



**University Of Jordan**  
**Faculty of Engineering and Technology**  
**Industrial Engineering Department**

**Measurement Lab.**

**STRAIN GAUGES**

**Student Name :**

**Student No. :**

**GROUP (      )**

## Objectives

Upon completion of this study and the evaluation of experimental measurements, the student will be able to:

- Describe how strain gauge devices are used for measurements,
- Describe the type of circuitry used in connecting strain gauge transducers,
- Describe how a strain gauge should be physically attached to objects.

## Introduction

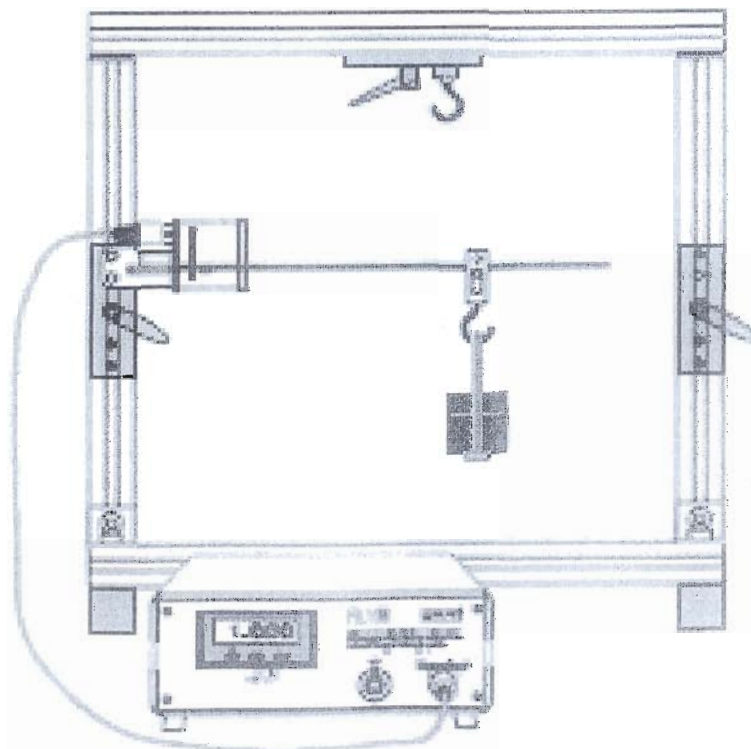
**Strain gauges** permit simple and reliable determination of stress and strain distribution at real components under load. The strain-gauge technique is thus an indispensable part of experimental stress analysis. Widespread use is also made of strain gauges in sensor construction (scales, dynamometers and pressure gauges, torque meters).

All **test objects** are provided with a full-bridge circuit and are ready wired. A Perspex cover protects the element whilst giving a clear view.

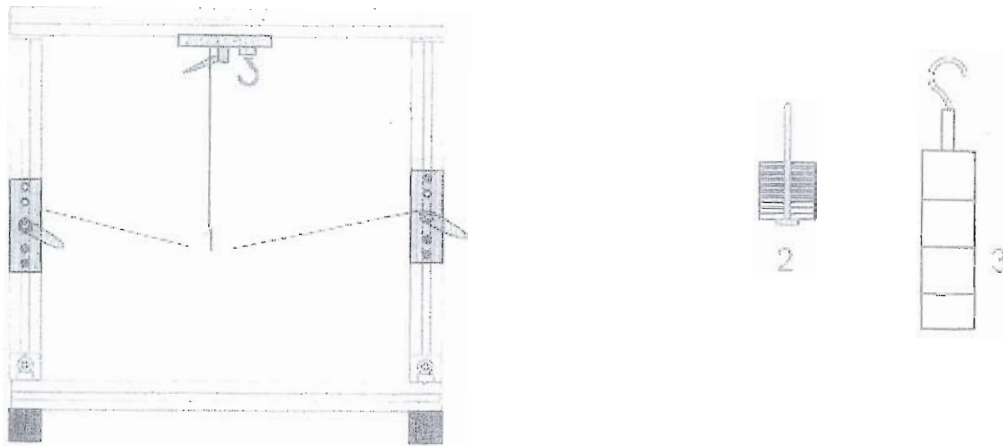
The test objects are inserted in a frame and loaded with weights.

The **measuring amplifier** has a large bright digital LED display, which is still easy to read from a distance. The unit is thus also eminently suited to demonstration experiments.

## 2 Unit description



## 2.1 Loading frame



The loading frame is made of light-alloy sections and serves to accommodate the different test objects. Various holders (1) are attached to the frame for this purpose. Clamping levers enable these holders to be quickly and easily moved in the grooves of the frame and fixed in position. The training system is provided with two different sets of weights for loading the test objects.

