Inverse creep in some textile yarns

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Some exploratory work on creep and inverse creep in nylon 6 monofilament, polyester multifilament yarn and wool and cotton spun yarns has been presented. It is observed that the extent of creep and inverse creep differs from material to material and depends on the initial stress. Cotton shows minimum inverse creep while nylon shows maximum inverse creep. Wool and polyester have intermediate inverse creep values.

Keywords: Cotton, Creep, Inverse Creep, Nylon 6, Polyester, Stress relaxation, Wool

1 Introduction

All textile materials are made up of either natural or synthetic polymers. Being viscoelastic in nature, they exhibit phenomena like creep and stress relaxation associated with polymer substances.

Stress relaxation means decrease in stress of a viscoelastic material constrained at a constant strain. Increase in strain of such a material over a period when subjected to a load (preferably a constant stress) is called creep. When the load is removed, there is immediate partial recovery of the deformation followed by a delayed recovery over a period. This recovery is known as creep recovery.

All these phenomena have been studied for most of the textile fibres and yarns by the earlier research workers. The phenomenon of inverse relaxation, in which strain in a viscoelastic material is partially removed giving rise to an increase in stress, has been studied to some extent in our Institute and elsewhere. Bhuvanesh and Gupta have observed that when the as drawn polypropylene multifilament yarn at temperature of 60°C and above is strained to less than 2% and is constrained to remain at that level, there is stress relaxation to start with, followed by inverse relaxation. But there is little work carried out on inverse creep.

Inverse creep is a phenomenon found to occur in a viscoelastic material when the applied stress is partially reduced. At this reduced stress, the strain in the material goes on reducing continuously with time, though it is still under stress. This phenomenon is a corollary of inverse relaxation and appears to depend very much on the stress history of the polymeric material.

The present article explains the phenomenon of inverse creep and gives some data obtained on nylon 6 monofilament, polyester multifilament yarn and wool and cotton spun yarns.

2 Materials and Methods

To carry out an exploratory study on the phenomenon of inverse creep, cotton spun yarn of 10s count (57.4 tex) prepared from a variety 'wagad' with a mean fibre length of 20 mm, wool spun yarn of 2/28s count (43.8 tex) from Australian Merino wool, polyester [poly(ethylene terephthalate)] multifilament yarn (8.67 tex) and nylon 6 monofilament (17.5 tex) were used.

As shown in Fig. 1, one end of the yarn (A) was attached to the upper load cell (P) and the lower end (E) was fastened to a metal ring (C) which was fixed to a pulley (D). The load cell (B) was placed below the ring (C) to measure the load. The other end of the yarn was attached to a balance (A). The experimental set-up is shown in Fig. 1.

Fig. 1—Experimental set-up for creep and inverse creep measurements
fixed and the other end was attached to a pan (C) over a frictionless pulley (P). A horizontal pointer (D) attached to the pan moves over the vertical meter scale (E). The length of yarn from the fixed end A up to the point B that corresponds to zero of the vertical scale was first determined. This takes care of the yarn portion passing over the pulley. In the present set-up used in the experiment, the length AB was 2.89 m. The reading on the meter scale corresponding to the pointer D when added to the length AB gave the total length of the specimen.

Each specimen was first loaded with 112 g for 600 s. The load was then completely removed and the yarn was allowed to undergo creep recovery for 600 s. This cycle of loading and unloading was carried out three times. In the third cycle itself, recovered length after unloading was almost equal to the length of the yarn before it was loaded for that cycle. It was, therefore, assumed that this procedure was sufficient to remove any permanent set and condition the specimen mechanically. This specimen was used for further investigation.

The initial length of the yarn was measured without any load. Then a load of 112 g was applied to the specimen. The immediate extension was noted. Further, creep at different time intervals up to 200 s was measured. Then 50 g load was removed. The immediate reduction in length was noted. Although the yarn was under a load of 62 g, it was observed that the reduction in length was going on continuously. Length at different time intervals up to 200 s was measured to find out the reduction, i.e., inverse creep. The inverse creep at the load of 12 g after removing additional 50 g load (total 100 g with respect to the starting load) was determined.

The same experiment was repeated for another specimen with initial load of 62 g. The inverse creep in this case was measured after removing 50 g, i.e., at 12 g load. The entire experiment was conducted at ambient atmospheric conditions, i.e., at 65±2% RH and 25±2°C.

3 Results and Discussion

A typical inverse creep experiment is shown in Fig. 2. Point O corresponds to the start of the experiment. At O, certain load (i.e., stress $S_1$) is applied to the yarn. As a result, there is immediate extension OA in the yarn followed by extension corresponding to the curve AB over a period zero to $t_1$. At time $t_1$, the stress $S_1$ is reduced partially to $S_2$ by removing a part of the load. Corresponding to this reduction in stress from $S_1$ to $S_2$, we get immediate reduction BC in the extension of the yarn, followed by reduction in extension corresponding to the curve CD over the period from $t_1$ to $t_2$. In the present experiments, zero to $t_1$ and $t_1$ to $t_2$ were both 200 s. It may be seen from Fig. 2 that extension $A'B'$ corresponds to creep in the specimen over the period zero to $t_1$ under stress $S_1$. The reduction in extension $C'D'$ corresponds to inverse creep in the specimen at reduced stress level $S_2$ over the period $t_1$ to $t_2$. These creep and inverse creep values have been reported in Tables 1 and 2.

