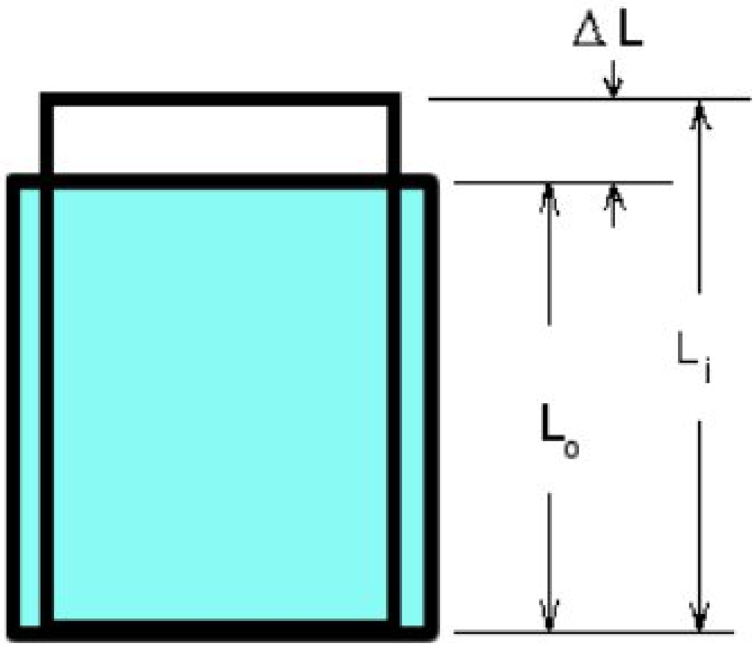
The Measurement of Deflection and Strain



Engineering Strain
is defined as the

change in length ΔL
divided by -----
the initial length L_0

For most purposes this definition is adequate for strains up to +/- 0.01

For larger strain calculations it is better to use the True Strain.

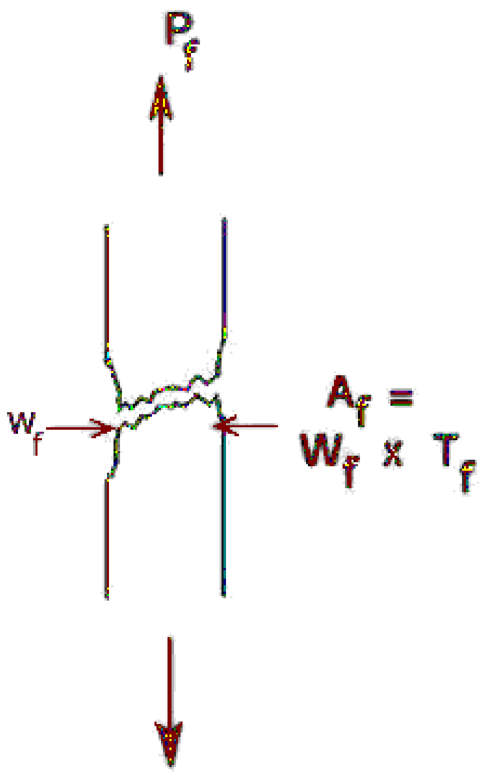
$$e = \Delta L / L_O$$

Engr. Strain

$$\varepsilon = \ln(1 + e)$$

True Strain

https://en.wikipedia.org/wiki/Strain_(materials_Science)#Strain



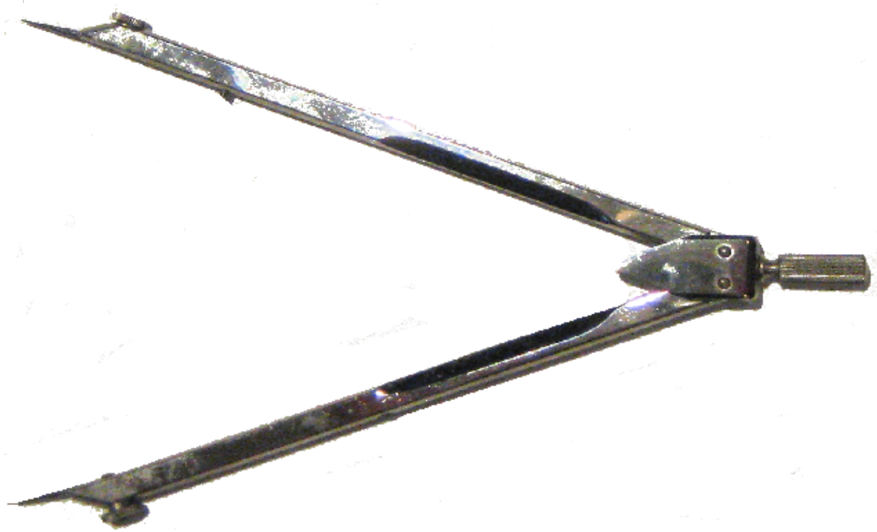
$$\varepsilon_f = \ln (A_o / A_f)$$

Fracture Strain

True strain can also be defined as the ln of initial area Ao divided by the instantaneous area Ai

