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EXPERIMENTAL ABRASION ANALYSIS OF TEXTILE CAPACITIVE SENSORS

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ABSTRACT

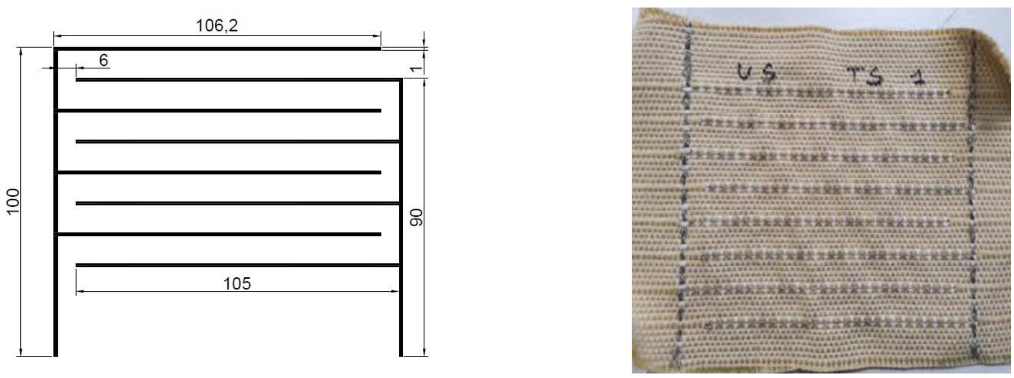
This paper presents an experimental abrasion analysis of textile capacitive sensors based on Martindale test. The textile sensor is manufactured with a well-known woven technology where some yarns are replaced by electrical conductive yarn. Specifically, two types of conductive yarns were used to compare the abrasion behaviour respect to conventional fabrics and the impact of abrasion on sensors functionality. The results show that the integration of conductive yarn on fabric don't reduce the fabric lifetime and moreover the sensing behaviour remains unalterable during the lifetime of the textile.

KEYWORDS

Smart-textile, sensor, textile, woven, abrasion, Martindale.

MATERIALS AND METHODS

The sensors under test are based on an interdigitated structure manufactured by means of woven technology, which improves the usability and comfort, when in contact with human skin, in comparison with another textile technology previously used, such us embroidered [1]. The sensor is manufactured with a combination of electrical conductive and non-conductive yarns. To produce the sensor, a Dornier LWV8/J 71 weaving machine moved by a Jacquard Stäubli LX1600B was set up to produce plain weave fabric. Warps beam were formed by 100% cotton yarns and weft yarns were polyester/cotton yarns produced with a proportion of 35/65%, respectively (Figure 1).



a) Sensor dimensions (mm) b) Sensor manufactured prototype

Figure 1. Interdigital geometry.

To integrate the sensor on the plain weave structure, two type of conductive yarns were used and analysed during the process; Shieldex 117/17 2-ply and Bekaert 20/2 Tex. Each yarn was produced by different processes. Shieldex yarn is based on a silver coating covering a polyamide filament, whereas Bekaert yarn was produced by mixing polyester and stainless-steel fibres with a 60/40% proportion, respectively.

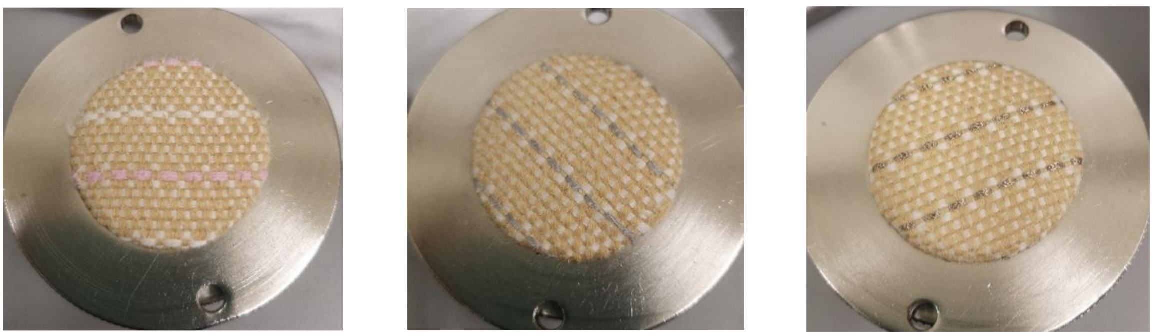
To analyse the impact of abrasion on sensor functionality, Martindale abrasion test was performed with the manufactured sensors (Figure 2). The test consists on the abrasion of the fabric under test against a normalized abrasive fabric. The force applied during the movement is determined by the EN ISO 12947-2:2016 [2], which determines that for upholstery fabric the weight used is (795±7) g. The movement performed by Martindale follows a Lissajous curve pattern. The fabric physical state and the properties of the measured conductive yarn are verified periodically after each step of the Martindale test, Table 1. The test is finished when more than three yarns are broken or conductive yarns lost completely their electrical continuity (i.e. resistance lower than 50 Ω).

