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Challenges in making the ideal sensor fabric

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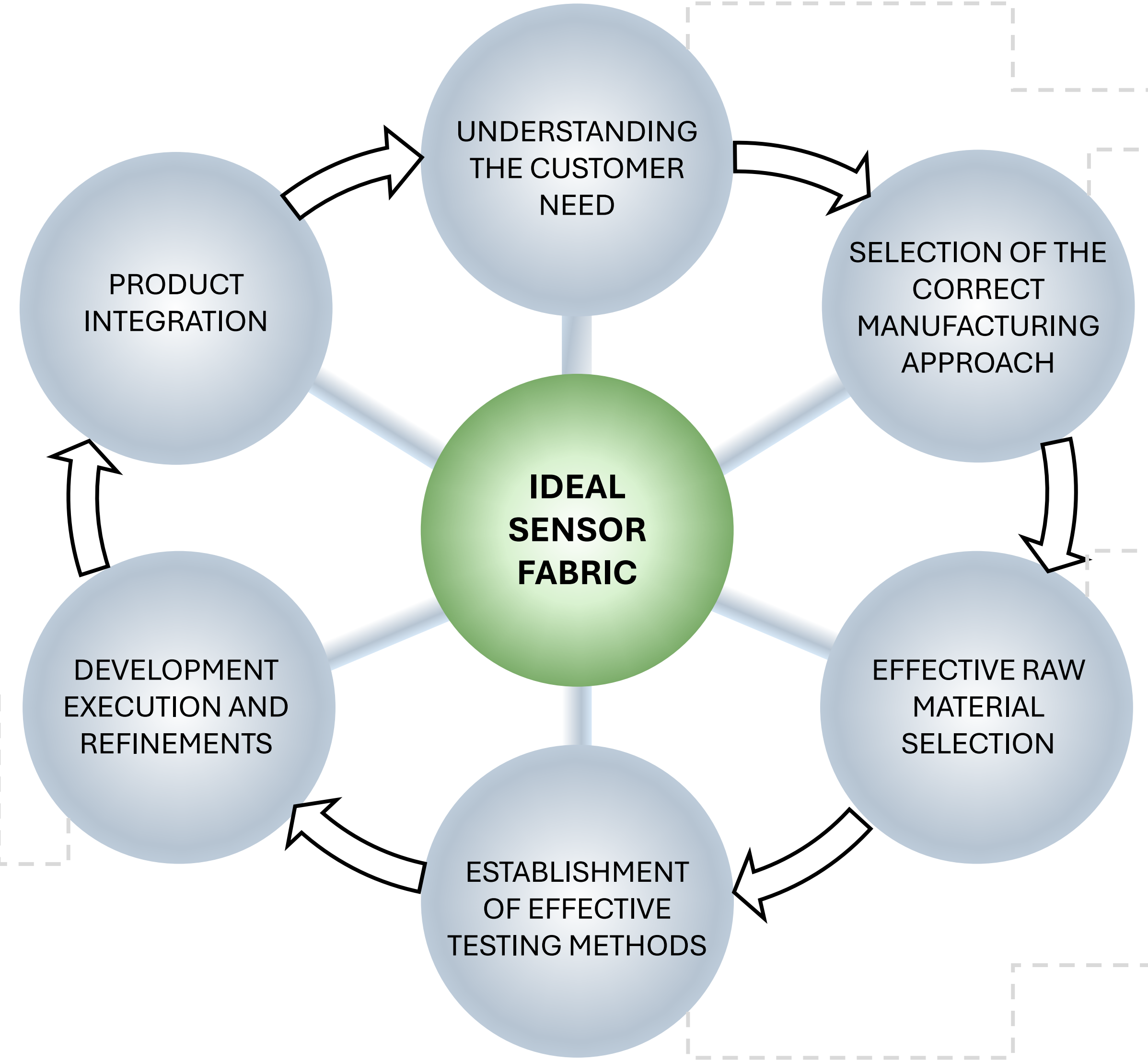
EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

CHALLENGES IN MAKING THE IDEAL SENSOR FABRIC - OVERVIEW

Presentation will discuss some challenges faced by a small specialized fabric coating company in making pressure sensor fabrics:



Speaking the same language

Location of conductive media within a coated conductive fabric and its effect on performance

Effect of non-uniformity of the coating substrate

Selection of suitable testing methods

Understanding the performance requirement

Speaking the same language

I need a resistance of …

It needs to be uniform …

I need a wide range of sensitivity …

I need to protect the confidentiality of what I am doing…

It has to be integrated with my existing hardware/ software…

Textile Technologists are not Electrical Engineers and Electrical Engineers are not Textile Technologists. We don't always effectively understand each other.

What kind of resistance do you need?

How tight a tolerance is required?

What are you measuring?

How are you intending to use the fabric?

Is there any flexibility in hardware/software design changes?

In order to conduct a successful, focused conductive fabric product development, both need to speak the same language and understand the limitations as to what can be done and what, simply, cannot.