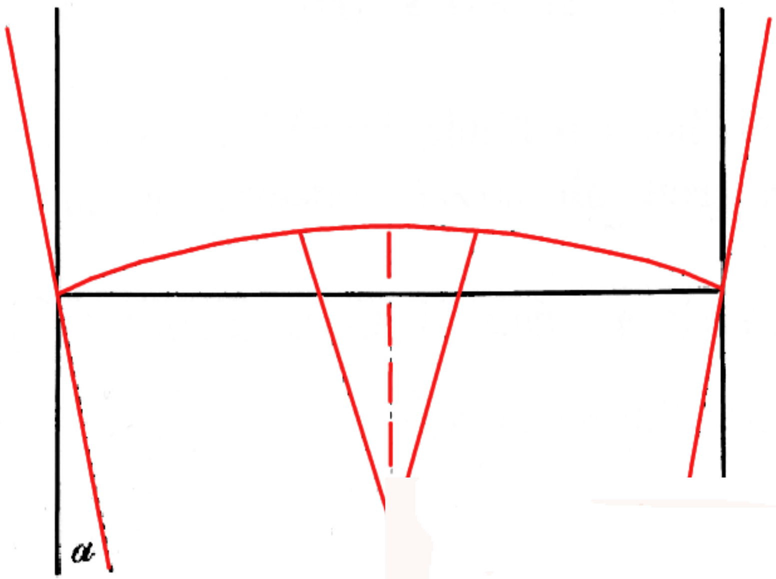
In the case shown, after specimen fracture, the instantaneous area Ai, is the fracture area Af projected onto a plane perpendicular to line of loading.

If a specimen is long enough or has lots of deflection one can place fine marks on the gauge length and measure with a ruler, but this is laborious for many measurements and not very accurate.



A specimen as long as the one shown will also buckle if compressed, so it is unsuitable for Tension-Compression fatigue testing.

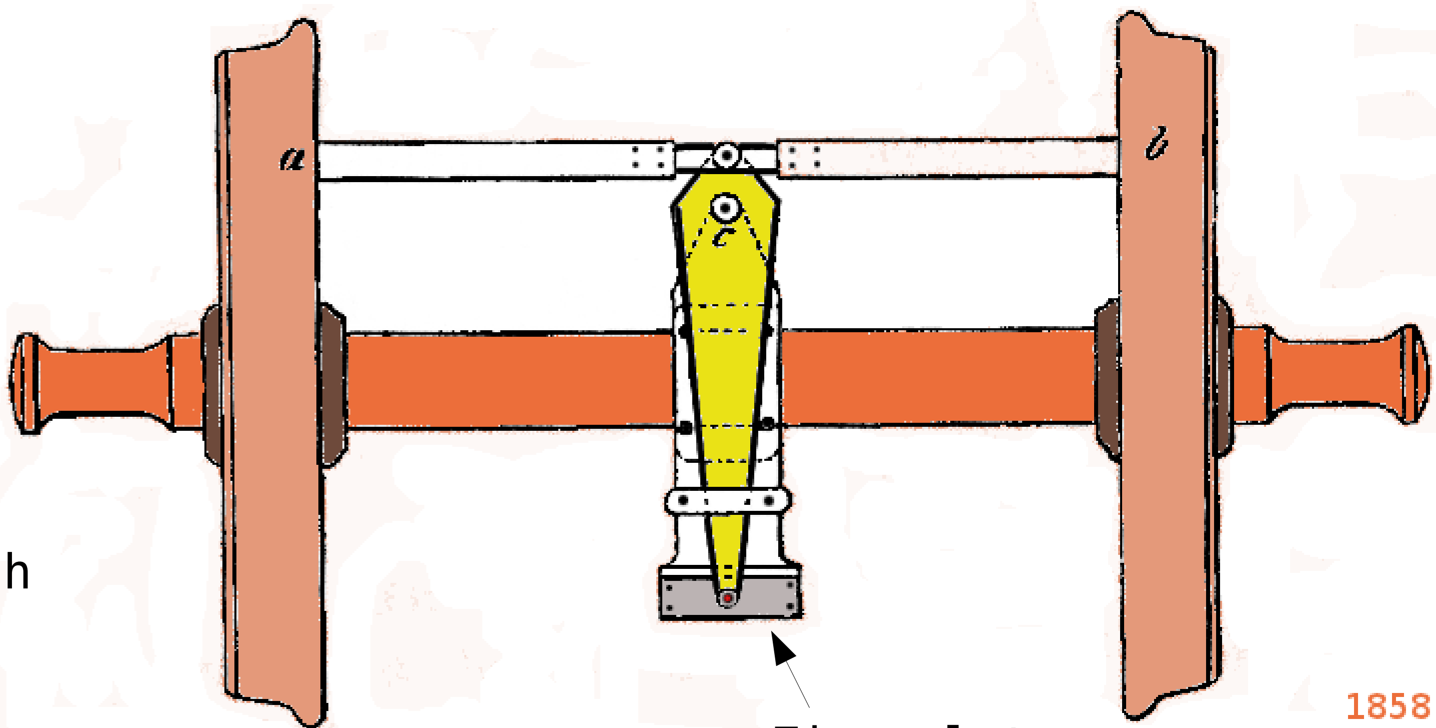
Fig. 3.



Wöhler axle bending strain
Measurement linkage:

The lever arm(yellow) pivots at *C*
and scribes a zinc plate(grey)
as train is moving.

Fig. 4.

