INVESTIGATION OF DYEING EFFECT ON THE MORPHOLOGY OF COTTON FIBRE AND COTTON/PES BLEND BY THERMAL ANALYSIS

BY

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Abstract. The aim of this paper is to investigate the thermal behaviour of 100% cotton fibres and 50/50% cotton/PES blend (50/50%) before and after dyeing treatment using a Perkin Elmer DSC-7 differential scanning calorimeter. To follow the behaviour of the samples for temperature ranging from 30°C to 350°C a Mettler Toledo Thermo System FP82 hot stage& Optical Microscopy were used. The experimental results showed an exothermic effect recorded for the raw and dyed cotton samples which correspond to the cotton pyrolysis and an endothermic effect recorded for raw and dyed cotton/PES fibres assigned to the melting of PES. Also, the thermal resistance was found to be higher for 100% cotton fibres than for the raw and finished cotton/PES blend (50/50%).

Key words: fibres, thermal properties, pyrolysis, crystallinity, DSC analysis.

1. Introduction

There are numerous references in the literature regarding the significance of fibre properties and their influence at material level. Structure is

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show to play an important part in their behaviour. The importance of cotton fibres make them well studied (Abidi et al., 2007).

The structure is defined as 95% cellulose I (β-1, 4-d-anhydroglycopyranose) (Lewin & Pearce, 1998). Cotton fibre is made of cuticle, primary cell wall and contains wax, pectic substances, organic acids, sugars and ash-producing organic salts (Hartzell & Hsieh, 2000). Its chemical processing (scouring and bleaching) removes all non-cellulosic substances (Maxwell et al., 2003).

One method of controlling cotton fibres properties is blending. PES is a fibre often used for such purposes, due to its improved mechanical behaviour and dimensional stability (Basak et al., 1981).

Thermal analysis DSC is a common method used to characterise textile materials (Xi et al., 2005). It only gives the changes temperature and heat determined during pyrolysis, therefore its range of thermal characterisation is somewhat limited (Zhu et al., 2004).

The aim of this study is to investigate the effect of dyeing process on the morphology of 100% cotton and 50/50% cotton/PES fibres using a Perkin Elmer DSC-7 differential scanning calorimeter.

2. Materials and Method

2.1. Materials

The samples used in this investigation were 50/50% cotton/PES blend and 100% cotton fibres; both had been dyed using a direct dye (Sirius Orange K-CFN) and disperse dye (Dianix Luminous Red B). After dyeing according to diagram, the fibres were maintained in standard atmosphere for 24 h (Butnaru & Bertea, 2001).

2.2. Testing Method

The thermal behaviour of raw and dyed cotton and cotton/PES samples was investigated using a Perkin Elmer DSC-7 differential scanning calorimeter. About 5-10 mg fibre samples cut into fine snippets were placed in aluminium pans whose lids were perforated with two holes. The reference was always an empty pan. The pans were heated from 20 to 450°C with a heating rate of 10°C/min under a flow of nitrogen of 20 mL/min, and the data was processed by the equipment software (Pyris Analysis).

3. Results and Discussions

Table 1 summarizes the melting and combustion behaviour of the raw and dyed cotton samples.
Table 1

Thermal Properties of the Raw and Dyed Cotton Fibres

<table>
<thead>
<tr>
<th>Sample</th>
<th>Melting temperature $T_m$ [°C]</th>
<th>$\Delta H_m$ [J/g]</th>
<th>Combustion temperature $T_c$ [°C]</th>
<th>$\Delta H_c$ [J/g]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton 100% raw</td>
<td>–</td>
<td>–</td>
<td>346.2</td>
<td>−139.9</td>
</tr>
<tr>
<td>Cotton 100% dyed</td>
<td>–</td>
<td>–</td>
<td>342.8</td>
<td>−148.5</td>
</tr>
<tr>
<td>Cotton/PES 50/50% raw</td>
<td>256.7</td>
<td>26.9</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Cotton/PES 50/50% dyed</td>
<td>257.5</td>
<td>31.3</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

Note: the temperature determined is the peak temperature.

A METTLER TOLEDO Thermo System FP90 with FP82 hot stage & Optical Microscopy were used to follow the behaviour of the samples for temperature ranging from 30°C to 350°C.