Speaking the same language

Questions where answers are useful for focused development of a sensor fabric, can be simple, and include:

- *Will the hardware be located on one side of the fabric or both sides?*
- *How big will the fabric appliqué be in the assembly and what will be the minimum distinct measurement size required on the fabric?*
- *Will the fabric be encased in the final article?*
- *What are the upper and lower limits for the power (voltage, current) applied?*
- *Will the product be laundered during use?*
- *Is there a thickness tolerance for the fabric?*
- *What is the range of compression force, or extension, the fabric will be subjected to?*
- *What is the level of durability required and how is it measured?*

Often the answers to these questions still do not provide enough information to launch a development for a successful outcome and further information can be gained with the proposal of "*we will supply you with a sample of a material that we currently have in inventory, which we know may NOT work in your application, but if you can test it and tell us, in as much detail, as possible why it doesn't work, then it will help us develop something more suitable for you*"

Speaking the same language

One of the most common specification requests is, as would be expected, a Resistance of the conductive fabric.

- Many times the type of electrical resistance will be unspecified or incorrectly specified.
- Of first importance is to ascertain the type of electrical resistance that they are looking for in the fabric, for example surface resistance or volume resistance:

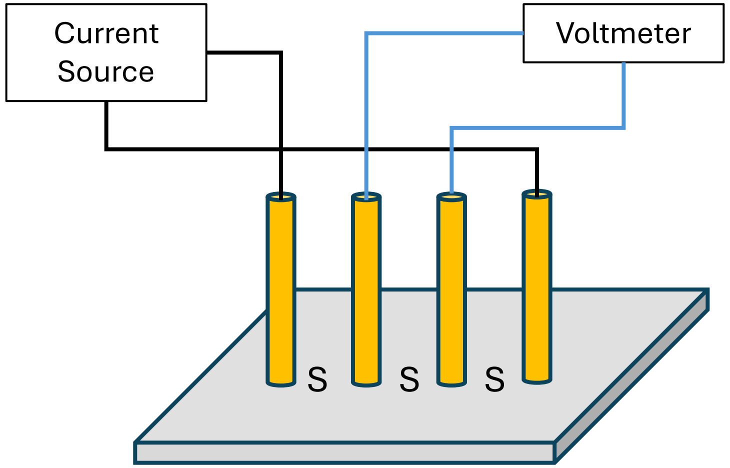
Surface Resistance	Volume Resistance
Surface resistance is the measurement of the resistance if the current solely passes along the surface of a material.	Volume resistance is the measurement of resistance if the electric current passes through the body of the material.

Provision of information from the customer as to how the fabric is integrated with the electronic hardware and whether one or both sides of the fabric are expected to be used as the sensor matrix, is the start of designing the correct fabric.

Selection of suitable testing methods – electrical resistance

Textile materials often have very three dimensional surface structures.

- Consequently surface resistance measurement techniques, using standard 4-point surface probe or similar techniques may not be accurate or relevant in certain cases, dependent upon the location of the electrically conductive coating within the fabric.



Source: https://www.napson-resistivity.com/technique/

$$Resistivity, \rho = 2\pi S \frac{V}{I} \quad \Omega.\text{cm}$$

$$Sheet\ Resistance, \rho_s = \frac{\pi}{ln\ 2} \frac{V}{I} \quad \Omega/\text{sq}$$

Where:

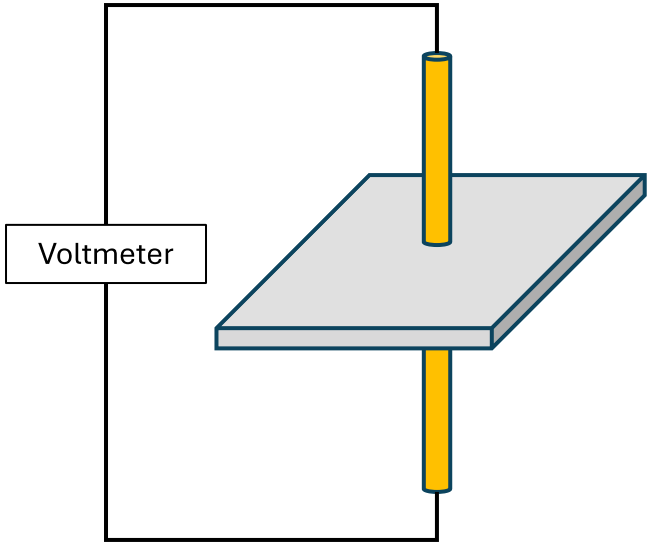
V = Voltage between the inner probes
I = Current through the outer probes
S = Spacing between the probes (based upon equal spacing).

Measurement technique originally developed for thin films.

With coated fabrics, surface resistance measurement will also be strongly dependent upon coating thickness and location of conductive particles within the fabric matrix.

