Technology Opportunity

Capacitive Extensometer for Measuring Principal Strains in a Material

The National Aeronautics and Space Administration (NASA) seeks to develop and transfer a capacitive extensometer that is designed to allow calculation of principal strain magnitudes and their direction, which can discern between axial and bending strains within a material. The extensometer was developed for use *in vivo* in human bone.

Potential Commercial Uses

- Materials testing applications where principal strain measurement is desired, and extensometry is the preferred measurement method
- Strain measurement in environments where surface preparation for bonded strain gages is not feasible
- Biomedical or orthopedic applications
- Strain measurement in materials such as porous metals, plastics, and ceramics
- Strain measurement in stiff biological materials such as bone
- Strain measurement in aggregates such as concrete
- Explosive or destructive testing where fragmentation of specimen occurs

Benefits

The capacitive delta extensometer can measure principal strain magnitudes and their direction, and maximum shear strain in a specimen (i.e., can develop Mohr's Circle for strain).

Like other extensometers, the delta extensometer eliminates the need for degreasing agents, chemical bonding agents, or surface preparation such as drying, sanding, and filling associated with resistance-type bonded strain gages.

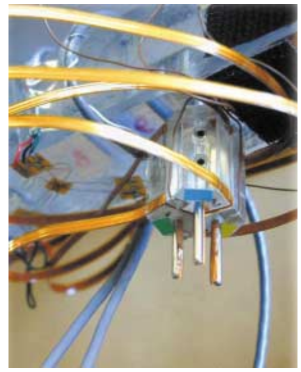
Compared to other extensometers:

Can measure degree and sense of bending in plane normal to pin axis

Device is lightweight (weighs 8 grams)

Device has a high frequency response. This type of device is capable of tracking strain up to strain rates in excess of 90 000 με/sec. Capacitive probe frequency responses are limited only to signal conditioner response

A wide range of gage lengths is possible


Prototype capacitive delta extensometer shown mounted in a test specimen.

Compared to bonded strain gages:

Less invasive when used *in vivo*; less complicated surgical procedure

No bonding agents required; no special surface preparation

Possibly more reliable — sensing portion of device not exposed to biological, harsh, or corrosive environment

No reinforcing effect (capacitive probes are noncontact)

Device is reusable

Limitations of device:

Must implant pins into specimen—method is invasive

Resolution is lower than bonded strain gages and other extensometers (+/-10 to 20 με at best versus +/-1 to 2 με)

More expensive than bonded strain gages

Method requires precise measurement of geometry or some form of medical imaging (MRI or fluoroscopy) when used *in vivo*. Strain calculation is very sensitive to geometry definition, such as gage length

	Measurement Environment	
Technology	Unidirectional Strain (direction known)	Multidirectional Strain (direction unknown)
Bonded Strain Gages	Uniaxial Strain Gage	Rosette Strain Gage
Extensometers	Uniaxial Extensometer	Delta Extensometer

Technology versus measurement environment. Dark shaded areas show commercially available technology. Delta extensometer described here is designed for strain measurement in environments where strain direction is unknown or is changing.

Technology

Termed for its similarity in shape to a delta rosette strain gage, the delta extensometer uses six paired capacitive linear displacement probes mounted to small pins, which are inserted into the specimen. The capacitive probes sense linear displacement of the pins, and these data are used to compute strain. This device is capable of monitoring physiological strains *in vivo*, and because of its unique configuration can differentiate between bending and axial strains.

The delta extensometer uses commercially available capacitive probes (as HPS-1X4C-A-200-FX, Capacitec, Inc., Ayer, MA) and signal conditioning equipment. Measured data are processed through a personal computer for calculation of parameters of interest.

The device was developed for measuring strain *in vivo* in human bone, in order to evaluate the efficacy of certain exercises for maintaining bone mass. NASA has a special interest in developing ways to understand the physiological effects of spaceflight and in devising countermeasures to ameliorate these changes. One of the most promising countermeasures to spaceflight-induced bone loss is exercise, but no exercise regime has yet been fully successful. The challenging task of obtaining strain data in human bone during physiological activity provided the motivation for development of this device. The research was done in collaboration with the Cleveland Clinic Foundation under Space Act Agreement FA-131.

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Key Words

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References

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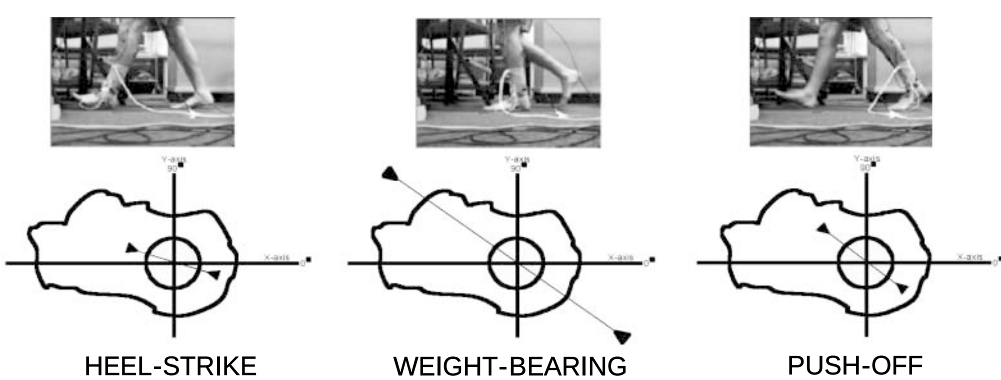

In vivo data collected from a human calcaneus (heel bone) during walking. Shown below each video frame is the corresponding principal compressive strain vector (magnitude and direction) overlaid on an outline of the left calcaneus in sagittal (side) view.