Mechanical Characterization of Low-Cost Piezoresistive Fabrics for Sensors Design

Student: Matteo Piratoni

Biomedical Engineering, Master level, Department of Civil and Industrial Engineering,
Sapienza University of Rome, Italy
piratoni.1960645@studenti.uniroma1.it

Mentors: Ilaria Mileti [1], Gennaro Ponticelli [1], Eduardo Palermo [2]

[1] Department of Engineering, Niccolò Cusano University, Rome, Italy
[2] Department of Mechanical and Aerospace Engineering, Sapienza University of Rome, Italy
{ilaria.mileti, gennaro.ponticelli}@unicusano.it, eduardo.palermo@uniroma1.it

Abstract. *Thanks to their intrinsic properties of stretchability, flexibility and lightweight, wearable piezoresistive sensors are remarkable devices to capture physiological parameters and joint motion monitoring. Many sensors' designs were evaluated since the discover of piezoresistivity but repeatability and hysteresis persist to be the most crucial parameters. The aim of the study is to characterize conventional low-cost sheets of piezoresistive fabrics in terms of mechanical properties. We laser cut two types of conductive sheets (Eeontex and Velostat) in according to ASTM D882 and tested them with a tensile machine (MTS Insight Electromechanical 50 kN). Differences between two orthogonal directions of the same fabric in break stress, elongation and Young's modulus was statistically evaluated with a t-test.*

Keywords. Wearable sensors, piezoresistive, low-cost, tensile test, statistics

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1 Introduction

In the past years, wearable devices held great significance in several areas, such as rehabilitation, clinical evaluation and sports [1]. The exploration of smart fabric interfaces offers the opportunity to integrate wearable technology into daily life and access data generated by the body. The ability to connect ordinary objects and obtain data from them in real time has the potential to increase and improve decision making. Sensors are the main element of wearable technology. Wearable sensors based on the detection of small changes in resistance are universally recognized as piezoresistive. The most used piezoresistive textile are typically carbon filled Low Density Polyethylene (LDPE) [2]. Polymerized conductive silicon treated with high temperature is also used for such sensors [3]. However, the fabrics that seems to be more promising in terms of sensitivity, hysteresis and responsiveness are the sheets made by *Eeonyx* [4].

2 Background and Motivation

Smart textile sensors can rely on several configurations but the most common and used ones are sandwich or multilayer and machine sewn. The first class is based on piezoresistive sheet placed between two layers of conductive elements and it's the simplest one. Knitting conductive yarns with elastic ones is a solution but textile equipment is required, and they are more expensive. Recent studies pushed the upper limit by developing weft-knitted sensors capable of reaching extremely low hysteresis values [5]. Sewing multiple conductive threads was used to develop multilayer matrix structure, confirming that hysteresis is the main drawback of piezoresistive soft materials [6]. Simplest and low-cost sensors were investigated for real time pressure sensing profiles in prosthetic socket [7], and wearable tactile dataglove [8]. Stretchable wearable sensors can also be used to measure human body joint kinematics [9], or to detect inappropriate sitting posture [10]. In sports applications, design and size are crucial and the responsiveness of this fabrics to sweat is something to evaluate [11]. It's clear that the main problematics of low-cost multilayer sensors is their hysteresis and repeatability. Despite the high research interest in this type of sensors, there's still no exhaustive study on the mechanical characterization of these smart fabrics. A more in-depth analysis of the mechanical characteristics of these piezoresistive materials may be necessary for the improvement of the performance of textile sensors. Attaching and combining different sheets to make a reliable device needs to be supported by a well-defined evaluation of their properties. In this paper two different types of piezoresistive fabrics were tested, by cutting them with laser along two directions and by pulling them with a tensile machine. Ensuring the highest reliability and repeatability, the samples were compared in terms of break stress, elongation and Young's modulus.

