NON UNIFORM GEOMETRY BEND SENSORS EXPLOITED FOR BIOMEDICAL SYSTEMS

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Abstract: In biomedical systems the bend sensors have been increasingly used stands their interesting properties useful to measure human joint static and dynamic postures. These commercially available sensors are usually made of a polyester film printed on with a special carbon ink. The film acts as a support while the ink's resistance value changes with bending dues to an applied external force. The substrate film material is usually made by Kapton and/or Mylar for their properties, stands the fact that substrate must be able to bend repeatedly without failure for the sensor to work. In spite of their interesting properties the commercial bend sensors have a resistance vs. bent angle characteristic which is not actually ideal as a linear function, to measure human postures, would be. So we introduce here a novel solution useful to linearize the sensor response.

1 INTRODUCTION

Commercial bend sensors are usually made of a few micrometer tick resistive material deposited onto a thicker plastic insulating substrate. The overall thickness is anyway negligible compared to the total largeness and lengthiness, giving to the sensor a rectangular geometry, with one side somewhat larger than the other.

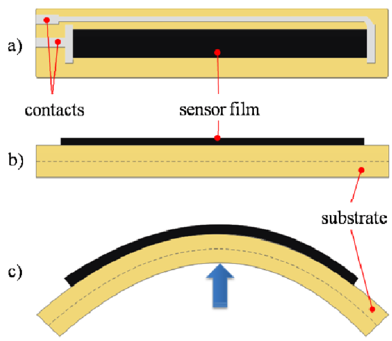

Figure 1: Unbent sensor (a) top (b) lateral view and bent sensor (c) with the sensible part elongated.

These devices can be adopted as sensors when placed on human joints with the larger side bent according to the joints.

From a characterization point of view, the model which takes into account the mechanical aspect of the sensor predicts a linear behavior of the electric resistive variation with the bending angle (Saggio et al., 2009). Even the Ohm's law, $R = \rho\, l/S$, with ρ resistivity, l length and S section, suggests that when the lengthiness l of the resistive sensor material increases due to bending (see Fig. 1), supposing a constant value of ρ, it must correspond a linear increase of the value R.

Nevertheless an electrical characterization of the sensors furnishes non linear characteristics.

2 SENSOR CHARACTERIZATION

We measured the characteristic of several commercial bend sensors thanks to an home made set-up previously described (Saggio et al., 2009; Orengo et al., 2009) and as a result we selected sensors provided by Flexpoint Inc. In particular, we investigated the 2 inches long Flexpoint non encapsulated sensors, polyester encapsulated sensors and polyimide encapsulated sensors.

The results of our measurements, reported in Fig. 2, demonstrated the non linear mentioned characteristic. In particular the resistance variation is greater for non encapsulated sensors stands their higher flexibility.

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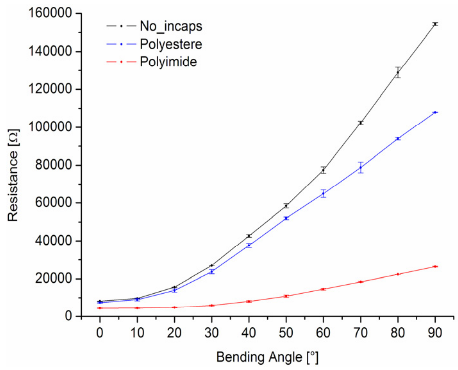

Figure 2: Resistance variation vs bending angle for three different Flexpoint sensors.

These imply that the resistive material must be non isotropic and must present non uniformity variation when bent. This hypothesis can be demonstrated by the profilometer measure we performed on the shorter side of a Flexpoint bend sensor and reported in Fig. 3.

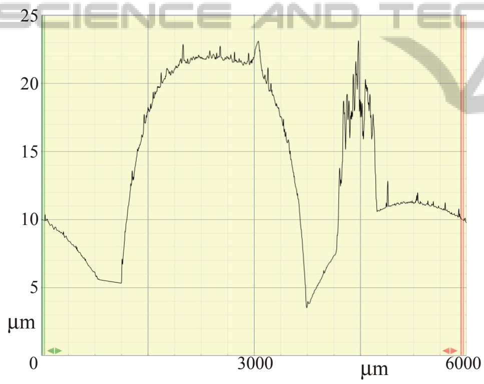

Figure 3: Profilometer characteristic of the sensor by Flexpoint. The two profiles are of the sensible film and the contact film respectively.

3 LINEARITY VS NON LINEARITY

The non linearity in the sensor's characteristic is the cause of some important drawbacks such as the time consuming calibration and the more complexity in designing both the conditioning electronics and the algorithms to analyze the recorded data.

