A LOW-COST TRI-AXIAL LOAD SENSOR SYSTEM: DESIGN, CHARACTERISTICS AND ITS POTENTIALS.

[1] Hin Chung Lau, [2]Benedict Stansfield, [1]Scott Wearing, [1]Stephan Solomonidis, and [1]William Spence
[1]Medical Devices Doctoral Training Centre, Bioengineering Unit, University of Strathclyde, UK,
[2]School of Health and Social Care, Glasgow Caledonian University, UK; email: lauhinchung@gmail.com

INTRODUCTION

Measurment of tri-axial loads is highly desirable in a variety of applications including, but not limited to, gait/sport analysis, ergonomic studies as well as in robotics. Commercial strain-gauged tri-axial load cells are often too large in size or too expensive to be incorporated in research studies. This study presents a novel, low-cost, tri-axial load system, in which the sensing elements and output circuitry can be easily assembled from commerically available products.

METHODS

The technique chosen for load sensing was based on a basic hydraulic uni-axial force measurement system used during functional magnetic resonance imaging (fMRI) [1]. Expanding from the technique, the operating principle of tri-axial load detection relied on the locations of sensor-tubes in a housing (Figure 1). PVC tubes (1mm wall, 2mm bore) were filled with oil and fitted to pre-amplified pressure transducers (40PC250G1A, Honeywell, USA). Force applied to the device displaced the square-topped column relative to the sensor housing inducing a pressure change in the sensor-tubes, which was then detected by the pressure transducers. The housing and the column of this prototype sensor were made of aluminum alloy and the completed sensor measured 30x30x26mm.

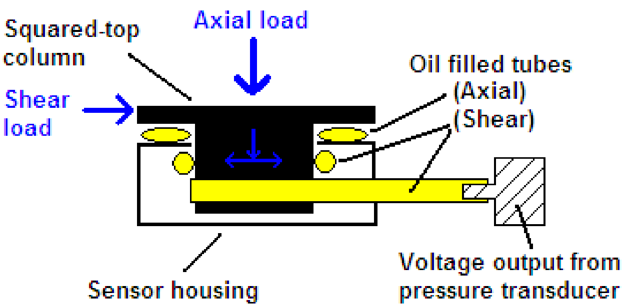

Figure 1: The basic configuration of the sensor device for tri-axial load detection.

During calibration, the sensor was secured to a six-channel load cell (Nano25, ATI Industrial Automation, USA) which was used as the reference of the applied load. Force outputs from the load cell and voltage outputs from the sensor-tubes were sampled simultaneously at 400Hz. Dynamic calibration tests were conducted over a range of force (0N-40N) for each axes' direction. A preliminary investigation of the tri-axial load beneath the hallux was recorded during unipedal stance with the same setup.

RESULTS AND DISCUSSION

The average full-scale non-linearity for the axial and shear axes was found to be better than 2.6% and 3.2%, respectively (Figure 2). For the shear axes, the average hysteresis was found to be less than 4.7% and for the axial axis was 1.1%.

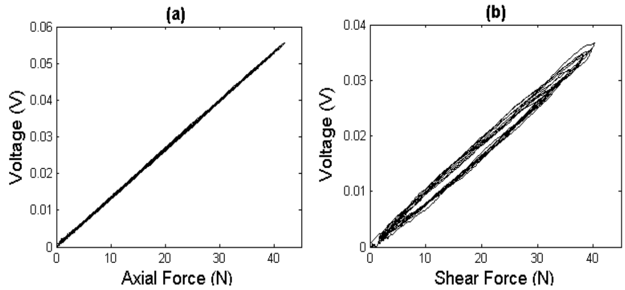

Figure 2: Calibration graph for the (a) axial axis, and (b) a typical shear axis of the tri-axial load sensor.

Theoretically, the location of the sensor-tubes within the housing predicts zero crosstalk. However, off-centered or unevenly distributed loading of the sensing surface may induce mechanical crosstalk. Thus, as with pressure transducers, sensor performance is predicated on uniform loading of the sensing surface. Dynamic performance of the sensor revealed average differences <3.5N between the sensor and the load cell (Figure 3), which is comparable to other expensive strain-gauge based tri-axial devices [2].

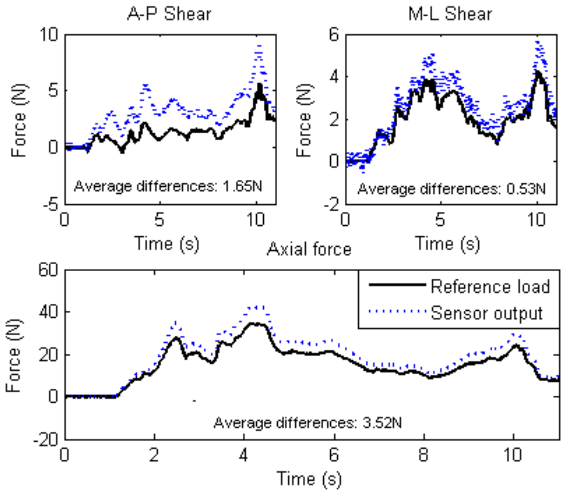

Figure 3: Comparison of tri-axial force profiles for the sensor system and the reference load cell during subject trial.

The sensor system can be assembled easily using the fully signal conditioned and amplified pressure transducer to form arrays of various sizes, making it suitable for force distribution measurement in applications such as gait analysis [2]. The dimensions and properties of the oil filled tubes could be readily modified to suit different force ranges and have the potential to be considerably smaller in size than the prototype. The pressure transducer incorporated within the design can measure pressures up to 1.7MPa. Thus the system could up-scale for larger engineering purposes [3].

REFERENCES

1. Liu JZ, et al, *J Neurosci Methods*. **101**:49-57, 2000.
2. Davis BL, et al, *J Appl Biomech*. **14**:93-104, 1998.
3. Perino VV, et al, *J Equine Vet. Sci.*. **27**:161-166, 2007.