Experimental stress and strain analysis

When dimensioning components are subject to mechanical load so that they can properly perform their function, it is necessary to know the nature of the loads. In particular, it is important to determine the maximum occurring stresses, which ultimately define the dimensions. These stresses should be determined in advance and then tested by experiment. Experimental stress and strain analysis can therefore be regarded as a link between theoretical calculation and experimental evidence.

Two methods of non-destructive experimental stress and strain analysis are presented here:

- the **electrical method** of strain measurement using strain gauges to indirectly determine the actual stresses
- the **photoelastic method** for a direct representation of the stress distribution

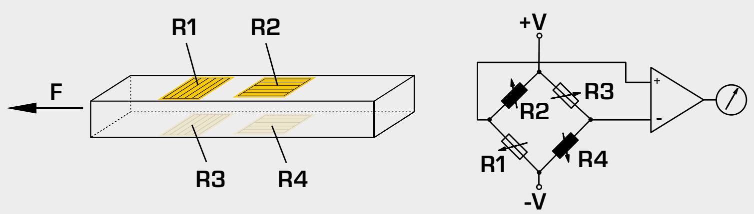
Strain measurement using strain gauges

Stresses in components can be determined via the circuitous route of strain measurement, as the strain of the material is directly related to the material stress. An important branch of experimental stress and strain analysis is based on the principle of strain measurement. The advantage of this method is that strain gauges can be used on real components in operation.

Strain gauges comprise resistance wires that are adhered to the surface of the workpiece. If the surface is extended, the wire is lengthened and its cross-section decreases. This increases the electrical resistance. In the case of compression, the resistance decreases. In a Wheatstone bridge, the resistors are connected as a voltage divider. The measuring circuit is particularly suited for measuring small changes in resistance and, therefore, for determining the resistance change of a strain gauge.

Determining the magnitude and direction of mechanical stresses

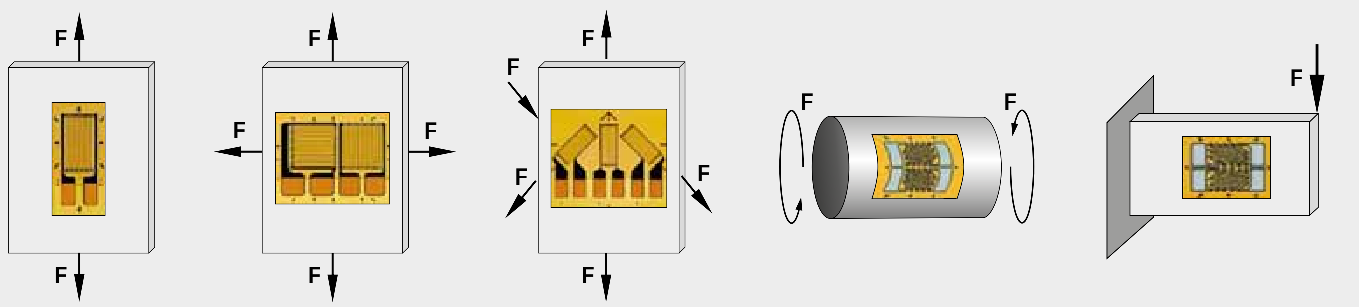
Using the generalised Hooke's law, we can calculate the stresses σ from the strain ε measured at the surface.



Measuring the strain to determine the tensile stress

R2 + **R4** measurement of longitudinal strain,
R1 + **R3** measurement of lateral strain, **F** force

