# SHORT-TERM OUTDOOR EXPOSURE EFFECTS ON COTTON FABRIC ABRASION PROPERTIES

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ABSTRACT

The comfort of textile products that include cotton fibre after exposure to outdoor environments has been emphasized as a sustainable development goal. For textile products, abrasion between fabric and human skin can occur. Moreover, after abrasion, textile products present disposal difficulties. Therefore, evaluation of abrasion properties of textile products is important for comfort and reuse. This study investigated effects of short-term outdoor environments on abrasion properties of cotton fabric as a constituent material of textile products. The cotton knit fabric specimen colours were blue and red. Outdoor exposure tests were conducted based on Japanese Industrial Standard (JIS) Z 2381. Test times were 0, 2, and 4 weeks (28 October 2019–22 January 2020) for tests conducted in Tokyo (Japan). After outdoor exposure testing, abrasion resistance tests were conducted based on JIS L 1096, yielding the following conclusions. Abrasion tests indicated that the number of cycles to failure of blue cotton knit fabrics were similar to those of red cotton knit fabrics during the 4-week test period. The number of cycles to failure of all cotton knit fabrics during the 2-week test period increased compared with that of all cotton knit fabrics before outdoor exposure tests. The number of cycles to failure of all cotton knit fabrics during the 4-week test period remained almost unchanged compared to those of all cotton knit fabrics during the 2-week test period. The 2-week outdoor environment exposure affected the cotton knit fabric shrinkage because cotton fibre has a hydrophilic group of cellulose. Results suggest that structural changes of cotton knit fabric affected the fabric abrasion properties during outdoor exposure.

*Keywords: abrasion property, comfortable, cotton, outdoor exposure, short-term.*

## 1 INTRODUCTION

Recently, electronic textile (e-textile) products have been emphasized for health and sports [1]–[3]. Usually, constituent materials of fibre products are petroleum-based fibres such as nylon fibre, polyester fibre, and acrylic fibre. However, petroleum-based fibres represent disposal difficulties. Furthermore, petroleum-based fibre constituent materials of fibre products have low moisture. When petroleum-based fibre products are exposed to perspiration, bacteria can exist between the cloth and human skin. Therefore, moisture and abrasion properties of fibre products can strongly affect human comfort.

Numerous reports have described fatigue and tensile properties of natural fibres [4]–[6]. Natural fibres have good moisture and mechanical properties. For wider application, mechanical properties of green composites using natural fibre have been studied [7]–[12]. In addition, fibre products using woven and knit fabrics using natural fibres have been studied to assess their compatibility with sustainable development goals (SDGs) [13]–[20].

Tania et al. [19] reported ZnO coating effects on mechanical properties of cotton fabric. The tensile strength of cotton fabric was decreased by a ZnO coating. However, the ZnO coating increased the cotton fabric bending length.

Zhao et al. [20] reported aspects of the thermal stability of cotton fabric. Thermogravimetric analyses revealed that thermal degradation of pure cotton occurred at 298°C. The thermal conductivity of pure cotton fabric was about 0.05 W/mK.

Nevertheless, despite cotton fabric abrasion properties' importance for SDGs and wider applications, few reports have described them under outdoor exposure environments.

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Therefore, this study investigated effects of short-term outdoor exposure on abrasion properties of cotton knit fabric.

## 2 MATERIALS AND METHODS

### 2.1 Materials

The 120 mm wide and 120 mm long cotton knit fabric specimens were red and blue.

### 2.2 Outdoor exposure testing method

The outdoor exposure test was conducted based on Japanese industrial standard (JIS) Z 2381. The 4-week-long tests (28 October 2019–22 January 2020) were conducted at Hino, Japan. A stand for outdoor exposure testing (Fig. 1) was created in our laboratory. Each of the three specimens examined was fixed at four corners. After outdoor exposure testing, the surface of each specimen was observed using ultraviolet (UV) light in a darkroom with constant temperature and humidity (20°C, 65%RH).

