Force Measurement

Supplementary Information

Axial-Load

Torsion

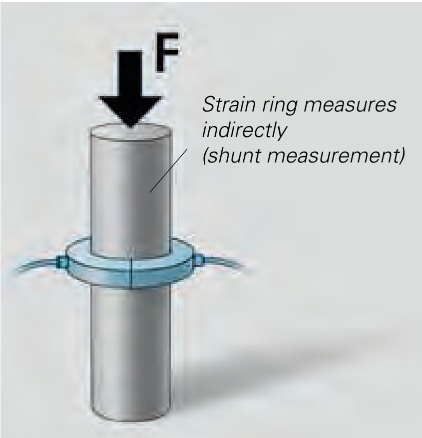
Hydraulic

Presses

Indirect Force Measurement

Bending

Overview of applications for STRAIN-MATE™ and other surface strain sensors



Axial Load in Cylinder

Calibrated measurement with strain ring type DSRC. The applied force can be directly calculated by the following formula:

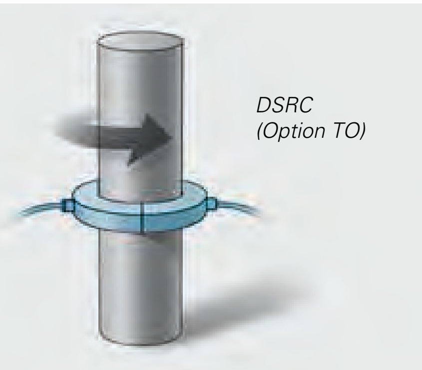
$$F = A \times E \times \varepsilon$$

A = Cross section [mm^2]
E = E-Modulus [N/mm^2]
ε = Strain Δ l/l

The entire force passes through the cylinder and is measured with two pressed-on strain gages. The more accurate the Young's modulus is known the more precise the force can be measured.

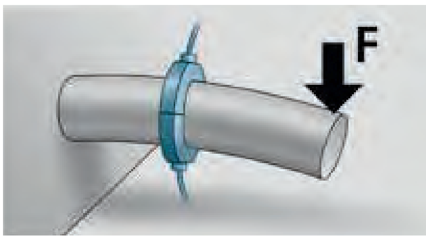
Elastic modulus E

Steel	210'000 N/mm^2	Titan	105'000 N/mm^2
Aluminum	70'500 N/mm^2	Copper	120'000 N/mm^2



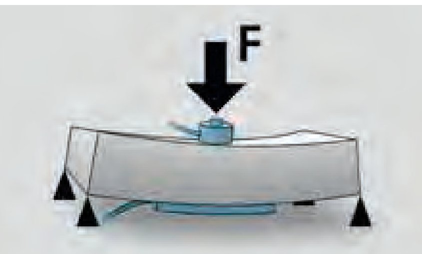
Torsion

Torsion measurement is easy with the strain ring type DSRC/Option TO.
Strain rings with option TO can be connected to standard sensopress amplifiers.
For rotating torque measurements the strain ring may be connected to a commercially available telemetry system.



Bending on a Cylinder

The strain ring type DSRC used in a 1/2-bridge arrangement directly measures the axial load compensated bending strain.



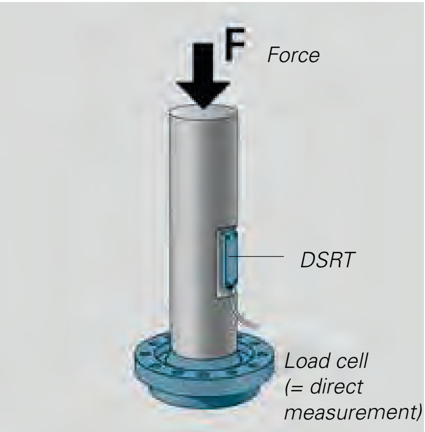
Bending on Beams or Cross Heads

Bending measurements on beams with strain link type DSRT.

Supplementary Information

Force Measurement

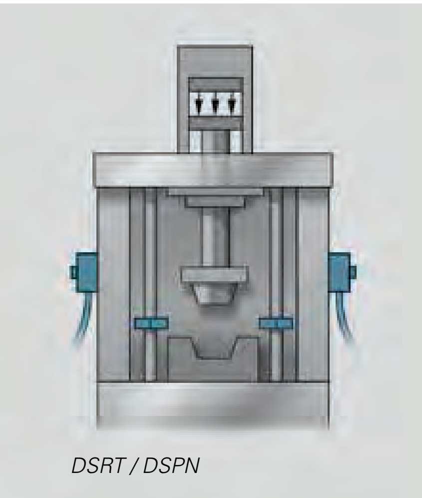
Load cells measure the force directly. The advantage is that the force can be directly recorded in kN. Alternatively, the indirect (or shunt) force measurement with strain sensors offers the advantage that there is no need to install a load cell into the load flow. In addition the strain sensors cannot be overloaded. On the other hand, it is necessary to calibrate the measuring chain. The indirect measurement always guarantees excellent repeatability.



