STRENGTH PROPERTY EVALUATION OF SURFACE-TREATED NYLON FABRICS FOR WATERPROOF PRODUCTS AFTER SEAM PROCESSING

HIDEAKI KATOGI
Department of Human Environmental Sciences, Jissen Women's University, Japan

ABSTRACT

Many companies have announced waterproof clothing, cover sheets, fishing wear and other products. Functionality of the constituent materials of waterproof products is extremely important for comfort. However, the manufacture of products using waterproof fabrics must be conducted using seam treatments. Therefore, this study examined seam method effects on strength properties of waterproof treated nylon fabrics for sustainable development goals. Fabric surfaces were treated using polyvinyl chloride (PVC) processing. Evaluation of waterproof fabric contact angles was conducted before seam tensile testing. The seam treatment was straight with embroidered seams. Seam tensile tests of PVC-treated nylon fabrics were conducted after those of straight and embroidered seams. Polyester yarn sewing thread was used. The environment temperature was room temperature. The crosshead speed was 100 mm/min. The following results were obtained. The contact angle on the surface of PVC-treated nylon fabric was about 86°. Load–displacement curves suggested that the fracture toughness of PVC-treated nylon fabric with an embroidered seam was much larger than that of PVC-treated nylon fabric with a straight seam. Their results implied that the fracture toughness of PVC-treated nylon fabric was affected mainly by the seam method.

Keywords: clothing, embroidered seam, fracture toughness, load–displacement curve, straight seam.

1 INTRODUCTION

Fabric sewing processes are applied to products using sewing machines. Stitch method effects on the mechanical properties of composite materials have been investigated for improvement of new products. In fact, many reports have described mechanical properties of non-stitched and stitched composite materials [1]–[11].

Ai et al. [12] reported some details about mechanical properties of stitched sandwich panel structures. The stitching parameters have strengths and failure features of the stitched sandwich panel structure. Tapullima et al. [13] reported characterization of a mode II specimen using I-fibre stitching processing. The cohesive law for mode II fracture mechanisms was affected by stitching parameters. Song et al. [14] reported some effects of stitching yarn types on the flexural fatigue properties of 3D-stitched carbon fibre composites. The flexural fatigue life (10^6 cycles) of 3D-stitched carbon fibre composites continued even when the maximum fatigue stress was 542 MPa.

Moreover, many reports have described mechanical properties of fibres, yarns, and fabrics for application to new fibre products [15]–[18].

Regarding new products, Katogi et al. [19] reported the biodegradation of coffee with added regenerated cellulose fibre designed to advance sustainable development goals. The coffee with added regenerated cellulose fibre exhibited good performance. Singal et al. [20] reported mechanics in knitted materials using stitching. Finite element analysis of the knitted material was conducted for prototype models of fibre products, revealing the deformation mechanics in the knitted fabric constituent material.

Clothing is used occasionally underwater and in moist environments. Waterproof fabrics are used outdoors for plumbing work and similar tasks. Functionalities of the waterproof products' constituent materials are extremely important for comfort. Generally, tensile

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properties of constituent materials are decreased by water absorption. Water and moisture absorption affect some constituent materials of the product. Therefore, the clothing should be investigated for its mechanical properties when using a waterproof fabric as a constituent material. Moreover, the manufacture of products using waterproof fabrics must be done using seam treatment. Nevertheless, few papers have described seam method effects on mechanical properties of fabrics used for waterproofing of clothing.

For this study, the strength properties of surface treated nylon fabrics were evaluated for waterproof products after seam processing.

2 MATERIAL AND SEAM METHOD

The material is PVC-treated nylon fabric. Fig. 1 shows the PVC-treated nylon fabric surface. The constituent material of the yarn was polyester yarn for sewing processing. Fig. 2 portrays the surfaces of straight and embroidered-seam nylon fabrics. The sewing process was conducted using a sewing machine (HZL-J900R; Juki Corp.).