3 Materials, Methods and Preliminary Results

We studied and compared two types of piezoresistive sheets of fabrics, both low-cost (around 10 € for a 30 x 30 cm^2). The first one is called Eeontex NW170-PI-20 and it is composed of a filament blend of polyester and nylon 6 (70/30), 0,8 mm thick. The second one is called Velostat and it is a carbon filled polyethylene, 0,1 mm thick. A laser cutting machine (SnapMaker Original 1,6 mW*)* was used to ensure the highest repeatability of the samples. Preliminary cutting tests were made to define the suitable parameters for the laser cutting process. Eeontex was cut with 100 mm/min work speed, 50 % of max power with three passes. Velostat was cut with 550 mm/min work speed, 75 % of max power with one pass. For both materials the original design was 5 x 120 mm^2. For the tensile test we used MTS Insight Electromechanical 50 kN and we observed ASTM-D882 (Figure 1a). Unlike Eeontex samples, Velostat ones were tested considering PLA plates to improve grasping. In fact, in preliminary tests, the gripping of the Velostat to the machine showed slipping phenomena and tears near the hangers (Figure 1b), making the tests not compliant with the standards. The width of the samples was also doubled (from 5 to 10 mm) to avoid grip issues. Break stress, elongation and Young's modulus were acquired from five samples per direction of cut. For Eeontex, it is possible to define a wale and a course direction. As it is not possible to give the same definition for Velostat, the two directions will be defined: direction 1 and direction 2 (Figure 2). Wale and course are orthogonal as well as direction 1 and direction 2. To assess differences in mechanical characteristics of fabrics, unpaired t-tests were conducted between directions. For both fabrics there's a significant difference between values of Young's modulus. Eeontex shows differences in direction also for the Elongation parameter. In addition, it is evident from Figure 2 that there is a difference between Velostat and Eeontex for all parameters reported.

a

b

Figure 1. a) Velostat during the tensile test with PLA plates. b) Tears appeared after the test without PLA plates in 3 samples with different width.

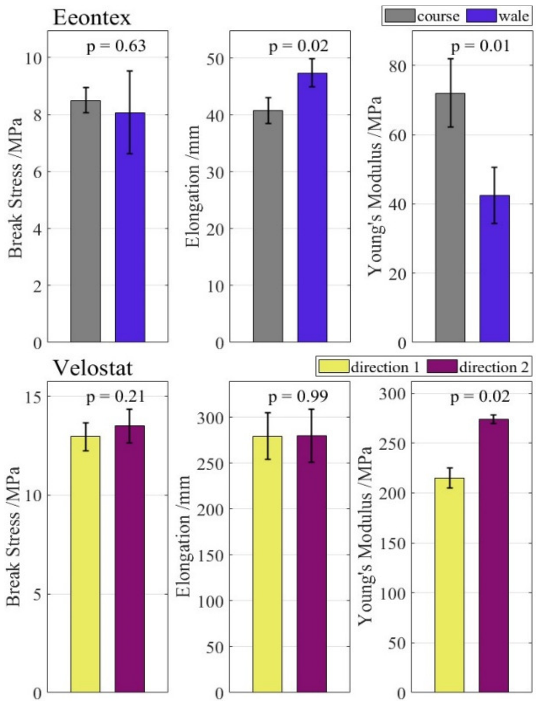

Figure 2. Statistic test results for Eeontex and Velostat.

4 Conclusions

Piezoresistive sheets of Eeontex and Velostat were evaluated with a tensile test for improving future sensors' design. The testing technique has reported problems regarding Velostat and needs to be improved in terms of grip with the hangers. Although on a small sample of material, preliminary results showed a difference between the two types of material and between the directions of weaving. Preliminary results are nevertheless shown to be interesting in terms of differences between Young's modulus: for Eeontex the value is almost doubled between directions. Future developments will aim to validate this result on a larger sample set, refine the test technique and verify the relevance of the design directions of textile-based wearable sensors.

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