ELECTROBLEACHING OF COTTON FABRICS IN SODIUM CHLORIDE SOLUTION

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Introduction

One of the most important objectives in raw cotton fabrics for textile industry is to achieve a high whiteness index, because it is necessary that an adequate finishing be applied before other kinds of treatment like dyeing or printing. Conventional techniques for bleaching of cotton are based on oxidative processes. One of them, which was developed long time ago, is chlorine bleaching. This process consists in a batch or pad immersion of the fabric in a solution containing sodium hypochlorite or other oxidizing chlorine compound. This technique has several advantages, like low chemical costs and no heating costs, because it works at an ambient temperature. However, it has several disadvantages because it requires the transport, storage and handling of hazardous, unstable chemicals and hence it poses stringent industrial safety and risk prevention concerns.

An alternative process based on electrochemistry is proposed to obtain a good whiteness index, while avoiding some of the disadvantages of conventional methods. In this work electrolysis of cotton fabrics soaked in proper electrolyte has been studied as a bleaching technology [1]. This kind of process is advantageous because the primary reactant, the electron, is cheap, clean, widely available and easily transferrable; in addition the bleaching species is produced on demand from a harmless precursor and its dosage can be easily set with precise control of the applied current.

In this work, the differences in whiteness index and the changes in surface morphology of the fibers submitted to conventional bleaching and electrobleaching were analyzed.

Experimental

A chloride-containing electrolyte was galvanostatically electrolyzed at low DC current in an electrochemical cell, using a DSA® anode and stainless steel cathode. All electrolysises were run at a self-adjusted pH of 9-9.5 and at 25 ºC. After bleaching, fabrics were submitted to antichlor treatment, washed repeatedly up to neutral pH and dried at 60ºC.
The conventional treatment consists in a treatment with bleach (at concentration of 3 g/L) during two hours in alkaline medium at room temperature. The effect of the addition of a wetting agent, like Leophen® RA by BASF (a hydrolysable wetting agent commonly used in the textile industry), to the electrolytic bath was studied. Also, we ran experiments where different cotton fabrics were electrobleached in batchwise mode with reutilization of the electrolyte. The surface morphology of raw and bleached cotton samples was examined by SEM. The whiteness index was determined in the CIELAB color space from diffuse reflectance measurements according to ISO 105-J01:1997 and ISO 105-J02:1997, by using the CIE formula. The tensile strength was measured according to ISO 13934-1:1999.

**Results**

Table 1 shows the evolution of whiteness index for different kinds of treatment. All the treatments have the same duration, two hours. Note that the amount of wetting agent used in the electrochemical treatment is ten times lower than in a conventional treatment.

**Table 1. Whiteness index and tensile strength loss**

<table>
<thead>
<tr>
<th>Wetting agent concentration</th>
<th>Conventional treatment</th>
<th>Electrochemical treatment Current 0.5 A</th>
<th>Electrochemical treatment Current 1.0 A</th>
<th>Tensile strength loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2 % v./v.</td>
<td>71±2</td>
<td>35±7</td>
<td>57±8</td>
<td>16±2</td>
</tr>
<tr>
<td>0.0 % v./v.</td>
<td></td>
<td></td>
<td></td>
<td>6±3 (*)</td>
</tr>
<tr>
<td>0.02 % v./v.</td>
<td></td>
<td>67.1±0.7</td>
<td>72.3±0.3</td>
<td>11±2(*)</td>
</tr>
</tbody>
</table>

(*) These values belong to an electrochemical treatment with an applied DC current of 1.0 A.

A high whiteness index was obtained in the electrochemical process when the wetting agent was used. This value was very similar to that reached in a conventional treatment, but it has the advantage of using a considerably lower concentration of wetting agent.
Another key advantage of the electrochemical method over the conventional one is that the electrolyte can be reused for bleaching of several cotton fabrics in batchwise mode. The bleaching action of hypochlorite is related to the following half reaction (Eq. 1):

\[
\text{ClO}^- + \text{H}_2\text{O} + 2e \rightarrow \text{Cl}^- + 2\text{OH}^- \quad \text{Equation 1.}
\]

In the conventional bleaching process, hypochlorite must be replenished as it is exhausted. However, the electrobleaching process is based on the electrooxidation of chloride ions at the anode to form aqueous chlorine (Eq. 2), which rapidly reacts with hydroxyl ions from the cathode to form hypochlorite (Eq. 3 & 4). The relevant reactions are:

Anode: \[ 2\text{Cl}^- \rightarrow \text{Cl}_2 + 2e \quad \text{Equation 2} \]
Cathode: \[ 2\text{H}_2\text{O}+2e\rightarrow\text{H}_2\text{+2OH}^- \quad \text{Equation 3} \]
\[ \text{Cl}_2 + 2\text{OH}^- \rightarrow \text{ClO}^- + \text{Cl}^- + \text{H}_2\text{O} \quad \text{Equation 4} \]

Thus, in the electrochemical process the chloride precursor is regenerated during the bleaching action itself, which potentially enables the electrolytic bath to be used indefinitely. To illustrate this behaviour a set of experiments were designed where a series of up to 6 identical cotton fabric samples were sequentially electrobleached in the same electrolyte with no further addition of sodium chloride.

<table>
<thead>
<tr>
<th>Fabric</th>
<th>Whiteness index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>55</td>
</tr>
<tr>
<td>2</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>65</td>
</tr>
<tr>
<td>4</td>
<td>70</td>
</tr>
<tr>
<td>5</td>
<td>75</td>
</tr>
<tr>
<td>6</td>
<td>80</td>
</tr>
</tbody>
</table>

Fpies with 0.02 % hydrolyzable wetting agent.

Without hydrolyzable wetting agent.
Figure 1. Whiteness index of different fabrics electrobleached in batchwise mode with reutilization of electrolyte. A DC current of 1 A was applied in both treatments.

Figure 1 shows the evolution of the whiteness index for different cotton fabrics in batchwise mode in the same electrolyte. When working without the wetting agent, acceptable whiteness index is reached only at the fourth fabric. This is because the free chlorine concentration reached a steady value. However, when a wetting agent is added, the whiteness index is satisfactory and very similar for all the fabrics. Despite the fact that maximum steady free chlorine concentration was not yet achieved in the first steps of the process, the wetting agent enables a facile access of the electrogenerated bleaching agent to the fiber, thus enhancing the bleaching rate and providing high whiteness indices.

SEM imaging of fabrics with electrobleaching treatment did not show any noticeable change in their surface morphology. When these images are compared with those of chemically bleached fabrics we cannot observe any prominent difference between fibers. With both treatments, the fiber appearance of twisted flat ribbons with cellulose fibrils assembled in spiral along the fiber axis and the cross-sectional bilateral structure is preserved. So, the electrochemical treatment produces the same surface condition as the conventional treatment.

It is well known that bleaching treatments reduce traction resistance of the fibers. With the conventional treatment there is a loss of 16 % (Table 1). On the contrary, lower losses of the tensile strength were measured in electrobleached cotton fabrics (Table 1). So, it is observed that the fabrics submitted to electrolysis had a better traction resistance than those submitted to conventional treatments.

References


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