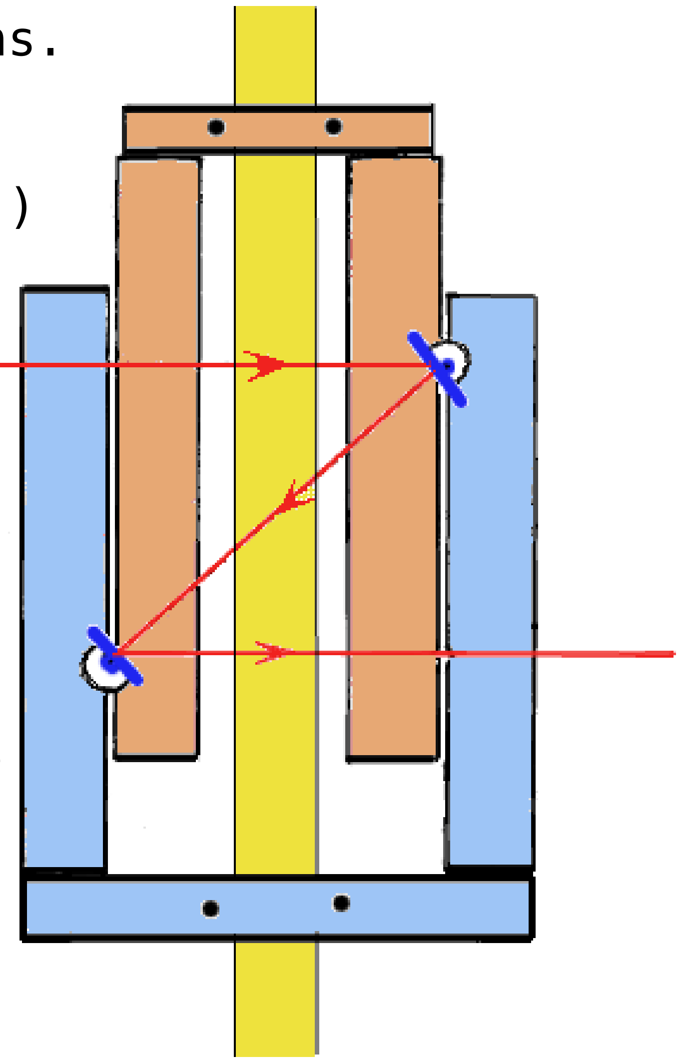


1858

Calibrated with
Known weights.

For improved accuracy other techniques have been invented to measure deflections.

This is a “Martens” extensometer (same guy who Martensite is named after)

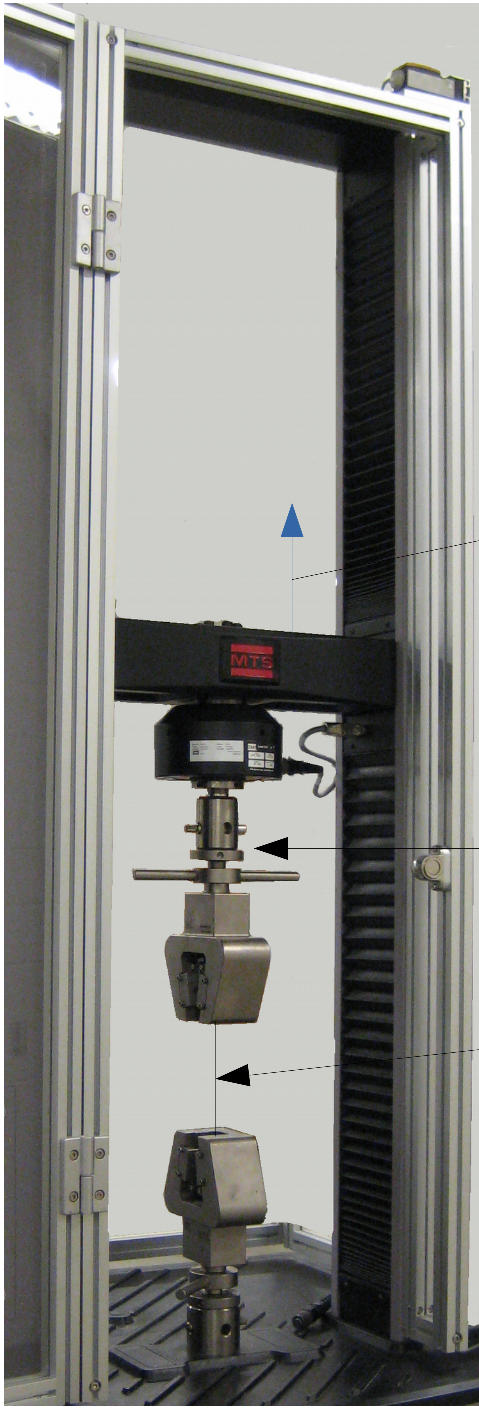


The brown and blue arms are clamped to the specimen and rotate the mirrors as the specimen is stretched or compressed.

The amount of deflection is read from the scale at right.

Bauschinger (later) used such an extensometer. As did many other experimenters before the electrical methods were developed.

The movement of the cross-head of screw drive test machine has been used in the past to slew one of the axes of an X-Y recorder or plotter, either thru a gear set or electrically.



Cross-head movement

-but cross-head deflection would also include the deflections of the gripping parts; thus making it difficult to calculate actual specimen deflections.

Specimen here

It is better to attach an extensometer of some sort to the specimen itself

Other Deflection Measurement Devices:

L.V.D.T. : Linear Variable Differential Transformer

Often used to measure the “stroke” or deflection of servohydraulic actuators.

