# Teach-in 2000: Time-dependant behavior of inshoe force sensors

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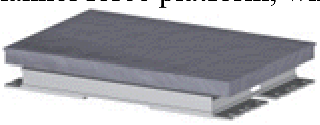
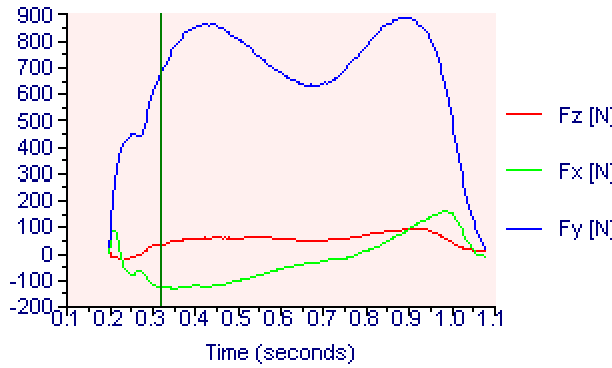
In 3D computerized gait analysis, Ground Reaction Force (GRF) data is normally recorded using a six-channel force platform, which measures the forces applied, and moments about the three orthogonal



axes.

Force platforms have some basic limitations, however:




- only one step is recorded each trial
- measurements are limited to the laboratory
- the subject must strike the platform cleanly
  - especially difficult for children and short step length
  - encourages targetting, which may invalidate the data
- no information is given about the distribution of the pressure over the sole of the foot

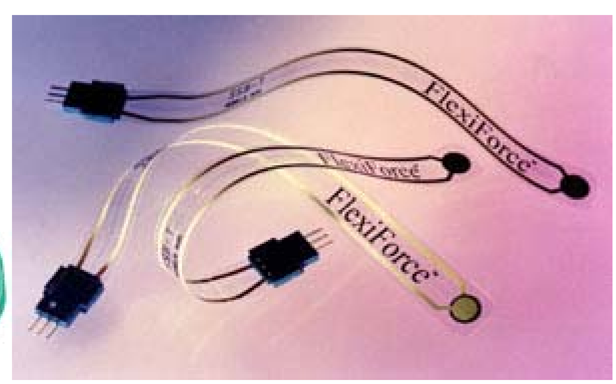
For these reasons, several attempts have been made at developing force transducers which can be mounted in the shoe itself. Basically, all sensors utilize one of the following techniques to sense the force:

- **capacitative** (Pedar, Novel, Munich): the plates of a capacitor move together as more force is applied
- **resistive** (force-sensitive resistor, FSR): intersection of two conductive polyester sheets modifies the current flow
  - Interlink - originally developed for electronic keyboards

  - Tekscan

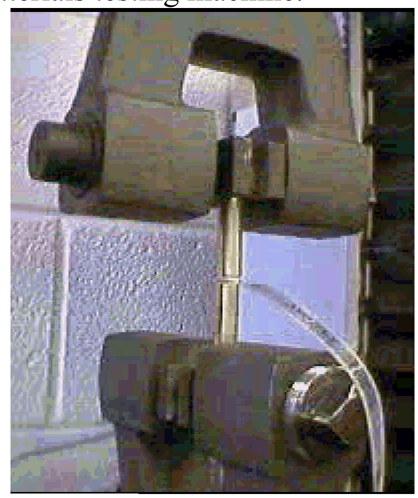
    
    

  F-Scan
  Flexiforce
- **piezo-electric** (GaitScan): charge production by PVdF film

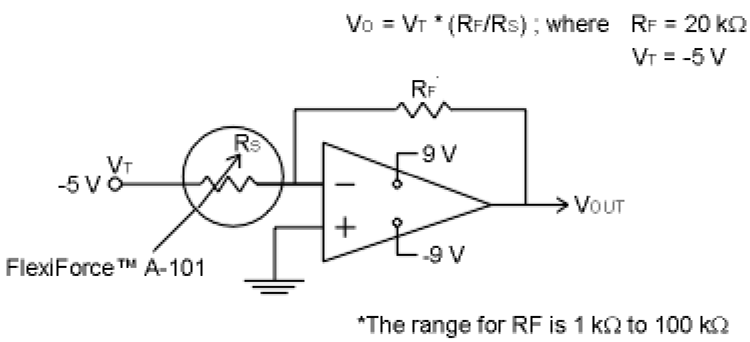
Unfortunately, all these sensors suffer to some extent from the following problems:

- **non-linearity** - the calibration curve (voltage measured versus force applied) is not completely straight
- **hysteresis** - the curve recorded as force is applied is not the same as the same force is removed
- **drift** - the voltage measured when a static load is applied gradually changes with time

In this experiment, two types of FSR sensor (Interlink and TekScan Flexiforce A101-100) were cyclically loaded by an Instron materials testing machine.