Selection of suitable testing methods – electrical resistance

- Volume resistance measurement techniques, may provide measurements which can be treated with more confidence in some cases, but have limited relevance to the end user, if all of the electrical hardware is located on one side of the fabric.



$$Volume\ Resistivity, \rho = \frac{V}{I}\frac{A}{t} \quad \Omega.cm$$

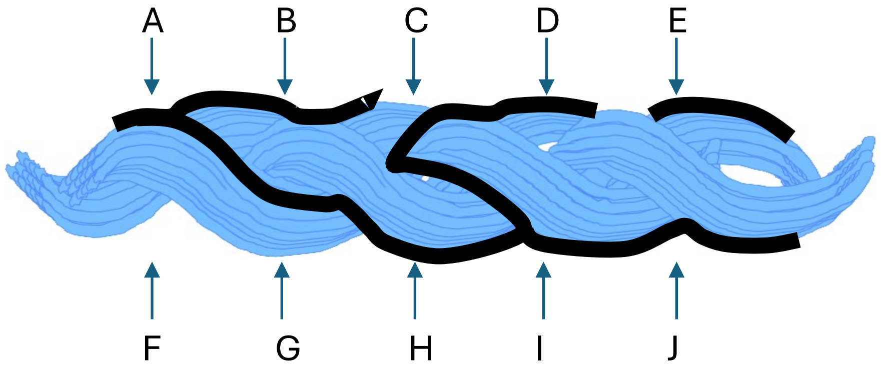
Where:

V = Voltage between the probes
I = Current through the probes
A = Cross sectional area under the probes
t = Thickness of the fabric

Again, as with Surface Resistance measurements with conductive fabrics, measurement will also be strongly dependent upon where the conductive components are within the fabric.

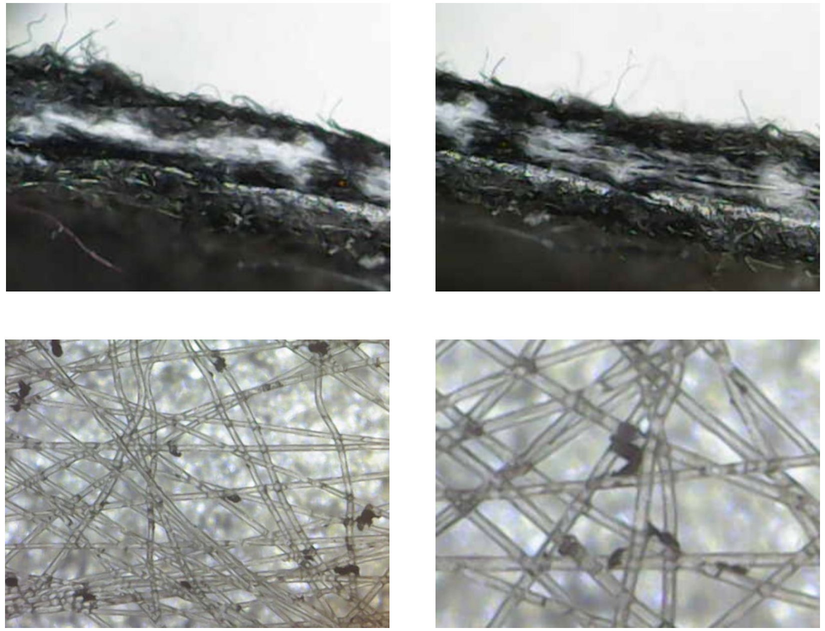
Level of impregnation and location of conductive media within a coated fabric matrix affects resistance measurements

Resistance measurements taken on impregnated conductive fabrics may not be as would be expected, based upon the electrically conductive paths available within the fabric.



Surface Resistance, R_s: $\overrightarrow{BC} > \overrightarrow{BD} > \overrightarrow{AD} > \overrightarrow{AB}$

Through Resistance, R_z: $\overrightarrow{CH} > \overrightarrow{BH} > \overrightarrow{DH} > \overrightarrow{DI}$

