TEXTILE SENSOR FOR CUT AND STAB DETECTION

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Abstract

Protective clothes with bullet, stab and cut resistance can be produced with tear-resistant fibers like aramid or high molecular weight polyethylene (UHMW-PE). Recently, a cardigan with stab resistant inlay was developed by Bache Modeland in cooperation with the Research Institute for Textile and Clothing (FTB). [1] This cardigan offers protection against attacks with knives and blades. The inlay consists of multiple layers of knitted fabrics. The construction of the knitted fabric as well as the selection of a specific UHMW-PE fiber leads to a certain stab resistance. A person wearing the cardigan will not be injured by a blade when stabbed, however the possibility of injury due to blunt trauma remains.

Introduction

In the last years, the violent tendency against taxi and bus drivers and conductors is growing in the society. The uniform becomes a target. [2] Furthermore persons working in public services such as labor offices and schools are endangered groups. Also staff of security services is endangered to become a victim of stabbing attacks.

This research focuses on the development of a sensor for stab detection. One possible style is based on the change of resistance after a stab or cut event.

Experimental

In this work, a sensor for the detection of cuts and pressure was developed and integrated into the inlay of the stab resistant cardigan. Three possibilities were evaluated:

- Cardigan inlay with an integrated sensor with a meander of conductive yarn knitted into the fabric
- Inlay with a printed sensor (circuit printed with conductive ink)
- Combination of knitting and printing

For the integrated sensor conductive yarns were evaluated. Important points were knitting feasibility, conductivity before and after the knitting process and the stab resistance. Therefore different yarns were investigated: steel staple fibers, silver coated yarns (Shieldex®), Bekinox, Amberstrand (Ag and Ni)). Additionally several construction types were investigated.

The printing was performed with a conductive carbon dispersion. It was printed in meanders on the fabric. The abrasion of the prints was evaluated with the Martindale method in accordance with the specification DIN EN ISO 12947-1:2007-04. Also the washing fastness of the knitted structures was investigated after three washing cycles.

Results and Discussion

First of all the resistivity of all used yarns was determined. Shieldex®-yarn was available in two degrees of fineness and with and without an insulating polyurethane (TPU) coating. The results are given in ***Table 1***.

Table 1: Investigated conductive yarns for cut detection

Material	**resistance [Ohm/m]**
Shieldex 235/34 2-ply HC+B	115
Shieldex 117/17 2-ply HC+B	190
Shieldex 235/34 2-ply HC+B with TPU coating	10^6 (after removing TPU-coating)
Shieldex 117/17 2-ply HC+B with TPU coating	10^6 (after removing TPU-coating)
Stahl-Stapelfaser	3700
Amberstrand 166-Ag	3,5
Amberstrand 166-Ni	3,25
Bekinox VN 12	32

With these yarns knitted structures were produced. Because of the uninsulated yarns, the stitch rows must not touch each other to avoid short circuits. The main challenge was the avoiding of broken yarns during the process, which put a high strain on the yarn surface and could therefore decrease the conductibility.

Rub fastness

The rub fastness was determined by abrasion tests with the Martindale method. The conductivity of knitted yarns was not influenced by abrasion tests and the TPU coating of the Shieldex® yarns was abraded. Also the stability of the stitches was not changed after 5,000 cycles.

Coating and prints with carbon ink are more conductive after 5,000 Martindale-cycles, whereas the conductivity of PEDOT:PSS is lower than before the abrasion tests (see Table 2). The better conductivity of carbon ink can be explained by removing a passive top, exposing the conductive carbon particles on the top (see Image 1).

Image 1: meander of printed carbon in after 5,000 Martindale cycles.

Table 2: Abrasion of conductive prints

sample	**R [Ohm] before abrasion**	**R [Ohm] after 5,000 Martindale**
printed meander with carbon ink	100	90
coating with PEDOT:PSS (Shieldex® als Mäander eingehängt)	58	2500
coating with carbon ink (Shieldex als Mäander eingehängt)	32	30
coating with PEDOT:PSS (with knitted Shieldex®)	110	175
coating Tubicoat ELH (with knitted Shieldex®)	79	65

Washing fastness

The washing fastness of knitted fabrics with conductive yarns was investigated. This can easily be observed on the example of a knitted tube fabric, which is shown in Table 3. The length of the Shieldex yarns in a fabric of 690 cm² was about 5 m. It embedded in a tube in form of a meander.

Table 3: Washing fastness of knitted tube fabrics

with Shieldex 117/17 2-ply HC+B		
	size [cm]	electrical resistance [Ohm]
before washing	30x23	789
after 1 washing	29x23	806
after 2 washings	29x23	896
after 3 washings	28x23	1150
with Shieldex 235/34 2-ply HC+B		
	size [cm]	electrical resistance [Ohm]
before washing	29,5x23	600
after 1 washing	28,5x23	713
after 2 washings	28,5x23	913
after 3 washings	28x23	1810

Both fabrics shrink slightly after the washing cycles; the resistance of the embedded conductive yarns is reduced.

Conclusions

The change of electrical properties after mechanical stress and washings must be taken in account, when a sensor for stab detection is produced. Therefore the sensor must be recalibrated after each washing.

Summary

In all cases the sensor registers a change of resistance in the circuit and triggers an alarm. Another approach is the registration of capacitance change. Therefore, small capacitors were integrated in the fabric, either by knitting or printing. With this method pressure changes can be detected even when the resistivity sensor is not activated.

Acknowledgements

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Literature

1. Marcus O. Weber, Susanne Aumann, Andrea Brücken, Andrea Ehrmann, Thorsten Bache, Sina Christin Beck, Stab resistant knitted clothing, Proceedings of the 8th Aachen Dresden International Textile Conference, Dresden 27.-28. November 2014
2. Naima Wolfsperger, Wenn die Uniform zur Angriffsfläche wird, Aachener Nachrichten, Aachen 11. April 2015