Novel Stretchable Textile-Based Transmission Bands: Electrical Performance and Appearance after Abrasion/Laundering, and Wearability

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Abstract. In this paper, we (1) compare the electrical performances and appearance changes of two textile-based transmission bands after repeated abrasion and laundering, and (2) evaluate their wearability with MP3 player jackets. The bands were made with non-stretchable Teflon-coated stainless steel yarns, or stretchable silicon-coated stainless steel yarns and spandex. The electrical resistance of the bands after repeated abrasion and laundering was measured with a RCL (resistance capacitance inductance) meter. The appearance changes were observed using a digital microscope. For wear tests, five subjects evaluated the degree of convenience while doing specific actions and other wear sensations using questionnaires with a 7-point Likert-type scale. Both non-stretchable and stretchable transmission bands were evaluated as excellent on electrical performances. Appearance changes after abrasion were tolerable, and there were neither exposure nor disconnection of stainless steel yarns. Convenience and other wear sensations for the MP3 player jacket using stretchable silicon-coated bands were evaluated as better than non-stretchable Teflon-coated bands.

Keywords: stretchable textile-based transmission band, silicon-coated stainless steel multifilament yarn, abrasion, laundering, electrical resistance, image analysis, MP3 player jacket, wear sensation.

1 Introduction

A typical smart clothing system comprises five basic functions–interaction, communication, energy supply, data management, and processing–and textile-based transmission lines are an effective solution for the communication component [1]. Textile-based transmission lines functioning in smart clothing like flat cables in standard electronic devices are e-textiles. They integrate the functions of electric components and the characteristics of woven fabrics. Thus, the properties of both domains should be considered when developing e-textiles.

Early textile-based transmission bands generally use metallic multifilament yarns covered with regular threads as signal transmission lines [2, 3, 4]. This structure poses problems for safety and operation, such as the risk of causing interferences between neighboring lines during use and the deterioration of electric insulation. As a solution,

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we had developed a textile-based transmission band using Teflon-coated stainless steel multifilament yarns. The physical and electrical performances of the band were improved [5].

Until now, research about textile-based transmission bands focused on verifying the stability of signal transmission, preventing interferences between neighboring lines, and improving the durability in physical and electrical aspects [5, 6, 7, 8]. However, to commercialize textile-based transmission bands, wearability as well as physical and electrical performances must be satisfactory.

When we used preexisting textile-based transmission bands to develop smart clothing, we had to use bands longer than the actual length because it was not elastic, in order to allow the wearer's body movements. Accordingly, we need to develop a textile-based transmission band with elasticity that makes the wearer's movements comfortable without using additional length. Preexisting textile-based transmission bands using Teflon-coated stainless steel multifilament yarns were too rigid to bend them into curvy shapes for stretchable construction. Therefore, we developed a new type of textile-based transmission line using silicon-coated stainless steel multifilament yarns, described hereafter.

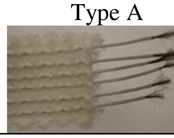
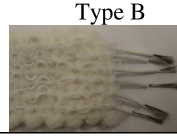
2 Experiments

This study was carried out in two phases. One was investigating the electrical resistance and appearance changes of two band types after abrasion and laundering. The other was evaluating the wearability of MP3 player jackets using the two types of bands for electrical signal transmission.

2.1 Phase I: Electrical Performance and Appearance

Specimen. The textile-based transmission bands were woven with yarns of polyester filaments. When weaving, six strands of signal transmission lines were placed 2.55mm from each other in the warp direction of the band, and the width of the band was set at 19mm to allow easy connections with regular connectors. Two types of signal transmission lines were used to manufacture the bands. The characteristics of the bands are shown in Table 1. Type B was stretchable whereas Type A was

Table 1. Characteristics of Specimen

		Type A	Type B
			
Base yarn		100% Polyester filament	100% Polyester filament
Conductive yarn	Material	100% stainless steel filament	100% stainless steel filament
	Yarn size	ø= 63㎛, 20 filaments	ø = 11㎛, 180 filaments
	Yarn coating	Teflon-coating: Wall thickness 0.18mm Outer diameter 0.7mm	Silicon-coating: wall thickness 0.20mm, Outer diameter 0.7mm

non-stretchable. To make the stretchable textile-based transmission band, coated stainless steel yarns were curled then wrapped with spandex yarns to fix the curling so that the band remains stretchable despite repeated extension and contractions.