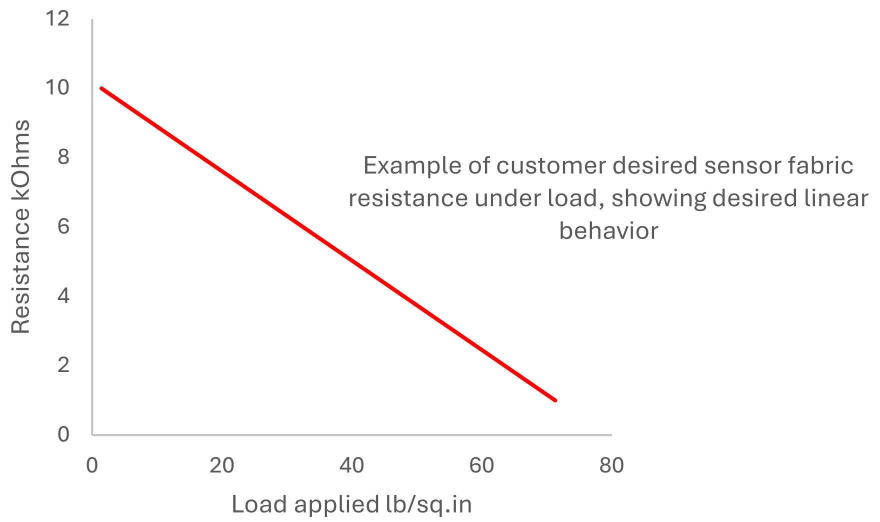


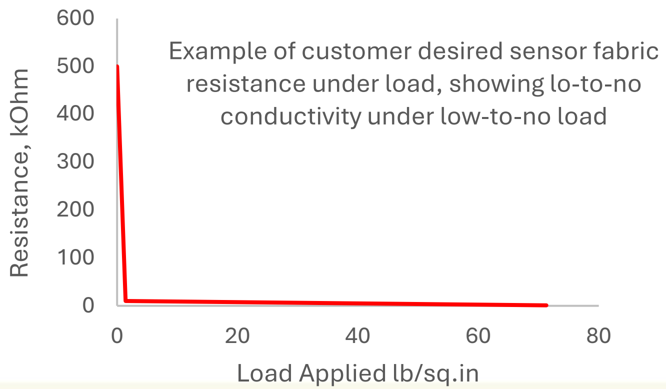
This can result in Resistance Variances, from cm to cm far outside end-user requirements.

Understanding the Performance Requirement

Sensor fabric integrators often “ideally” seek a conductive material that exhibits some or all of the following:

- Low-to-no conductivity at low-to-no loads, or a fixed high resistance, to minimize, or filter out, noise.
- Minimal variation in resistance per square centimeter.
- Linear relationship between load applied and change in electrical resistance.
- Absolute minimum resistance level, upon high load extremes above a value so as to prevent cross-talk in their sensor systems.

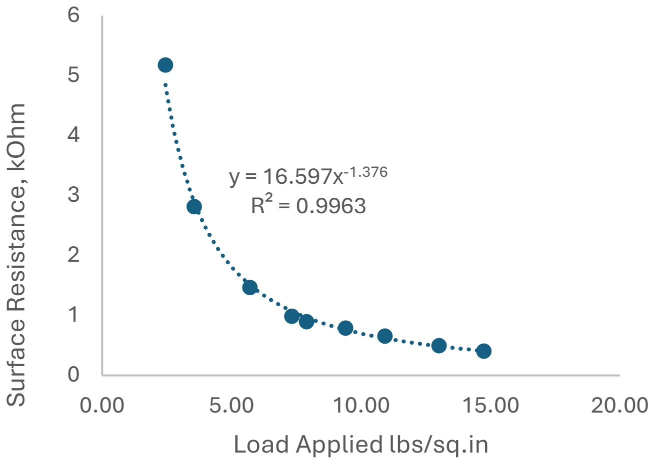


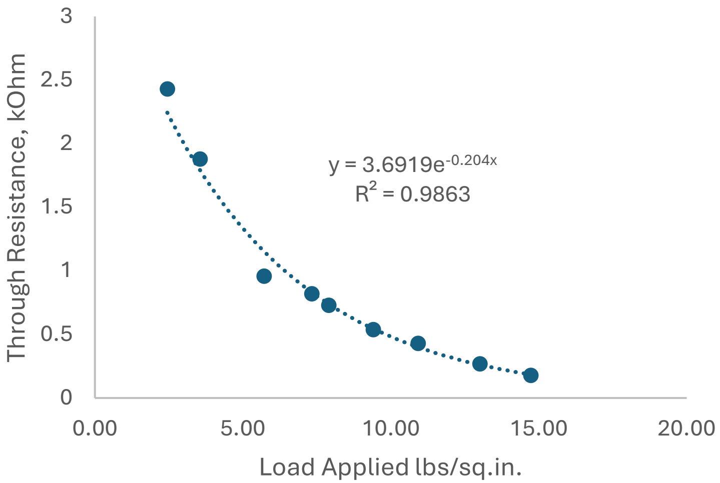


Understanding the Performance Requirement continued

Often fabrics do not exhibit true Hooke's law behavior across a typically requested wide force measurement range, whether such force be in extension or compression.

- Hookes law may apply to the fabric within a limited range where the fabric has high elastic properties.
- Fiber orientation and fabric structure have a large influence upon the level of recovery after load removal, resulting in hysteresis behavior.
- Fabric electrical resistance under load for sensor fabrics typically behaves in a pseudo-exponential, power, or similar, relationship.
- Stacking of fabric layers of different stiffness may help dampen this relationship but, as resistances are additive, may conversely exaggerate the behavior, with respect to through, z-axis, resistance.



