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► **To cite this version:**

Thibault Dormois, Cédric Cochrane, Vladan Koncar. Printed Piezoresistive Sensors for Measuring Elongation Of Parachute Canopy Fabric and Ribbons. ITMC 2024, Nov 2024, Ueda, Japan. <hal-04831311>

**HAL Id: hal-04831311**

**<https://lilloa.hal.science/hal-04831311v1>**

Submitted on 11 Dec 2024

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P-9

### Printed Piezoresistive Sensors for Measuring Elongation Of Parachute Canopy Fabric and Ribbons

Thibault DORMOIS<sup>1,\*</sup>, Cédric COCHRANE<sup>1</sup>, and Vladan KONCAR<sup>1</sup>

<sup>1</sup>Univ.Lille, ENSAIT ULR 2461-GEMTEX–Génie et Matériaux Textiles, F-59000 Lille,  
France

\* thibault.dormois@ensait.fr

**Keywords:** Smart Textiles, Parachute Canopy, Piezoresistive Sensors, Strain Measurement

**Abstract:** Canopies and parachute lines experience high stresses during the opening phase. The study aims to measure the strain on these components to enhance our understanding of these materials and their life span. To avoid altering the parachute structure and affecting data accuracy, measurements are conducted non-intrusively. This necessitates designing and implementing a discreet and robust interface between sensors and textiles. Additionally, this project involves developing an electronic measurement device capable of recording data from embedded sensors.

Different types of sensing technologies can be used to measure the strain or stress experienced by textiles ranging from optical fibers [1] and metallic yarns [2] to piezoresistive films or polymers [3]. This study aims to develop flexible printed piezoresistive strain sensors.

The characterization of the sensors in static and dynamic strain is crucial for understanding the sensing capabilities of the system (sensor + substrate + connections) and for adapting the data processing and analysis based on the sensing system's gauge factor (GF). The GF represents the ratio of the relative change in electrical resistance to the mechanical strain, quantifying the sensitivity of a strain sensor. *Table 1* illustrates the measured GF at different testing speeds of the sensors deposited on the Meridional Ribbon.

	100 mm/mn	250 mm/mn	500 mm/mn	1000 mm/mn
<b>Gauge Factor</b>	6.4 [+/- 1.2]	3.3 [+/- 0.5]	8.9 [+/- 0.3]	9 [+/-1]

**Table 1** Gauge Factor of carbon-based printed sensors on the meridional ribbon tensile tested at various testing speeds.

This study demonstrates the performance of printed piezoresistive sensors in measuring strain in textiles. The sensors exhibit a response close to linear when subjected to controlled strain at 10%, although this behavior is influenced by the properties of the ink and printing conditions. Additionally, the sensor's response is affected by the interface between the sensor and the textile, as well as the speed of the applied stress.

**References:**

- [1] M. El-Sherif et al., « A Novel Fiber Optic System for Measuring the Dynamic Structural Behavior of Parachutes », 2000
- [2] D. Budolak, L. Hantsche, et E. Rossi De La Fuente, « Strain Sensor Survey for Parachute Canopy Load Measurements », 2022
- [3] C. Cochrane, M. Lewandowski, and V. Koncar, "A Flexible Strain Sensor Based on a Conductive Polymer Composite for in situ Measurement of Parachute Canopy Deformation," 2010