3.1. Effect of Dyeing Process on 100% Cotton Fibres

Figs. 1 and 3 show the exothermic effect recorded for the raw and dyed cotton sample, respectively. The process corresponds to the cotton pyrolysis followed by the oxidation of the gases with oxygen resulted from cellulose pyrolysis. The peak temperature of the raw sample was found to be at 346.2°C and those of the dyed sample at 342.8°C. The decrease of peak temperature with 4 degrees after dyeing is likely to be due to an effect of depolymerisation of the cellulose chains as a result of the dyeing parameters (temperature, time and pH).

The OM photos (Figs. 2 and 4) show the behaviour at different temperatures. It can be seen that the cotton fibres are carbonized at 350°C.

Fig. 1 – DSC curve of the 100% raw cotton fibres.
Fig. 2 – The combustion behaviour of the 100% raw cotton fibres at:
a − 280°C; b − 300°C; c − 350°C.

Fig. 3 – DSC curve of the 100% dyed cotton fibres.
Fig. 4 – The combustion behaviour of the 100% dyed cotton fibres at:
   a – 280°C; b – 300°C; c – 350°C.

3.2. Effect of Dyeing Process on 50/50% Cotton/PES Fibres

The DSC records of cotton/PES fibres before and after dyeing are given in Figs. 5 and 7, respectively. The endothermic effect is assigned to the melting of PES and has the peak at 256.7°C for raw fibres, and at 257.5°C for the dyed sample, respectively. The values of enthalpy for both cases are almost the same, of 26.9 and 31.3 J/g, which suggests that the dyeing treatment does not influence the crystallinity of the PES fibres.

The cotton pyrolysis is recorded at around 350°C, and this time it is an endothermic process. This is due to the fact that the cotton fibres are surrounded by the melted polyester and the gases of pyrolysis cannot proceed into the oxidation reactions, like in the case of pure cotton fabric. As a result, the recorded effect is the endothermic one, corresponding to the pyrolysis of cellulose chains.
Fig. 5 – DSC curve of the 50/50% cotton/PES raw fibres.

Fig. 6 – The combustion behaviour of the 100% raw cotton fibres at:

\[ a - 280^\circ C; \quad b - 300^\circ C; \quad c - 350^\circ C. \]
Fig. 7 – DSC curve of the 50/50% cotton/PES dyed fibres.

Fig. 8 – The melting behaviour of the 50/50% cotton/PES raw fibres at:

\[ a - 250^\circC; \ b - 320^\circC; \ c - 350^\circC. \]
4. Conclusions

The conclusions from our investigation may be summarized as follows:
1. The decrease of peak temperature of the dyed sample with 4 degrees leads to a lower thermal resistance of cellulosic fibres – 100% cotton as a result of dyeing process.
2. The presence of PES fibres in blend composition maintains the resistance to thermal decomposition, in this case there is no difference between the melting temperature of the raw and dyed samples.
3. The thermal resistance was found to be higher for 100% cotton samples than for 50/50% cotton/PES blend in both cases, the raw and dyed.
4. Technical use of these fabrics for thermal insulation is recommended materials made of 100% cotton raw fibres due to their higher thermal resistance.

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REFERENCES


INVESTIGAREA EFECTULUI VOPSIRII ASUPRA MORFOLOGIEI FIBREI DIN BUMBAC ŞI BUMBAC/PES PRIN ANALIZE TERMICE

(Rezumat)

Scopul acestei lucrări este de a investiga comportarea termică a fibrelor din bumbac 100% şi a amestecului bumbac/PES 50/50%, înainte şi după tratamentul de vopsire, folosind calorimetrul cu scanare diferenţiată DSC-7 Perkin Elmer. Pentru a
urmări comportarea probelor la temperaturi variind de la 30°C la 350°C s-a folosit un echipament METTLER TOLEDO Thermo System FP90 cu etape de ardere FP82 și Microscopie Optică. Rezultatele experimentale au arătat un efect exoterm înregistrat în cazul probelor crude și vopsite din bumbac ce corespunde pirolizei bumbacului și un efect endoterm înregistrat în cazul probelor nevopsite și vopsite din bumbac/PES atribuit topirii PES-ului. De asemenea, rezistența termică s-a dovedit a fi superioară în cazul probelor din bumbac 100% față de probele din bumbac/PES crude, respectiv vopsite.