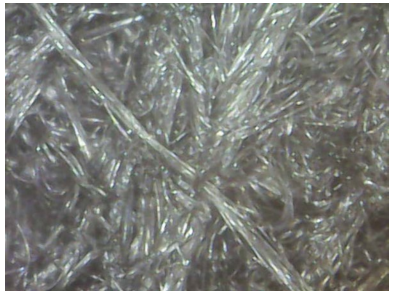


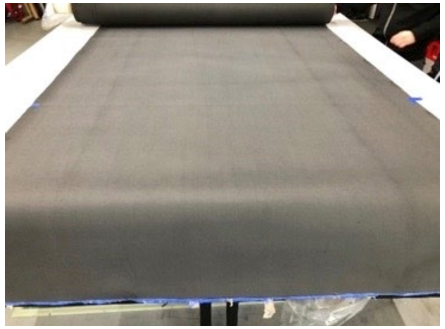
Successful integration of a sensor fabric, often entails:

- The production of a conductive fabric with the highest level of sensitivity within the typical operating range.
- Programming of the hardware to overcome the non-linear relationship of the fabric under load conditions.

Effect of non-uniformity of the coating substrate

Long running machine direction non-uniformities in the surface of fabrics, typically considered as acceptable in other applications, and not necessarily classified as defects, can be seriously problematic in sensor fabrics:



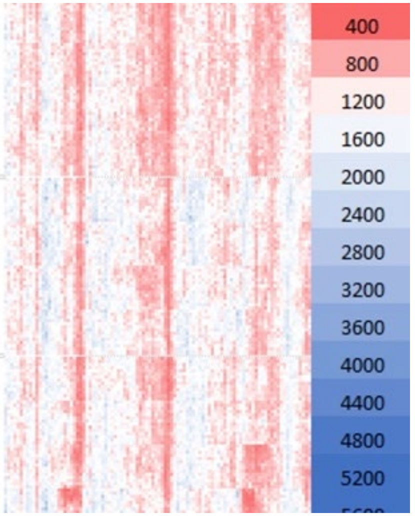


Slight variances in weight, dragged fibers during nonwoven lay down/fiber entanglement and other surface effects can lead to visible surface blemishes.......

Yard 16

Yard 38

Yard 89

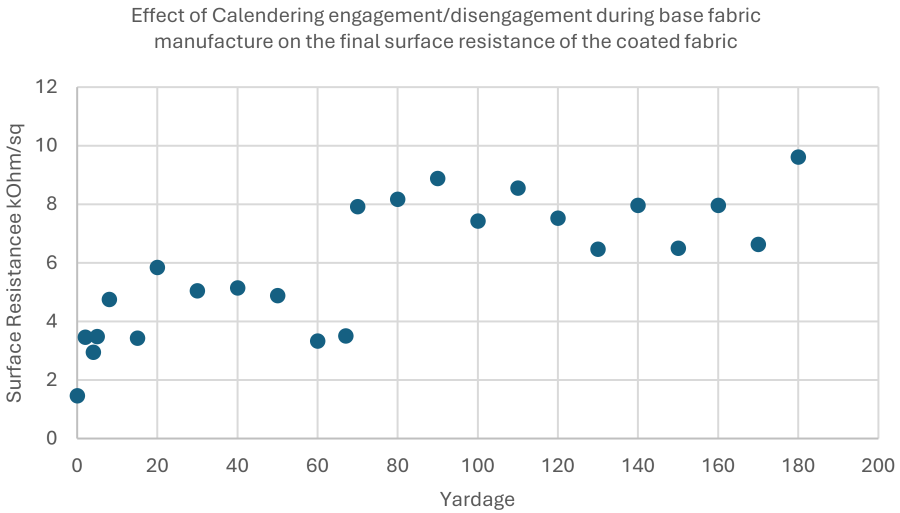


.... Resulting in major differences in the surface resistance of the final coated fabric.

Effect of non-uniformity of the coating substrate (continued)

Engaging and disengaging of post treatment processes during the manufacture of the base fabric, can also seriously effect the quality of the fabric, when coated, for sensor applications:

Hot calender roll engaged and disengaged during at 67 yard mark during base nonwoven manufacture ....

