Properties and Comfort Evaluation of Elastic Nonwoven Fabrics: Effects of the Blending Ratios and Number of Layers

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ABSTRACT

Imitation latex fibers and degreasing cotton fibers are blended with ratios of 70:30, 80:20, and 90:10 wt%, followed by being processed with a needle-punched nonwoven process and then a thermal treatment, in order to form elastic nonwoven fabrics. These fabrics are then laminated in 1, 2, and 3 layers via a machine sewing method. Afterwards, the elastic nonwoven fabrics are tested for air permeability, water absorption, and compression strength, and are then eventually tested with a compression strength fatigue test. The test results indicate that a combination of a blending ratio of 80:20 wt% and a number of layers of 2 result in a satisfactory ruggedness, and are thus proved to have the optimal parameters. The elastic nonwoven fabrics are suitable to make knee caps.

1 INTRODUCTION

In response to increasingly popular sports pursuits, there has been more consumption of sports accessories, such as knee pads and sneakers [1-4]. In particular, aerobic exercises commonly cause sports injuries, which make the sports accessories that offer the protection of articulation important [5]. In addition to...
protection, knee pads are also required to be comfortable. For example, knee pads need to repel the perspiration of athletes. Knee pads are primarily used to support and protect the tissues and muscles surrounding the articulation of knees, to release the pressure that is exerted to the knee tissues, to increase the stability of articulation of knees, and maintain the normal position of the patella [6]. Commercially available knee pads commonly have a buffering layer made of foam material (EVA). However, foaming materials require complex manufacturing with a low production capacity. In order to compensate for these disadvantages, this study thus uses nonwoven fabric manufacturing in order to obtain an efficient manufacturing that provides a great variety of knee pads, and then replace foaming materials [7-11].

For the purposes of meeting market demands and gain a feasible industrial application, imitation latex fibers and degreasing cotton fibers are made into nonwoven fabrics via using a needle-punched nonwoven process with a high production capacity, followed by being thermally treated. The fibers where they are entangled or intersected are thermally bonded in order to improve the strengths of nonwoven fabrics [12, 13]. The effects of different numbers of layers and blending ratios of imitation latex fibers to degreasing cotton fibers are examined in terms of air permeability, water absorption, and compression strength. The optimal elastic nonwoven fabrics are finally tested for their ruggedness.

EXPERIMENTAL

Materials

Imitation latex fibers (Far Eastern New Century Corporation) have a fineness of 4D, a length of 51mm, and a melting point of 110 °C. Degreasing cotton fibers (Phenix Health & Medical Supply Corporation) have a fineness of 0.81 D~1.53 D and a length of 20 mm-22 mm.

Preparation of Samples

Imitation latex fibers and degreasing cotton fibers at ratios of 70:30, 80:20, and 90:10 wt% are blended, needle punched, and thermally treated at 180 °C for 30 minutes in order to form nonwoven fabrics. These nonwoven fabrics with 1, 2, or 3 layers are then needle punched in order to form elastic nonwoven fabrics, the specifications of which are indicated in Table 1.

| Elastic nonwoven fabrics | Number of layers |
|-------------------------|------------------|
|                         | 1    | 2    | 3    |
| Mass per unit area (g/m²) | 310±20 | 590±18 | 940±27 |
| Thickness (mm)          | 13±2     | 25±1     | 37±2     |

TESTS

Air Permeability Test

An air permeability tester (TEXTEST FX3300, GO-IN International Co., Ltd., Germany) is used to measure the elastic nonwoven fabrics, as specified in ASTM...
D737. Samples have a size of 250 mm × 250 mm. A total of twenty samples for each specification are tested in order to obtain the means and standard deviations.

**Water Absorption Test**

This test follows the sinking time as specified in the Physical Testing of Textiles. A beaker is filled with 200mL distilled water, and samples are then added. The length of time that samples take to sink to the bottom of a beak is recorded. Samples have a size of 30 mm × 30 mm. A total of ten samples for each specification are tested in order to obtain the means and standard deviations.

**Compression Strength Test**

The compression strength of samples is measured via using an Instron 5566 (Instron, US), as specified in ASTM D3575 for cushioning materials. When the thickness of samples is compressed to 25 % compression, the force that is sensed by the load cell is used to compute the compression strength of the samples. The sample have a size of 100mm×100mm. The compression speed is 12.7 mm/min, and the distance between the compression fixtures is changed according to the thickness of the samples. The pre-load is 0.2 % less than the maximum compression strength of the sample. The equation for compression strength is as follows.

\[ S = \frac{W}{A} \]  

where \( S \) is the compression strength (Pa), \( W \) is the load (N) when the sample is compressed to a specified thickness, and \( A \) is the area that bears the pressure (m²).