Table 1 gives inverse creep data for the four yarn samples studied with initial stress $S_1$ corresponding to 62 g load. This load was reduced to 12 g after 200 s, giving reduced stress $S_2$ in the yarns. Table 2 gives inverse creep data for the yarns with initial stress $S_1$ corresponding to 112 g load. This load was reduced to 62 g and 12 g corresponding to reduced stress levels of $S_2$ and $S_3$, respectively. For each of these stresses ($S_1$, $S_2$, and $S_3$), change in extension over 200 s was measured. The stress values are expressed in mN/dtex while...
Table 1—Inverse creep data for yarns loaded up to 62 g load

<table>
<thead>
<tr>
<th>Yarn sample</th>
<th>Initial stress ($S_1$) mN/dtex</th>
<th>Immediate extension %</th>
<th>Creep over 200 s %</th>
<th>Reduced stress ($S_2$) mN/dtex</th>
<th>Inverse creep over 200 s %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyester</td>
<td>7.01</td>
<td>1.09</td>
<td>0.43</td>
<td>1.36</td>
<td>0.33</td>
</tr>
<tr>
<td>Cotton</td>
<td>1.06</td>
<td>0.38</td>
<td>0.13</td>
<td>0.20</td>
<td>0.07</td>
</tr>
<tr>
<td>Wool</td>
<td>1.39</td>
<td>0.94</td>
<td>0.14</td>
<td>0.27</td>
<td>0.12</td>
</tr>
<tr>
<td>Nylon</td>
<td>3.47</td>
<td>2.50</td>
<td>0.82</td>
<td>0.67</td>
<td>0.55</td>
</tr>
</tbody>
</table>

$S_1$ and $S_2$ correspond to 62 g and 12 g load respectively. All creep and inverse creep measurements were carried out over 200 s.

Table 2—Inverse creep data for yarns loaded up to 112 g load

<table>
<thead>
<tr>
<th>Yarn sample</th>
<th>Initial stress ($S_1$) mN/dtex</th>
<th>Immediate extension %</th>
<th>Creep at $S_1$ %</th>
<th>Reduced stress ($S_2$) mN/dtex</th>
<th>Inverse creep at $S_2$ %</th>
<th>Reduced stress ($S_3$) mN/dtex</th>
<th>Inverse creep at $S_3$ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyester</td>
<td>12.66</td>
<td>2.78</td>
<td>0.63</td>
<td>7.01</td>
<td>0.24</td>
<td>1.36</td>
<td>0.79</td>
</tr>
<tr>
<td>Cotton</td>
<td>1.91</td>
<td>0.88</td>
<td>0.20</td>
<td>1.06</td>
<td>0.03</td>
<td>0.20</td>
<td>0.18</td>
</tr>
<tr>
<td>Wool</td>
<td>2.51</td>
<td>1.74</td>
<td>0.32</td>
<td>1.39</td>
<td>0.09</td>
<td>0.27</td>
<td>0.16</td>
</tr>
<tr>
<td>Nylon</td>
<td>6.27</td>
<td>4.58</td>
<td>1.16</td>
<td>3.47</td>
<td>0.33</td>
<td>0.67</td>
<td>0.80</td>
</tr>
</tbody>
</table>

$S_1$, $S_2$, and $S_3$ correspond to 112 g, 62 g and 12 g load respectively. All creep and inverse creep measurements were carried out over 200 s.

Fig. 3—Extension versus time curve for cotton yarn. AB and BC correspond to immediate extension and creep respectively at 1.91 mN/dtex stress. CD and DE correspond to immediate reduction and inverse creep respectively at 1.06 mN/dtex stress. EF and FG correspond to immediate reduction and inverse creep respectively at 0.20 mN/dtex stress.

Fig. 4—Extension versus time curve for wool yarn. AB and BC correspond to immediate extension and creep respectively at 2.51 mN/dtex stress. CD and DE correspond to immediate reduction and inverse creep respectively at 1.39 mN/dtex stress. EF and FG correspond to immediate reduction and inverse creep respectively at 0.27 mN/dtex stress.

the extension values are expressed in percentage of the initial length of the yarn.

It may be seen from Figs 3-6 that at stress level $S_1$ all the samples show creep as expected. For reduced stress levels $S_2$ and $S_3$, all the samples show inverse creep. When 112 g load is reduced to 62 g, it is found that the ratio of inverse creep at stress $S_2$ to creep at stress $S_1$ is comparatively small. These ratios for cotton, wool, nylon and polyester are 15, 28, 23 and 38% respectively. When this load is further reduced to 12 g, the inverse creep at reduced stress $S_3$ is 90, 50, 68 and 125% of the creep at $S_1$ for cotton, wool, nylon and polyester yarns respectively. For 62 g load reduced to 12 g, inverse creep is about 50% of the creep in the case of cotton yarn while it is about 85% of the
These materials exhibit inverse creep and the extent of creep and inverse creep differs from material to material.

Inverse creep values depend on the material and also on its stress history. In everyday life, we come across textile materials which are being stressed and strained to different levels. For example, a weft thread undergoes variation in stress during weaving. It is at a high stress when it is being laid down in the fabric. But the stress reduces when the shuttle leaves it for the next weft yarn to be laid in the fabric. But the stress may not reduce to zero, thus giving rise to the phenomenon of inverse creep. Variations in inverse creep behaviour for the same higher and lower stress levels in a given yarn can lead to fabric defects. There can be many more such examples.

References