Indirect Force Measurement

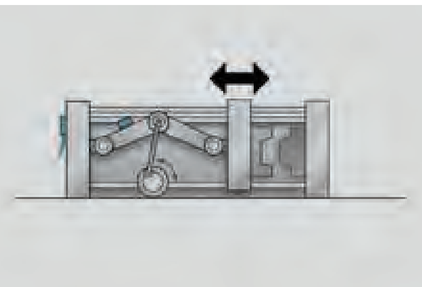
Indirect force measurement can be done with asymmetrically attached strain sensors. The surface strain can contain a superimposed bending component. For a given set up, this component remains proportional to the force. Process monitoring can be performed with or without calibration.

Application:
- Strain link DSRT for standard applications



Hydraulic Presses

The load distribution on a hydraulic frame press is measured with two strain sensors. To determine the magnitude of the force, a pressure sensor may be used to measure the hydraulic pressure in the cylinder. For accurate measurements, the system must be calibrated with a load cell installed in the load flow. The load cell for instance, can be temporarily put in place of the tool.



Mechanical Presses

On presses with a mechanical clamping mechanism, the force can be measured indirectly on the toggle mechanism or on one of the plates.
Using sensors with sufficiently high resolution (DSPN), allows one to measure the clamping force and at the same time detect a potential collision. For instance, a collision can be caused by a part not completely removed. With such a high resolution sensor, it is possible to implement a tool protection system on production machinery.

Hysteresis

Glossary and Explanations

Gage

Nominal

Zero Signal

Thin-Film

Strain

$$\varepsilon = \frac{\Delta l}{l}$$

Strain is defined as the non-dimensional ratio of length change / initial length. Microstrain is often used as strain unit.

$$1 \text{ microstrain } [\mu\varepsilon] = 10^{-6} \frac{m}{m} = 1 \frac{\mu m}{m}$$

Mechanical strain

The mechanical strain results of the strain of the E-modulus of the material respectively of the force per area.

$\sigma = \varepsilon * E$ (in the flexible span)

bzw. $\sigma = F/(E*A)$

Material	E-modulus (typical)
Steel	210 kN/mm^2
Aluminium	70.5 kN/mm^2

Example: 250 µm/m strain equals to a mechanical strain of 52,2 N/mm^2 respectively (52,5 MPa) on steel.

Output range

The output voltage is the difference between the output signal at zero load and the output signal at nominal load.

Nominal characteristic value

Specified output signal at nominal load (nom. output voltage).

Characteristic value

Actual (measured) output range.

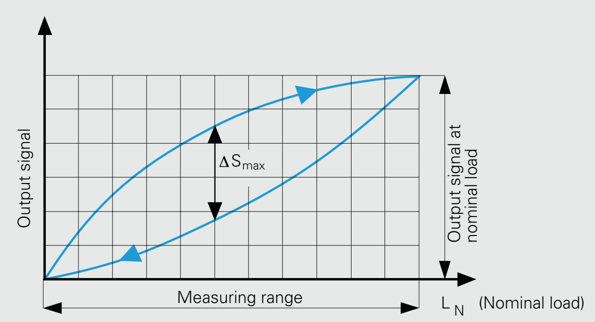
Measuring range

Load range in which the specified errors are not exceeded.

Hysteresis

Hysteresis signifies the hysteresis error F_h. ΔS_{max} is the largest difference between the increasing and decreasing calibration curve up to the nominal load. Hysteresis is expressed in % of full scale.

$$F_h = \frac{\Delta S_{max}}{F_N}$$

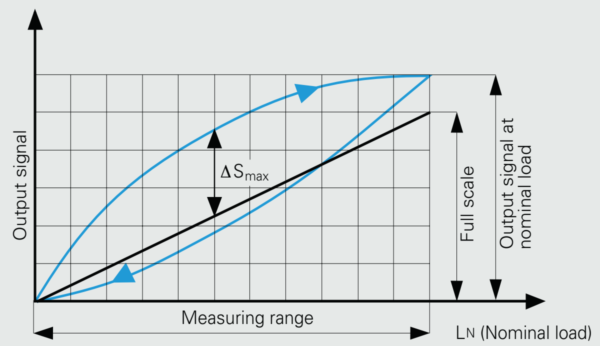


Terms/Explanations
General

Characteristic curve deviation

The characteristic curve deviation signifies the maximum deviation of the calibration curve to the specified straight line. The specified straight line passes through the origin. The end point results from the origin + nominal output voltage.
The characteristic curve deviation contains hysteresis, linearity error, repeatability and deviation of real to nominal output voltage.