In addition, this test method is then repeated for 10 to 100 times in order to evaluate the influence of compression cycles on the compression strength of the elastic fabrics.

**RESULTS AND DISCUSSION**

**Air Permeability**

Figure 1 shows that a high amount of imitation latex fibers causes the air permeability of elastic nonwoven fabrics to decrease. More imitation latex fibers form more entangled points between fibers as a result of the needle punching, and as such, there are more thermal bonding points after a thermal treatment. The more the thermal bonding points, the lower the air permeability of the elastic nonwoven fabrics. Moreover, the single-layer elastic nonwoven fabrics have the maximum air permeability. The air permeability has a decreasing trend when the number of layers is increased, as indicated in Figure 1. The pore size in the nonwoven fabrics is decreased with the increasing number of layers, which is adverse to the air permeability of the elastic nonwoven fabrics.
Water Absorption

Figure 2 indicates the water absorption of the elastic nonwoven fabrics. A short length of sinking time refers to high water absorption efficiency. Moreover, a high content of degreasing cotton fibers results in a high water absorption, as cotton fibers are natural fibers that are featured with having a high water absorption. Single-layer elastic nonwoven fabrics have a low mass per unit area, which prevents them from efficiently absorbing water. Therefore, samples used for water absorption test are only two- or three-layer elastic nonwoven fabrics. The sinking time of 3-layer nonwoven fabrics is two folds to that of 2-layer nonwoven fabrics. This result is ascribed to the fact that 3-layer nonwoven fabrics are composed of there being more degreasing cotton fibers in comparison to the 2-layer nonwoven fabrics, which facilitates the water transmission in the materials[14, 15].

Compression Strength Test

Table 2 indicates that a high content of degreasing cotton fibers results in a low compression strength. As cotton fibers are natural fibers, and thus have low mechanical properties. Namely, a low content of cotton fibers is conducive for the compression strength of the elastic nonwoven fabrics. In addition, the elastic nonwoven fabrics proposed in this study possess satisfactory compression strength, which is attributed to the manufacturing method. The webs composed of fibers are needle punched in order to create entanglement between fibers, after which the webs are thermally treated in an oven in order to transform the entanglement of fibers into
thermal bonding points. As a result, the elastic nonwoven fabrics possess satisfactory compression strength [16, 17].

Table 2. Compression strength of elastic nonwoven fabrics, as related to blending ratios and numbers of layers.

| Compression strength (MPa) | layer 1   | layer 2   | layer 3   |
|---------------------------|-----------|-----------|-----------|
| Imitation latex fiber 70% / Degreasing cotton fiber 30% | 0.74±0.03 | 0.72±0.10 | 0.53±0.09 |
| Imitation latex fiber 80% / Degreasing cotton fiber 20% | 2.37±0.29 | 2.15±0.05 | 1.87±0.10 |
| Imitation latex fiber 90% / Degreasing cotton fiber 10% | 2.46±0.06 | 2.37±0.11 | 2.22±0.07 |

Compression Fatigue Test

The optimal elastic nonwoven fabrics are composed of 80:20 wt% and are laminated with 2 layers according to the aforementioned discussions. These parameters can produce the elastic nonwoven fabrics with a high compression strength, a high water absorption, and a high air permeability. These features thus provide the knee pads with compression resistance and comfort. The optimal elastic nonwoven fabrics are then tested with a compression fatigue test. Figure 3 indicates that a 100-time repetitive compression does not cause the compression strength of the elastic nonwoven fabrics to decrease, and they still have compression strength around 2.15 MPa. This indicates that the nonwoven fabrics have desired compression resistance and ruggedness.

Figure 3. Compression strength of elastic nonwoven fabrics that are made of blending ratio of 80:20 wt% and a number of layers of 2.

CONCLUSIONS

This study successfully prepares elastic nonwoven fabrics by using imitation latex fibers and degreasing cotton fibers. In light of the test results, a blending ratio of 80:20 wt% and 2-layer lamination provide the elastic nonwoven fabrics with a high compression strength, a high water absorption, and a high air permeability, and are proven to have the optimal parameters. In addition, the compression fatigue test results also show that the elastic nonwoven fabrics retain desired compression strength, indicating that the products have good ruggedness and are suitable for the use as the buffering material of knee pads.
ACKNOWLEDGMENTS

The authors would especially like to thank Ministry of Science and Technology of Taiwan, for financially supporting this research under Contract MOST 104-2622-E-035-023-CC2.

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