Selecting and installing the strain gauge to investigate different stress states



Uniaxial stress state such as tension or pressure

Biaxial stress state

Unknown direction of principal stress

Torsional strain

Shear stress in the neutral strand

Different structural shapes for different applications

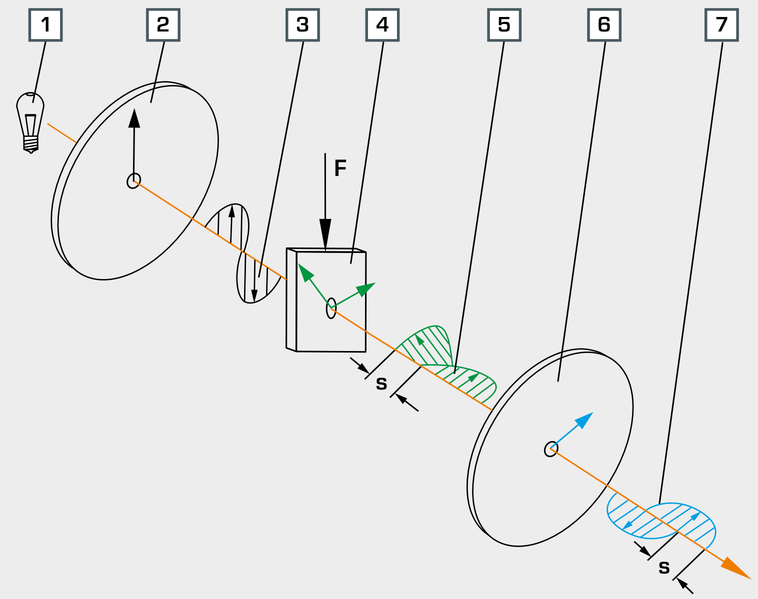
F force

Representation of the stress distribution using photoelasticity

Photoelasticity is a method with great illustrative qualities and a simple experimental setup, in which two-dimensional stresses in the model of a component are made visible. Polarised light shines through the model – which is made of a special transparent plastic – and it is subjected to mechanical load. The load causes stresses in the model. This causes birefringence in the plastic in the direction of the principal stresses. Stresses can be made visible in the model using a polarisation filter (analyser). Photoelasticity, therefore, provides a complete picture of the stress field and offers a good overview of areas of high stress concentration and areas of low stress. Consequently, analytically or numerically performed stress considerations can be visually verified.

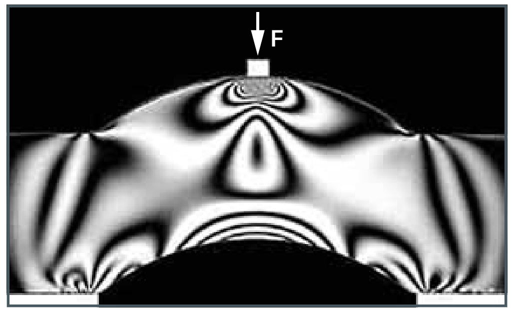
The relevant effect is attributed to the birefringence of transparent materials under mechanical load and light exposure. In plastics, birefringence occurs in the direction of the principal stresses. These physical properties are used in photoelasticity to make visible stresses or the resulting strains. This is why plastic models are used in these experiments instead of the original materials.

Principle of photoelasticity

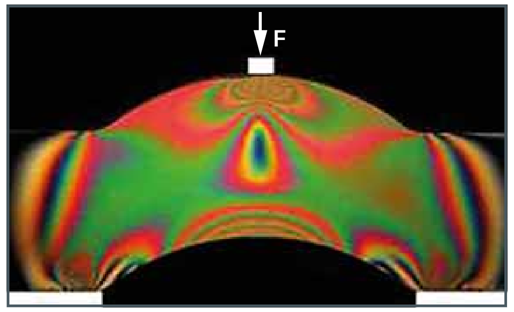


1 light source,
2 polariser,
3 linearly polarised light,
4 model,
5 light decomposed into two components in the direction of the principal stress,
6 analyser,
7 horizontal components of the light

F force,
s path difference



Dark field of an arch in monochromatic light, **F** force



Dark field of an arch in white light, **F** force

A polariscope can be used to study transparent models of components, whose optical properties change under the influence of internal stresses. If the model is stress-free, there is no birefringence and the model appears black. If a load is applied and increased, this creates a path difference that increases in proportion to the magnitude of the difference in the principal stresses.

The arch shown here is loaded by the force F like a vault. The high density of isochromats in the inner circle of the arch – where the highest stresses occur – can be clearly seen. The individual lines are better resolved in monochromatic light, and in the above illustration, we can clearly recognise the onion-like linear paths under the application of force.