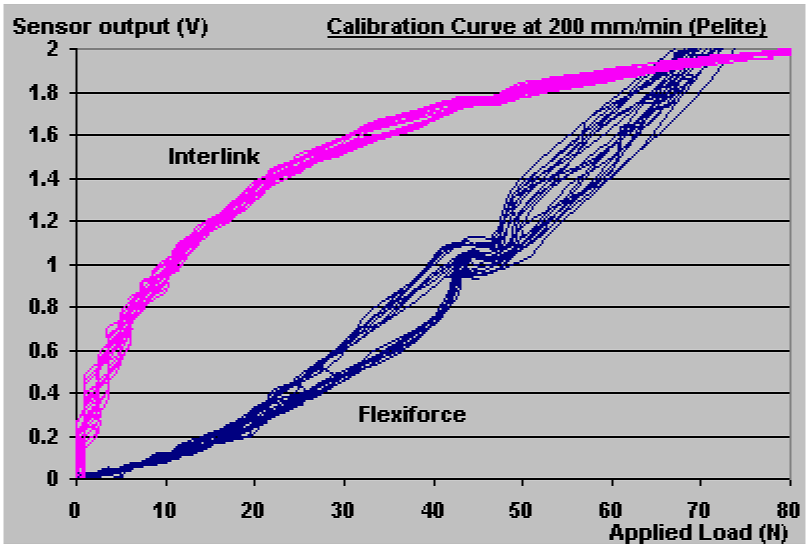
The FSR was incorporated in a simple operational amplifier circuit:



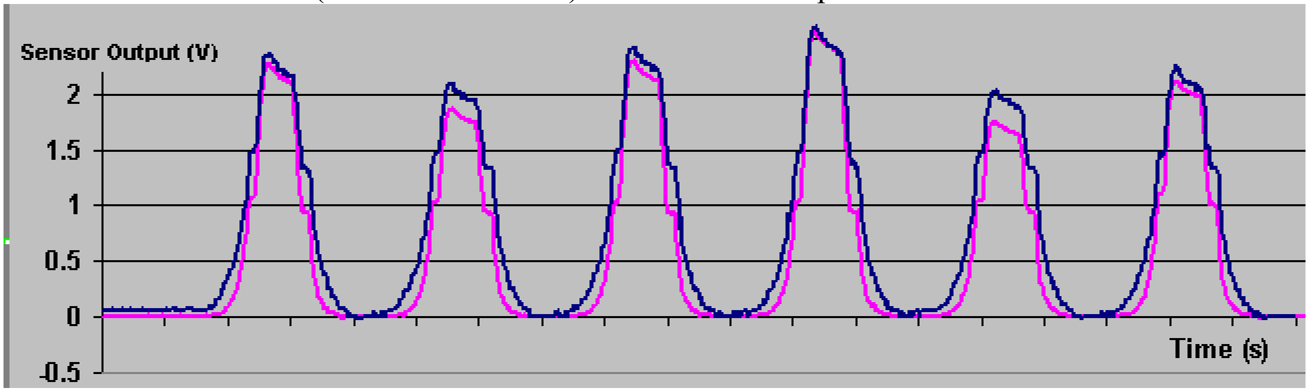

The voltages from the FSRs were plotted against the voltage from the Instron machine (LVDT) at a range of maximum loads and loading rates, with the sensors sandwiched between two 5mm layers of Pelite foam.

## Results

Here are the calibration curves for both sensors at a loading rate of 200 mm/min:

