Time-dependent behaviour of compressional properties of nonwoven fabrics

V K Kothari & A Das
Department of Textile Technology, Indian Institute of Technology, Hauz Khas, New Delhi 110 016, India
Received 8 September 1993; accepted 4 April 1994

The time dependent behaviour of compressional properties of different nonwoven fabrics has been studied. It is observed that after a compression-recovery cycle, if the fabrics are allowed to relax for certain time they tend to recover and the recovery from the deformed state increases with the increase in relaxation time. The time dependent effect is very little in case of heat-sealed nonwovens as most of the recovery is instantaneous. The number of compression-recovery cycles has marked effect on the compressional behaviour, particularly in case of needle-punched fabrics.

Keywords: Compression-recovery cycle, Energy loss, Heat-sealed spunbonded nonwoven, Needle-punched nonwoven, Relaxation time

1 Introduction
The compressional behaviour of loose fibre mass, yarns and fabrics has been studied for purposes such as the comparison of their ability to perform satisfactorily in various end-uses. Now-a-days, nonwoven fabrics are extensively being used in a number of technical end-uses due to their physical, tensile and hydraulic characteristics. In many applications, these fabrics are subjected to normal compressive load which changes their tensile and hydraulic properties. These changes depend on the compressional behaviour of the fabric. Therefore, a good understanding of the compressional behaviour of different nonwoven structures is necessary to predict their behaviour in many practical uses.

In our earlier papers\textsuperscript{1,2}, we have described in detail the working principle of an instrument developed by us for measuring the compressional behaviour of nonwoven fabrics at a constant rate of deformation and the effect of various test parameters on the compressional behaviour of different nonwoven fabrics. In the present study, an attempt has been made to study in detail the time-dependent compressional behaviour of nonwoven fabrics using the same constant rate deformation tester\textsuperscript{1}. As the time-dependent compressional behaviour of fabrics depends on the fabric structure, relaxation time available and the number of compression-recovery cycles, a number of spunbonded and needle-punched fabrics were subjected to compression-recovery cycle(s) and the time-dependent changes in compression-recovery behaviour were studied.

2 Materials and Methods
Four different nonwoven fabrics (Table 1) were used to study the effect of relaxation time on the compressional behaviour using the pressure foot of 5 cm\textsuperscript{2} area and 1.87 mm/min deformation rate. Five samples, taken from each fabric, were subjected to single compression-recovery cycle between 2 kPa and 200 kPa at different places, the corresponding compressional data were recorded and average values taken. The position subjected to compression-recovery cycle was marked in each sample. The fabrics were then allowed to relax for different durations [Sample 1 (1 h), Sample 2 (2 h), Sample 3 (5 h), Sample 4 (10 h), and Sample 5 (24 h)]. After the stipulated relaxation, the samples were again subjected to a compression-recovery cycle at the same places as marked earlier and the results were recorded. The percentage change in the average values of compression and related parameters with respect to initial values were calculated.

In another set of experiments, the fabrics were subjected to five consecutive compression-recovery cycles.
les between 2 kPa and 200 kPa pressure at five different places, the corresponding compression and related data were recorded, and the average values taken. The fabrics were then allowed to relax for 24 h and subjected to another five compression-recovery cycles at the same places and the average values taken as above.

3 Results and Discussion

Fig. 1 shows the effect of relaxation time on the percentage change in initial thickness ($T_0$), compressional parameter ($x$), and energy loss ($E_t$) for different nonwoven fabrics. The staple fibre needle-punched nonwoven fabric shows the maximum change in initial thickness followed by the spun bonded needle-punched and needle-punched surface calendared nonwoven fabrics. The spun bonded heat-sealed nonwoven fabric shows very small change in thickness after relaxation. With the increase in relaxation time, the recovery in thickness increases but the percentage change in thickness decreases gradually. As the needle-punched fabrics allow more slippage among the fibres during compression, the stored bending energy in the fibres will be less. Further, due to more fibre-to-fibre slippage in needle-punched fabrics, frictional locking will be more, causing higher percentage change in thickness as shown in Fig. 1. On the other hand, the heat-sealed fabrics show very less percentage change in initial thickness because of very little fibre-to-fibre slippage during compression. In these fabrics, most of the recovery is instantaneous and the percentage change in initial thickness is not affected by the relaxation time. The compressional parameter also shows a similar trend with relaxation time (Fig. 1). As the recovery in initial thickness in case of needle-punched fabrics is gradual, the change in compressibility will also be gradual.