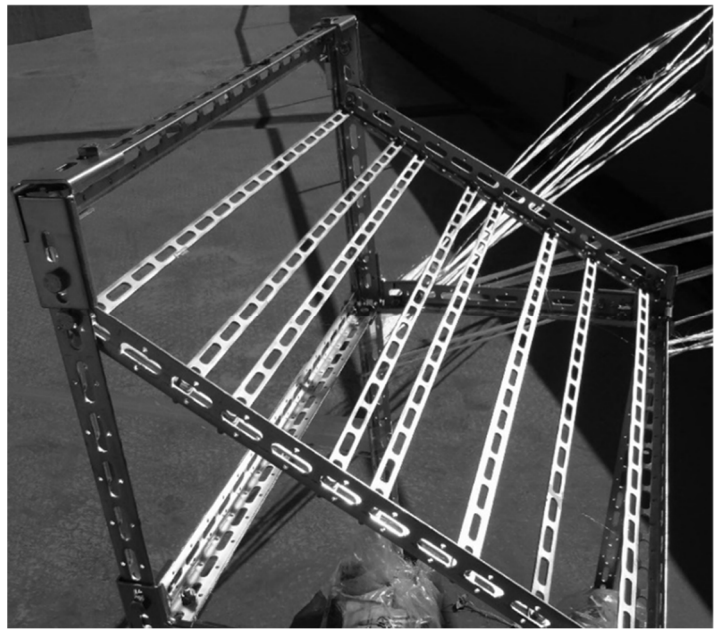


Figure 1: Stand for outdoor exposure test.

### 2.3 Abrasion testing method and thickness measurement

Abrasion testing of three cotton knit fabric specimens was conducted based on JIS L 1096 after outdoor exposure. The abrasion testing machine was a universal textile abrasion tester (CAT-125A; Daiei Kagaku Seiki Mfg. Co., Ltd.).

The cotton knit fabric thickness of three specimens was measured using a micrometer after outdoor exposure testing.

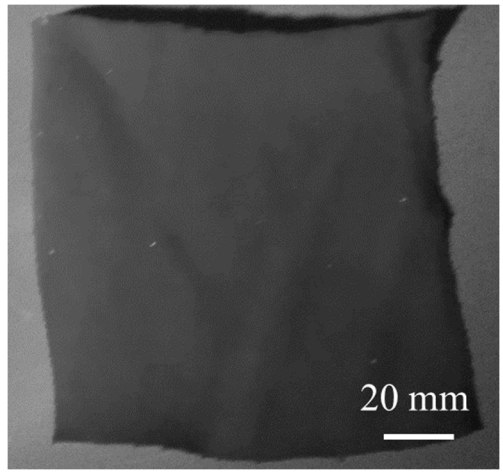
### 2.4 Ventilation resistance

After outdoor exposure, air permeability testing of three cotton knit fabric specimens was conducted based on JIS L 1096. The testing machine was an air permeability tester (KES-F8-AP1; Kato Tech Co., Ltd.).

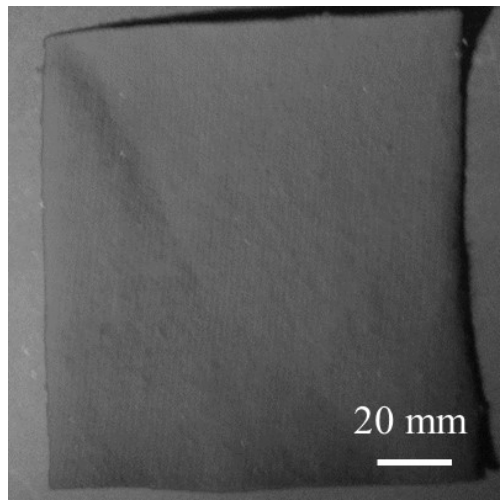
## 3 RESULTS AND DISCUSSION

### 3.1 Surface observation and thickness measurements

Fig. 2 portrays surfaces of blue and red cotton knit fabrics before outdoor exposure.



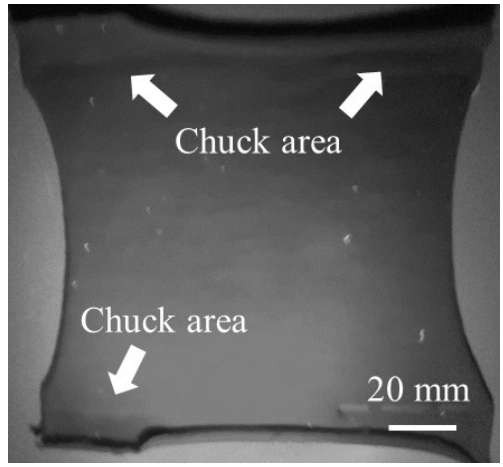

(a)



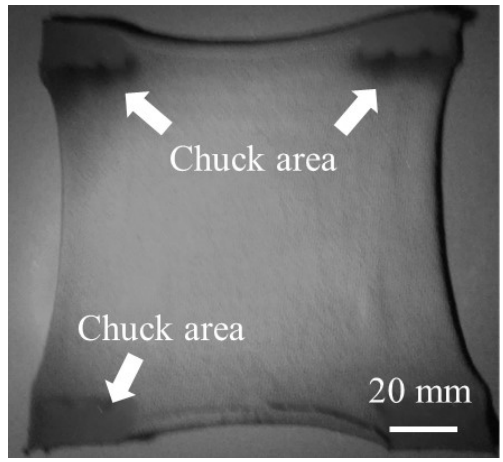

(b)

Figure 2: Surfaces of cotton knit fabrics at blue and red colours before outdoor exposure. (a) Blue; and (b) Red.