Abrasion Tests. To evaluate the abrasion durability of the bands, we used equipment and procedures recommended for general textile evaluation standards. The bands were tested following the Inflated diaphragm method (ASTM D3786) [9] using a Universal Textile Abrasion Tester (Intec Co. LTD., SEC. 28 NO. AR-1). The abrasion repetitions were selected at 500, 1.000, and 1.500 cycles, and the test was repeated three times for each type of sample. The test was conducted by the KATRI (Korea Apparel Testing & Research Institute) [10].

Laundering Tests. We laundered the bands up to 10 times using a drum washer (Samsung, SEW-5HR120) with 30 RPM, water temperature at 20℃, and 70g of detergent for 5Kg of total laundry weight with dummies according to the testing conditions of ISO 6330 [11]. A single washing cycle consisted of 15min. washing, 13min. rinsing, and 13min. spin-drying.

Measurement of Electrical Resistances. For electrical performances, we measured the electrical resistances of the bands that went through abrasion and laundering. We verified whether the electrical resistance of the transmission lines was maintained after the treatments using a RCL meter (Fluke, PM6304). Checking the six strands of the transmission lines within the band, we measured the resistance of each line and averaged the results, stated in Ω/cm.

Image Analysis. The appearance of the bands before and after abrasion and laundering were observed with a digital microscope (ANMO, AM-311S) with 10 times magnification.

2.2 Phase II: Wearability Test

Clothing Prototype. Two identical MP3 player jackets were prepared with different textile-based transmission lines. As shown in Fig. 1, textile-based transmission bands were used in this clothing to connect a textile-based keypad placed in the left sleeve to a MP3 Player in the left inner pocket.

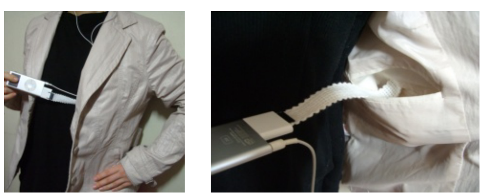


Fig. 1. MP3 Player Jacket and Inner Pocket of the Jacket

Subjects. We selected five female university students aged 25 to 28 year old as subjects. They had similar body sizes and were in the Korean standard size range.

Wear sensation measurements. To evaluate according to the type of textile-based transmission line, the two clothes were presented to the subjects in random order. They estimated convenience of action, feeling the presence of the MP3 player and band, hardness, and overall satisfaction for each cloth. The questionnaire consisted of 6 questions using a 7-point Likert-type scale. Convenience was evaluated with three questions about representative actions for MP3 player jackets: connecting the MP3 player to a band, putting the MP3 player in and out the inner pocket of the jacket. Three questions about annoyance notably due to feeling the presence of the system, about its hardness, and about the overall sensation were developed in a previous study [12].

3 Results and Discussion

3.1 Changes of Electrical Resistance after Abrasion and Laundering

When we examined the effect of abrasion and laundering on electrical resistance, the bands appeared excellent before and after physical stress. As shown in Fig. 2 and 3, the electrical resistance of Type A and B were very low, revealing that electric current was flowing well even after abrasion and laundering were applied to the bands.