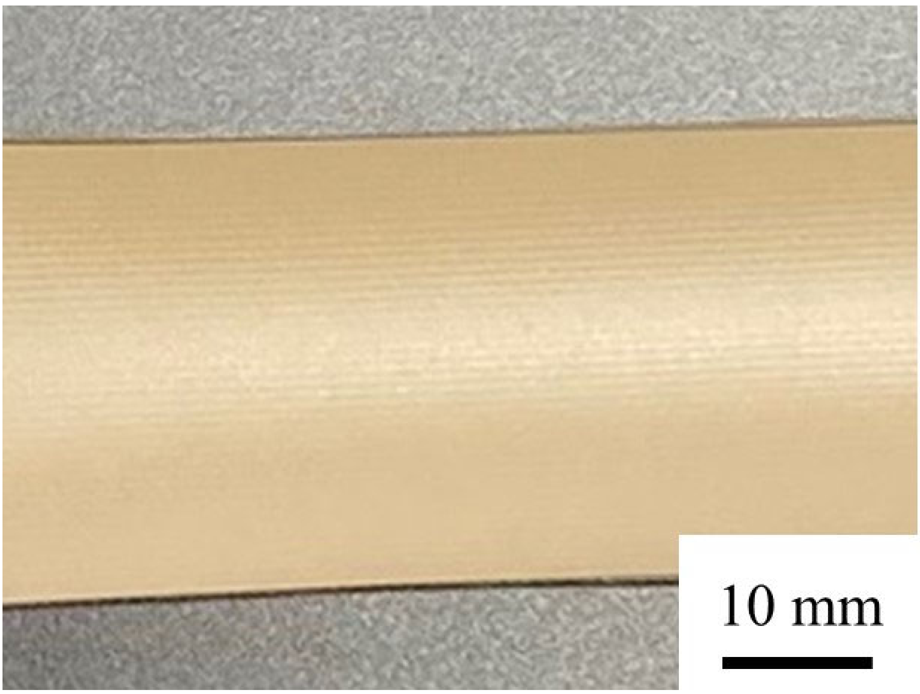
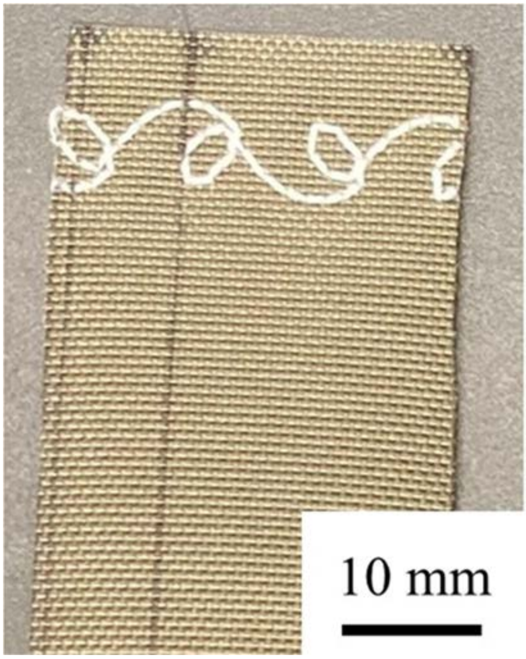


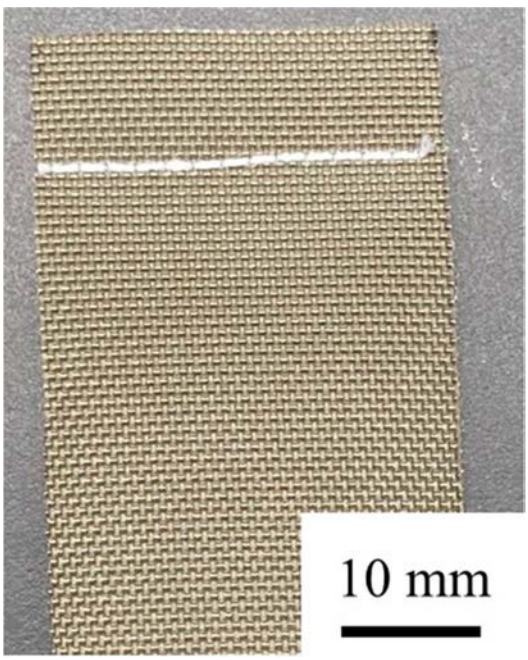
Figure 1: Surface of PVC-treated nylon fabric (front side).

3 TESTING METHOD

Seam tensile tests of PVC-treated nylon fabrics with straight and embroidered seams were conducted based on Japanese Industrial Standard (JIS) L 1093. The crosshead speed for static tensile testing was 100 mm/min. The gauge length was 100 mm. The environment temperature was room temperature. A testing machine for PVC-treated nylon fabrics with straight and embroidered seams was used (EMT-5kNV-50; Shimadzu Corp.). The seam allowance length was 10 mm. Fig. 3 presents a schematic drawing of the PVC-treated nylon fabric during seam tensile tests.



(a)



(b)

Figure 2: Surfaces of PVC-treated nylon fabrics. (a) Straight seams; and (b) Embroidered seams.

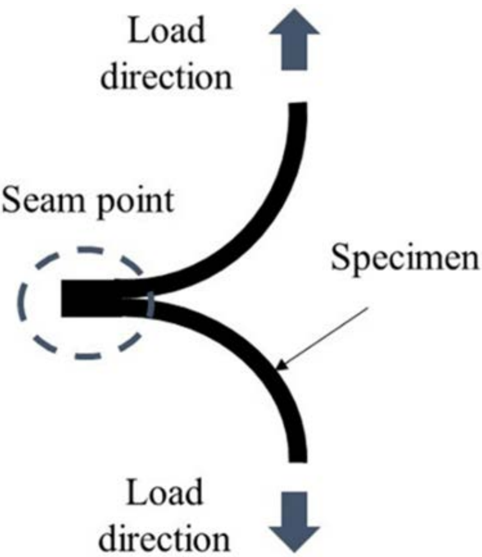


Figure 3: Schematic drawing of PVC-treated nylon fabric during seam tensile testing.