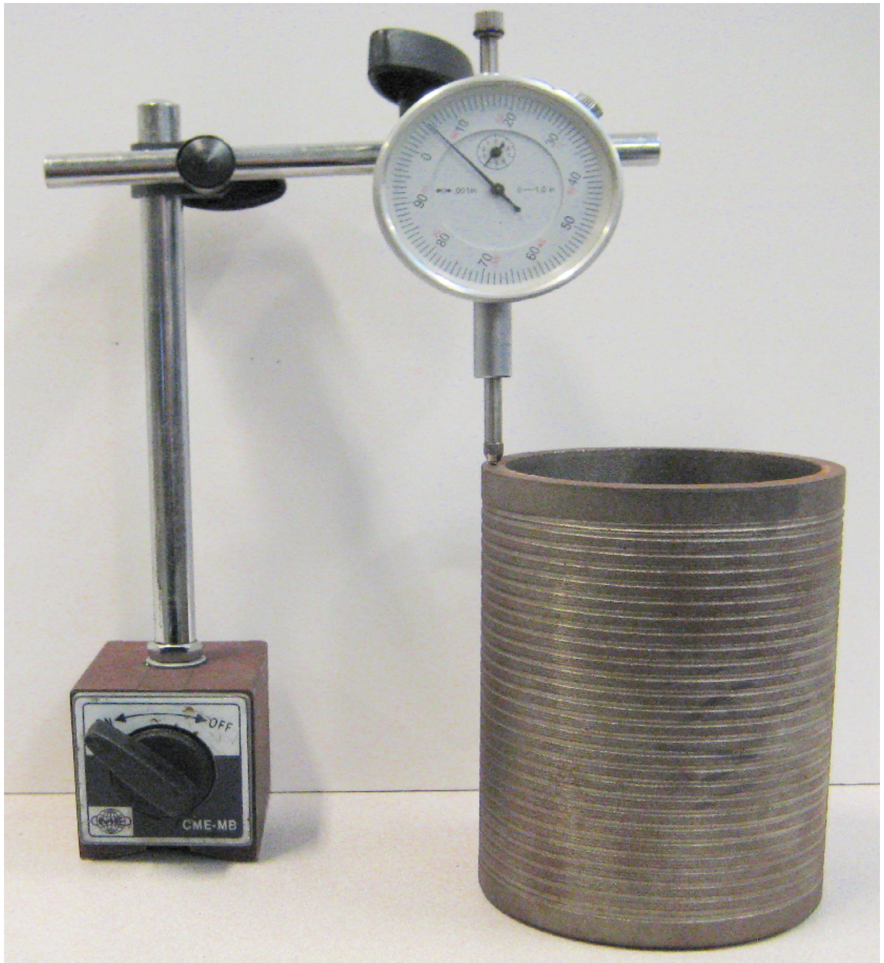
Their use for measuring strains in the lab has seen limited applications as they are usually too large/heavy to attach to small specimens.

Generally they are used to measure large deflections.

Wikipedia has a good description:

https://en.wikipedia.org/wiki/Linear_variable_differential_transformer

Other Deflection Measurement Devices:



Dial gauges translate deflections thru a set of gears to a dial display.

These are usually used in experiments that have slow, incremental loads applied; to a beam test for example.

They are not used in fatigue test situations where loads are fluctuating and being applied as fast as possible.

Capacitance gauges have been evaluated on rare occasions; basically two plates attached to the specimen alter the capacitance as they come closer in compression or further away in tension.

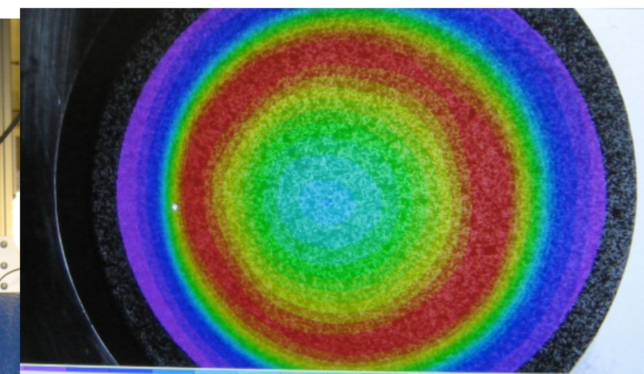
Capacitance gauges are not presently used in fatigue testing as far as I know.

Circa 1970 Optron developed a two lens (one for each end of the specimen gauge length) visual light based detector.

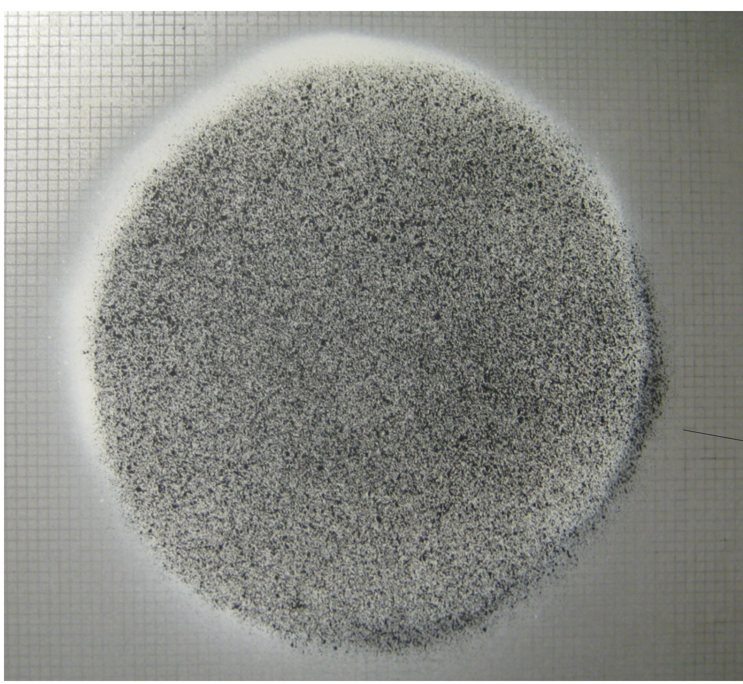
With increased computer speeds it has lately(2013) been possible to measure strains from the surface pattern of a specimen.

In this example, provided by Prof. D.Green and his students at U.Windsor, the strains are measured in a “bulge” test machine. A speckled paint pattern is sprayed onto the specimen and deformations are computed from spacing between each speckle or paint spot.