The staple fibre needle-punched fabric shows highest energy loss during a compression-recovery cycle followed by the spun bonded needle-punched fabric, while the spun bonded heat-sealed fabric shows the lowest energy loss (Fig. 1). With the increase in relaxation time, the gradual recovery from the deformed state in case of needle-punched fabrics causes reduction in the percentage change in energy loss. As the recovery is instantaneous in spun bonded heat-sealed fabric, the percentage change in energy loss is not affected by the relaxation time.

Fig. 2 shows the nature of change in initial thickness, compressional parameter and energy loss with the change in number of compression-recovery cycles initially and after relaxation for 24 h. The number of compression-recovery cycles has marked effect on the compressional and related parameters, particularly in case of needle-punched fabrics as the chances of fibre-to-fibre slippage are more. The initial thickness, compressional parameter and percentage energy loss change abruptly in first cycle and after that the curves gradually flatten. This is due to the fact that most of the fibre-to-fibre slippage takes place in the first cycle. When the fabrics are allowed to relax for 24 h after subjecting five compression-recovery cycles, the needle-punched fabrics show some change in compressional and related parameters. The staple fibre needle-punched fabric shows the highest change in the parameters as chances of permanent deformation are higher because of higher fibre-to-fibre slippage and subsequent frictional locking among the fibres. But after 2-3 cycles, the parameters show almost same values as of original sample as the compression after 2-3 cycles is mainly due to the fibre bending which is recoverable. Some permanent deformation takes place, particularly in case of needle-punched fabric, during the first phase of compression-recovery cycles. The time-dependent recovery that takes place during 24 h relaxation gives the values of compr-
professional and related parameters close to those of the original sample. The permanent deformation that takes place during the initial compression-recovery cycles makes the structure more compact than that of the original sample and thus the values of initial thickness, compressional parameter and energy loss for the first cycle are lower than those for the original sample. The heat-sealed fabric shows no change in parameters due to very low fibre-to-fibre slippage during compression and also due to relaxation of stress.

Table 2—Decrease in initial thickness ($T_o$), compressional parameter ($\alpha$), and energy loss ($E_L$) after 24 h of relaxation following one and five compression-recovery cycles

<table>
<thead>
<tr>
<th>Compression-recovery cycle(s)</th>
<th>Sample</th>
<th>$T_o$</th>
<th>$\alpha$</th>
<th>$E_L$</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>A</td>
<td>5.81</td>
<td>1.99</td>
<td>4.49</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>2.08</td>
<td>1.42</td>
<td>1.79</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>1.56</td>
<td>0.95</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>11.59</td>
<td>3.77</td>
<td>6.44</td>
</tr>
<tr>
<td>Five</td>
<td>A</td>
<td>7.63</td>
<td>4.29</td>
<td>9.41</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>4.94</td>
<td>4.62</td>
<td>8.02</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>1.89</td>
<td>1.16</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>12.46</td>
<td>4.54</td>
<td>8.98</td>
</tr>
</tbody>
</table>

Table 2 shows the % change in parameters for the fabrics subjected to one and five compression-recovery cycles. It is observed that the percentage decrease in initial thickness, compressional parameter and energy loss with respect to original values is higher when the fabrics are allowed to relax for 24 h after five consecutive compression-recovery cycles. This is due to the higher permanent deformations as a result of more fibre-to-fibre slippage when the fabrics are subjected to 5 initial compression-recovery cycles.

4 Conclusions

The compressional behaviour of nonwoven fabrics is affected by relaxation time. If the fabric is allowed to relax after a compression-recovery cycle, the fabric structure tends to recover from its compressed state. The rate of recovery is more initially but reduces gradually with the increase in relaxation time. The needle-punched fabrics show higher permanent deformation, i.e. less recovery from the deformed state. The heat-sealed fabric shows instantaneous and almost total recovery. The number of compression-recovery cycles has marked effect on the compressional and related parameters, particularly in case of needle-punched fabrics.

References