Fig. 3 shows surfaces of blue and red cotton knit fabrics after the 4-week test period. Almost no discolouration or damage of the cotton knit fabric surface was observable after the 4-week outdoor exposure test. However, shrinkage of all cotton knit fabric specimens had occurred during the 4-week test period. Shrinkage of all cotton knit fabrics probably occurred because of moisture absorption and desorption of the cotton fibres.




(a)




(b)

Figure 3: Surfaces of blue and red cotton knit fabrics after the 4-week test period. (a) Blue; and (b) Red.

Fig. 4 depicts blue and red cotton knit fabric thicknesses. During the test period, the red cotton knit fabric thickness increased with time. The blue cotton fabric thickness increased slightly during the 2-week test period. After the 4-week test period, the red cotton knit fabric thickness was greater than that of blue cotton knit fabric. Results show that the outdoor exposure environment slightly affected blue and red cotton knit fabric thicknesses.

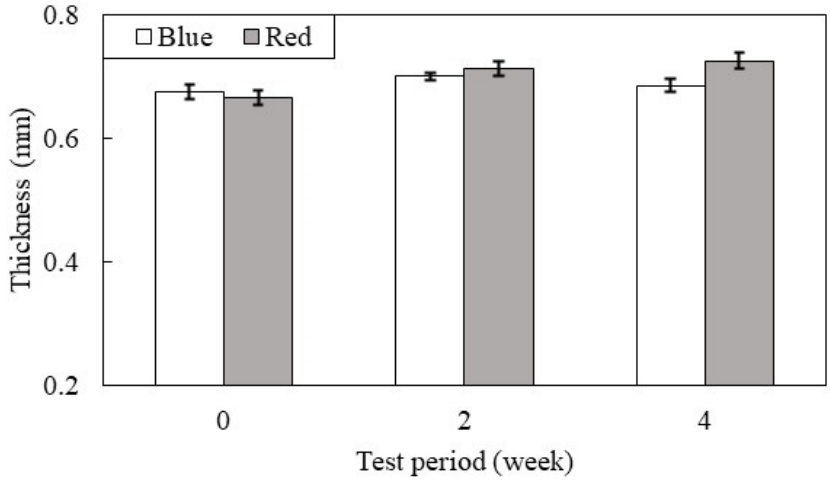



Figure 4: Cotton knit fabric thicknesses before and after outdoor exposure.

### 3.2 Ventilation resistance

Fig. 5 shows the ventilation resistance of blue and red cotton fabrics. Ventilation resistances of all cotton knit fabrics at the 2-week test period were greater than those of all cotton knit fabrics before outdoor exposure tests. Subsequently, the ventilation resistances of blue and red cotton knit fabrics remained almost unchanged. When outdoor exposure testing was conducted, the ventilation resistance of red cotton knit fabric became greater than that of the blue cotton knit fabric. The cotton fibre has cellulose, hemi-cellulose, lignin, and other components. The cellulose of the constituent material of cotton fibre has a hydroxyl group. Therefore, the knitting density of the cotton knit fabric probably affected the wet shrinkage of cotton knit fabric under exposure to light of these wavelengths.