Camera system



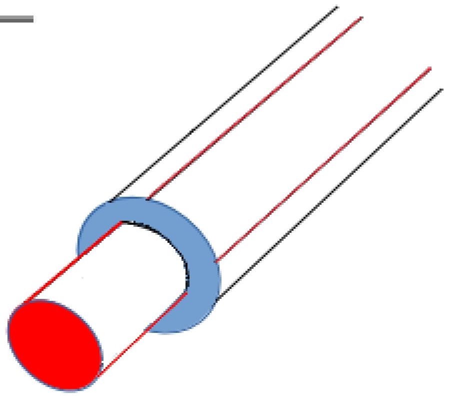
Strains



Electrical Resistance Strain Gages:

Pouillet's Law

$$R = \rho \frac{l}{A}$$

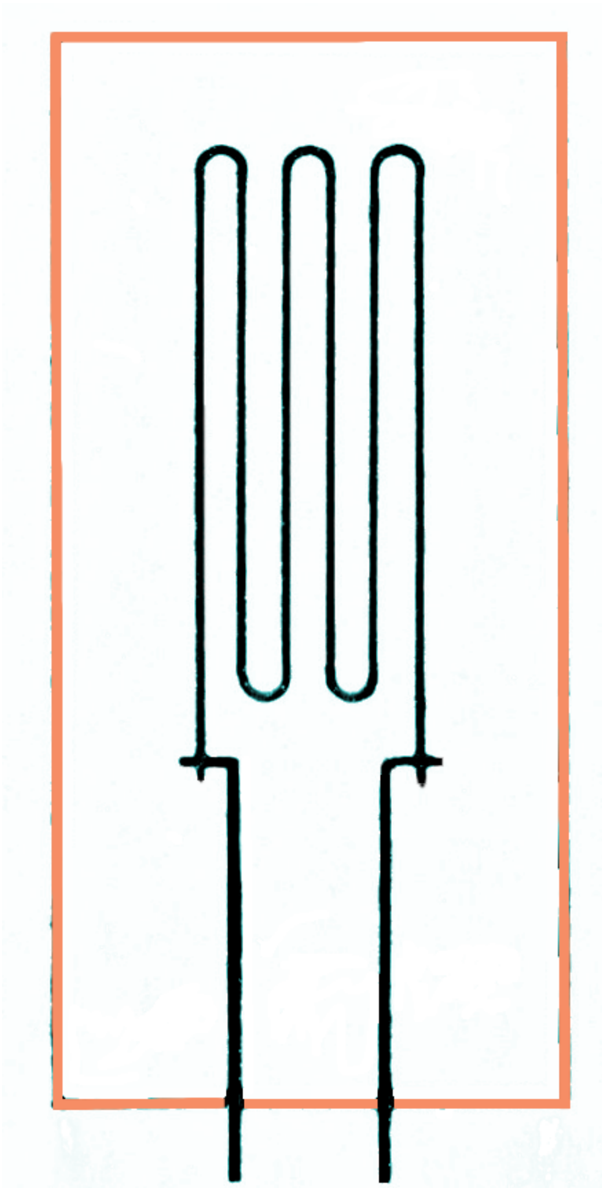


The resistance of a wire to electrical current flowing in it is dependent upon length and cross-sectional area. The current is forced though the wire by a voltage difference between each end.

R = Resistance
ρ = Resistivity
l = Length
A = Area

Thus if one glues a wire to a specimen and then stretches the specimen, the attached wire will deform and change its resistance.

Given a constant current, one can thus calibrate the voltage difference, between each end of the wire to known deflections.

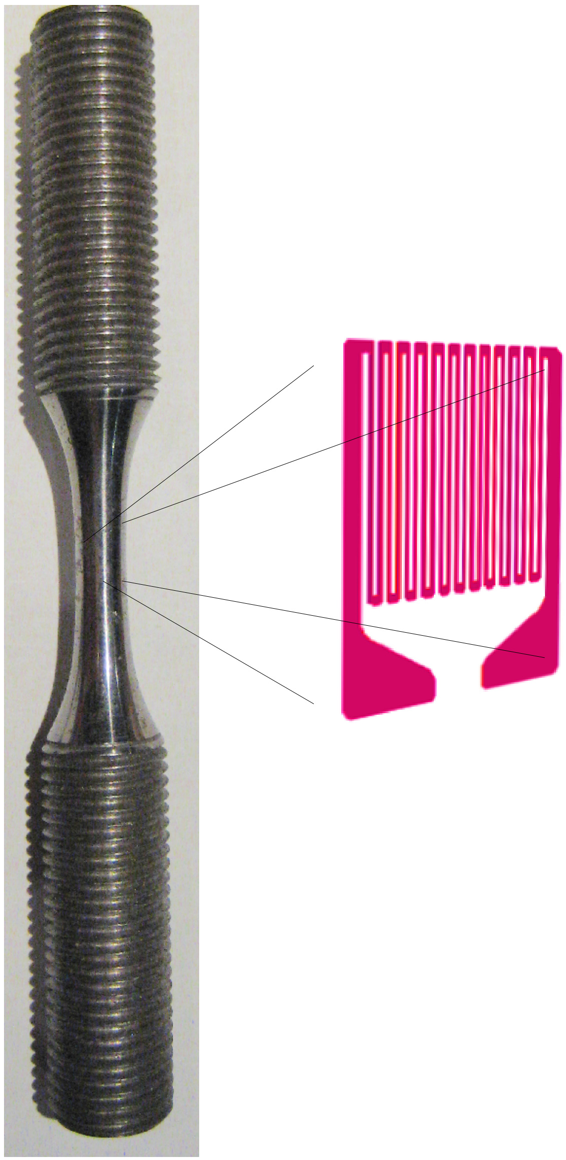


The original electrical resistance strain gages were round wires glued to the surface of an object.