- Small set of weights (2) ——— 1 - 6 N, graduations 0.5 N for bending experiments

## 2.2 Test objects



### 2.2.1 Bending beam

The test object used for **bending experiments** is a clamped steel cantilever beam (4).

- Length L: 385 mm

- Cross section Area:

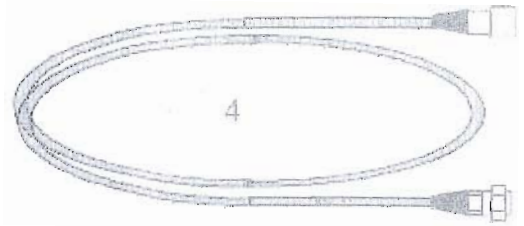
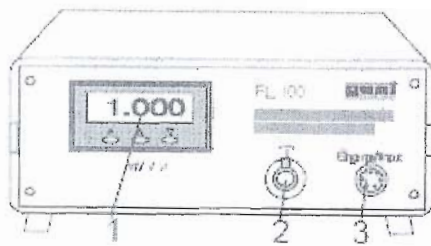
$$h=4.75 \text{ mm}$$

$$b=19.75 \text{ mm}$$

- Modulus of elasticity E: 210000 N/mm<sup>2</sup>

The strain-gauge element (2) (full-bridge circuit) is attached in the vicinity of the clamping point. Electrical connection is by way of a small PCB and a 5-pin socket (1) with bayonet lock. The strain-gauge configuration can be seen from the adjacent diagram. The element is protected by a Perspex housing. An adjustable slider (3) with hook permits loading with a single force at defined lever arm.

## 2.3 Measuring amplifier



The measuring amplifier with digital 4-position LED display (1) gives a direct indication of the bridge unbalance in mV/V. The connected strain-gauge bridge can be balanced by way of a ten-turn potentiometer (2).

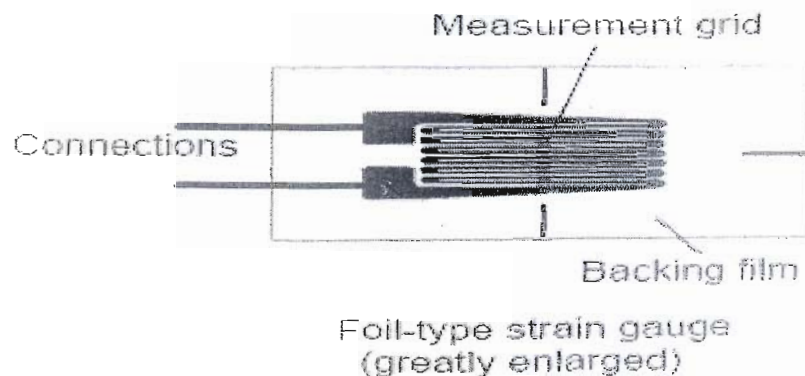
- Range:  $\pm 2.000$  mV/V
- Resolution:  $1 \mu\text{V/V}$ .
- Balancing range:  $\pm 1.0$  mV/V.
- Nominal strain-gauge resistance:  $350 \Omega$
- Strain-gauge feed voltage : 10V
- Power supply: 230V / 50Hz

The unit is envisaged for the connection of strain gauge full bridges. The test objects are connected by way of the cable (4) supplied to the 7-pin input socket (3) on the front.

## 3 Experiments

### 3.1 Principle of strain-gauge technique

When dimensioning components, the loads to be expected are generally calculated in advance within the scope of design work and the components then dimensioned accordingly. It is often of interest to compare the loads subsequently encountered in operation to the design forecasts. Precise knowledge of the actual load is also of great importance for establishing the cause of unexpected component failure. The mechanical stress is a measure of the load and a factor governing failure. This stress cannot generally be measured directly. As however the material strain is directly related to the material stress, the component load can be determined by way of strain measurement. An important branch of experimental stress analysis is based on the principle of strain measurement.



The use of the strain-gauge technique enables strain to be measured at the surface of the component. As the maximum stress is generally found at the surface, this does not represent a restriction. With metallic strain gauges, the type most frequently employed, use is made of the change in the electrical resistance of the mechanically strained thin metal strip or metal wire. The

change in resistance is the combination of tapering of the cross-sectional area and a change in the resistivity. Strain produces an increase in resistance. To achieve the greatest possible wire resistance with small dimensions, it is configured as a grid. The ratio of change in resistance to strain is designated  $k$

