A NOVEL DEVICE FOR CALIBRATING SHEET ARRAY PRESSURE SENSORS AND FOR MONITORING THEIR PERFORMANCE

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INTRODUCTION

Sheet array pressure sensors are used widely in biomechanical research, as well as in a variety of industrial settings, to measure interfacial contact stress in real time and with relatively high spatial resolution.

Sensors of this class generally consist of an array of electrical junctions between two sheets of thin, flexible plastic. Pressure on the sheets changes the electrical characteristics (*e.g.,* piezoresistivity, in the case of Tekscan®) of each junction, which is then interpreted according to a user-generated calibration curve and reported as an instantaneous contact stress value.

Accurate calibration of such sensors has often been problematic, however, due to the inherent difficulty of applying a suitably well-prescribed force distribution over the sensing area. Furthermore, applying enough force to load the entire sensor surface suitably into the functional regime for calibration purposes is impractical (*e.g.,* roughly 40 KN to reach 50% of the functional range in the case of the Tekscan® K-Scan knee sensor). Adding to the complexity of the problem is significant variation within the array on any given sensor and, by extension, from sensor to sensor. Further, during a typical experimental protocol, this variability may be exacerbated by functionally induced changes in the responses of individual elements.

THE DEVICE

To meet these challenges, a novel "wringer" device (**Fig. 1**) was built to transiently apply a known force to sequential rows of junctions as the sensor is passed between a pair of rollers.

Figure 1. Sheet Array Sensor Calibrator

A Shore 75D polyurethane rubber was identified as a material suitable to distribute the load over multiple rows of junctions, while being rigid enough to load the center row of the contact patch with enough force to achieve stresses substantially spanning the physically expected range.

The rollers were compressed against one another by an air cylinder. They were linked by gears so that they rotated at the same rate (but in opposite directions) to minimize shear stress on the surface of the sensor.

CALIBRATION PROCEDURE

Data Capture

The sensor is positioned between the rollers and a given load applied. The sensor is drawn slowly through the rollers and raw data are captured. The process is repeated for a range of roller compression loads.

The Computation

To convert raw values to calibrated pressures requires a computation of stress at each individual junction. A finite element model of the two parallel cylinders in contact was used to determine the load borne by the junctions in rows about the center of the contact patch.

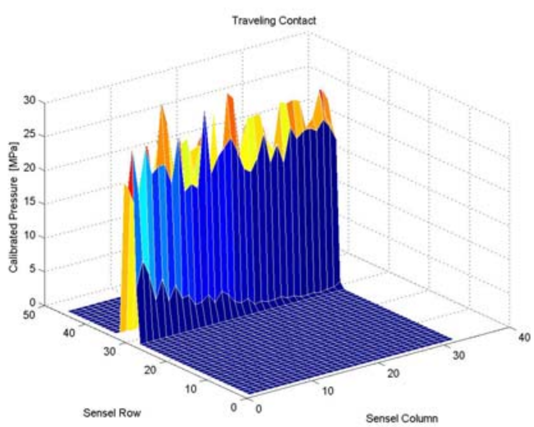

Figure 2. Transient response signal during roller loading

Each capture was post-processed using Matlab®. In an iterative process, the applied roller load was initially assumed to follow the FEA distribution for each level of roller load. These data were used to fit provisional power-law calibration curves. This in turn provided "traveling" waves of contact stress (**Fig. 2**), which could be integrated and compared with the applied roller force. This comparison generated an error signal, by means of which the fitted calibration coefficients could be iteratively adjusted so as to return an integrated load asymptotically closer to the applied roller force. The end result was an array of location-specific calibration curves of algebraically consistent form (**Fig. 3**). Sensor sites departing appreciably from these calibration norms were flagged as performing aberrantly (*e.g.,* due to local damage), a basis for not including their readings in the functional data stream.

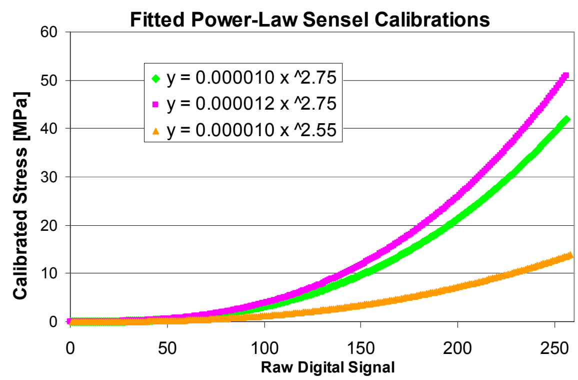

Figure 3. Iterated Power-Law Calibration curves for 3 specific sensor junctions

MONITORING

The device was designed so that the sensor can be removed from an experimental environment (*e.g.,* a cadaveric joint), passed between the rollers for evaluation, and returned to the experimental setting quickly and with a minimum of disturbance of the test setup. Logging the response of each junction to known loads over the course of the experiment makes it possible to accurately correct the data for both global and localized changes in sensor performance.

CONCLUSION

A new device and method are shown to be applicable to sheet array pressure sensors. The device both calibrates and monitors the performance of each individual sensing element in the array.

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