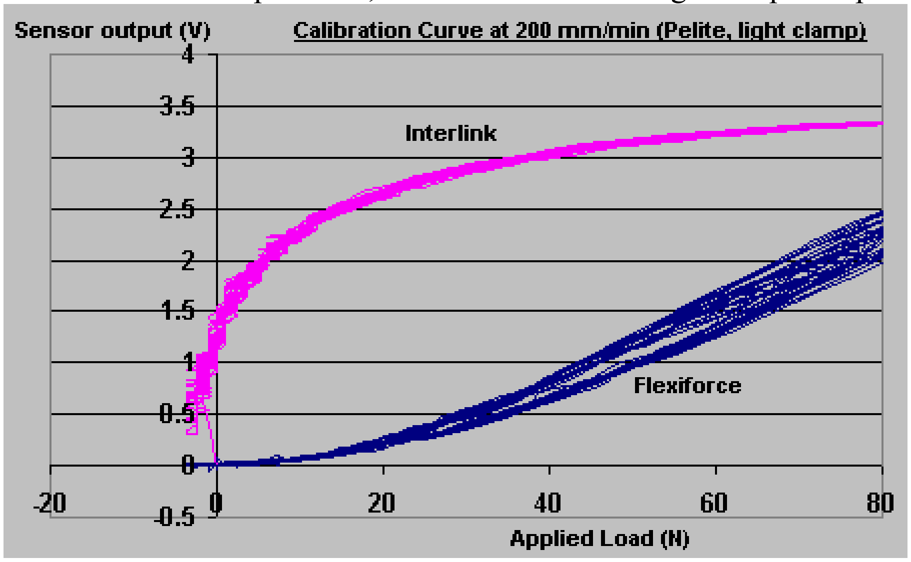



Here are the time series (same trial as above) of both sensor outputs:



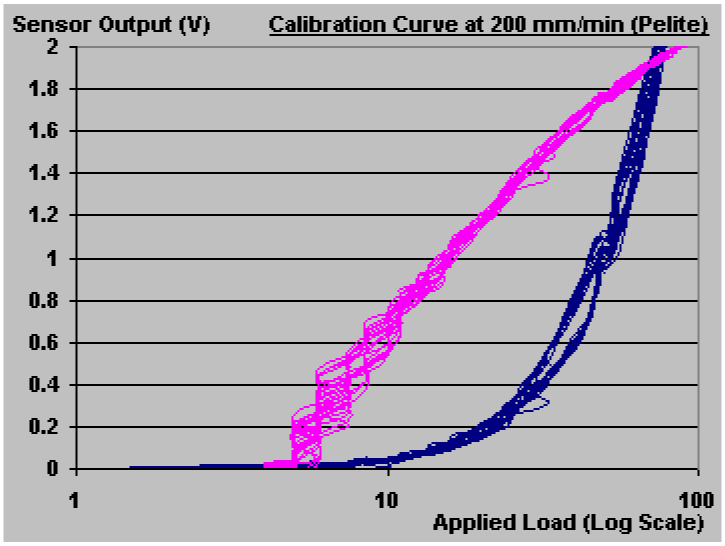

Notice that the loading is not sinusoidal - this Instron machine was not designed for cyclical loading, and was modified to enable automatic control via LabView. The LabView software simply switches the machine between compression and decompression when the force falls below and exceeds preset thresholds, respectively. The load cell of the Instron machine is situated in the head (top G-clamp in the picture above), which moves. The lower clamp is stationary.

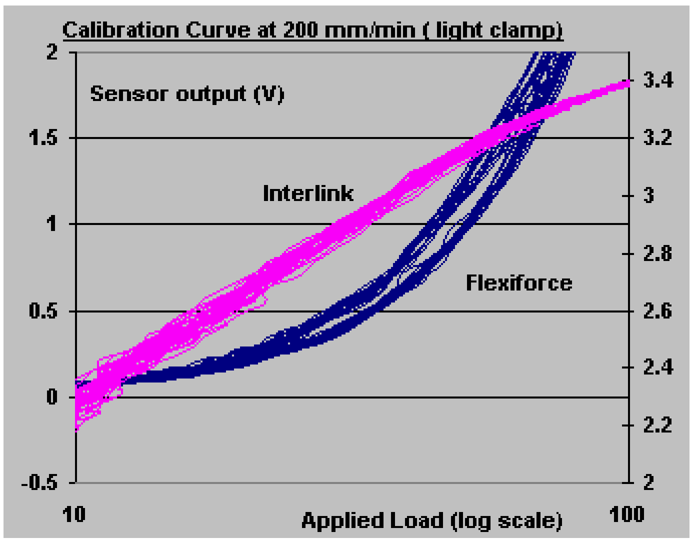
Here is the same experiment, but this time a much lighter top clamp was used:




Notice that the strange loop in the middle of the *Flexiforce* calibration curve has now disappeared.

Finally, here are the curves plotted again - this time on a log scale:




Notice that the Interlink curve is now linearized.

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# Questions

- Which sensor is most linear?
- Which sensor exhibits most hysteresis?
- What is the cause of the strange loop in the middle of the *Flexiforce* calibration curve?
- Do you think the type of backing material affects the results?
- Which sensor would you choose for in-shoe gait analysis?

Email your answers to cga@info.curtin.edu.au

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What we said on the CGA list

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