The wires were folded to increase the signal strength for a given deflection.

Strain gages today tend to be made of metal foil (flat wires) and there are many types available.
e.g.:

http://www.omega.com/prodinfo/StrainGages.html

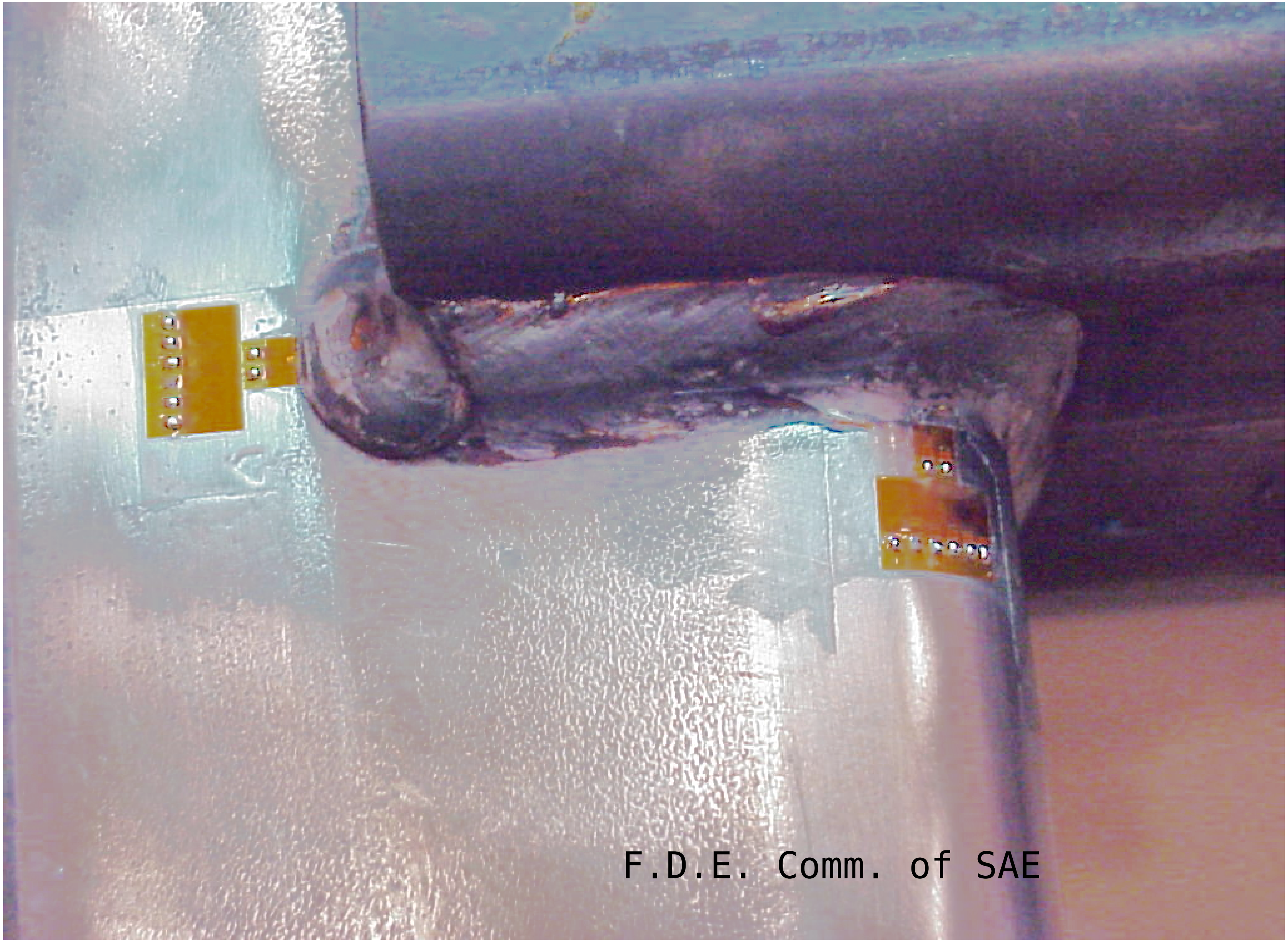


If one glues a strain gage directly to a specimen or a component the gage will experience the same deformations as the specimen.

In a fatigue test, where plastic deformations often occur, the gage will also experience plastic strains and lose its zero, become uncalibrated and quickly fail in fatigue.