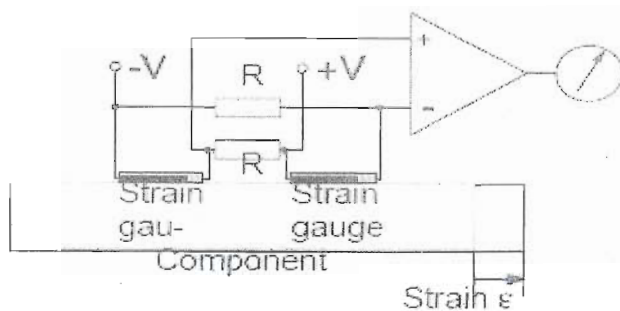
$$k = \frac{\Delta R / R_0}{\epsilon}$$

$\epsilon$  : strain

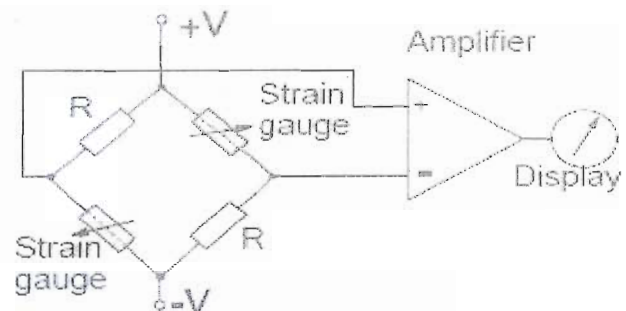
$R_0$  : resistance at zero point ( no force)  $\Omega$

$\Delta R$  : change in resistance after applying force  $\Omega$

Strain gauges with a large  $k$ -factor are more sensitive than those with a small one. The constantan strain gauges used have a  **$k$ -factor of 2.05**. In order to be able to assess the extremely small change in resistance, one or more strain gauges are combined to form a Wheatstone bridge, which is supplied with a regulated DC voltage ( $\pm V$ ).



Configuration of half bridge  
on component



Halve-bridge circuit

The bridge may be fully (full bridge) or only partially (half and quarter bridge) configured with active strain gauges. The resistors  $R$  required to complete the bridge are called complementary resistors. The output voltage of the bridge reacts very sensitively to changes in resistance in the bridge branches. The voltage differences occurring are then amplified in differential amplifiers and displayed.

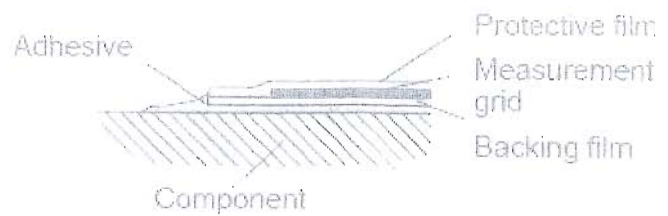
The design of a strain gauge is shown in the adjacent illustration. The wave-form metal strips are mounted on a backing material, e.g. a thin elastic polyimide film and covered with a protective film. Today's metal strips are usually produced by etching from a thin metal foil (foil-type strain gauges). Thin connecting wires are often welded directly to the strain gauge.

The strain gauge is bonded to the component with a special adhesive, which must provide loss-free transmission of the component strain to the strain gauge.

Adhesive



Design of strain gauge



### 3.3 Bending experiment



#### 3.3.1 Fundamentals

The stress at the surface of the bending beam can be calculated from the bending moment  $M_b$  and the section modulus  $W_y$

$$\sigma = \frac{M_b}{W_y}$$

Bending moment calculated for cantilever beam

$$M_b = -F \cdot L$$

where  $F$  is the load and  $L$  the distance between the point at which the load is introduced and the measurement point. The section modulus for the rectangular cross section of width  $b$  and height  $h$  is

$$W_y = \frac{b \cdot h^2}{6}$$

For **experimental determination** of the bending stresses, the bending beam is provided with two strain gauges each on the compression and tension sides. The strain gauges of each side are arranged diagonally in the bridge circuit. This leads to summation of all changes in resistance and a high level of sensitivity. The output signal  $U_A$  of the measuring bridge is referenced to the feed voltage  $U_E$ . The sensitivity  $k$  of the strain gauge enables the strain  $\varepsilon$  to be calculated for the full bridge as follows