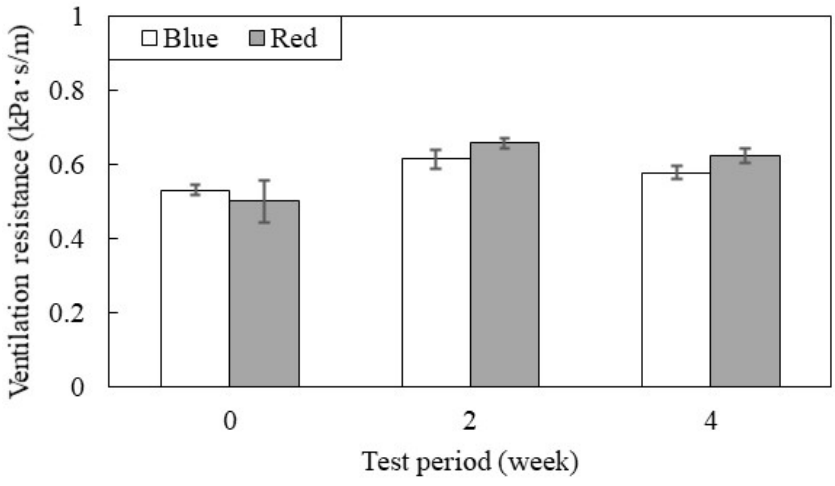



Figure 5: Ventilation resistances of cotton knit fabric before and after outdoor exposure.

### 3.3 Abrasion properties

Fig. 6 presents the abrasion properties of cotton knit fabrics before and after outdoor exposure testing. Before outdoor exposure testing, the numbers of cycles to failure of blue and red cotton knit fabrics were, respectively, 165 cycles and 149 cycles. The number of cycles to failure of all cotton fabrics at 2 weeks was greater than that of all cotton knit fabrics before outdoor exposure testing. Subsequently, the number of cycles to failure of all cotton fabrics remained almost unchanged with the test period duration. The cotton yarn tensile strength decreased with an increased test period during 100 h UV irradiation [21]. Generally, moisture absorption increases the tensile strength and elongation at breaking of the cotton fibre [22]. The cotton knit fabric abrasion properties were mainly affected by improvement of the fracture toughness and moisture absorbed fabric structure under outdoor exposure during the 2-week test period. To verify the abrasion mechanisms, future research must be conducted on the effects of the moisture environment on the fracture toughness and structural change of the cotton knit fabric.

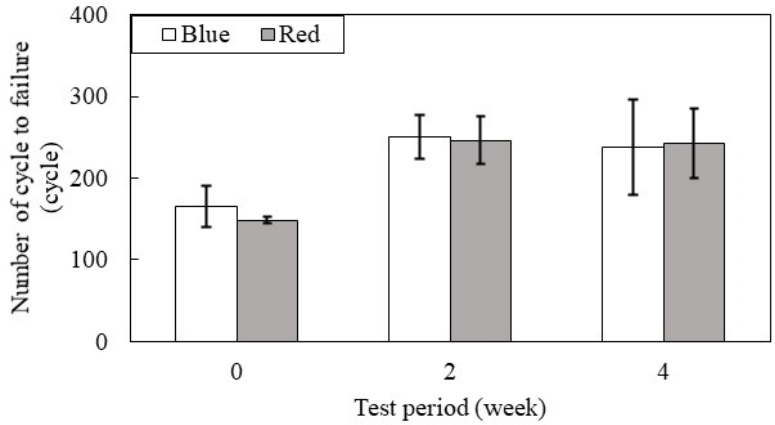



Figure 6: Abrasion properties of cotton knit fabric before and after outdoor exposure.

## 4 CONCLUSIONS

This study investigated the effects of short-term outdoor exposure on the abrasion properties of cotton knit fabric. The results indicate that the thickness and ventilation resistance of blue and red cotton knit fabric at colours increased slightly after a short-term outdoor exposure test. The number of cycles to failure of cotton knit fabric during outdoor exposure for the 2-week test period was greater than that of the cotton knit fabric before outdoor exposure testing. The number of cycles to failure of all cotton knit fabrics remained unchanged. The surface colour effects on the abrasion properties of cotton knit fabric were almost unchanged after short-term outdoor exposure testing. The results suggest that structural changes of the cotton knit fabric affected their abrasion properties during outdoor exposure.

## REFERENCES

[1] Grancarić, A.M. et al., Conductive polymers for smart textile applications. *Journal of Industrial Textiles*, **48**(3), pp. 612–642, 2018.