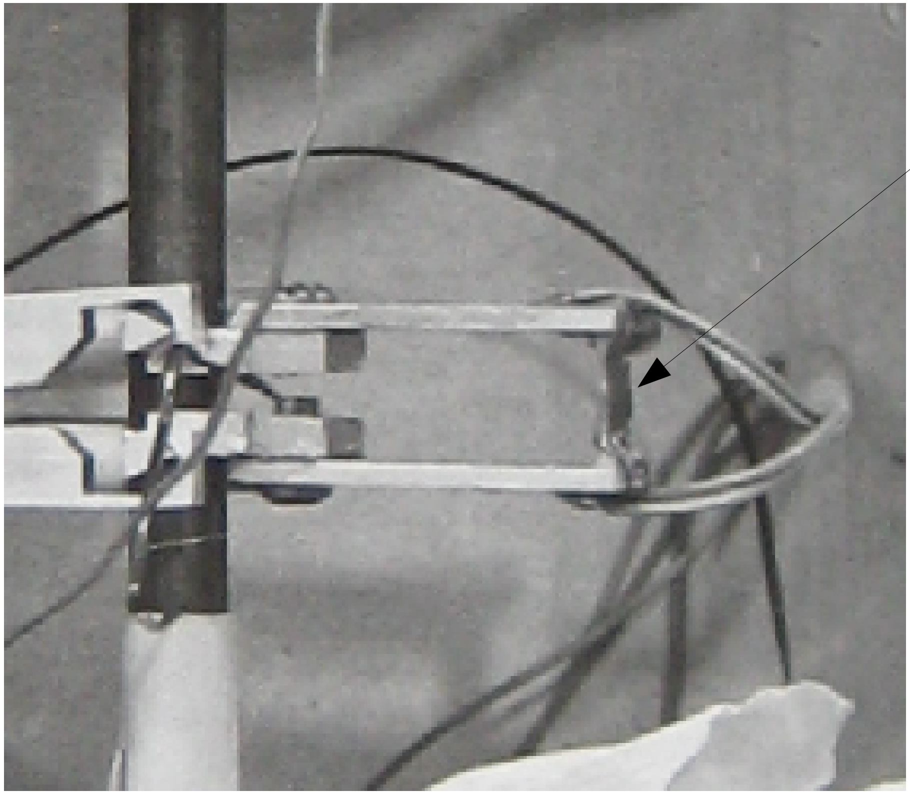
A glued-on gage used for feedback in a closed loop feedback control test is prone to error and can damage machine or operator.

Techniques must be employed to keep the gage in its elastic infinite life deformation zone



Strain gages are often used to quickly measure the strains at fatigue critical locations of components.
Close to a weld for example. (wires not attached)
Also to check Finite Elem. predictions.

Strain gaged extensometers were created to overcome gage plasticity problems.



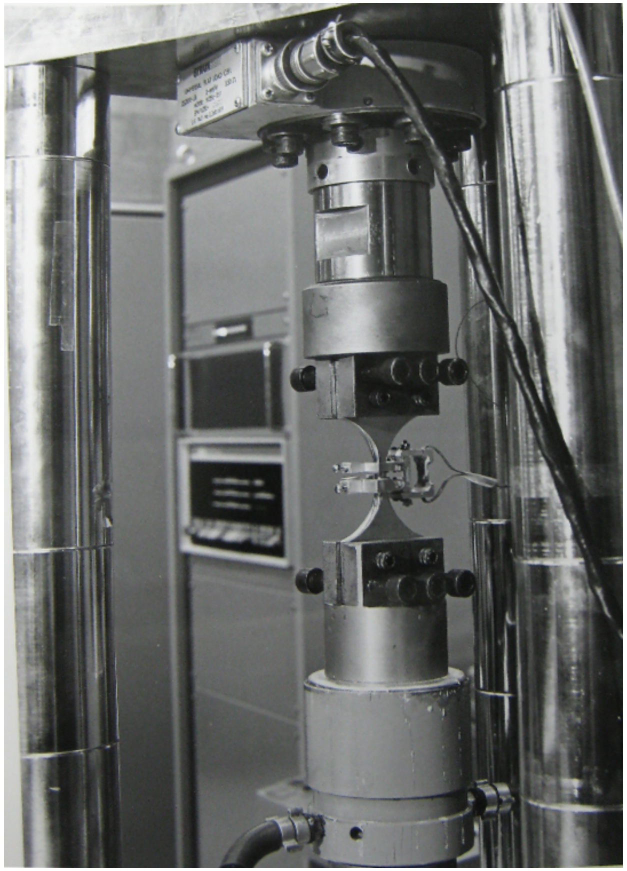
Strain gages

(Full Wheatstone Bridge)

See Wikipedia:

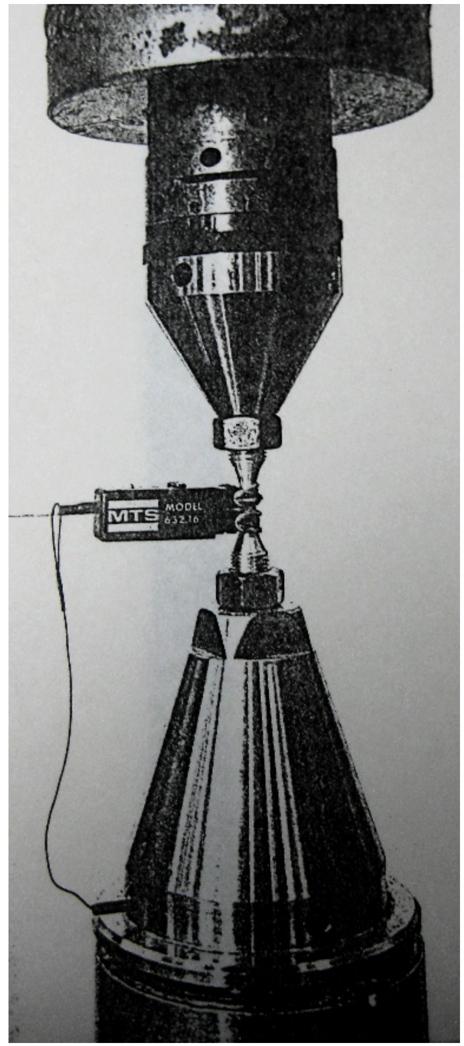
https://en.wikipedia.org/wiki/Wheatstone_bridge