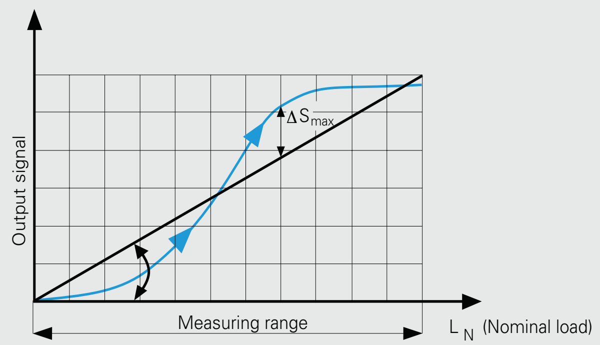
$$F_{Com} = \frac{\Delta S_{max}}{FS}$$



Linearity

Linearity error F_L is the largest difference ΔS_{max} between the increasing calibration curve and the straight line through the origin with slope C_L.
C_L is selected such that ΔS_{max} is minimized. The linearity is expressed in % of full scale.

$$F_L = \frac{\Delta S_{max}}{C_L \cdot L_N}$$



Micro strain [με]

See strain.

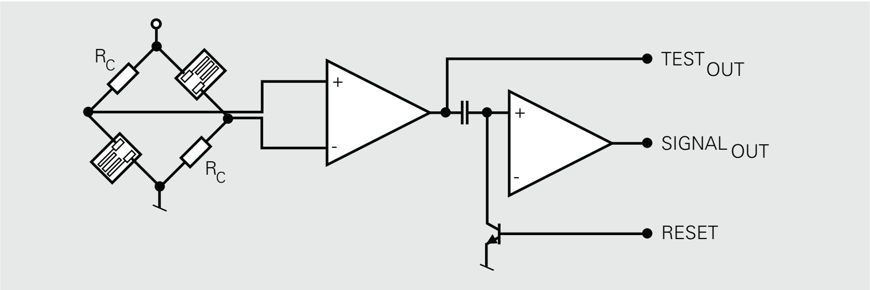
Zero, bridge balance

Generally all S/G bridges exhibit an initial offset which can be tared by different means. After the installation the offset of STRAIN MATE™ sensors may be quiet large due to the press-on technique. Baumer amplifiers and display instruments are equipped with a reset circuit which allows fast and convenient zeroing over a large range. For static applications, amplifiers with zero balance potentiometers or digital taring are used.

Repeatability

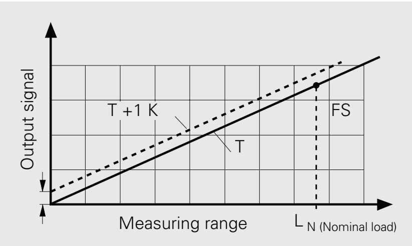
The difference in reference to the characteristic value between the max. and the min. display value of equal measuring points in case of repeatation of identical load cycles.

$Test_{OUT}$



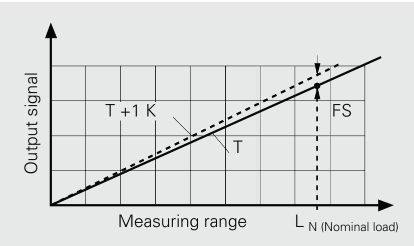
The non-tared signal is available at the output $Test_{OUT}$. To prevent saturation of subsequent stages, $Test_{OUT}$ should ideally read between -2 V and +2 V when the sensor is installed and no load is applied. During operation this value may then be between -5 V and +5 V. The $Test_{OUT}$ output can furthermore be used to check the measuring chain. In case of an open bridge circut, $Test_{OUT}$ goes into saturation.

TC of zero signal



The maximum temperature coefficient (TC) of the zero signal is the largest variation of the zero signal which occurs during a change in temperature by 1 Kelvin. It is expressed in percent of full-scale per Kelvin.

TC of output range



The largest temperature coefficient (TC) of output range is the largest variation in output range which occurs during a change in temperature by 1 Kelvin. It is expressed in percent of FS*) per Kelvin.

*) FS = Fullscale of output range

Terms/Explanations
Strain Gages

Strain gage (S/G)

Strain Gage. The S/G changes the electrical resistance proportionally to the applied strain.

Gage factor

The sensitivity of a S/G is expressed by the ratio of the relative resistance change to the strain:

$$k = \frac{\Delta R}{R} \times \frac{1}{\varepsilon}$$

R Resistance of S/G
ΔR Resistance change due to strain
ε Strain of S/G

Transverse sensitivity

Ideally S/G should only react with a resistance change as expressed by the gage factor when strain is applied in the «active» direction of the gage. A resistance change is also observed when strain is exerted transverse to its «active» direction. This is known as transverse sensitivity and is expressed in percent of the gage factor.

Temperature compensation

When the temperature of the measurement location changes, an output signal is produced. This is due to the change in specific resistance and the thermal expansion of the object. This signal which is known as the temperature output of the measurement point is independent of the mechanical load applied to the object to be measured. The temperature output of a strain gage is controlled through the material properties such that the temperature effects are largely compensated.