acid (checked by universal indicator), washed thoroughly with reverse osmosis water and dried in open air.

2.2.3 Determination of Weight Loss

The weight loss of polyester fabrics was determined using the following formula:

\[ \text{Weight loss (\%) = } \frac{W_i - W_f}{W_i} \times 100 \]

where \( W_i \) is the initial weight of the fabric; and \( W_f \) the final weight of the treated fabric.

2.2.4 End Group Analysis

The end groups (-COOH) of polyester fabric samples treated with NaOH with and without methanol were analyzed by the method\(^4\) described below:

Accurately weighed samples (4g each) were cut into very small pieces, transferred into a round-bottom flask and then 55ml of 1:1 (v/v) phenol-chloroform solution was added to it. The above solution was refluxed for 30 min, cooled and then titrated against 0.1N benzylic alcoholic KOH. Similarly, for blank, it was titrated against 1:1 phenol-chloroform solution. The end point was observed at the colour change from yellow to greenish blue. End groups (-COOH) were calculated using the following formula:

\[ \text{End groups (meq/kg) = } \frac{(a-b) \times N \times 100}{W} \]

where \( a \) is the titration reading (in ml) for sample; \( b \), the blank reading (in ml); \( N \), the normality of benzylic alcoholic KOH; and \( W \), the weight of the sample.

2.2.5 Viscosity Measurement

Relative viscosity and inherent viscosity of different samples were measured\(^4\) on Ubbelhode suspended viscometer at 25±1°C using phenol-tetra-chloroethylene (60:40) solvent. Relative and inherent viscosities were calculated using the following formula:

\[ n_r = \frac{t}{t_0} \]

where \( n_r \) is the relative viscosity; \( t \), the time recorded for sample solution to flow; and \( t_o \), the time recorded for only solvent to flow.

2.2.6 Total Hand Value

Total hand values of different samples were evaluated using the Kawabata Evaluation System (KES-FB)\(^5\). This instrument basically measures the low-stress mechanical and surface properties of fabrics and converts these properties into primary hand value and total hand value. The end use of the fabric was defined as lady dress material and the hand values of fabrics were obtained using the equation KN-202-DS/KN-303-Summer, the equation for translating mechanical properties into hand values. The primary hand value (stiffness, smoothness, antidrape stiffness, fullness and softness, crispness) ranges from 1 to 10 and the total hand value varies from 1 to 5 (1-poor and 5-excellent).

2.2.7 Thermal Insulation

The thermal insulation of the fabric samples was evaluated using the Kawabata thermolabo tester by the dry contact method\(^6\). The values were calculated using the following formula:

\[ \text{Insulation (\%) = } \frac{W_o - W_w}{W_o} \times 100 \]

where \( W_o \) is the heat loss without sample; and \( W_w \), the heat loss with sample.

2.2.8 Vertical Wicking Height

Wicking height was determined according to AATCC:39-1971 test method. A stripe of fabric (1 in. \times 10 in.) was hang tightly on a glass rod, keeping 1/4 in. of its lower end immersed in a coloured water reservoir. The height of water transported after 50 min was measured.
2.2.9 Water Absorbency

A piece of fabric was spread across a point source of water and the time required to take up 2 ml water was measured. AATCC:48-1972 method was used to determine the time required for complete absorption of water drops by the conditioned fabrics.

2.2.10 Moisture Content

The moisture content of various fabric samples was determined at 65% R.H. and 25°C. The values were calculated using the following equation:

\[
\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1} \times 100
\]

where \(W_1\) is the weight of the sample before bone dry; and \(W_2\), the weight of the sample after bone dry.

2.2.11 Tensile Strength

The tensile strength was measured on Goodbrand's tensile strength tester according to ASTM : D5035-1990.

2.2.12 Air Permeability

The air permeability of fabrics was measured on Toyoseiki brand (Japan) air permeability tester according to ASTM: D737-1975.

2.2.13 Density

The density of different fabric samples was determined using the Davenport density gradient column filled with toluene (sp. gr. 0.866 g/cc) and carbon tetrachloride (sp. gr. 1.595 g/cc).

3 Results and Discussion

The samples hydrolyzed under optimized conditions, keeping the weight loss at around 5%, were analyzed critically. The weight loss was kept at around 5% considering the mechanical and comfort related properties at a compromised level. The performance of various hydrolyzed samples in terms of weight loss is shown in Table 1. It is observed that the weight loss is very less (0.15%) for controlled sample compared to other samples. This may be due to the fact that at the given treatment conditions, the polyester fibres, being extremely hydrophobic and crystalline in nature, do not undergo the hydrolysis process effectively. Sample treated with only 5% NaOH solution showed marginal weight loss (0.98%). However, the weight loss is maximum (4.89%) for the sample treated with 5% NaOH in the presence of 20% methanol. This may be due to the catalytic effect of methanol. The various aesthetic and comfort related properties of above three fabrics have been investigated.