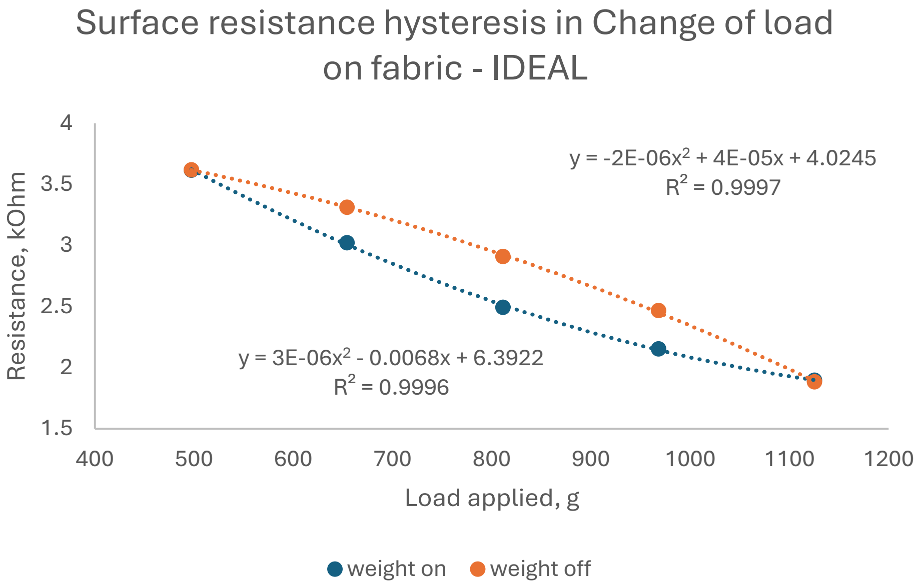


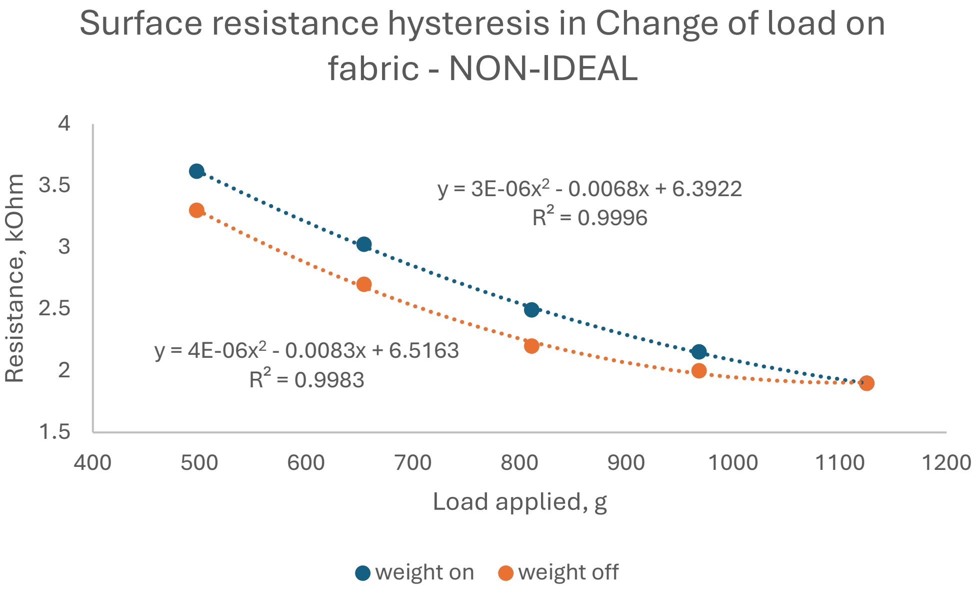
.... Resulted in a major difference in surface resistance of the final coated fabric.

UNDERSTANDING THE PERFORMANCE REQUIREMENTS – DELIVERING CONSISTENCY DURING USE

Overcoming the effects of Hysteresis and desensitization during use

An ideal pressure sensor fabric will maintain the same electrical resistance through repeated depressions and fully recover this resistance quickly after the load has been removed:





This is often not the case, as the fabric can suffer from poor hysteresis during recovery after each depression...