Strain gage extensometers come in many shapes and sizes to fit the test



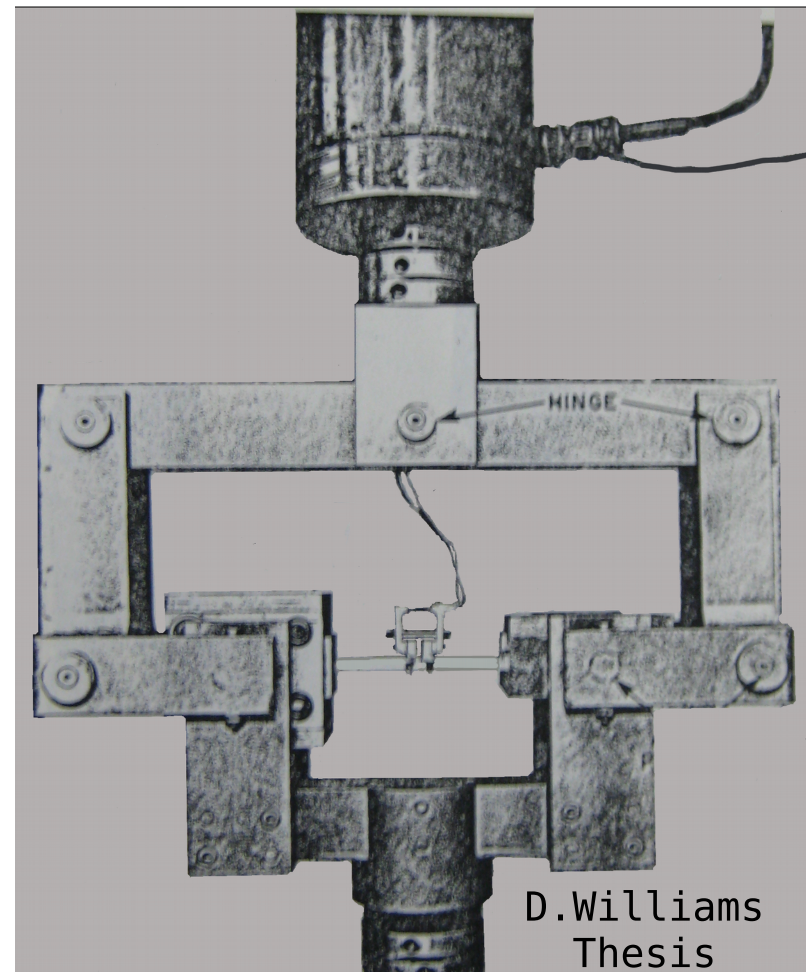
P.Watson Thesis

Axial Specimen
Extensometers
(feedback control)



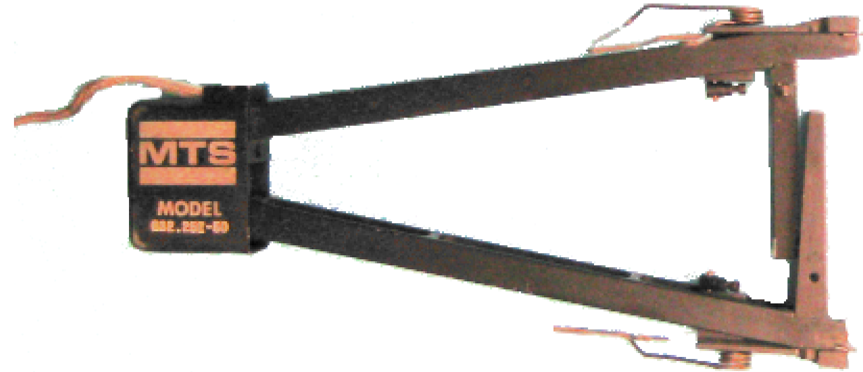
T.Lam thesis

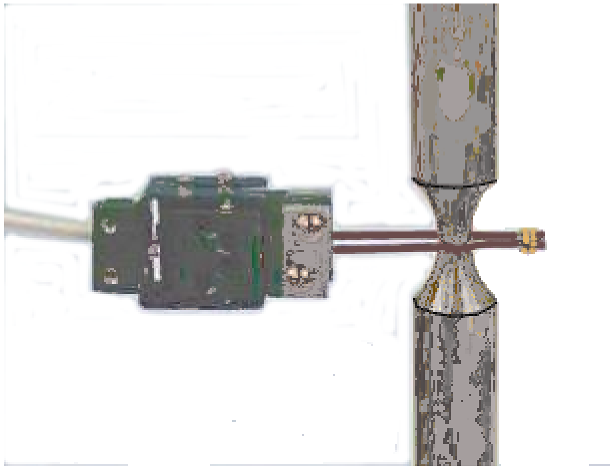
4-Point Bending Beam
Extensometer
(monitors strains while
test is stroke control)



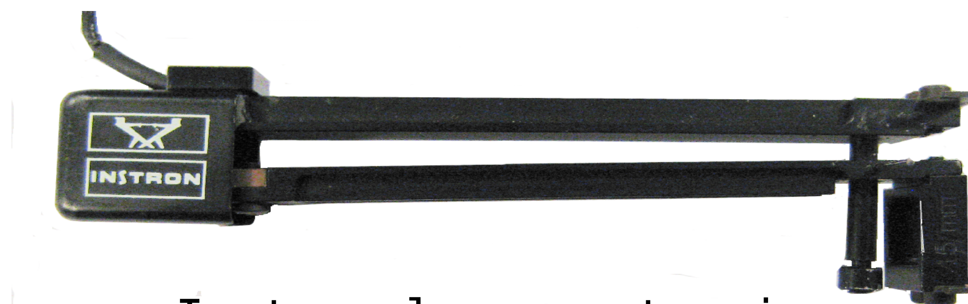
D.Williams
Thesis

MTS long gauge length
For tensile testing





Epsilon Diametral
Extensometer
(Ok for test control)



Instron large extension
For tensile testing