3.1 Moisture Related Properties

The moisture related properties of various treated polyester fabrics were elucidated (Table 2) by measuring the carboxyl group content in the treated fabrics, as this group is responsible for improving the moisture content in the fabric vis-à-vis aesthetic and other properties. Table 2 shows that the moisture content of control fabric is very low (0.44%) and it relatively remains unchanged after hydrolysis. However, the wicking height and carboxyl group content increase significantly on hydrolysis. This indicates that the carboxyl group formation is restricted on the fibre surface only.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Moisture content (%)</th>
<th>Wicking height (cm)</th>
<th>COOH group %</th>
<th>COOH group mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.44</td>
<td>5.8</td>
<td></td>
<td>38.33</td>
</tr>
<tr>
<td>Treated</td>
<td>0.48</td>
<td>9.6</td>
<td></td>
<td>43.80</td>
</tr>
<tr>
<td>5% NaOH</td>
<td>0.56</td>
<td>13.4</td>
<td></td>
<td>51.10</td>
</tr>
</tbody>
</table>

3.1.1 Wicking Behaviour

Table 2 shows that there is a substantial increase in the wicking height with the increase in weight loss. The wicking height is maximum for the sample treated with sodium hydroxide and methanol followed by that for the sample treated with only sodium hydroxide. This may be due to the flow of water...
through the inter fibre spaces in the yarn by the interfacial tension between water and fibre surfaces.

3.1.2 Water Absorbency

Fig. 1 shows that the drop absorbency time decreases considerably for fabrics treated with NaOH alone and NaOH-methanol. This may be due to the pitting of the surface of polyester fabric by partial hydrolysis, resulting in increase in the accessibility of polymer's hydrophilic groups to water. This can be observed from the carboxyl group content of various treated polyester fabrics (Table 2). The higher value of −COOH confirms the partial hydrolysis of polyester.

3.2 Density and Viscosity

Table 3 shows the density and viscosity (relative and inherent) of treated and untreated polyester fabrics. The density of polyester fibre remains relatively constant as it progressively loses its weight owing to alkaline hydrolysis. It is well-known that fibre density is a measure of its crystallinity. Thus, it appears that the crystallinity of polyester remains unchanged while it is being hydrolysed. This indicates that the hydrolysis may have occurred at the fibre surface. On the other hand, if the sodium hydroxide had penetrated the fibre core and preferentially attacked the low order regions of the sample, then an increase in density might have been expected. It may also be observed from Table 3 that there is a substantial decrease in viscosity for samples treated with sodium hydroxide and methanol. It is commonly believed that the viscosity is a measure of molecular weight of polymers. Thus, the decrease in the viscosity may be due to the decrease in molecular weight because of the partial hydrolysis of polyester.

3.3 Tensile Property

Table 3 shows that there is a marginal deterioration (2.5%) in tensile strength when polyester is treated with only sodium hydroxide but the loss in strength increases gradually when polyester is treated with sodium hydroxide in the presence of methanol (4.8%).

3.4 Comfort Related Properties

3.4.1 Total Hand Value

Table 4 shows that the total hand value gradually increases as the weight loss of polyester increases and it is maximum (3.87) for the sample treated with sodium hydroxide in the presence of methanol. The total hand value of control and treated polyester fabrics indicate that it is possible to impart the improved handle property to polyester fabric by simple chemical reaction like sodium hydroxide treatment in presence of methanol.

3.4.2 Thermal Insulation

Table 4 shows that the thermal insulation value is highest for the sample treated with sodium hydroxide and methanol. This may be because of the increase in effective gap between yarns at crossover points as a
result of which more air is entrapped inside the fabric and thus showing higher thermal insulation values.

3.4.3 Air Permeability

It is observed from Table 4 that the air permeability increases with the increase in weight loss of polyester and that it is highest for the sample treated with sodium hydroxide and methanol. This may be due to the generation of effective gap between yarns at crossover points and decrease in fibre diameter.

4 Conclusion

The aesthetic and comfort related properties of polyester fabric can be improved appreciably by treating it with 5% NaOH in presence of 20% methanol at 60°C for 60 min without much deterioration in its mechanical properties. Thus, there is a lot of scope to substitute cotton-rich polyester blended fabric with polyester-rich cotton blended fabric.

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References