$$\varepsilon = \frac{1}{k} \cdot \frac{U_A}{U_E}$$

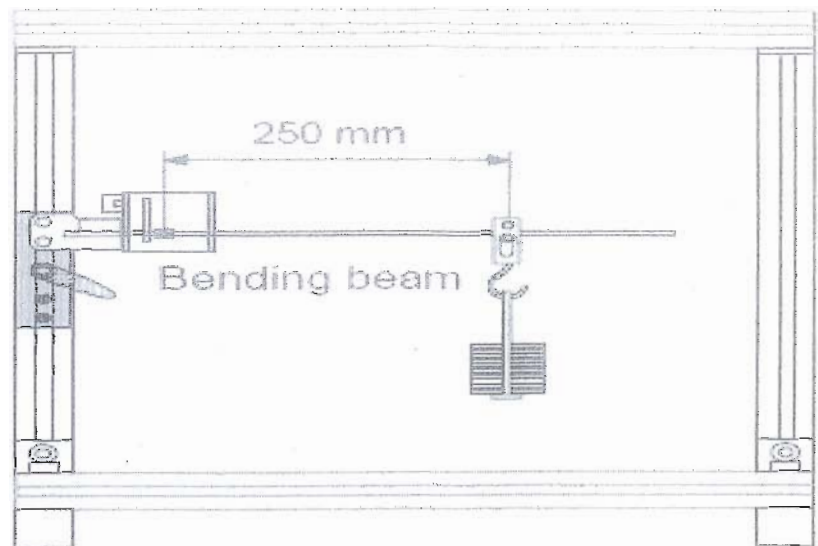
According to **Hooke's law** the stress being sought is obtained with the modulus of elasticity  $E$  (Modulus of elasticity for steel: 210000 N/mm<sup>2</sup>)

$$\sigma = \varepsilon \cdot E$$

### 3.3.2 Performance of experiment

- Fit bending beam in frame as shown using holder with two pins.
- Connect up and switch on measuring instrument.
- Set slider to distance of 250 mm.
- Use offset adjuster to balance display.
- Load beam with small set of weights.

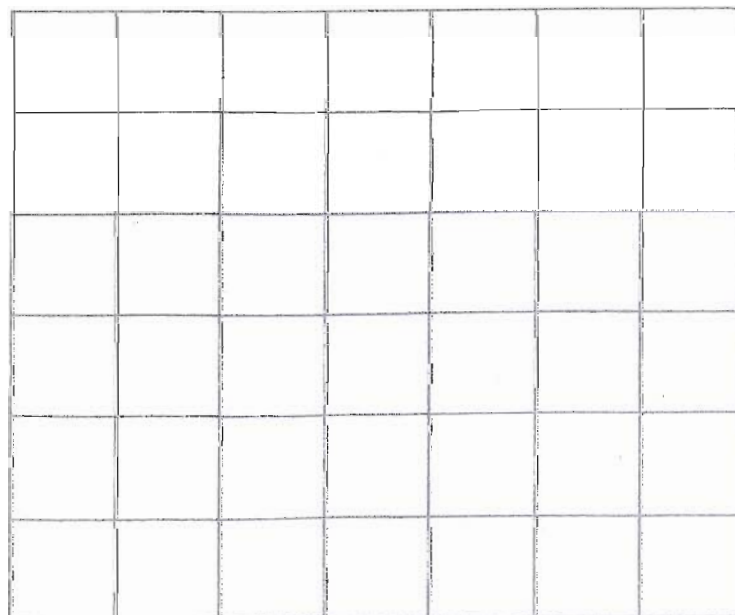
Increase load in steps and note down reading.



| Bending experiment, lever arm 250 mm      |   |                    |   |   |     |     |   |
|-------------------------------------------|---|--------------------|---|---|-----|-----|---|
| Load in N                                 | 0 | 1<br>(holder only) | 2 | 3 | 4.5 | 5.5 | 6 |
| Reading in<br>$\text{mV/V} \cdot 10^{-3}$ |   |                    |   |   |     |     |   |

### Discussion :

1. Plot the measurement results in a graph.



2. Calculate stress and strain.
3. Name two types of strain gauge.
4. Find the slope of the graph and compare the value with calculated one.

### Example:

The stress is now to be determined for a load of 6.5 N where the reading was  $-0.227 \cdot 10^{-3}$ . The following results for the strain

$$\begin{aligned}\varepsilon &= \frac{1}{k} \cdot \frac{U_A}{U_E} \\ &= \frac{1}{2.05} \cdot (-0.227 \cdot 10^{-3}) \\ &= -0.0001107.\end{aligned}$$

The modulus of elasticity for steel of 210000 N/mm<sup>2</sup> gives the following stress

$$\begin{aligned}\sigma &= \varepsilon \cdot E \\ &= -0.0001107 \cdot 210000 = -23.25 \text{ N/mm}^2.\end{aligned}$$

The measured stress is to be compared to the theoretical result in the following. The section modulus for the rectangular cross section is  $W_y = 74.26 \text{ mm}^3$ .

The calculation produces the following stress

$$\begin{aligned}\sigma &= \frac{Mb}{W_y} \\ &= -6.5 \cdot 250 / 74.26 = -21.88 \text{ N/mm}^2.\end{aligned}$$