[2] Shi, J. et al., Smart textile – integrated microelectronic systems for wearable applications. *Advanced Materials*, **32**(5), p. 1901958, 2020.
[3] Niu, B., Yang, S., Hua, T., Tian, X. & Koo, M., Facile fabrication of highly conductive, waterproof, and washable e-textiles for wearable applications. *Nano Research*, **14**(4), pp. 1043–1052, 2021.
[4] Katogi, H., Uematsu, K., Shimamura, Y., Tohgo, K., Fujii, T. & Takemura, K., Fatigue property and fatigue damage accumulation of jute monofilament. *Journal of the Japan Society for Composite Materials*, **41**(1), pp. 25–32, 2015 (in Japanese).
[5] Katogi, H., Uematsu, K., Shimamura, Y., Tohgo, K., Fujii, T. & Takemura, K., Effect of cyclic frequency and time-dependent fracture on fatigue strength of jute monofilament. *Journal of the Japan Society for Composite Materials*, **41**(2), pp. 47–54, 2015 (in Japanese).
[6] Nagasaka, T., Takemura, K., Matsumoto, K. & Katogi, H., Mechanical properties of jute fiber using the heat treatment method. *WIT Transactions on the Built Environment*, vol. 196, WIT Press: Southampton and Boston, pp. 61–68, 2020.
[7] Katogi, H., Shimamura, Y., Tohgo, K., Fujii, T. & Takemura, K., Effect of matrix ductility on fatigue strength of unidirectional jute spun yarns impregnated with biodegradable plastics. *Advanced Composite Materials*, **27**(3), pp. 235–247, 2018.
[8] Takagi, H., Review of functional properties of natural fiber-reinforced polymer composites: thermal insulation, biodegradation and vibration damping properties. *Advanced Composite Materials*, **28**(5), pp. 525–543, 2019.
[9] Maruyama, S., Takagi, H. & Nakagaito, A.N., Influence of silane treatment on water absorption and mechanical properties of pla/short bamboo fiber-reinforced green composites. *WIT Transactions on the Engineering Sciences*, vol. 124, WIT Press: Southampton and Boston, pp. 101–107, 2019.
[10] Mahdi, E. & Dean, A., The effect of filler content on the tensile behavior of polypropylene/cotton fiber and poly (vinyl chloride)/cotton fiber composites. *Materials*, **13**(3), p. 753, 2020.
[11] Morris, R.H. et al., Woven natural fibre reinforced composite materials for medical imaging. *Materials*, **13**(7), p. 1684, 2020.
[12] Chokshi, S., Gohil, P. & Patel, D., Experimental investigations of bamboo, cotton and viscose rayon fiber reinforced unidirectional composites. *Materials Today: Proceedings*, **28**, pp. 498–503, 2020.
[13] Ray, R., Das, S.N., Mohapatra, A. & Das, H.C., Comprehensive characterization of a novel natural bauhinia vahlii stem fiber. *Polymer Composites*, **41**(9), pp. 3807–3816, 2020.
[14] Madireddi, S., Aditya, K. & Hussain, S.A., Effect of combination of fabric material layers in reducing air pollution. *Materials Today: Proceedings*, **31**, pp. S197–S200, 2020.
[15] Xu, Q., Shen, L., Duan, P., Zhang, L., Fu, F. & Liu, X., Superhydrophobic cotton fabric with excellent healability fabricated by the “grafting to” method using a diblock copolymer mist. *Chemical Engineering Journal*, **379**, p. 122401, 2020.
[16] Mahmud, S., Pervez, N., Muhammad A.T., Mohiuddin, K. & Liu, H.H., Multifunctional organic cotton fabric based on silver nanoparticles green synthesized from sodium alginate. *Textile Research Journal*, **90**(11–12), pp. 1224–1236, 2020.
[17] Avadí, A., Marcin, M., Biard, Y., Renou, A., Gourlot, J.P. & Basset-Mens, C., Life cycle assessment of organic and conventional non-Bt cotton products from Mali. *The International Journal of Life Cycle Assessment*, **25**(4), pp. 678–697, 2020.

[18] Magovac, E., Jordanov, I., Grunlan, J.C. & Bischof, S., Environmentally benign phytic acid-based multilayer coating for flame retardant cotton. *Materials*, **13**(23), p. 5492, 2020.
[19] Tania, I.S. & Ali, M., Effect of the coating of zinc oxide (ZnO) nanoparticles with binder on the functional and mechanical properties of cotton fabric. *Materials Today: Proceedings*, **38**(5), pp. 2607–2611, 2020.
[20] Zhao, Z., Cai, W., Song, L., Mu, X. & Hu, Y., Comprehensive property investigation of mold inhibitor treated raw cotton and ramie fabric. *Materials*, **13**(5), p. 1105, 2020.
[21] Kikuchi, Y., Saito, M. & Kashiwagi M., Photodeterioration of silk and cotton. *Journal of Home Economics of Japan*, **38**(1), pp. 33–38, 1987 (in Japanese).
[22] Nakao, T. & Tsujim W., Restoration of hydrophilicity of field-opened cotton fibers by cyanoethylation treatment. *Sen'i Gakkaishi*, **52**(8), pp. 412–416, 1996 (in Japanese).