So to reduce these drawbacks an interesting method to increase sensor linearity has been previously proposed (Gentner & Classen, 2009).

Differing from that, here we propose a novel approach to solve the same problem in a simpler way.

4 SENSOR EXPLOITATION

These kind of sensors are usually (but not solely) adopted for realizing the so called data glove, i.e. a wearable system which is capable to measure all the static and dynamic postures of the human hand (Di Pietro et al., 2008). So, in order to measure finger joint positions and movements, as a usual way of proceeding, the sensors are commonly inserted in a closed sleeve on top of a Lycra glove in correspondence of each finger joints (Simone et al., 2007). Differing from that, we adopted each sensor in a open pocket a bit wider but a bit shorter than the sensor itself (see Fig. 4). The pocket's open end allows free sliding movements for the sensor. Only the sensor tip having the two electric terminals lodged is stitched with the pocket. All the system is then housed sewn on the Lycra glove in correspondence to a finger joint. Let's indicate this as the *1F* (1 end Fixed) configuration. With joint bending, this configuration does not bent always the same part of the sensor, because of a translation of the sensor itself (due also to skin and glove elongation), as depicted in Fig. 5 where is represented our measurement bench with a hinge applied to simulate the human finger joint.

(a)

(b)

Figure 4: (a) Data glove, 1F configuration (b) magnification of a detail.

So, since the section of the sensor bent depends on the bending angle, we can calculate exactly which section is concerned every time.

Stand these points our idea was to change the regular (rectangular) geometry of the sensor cutting some part of it, so to increase or decrease its resistance value, obtaining a linearization of the previously reported non linear behavior (Fig. 2). In particular our necessity was to increase the sensor resistance value especially near the stitched sensor tip, so the cut was done in a triangular shape with a greater amount near the contacts (in correspondence of the electrical terminals), matching the low bending angle values (as represented in Fig. 6).

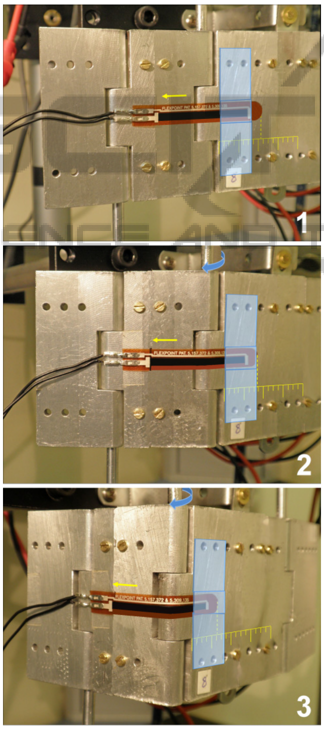

Figure 5: The sensor section which is bent changes @ every bending angle.

The validity of the idea was proved with ad hoc measures. Several sensors, differing from their triangular cut part in the shorter cathetus *b)* with respect to *a)* in Fig. 6, were characterized.

Figure 6: (a) Regular (uncut) geometry sensor, (b) changed (cut) geometry sensor.

Different amount of cuts were tried, and the results for some of them, in particular for the non encapsulated ones (which present greater non linearity), are reported in Fig. 7.

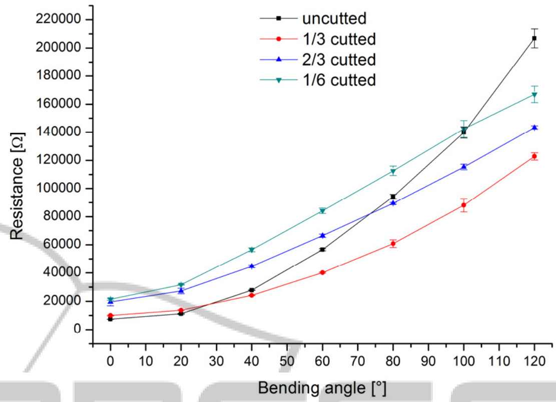

Figure 7: Resistance variation vs. bending angle measured for 3 different amount of cut.

As it can be noticed the linearization was increased with the amount of cut, leading to a very good behavior for a *b)* cathetus value of 1/6 with respect to the uncut sensor. Indeed our measurements demonstrated how a really interesting linearization of the sensor resistance variation vs. bending angle can be obtained with a sensor not rectangular shape differing with respect to the common commercial sensors.

5 CONCLUSIONS

The linearization of the bend sensor's characteristic leads to undeniable advantages. So here we demonstrated how a linearization can be obtained for such sensors especially when they are exploited for measure human joint static and dynamic postures.

The linear characteristic was obtained with a novel method operating few changes on the sensors geometry and the measures demonstrated really interesting results.

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