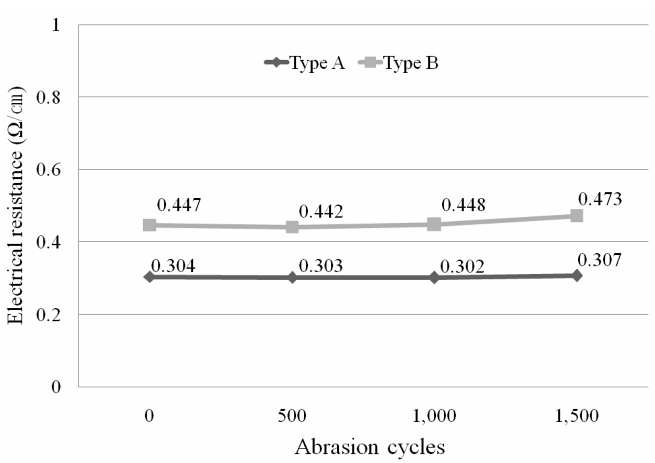


Fig. 2. Electrical Resistance Before and After Abrasion

Thus, the two types of textile-based transmission bands maintained their conductivity and showed excellent electrical durability. Therefore, both Teflon and silicon-coated stainless steel multifilament yarns can be used as signal transmission lines.

As we used Teflon-coated stainless steel multifilament yarns and silicon-coated stainless steel multifilament yarns manufactured by companies and commercially available, the electrical resistance of Type A and B differ.

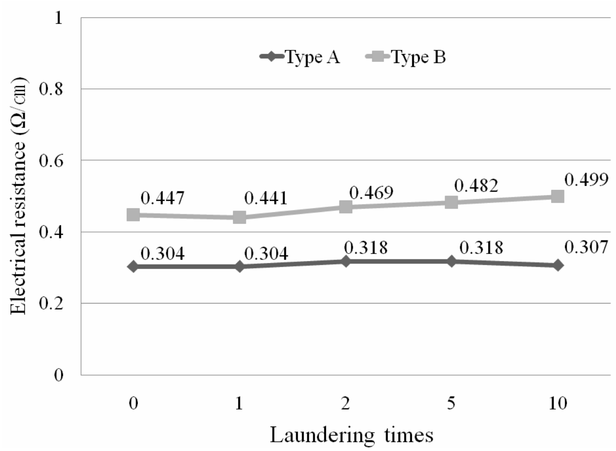


Fig. 3. Electrical Resistances Before and After Laundering

3.2 Appearance Changes after Abrasion and Laundering

The appearances of bands before and after abrasion are presented in Table 2. After repeated abrasion, there was neither stainless steel yarn exposure outside the Teflon and silicon coating nor disconnection for both types of bands. However, there was an increasing rate of transmission lines outside the band, and the base polyester fabric partly disconnected as the abrasion cycles increased. Even though disconnection of the polyester fabric doesn't influence electrical performances, it can be influence wear sensation. Therefore, manufacturing methods fixing the transmission lines tightly to the base fabric must be developed.

Both types of coated transmission lines remained unexposed outside the polyester fabric after laundering. As shown in Table 3, Type A had almost the same appearance before and after washing. Although the curvy shape of Type B became irregular and the edge of the bands slightly shrunk, its appearance barely differed after washing.

Table 2. Microscopic Images Before and After Abrasion

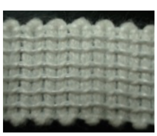
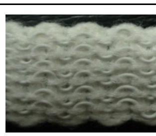
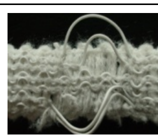
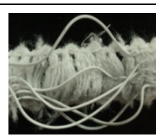
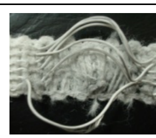
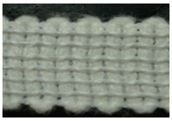
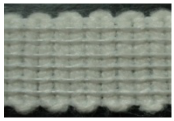
	Before abrasion	Abrasion cycles		
		500	1,000	1,500
Type A				
Type B				

Table 3. Microscopic Images Before and After Laundering

Type A		Type B	
Before Laundering	Laundered 10 times	Before Laundering	Laundered 10 times
			