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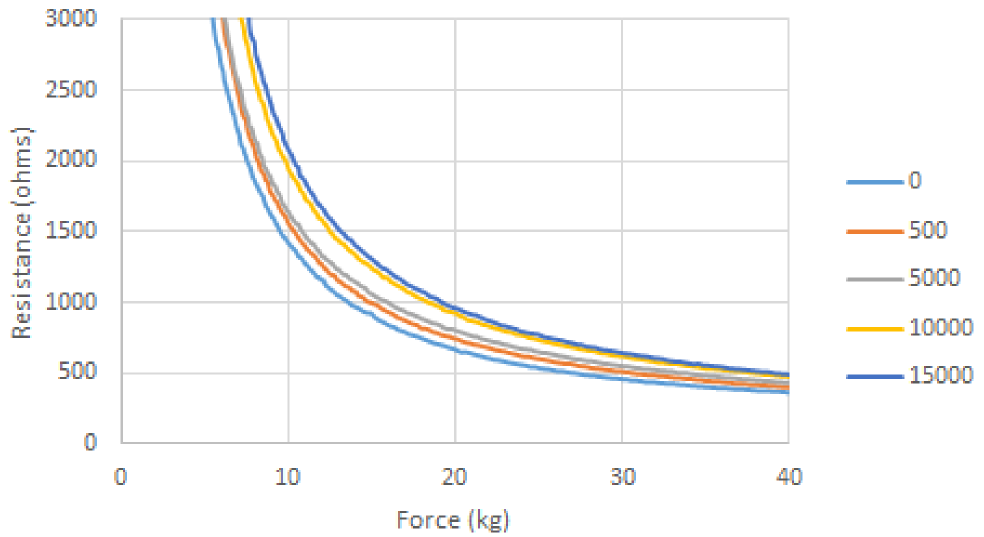
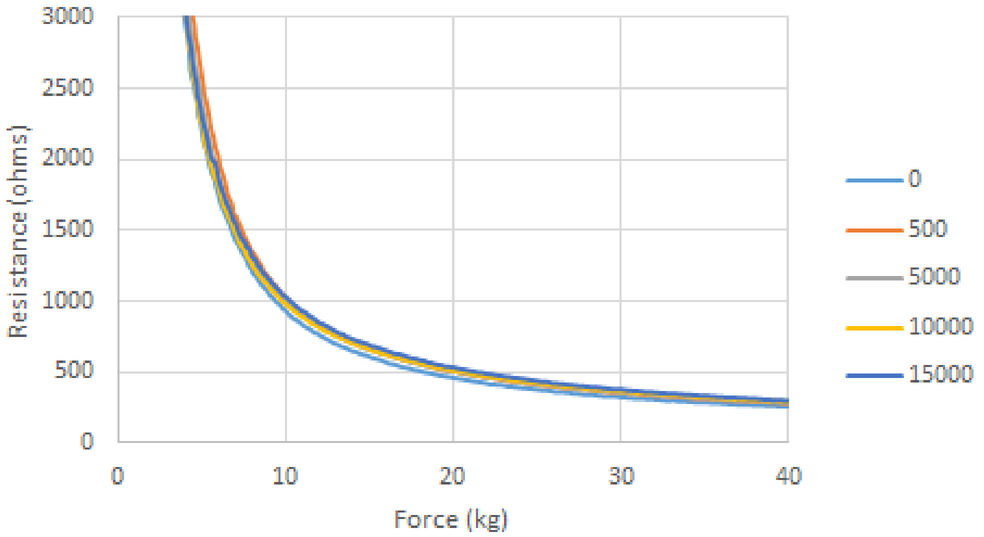
Overcoming the effects of Hysteresis and desensitization during use (continued)

... Furthermore, it is essential to ensure that the fabric performance does not deteriorate during prolonged use (desensitize/loss in sensitivity)

Drift in the resistance of the sensor fabric during repeated depressions – **NON-IDEAL**



STRONG consistency in the resistance of the sensor fabric during repeated depressions –**IDEAL**

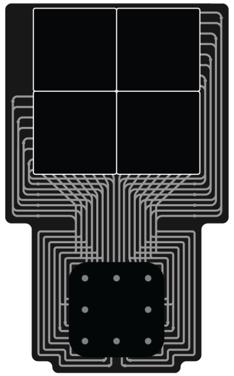


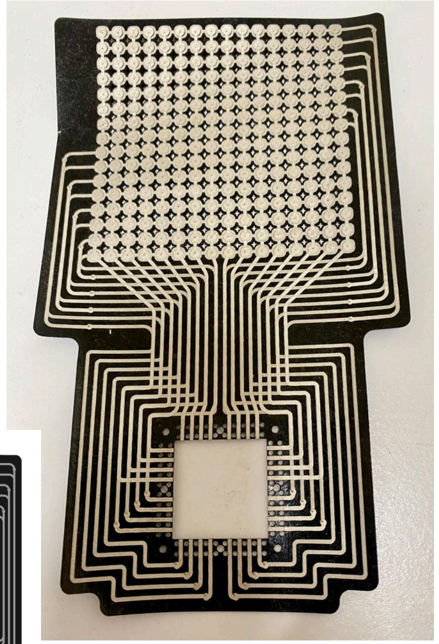
Creating an effective interface between the sensor fabric and the electronic componentry

In many cases with pressure sensor fabrics, the fabric is incorporated or encased between one of many other layers of material, onto which the required electrical componentry has been attached.

In this case the outer materials may be other e-textiles whereby circuitry has been attached using methods of attachment discussed later, or even films printed with conductive inks.

Sensor fabrics, themselves, can also be enhanced with the printing of conductive inks directly onto them, in the form of bus bars and/or more complicated designs.