Table 1. Frequency of Martindale evaluations steps from standard EN ISO 12947-2:2016.

Interval (nº cycles)	Martindale evaluation step (nº cycles)
1000-6000	1000
6000-20000	2000
20000-50000	5000
+50000	10000

Figure 2. Martindale machine performing a test.

Three different samples are prepared for the Martindale test: the substrate fabric without any conductive yarns, using conductive Bekaert yarns and using conductive Shieldex yarns integrated on it. The electrical conductivity of the conductive yarn was evaluated with a Multimeter Tenma 88 72-7730A after each Martindale evaluation step. The section of fabric under test is taken from the middle part of the sensor and consists of a circular section with diameter of 38 mm as shown in Figure 3.



a) b) c)

Figure 3. Samples initial state: a) non-conductive sample, b) Bekaert, c) Shieldex.

RESULTS AND DISCUSSION

During the first Martindale interval (up to 6000 cycles), the samples do not show any alteration, the electrical properties remain constant and the physical aspect do not have signs of wear out. However, at the end of the second Martindale interval (i.e. 20000 cycles) some wear out effects are observed (Figure 4). Specifically, the sample with normal yarns presents pilling which is not observed on the samples with the conductive yarn. From the electrical point of view, the conductive yarns do not lose their electrical continuity.

a) b) c)

Figure 4. Samples after 20.000 cycles: a) non-conductive sample, b) Bekaert, c) Shieldex.

At the third Martindale interval the conductive samples do not lose the continuity up to 35.000 cycle. However, after 40.000 cycle the electrical continuity is lost. Figure 5 shows the state of the samples after 40.000 cycles. It is observed an important wear out; the samples show pilling around all the surface. Broken yarns can be found on non-conductive sample but not on both conductive samples.

a) b) c)

Figure 5. Samples after 40.000 cycles: a) non-conductive sample, b) Bekaert, c) Shieldex.

With regard to electrical properties, both electrical samples decrease the electrical conductivity. However, this reduction on the electrical conductivity is not the same on each sample. In Bekaert the resistance increases from 16 Ω/cm up to 120 Ω/cm whereas in Shieldex it increases from 0.7 Ω/cm up to 200 Ω/cm. Results are summarized in Table 2.

Table 2. Comparison between electrical properties before and after the Martindale test.

	Bekaert		**Shieldex**	
	Initial	**35k cycles**	**Initial**	**35k cycles**
Resistance (Ω/cm)	16	<120	0.7	<200

The resistance rise on Bekaert yarn can be due to loss of weight which includes some conductive fibres (stainless-steel fibres). In case of Shieldex yarn, the resistance rise is due to the loss of silver coating. Despite of the resistance rise, it should be notice that sensor preserves its functionality.

CONCLUSION

Martindale test was performed to analyse the abrasion effects on woven textile capacitive sensors with two type of conductive yarns. The results show that the integration of conductive yarn reduces the pilling effect on the fabric. Moreover, any yarn is broken on conductive sample up to 40000 cycle, meanwhile some broken yarns are observed on non-conductive yarns. The electrical properties are being affected by the abrasion on conductive samples. Depending on the conductive yarn manufacture process, the electrical resistance increases after applying the abrasion test. In case of Bekaert yarns, the resistance increases due to the loss of conductive fibres and in case of Shieldex it is due to silver coating reduction. In both cases, however, the functionality of the sensor is preserved. This fact denotes that the integration of conductive yarn on fabrics do not affect negatively on the fabric properties and guarantees the sensor functionality during the fabric lifetime. The properties described denote the possibility to use the sensors into applications as upholstery where previously abrasion resistance could be a drawback.

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