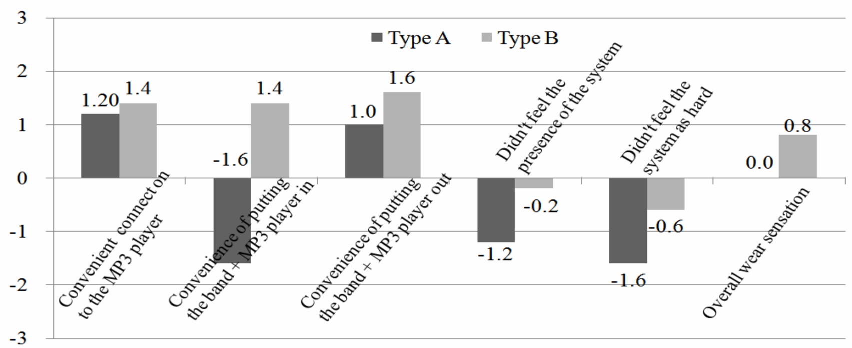


Fig. 4. Wearability Evaluation of an MP3 Player Jacket According to Band Types

3.3 Wearability

The result of the wearability evaluations is shown in Fig. 4. Both the Teflon-coated textile-based transmission line (Type A) and silicon-coated line (Type B) were estimated convenient to connect the MP3 player (1.2; 1.4). Four of the five subjects gave the same score to Type A and B for this action. Therefore, the convenience of connecting an MP3 player to the band was barely influenced by the elasticity of the textile-based transmission band.

Type A was evaluated less convenient than Type B, to put the MP3 player in (-1.6; 1.04) and out (1.0; 1.6) inner pocket of the jacket. Putting the band into the pocket was evaluated especially uncomfortable for Type A. We suppose that because Type A was non-stretchable and rigid, the band could not be easily moved into the pocket, on the contrary to Type B.

When wearing the MP3 player jacket, all subjects felt annoyance due to feeling the presence of the system (-1.2; -0.2) and hardness (-1.6; -0.6) regardless of the band type. However, the jacket using Type A was evaluated more negatively than the one using Type B. Silicon-coated transmission lines used in Type B bands were soft and stretchable, in contrast, Teflon- coated ones used in Type A were rigid and non-stretchable. Therefore, when putting the Type A band into the pocket, the volume of the inner pocket increased. It means that a wearer feels not only the MP3 player, but also additional annoyance because of the band. It makes the wearer significantly feel the presence of the system and hardness. However, the overall wear sensation was not evaluated negatively (0.0; 0.8). It means that this kind of sensation was not enough to make subjects uncomfortable.

In conclusion, the jacket using the Type B band for signal transmission was evaluated as more convenient and superior regarding wearablity. Therefore, to improve the wearability of an MP3 player jacket, it is more efficient to use the stretchable textile-based transmission band. Moreover, using soft and flexible materials such as silicon to make stretchable structure also improves wearability.

4 Conclusions

In this study, we developed stretchable textile-based transmission bands using silicon-coated stainless steel multifilament yarns to improve the wearability of smart clothing. The results of changes in appearance of Teflon-coated transmission lines and silicon-coated transmission lines both based on polyester fabric before and after abrasion and laundering, showed no exposure and disconnection of stainless steel yarns. In addition, electrical resistance was perfectly maintained in both types of bands. We proved that the electrical performances and abrasion and laundering durability of silicon-coated transmission lines are as good as Teflon-coated lines, even though silicon coating is soft and flexible.

The results of convenience and wearablity of MP3 player jackets using non-stretchable transmission bands based on Teflon-coated stainless steel yarns and stretchable bands based on silicon-coated stainless steel yarns showed that the stretchable band was more convenient and comfortable. Therefore, we developed better signal transmission lines that possess good physical durability and electrical performances as well as improved wearability.

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