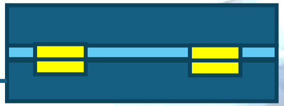


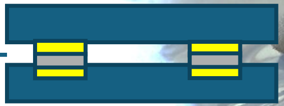
Photos courtesy of Keith McMillan

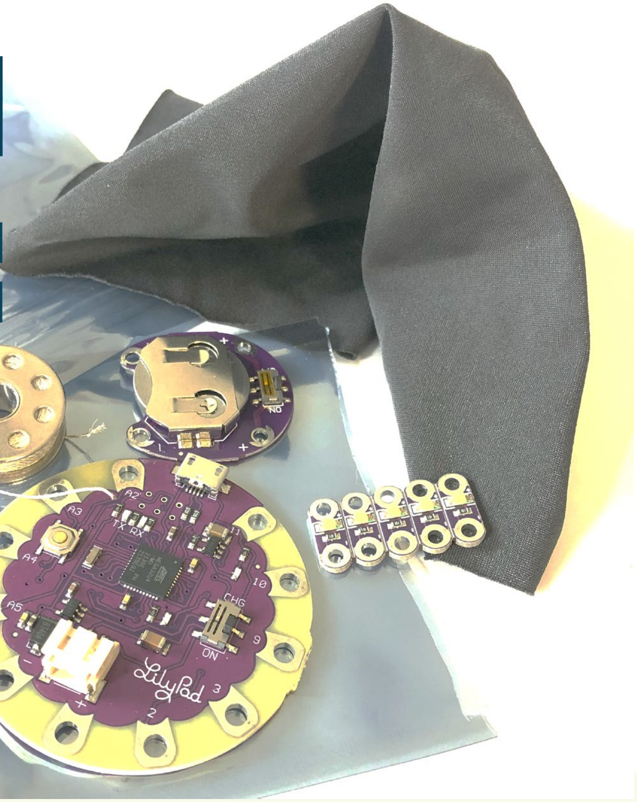
Creating an effective interface between the sensor fabric and the electronic componentry (continued)

Other methods of integrating electronics into sensor fabrics include:

- Molten bonding techniques
- Adhesive bonding techniques
  - Nonconductive
  - Isotropic conductive
  - Anisotropic conductive
- Encapsulation techniques
- Printing techniques
  - Direct
  - Transfer
- Embroidery techniques
- Mechanical attachments
  - Press studs
  - Rivets
  - Pogo pins & Other

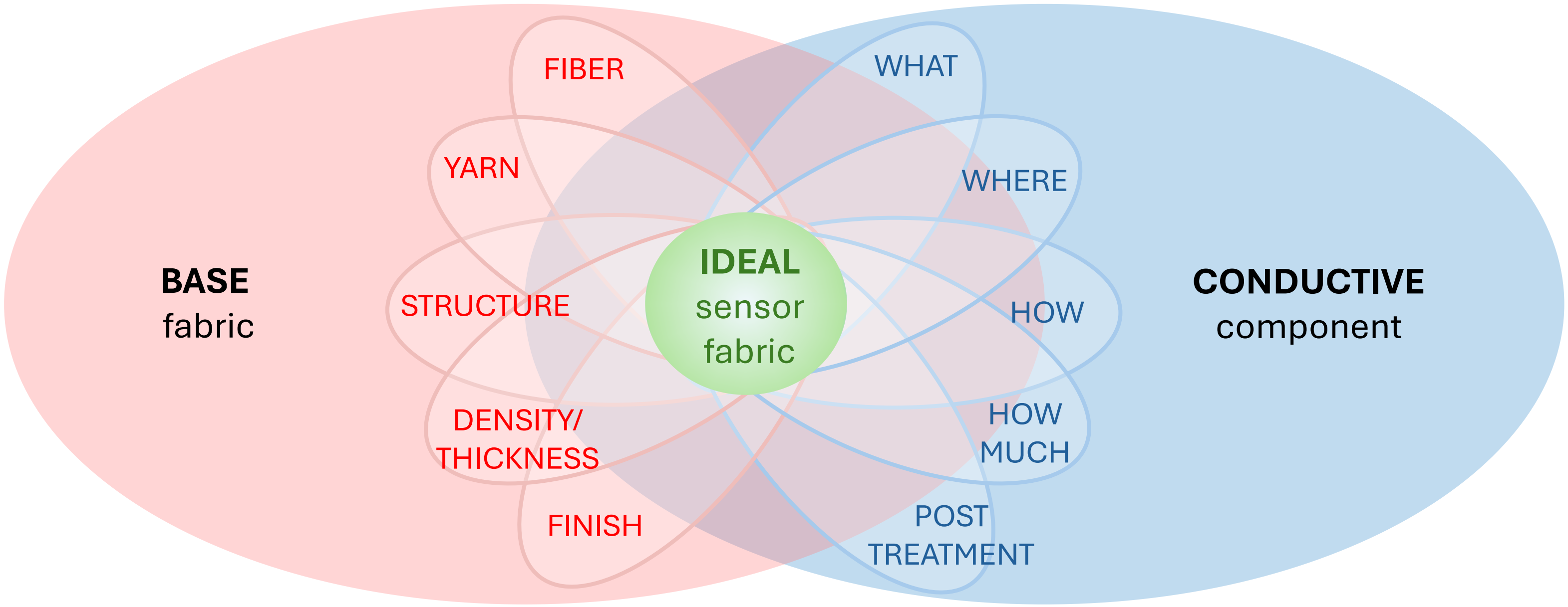






Considerations in designing the ideal sensor fabric

Designing a coated/impregnated pressure sensor fabric with ideal performance and good durability during use, requires consideration of the following:



Thank you for your time.

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