4 RESULTS AND DISCUSSION

4.1 Contact angle of nylon fabric

Fig. 4 presents contact angles on the surfaces of PVC-treated nylon fabrics for the front and back sides. The contact angles on surfaces of the nylon fabrics of the front and back sides were, respectively, approximately 86° and 70°. The nylon fabric surface at the front side had undergone using PVC treatment. The water absorption of PVC as a constituent material almost did not occur because water absorption of the PVC at 80°C was about 0.3% [21]. Therefore, the PVC treatment affected the nylon fabric waterproofing property.

4.2 Seam strength property

Fig. 5 shows load–displacement curves of PVC-treated nylon fabrics with straight and embroidered seams. Load–displacement curves of PVC-treated nylon fabrics with straight and embroidered seams were displaced approximately 3 mm during seam tensile testing. Subsequently, load–displacement curves of PVC-treated nylon fabrics with straight and embroidered seams became linear. After maximum loading at the breaking point, the load of PVC-treated nylon fabric with straight seams decreased slowly with increased displacement. However, the load of PVC-treated nylon fabric with an embroidered seam showed great variation with an increase of displacement after load at the breaking point. Maximum loads of PVC-treated nylon fabrics with straight and embroidered seams were, respectively, approximately 94 N and about 276 N. Displacements at breaking points of PVC-treated nylon fabrics with straight and embroidered seams were, respectively, about 13 mm and about 33 mm. The fracture toughness of PVC-treated nylon fabric with embroidered seams was greater than that of PVC-treated nylon fabric with a straight seam. These results imply that the seam strength properties of PVC-treated nylon fabrics were affected by the seam method using polyester yarn.

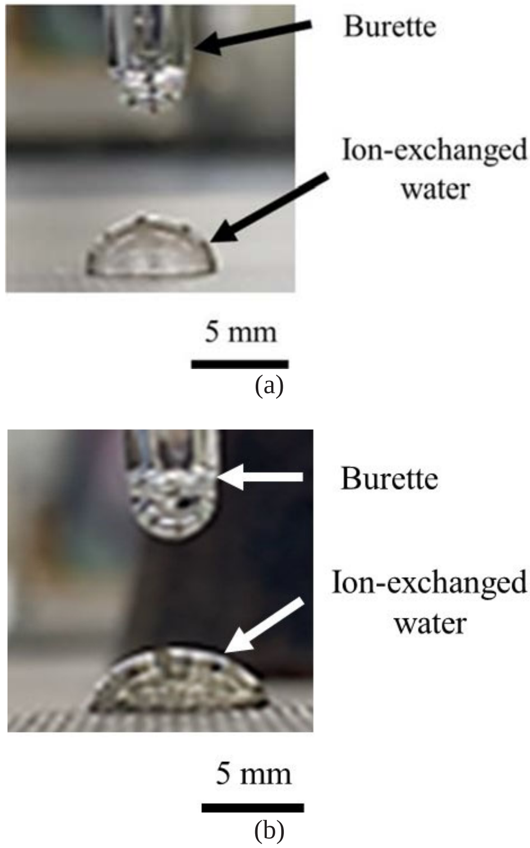


Figure 4: Measurements of contact angles of PVC-treated nylon fabrics. (a) Front side; and (b) Back side.

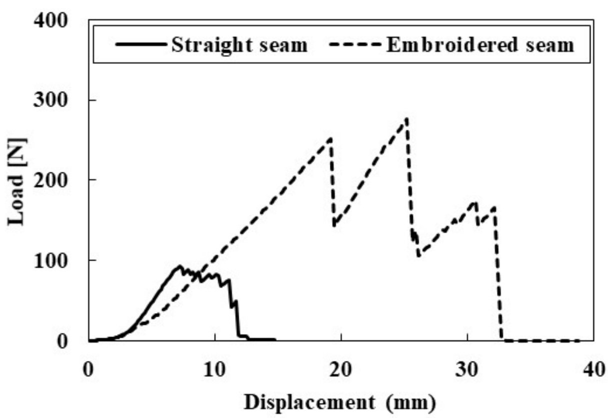


Figure 5: Load–displacement curves of PVC-treated nylon fabrics (straight and embroidered seams).

5 CONCLUSIONS

This study evaluated strength properties of surface-treated nylon fabrics designed for waterproof products after seam processing. The following conclusions were obtained.

The contact angle on the nylon fabric surface at the front side was greater than that of the nylon fabric at the back side because the nylon fabric surface at the front side had undergone PVC treatment. The maximum load of PVC-treated nylon fabric with an embroidered seam was higher than that of PVC-treated nylon fabric with a straight seam. Furthermore, the displacement at the breaking point of PVC-treated nylon fabric with the embroidered seam was greater than that of PVC-treated nylon fabric with a straight seam. The fracture toughness of PVC-treated nylon fabrics with the embroidered seam was larger than that of PVC-treated nylon fabrics with a straight seam. Therefore, seam strength properties of PVC-treated nylon fabric were affected mainly by the seam method.

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