**MARMARA UNIVERSITY**

**FACULTY OF ENGINEERING**

**DEPARTMENT OF MECHANICAL ENGINEERING**

**ME4111/ME4011/ME411 EXPERIMENTAL METHODS IN MECHANICAL ENGINEERING**

**EXPERIMENT NO. 2**

**Design of an Experiment for Estimating an Unknown Load By the Use of a Cantilever Beam and a Strain Gage**

1. **Objective**

This experiment is a continuation of our previous experiment. In the present experiment, an unknown load is to be estimated by using a strain gage. Besides, the uncertainty of this estimation will be determined.

1. **Introduction**

In this experiment, an electrical resistance strain gage will be used to measure the strain due to the given unknown load. Once the strain is measured, the unknown load can be calculated by making use of the well-known Hooke’s law and bending stress formulas.

1. **Theoretical background**

***3.1. Analysis of a cantilever beam under transverse loading***

Hooke’s law and bending stress formulas will be recalled again below. Consider the cantilever beam given below.

Strain gage

*d*

*h*

*b*

*P*

**Fig. 1** A cantilever beam under transverse loading

Referring to Fig. 1, recall that the bending stress *σ* at the gage location is given by

$σ=\frac{Mc}{I}$ (1)

where *M* is the bending moment at the gage location due to the applied load *P*, *c* is given by *c* = *h*/2 and *I* is the second moment of area about the neutral axis. The bending stress and strain are related to each other through Hooke’s law, which can be expressed as

$σ=Eε$ (2)

where *E* is the modulus of elasticity of the beam material, and $ε$ denotes the strain. For this experiment, take *E* as 69 GPa.

***3.2. Wheatstone bridge***

Recall that since a single active strain gage will also be used in this experiment, a quarter-bridge will be used [1] as shown below.

*R*1 = *Rg*

*R*2

*R*3

*R*4

*Vex*

*Vout*

**Fig. 2** A quarter-bridge (see, e.g., [1])

Under balanced condition, the voltage output *Vout* is zero [2]. The change in the output voltage due to a change in the resistance of the gage (i.e. *Rg*) can be related to the value of strain through the following expression [3,4]:

$V\_{out}=\frac{V\_{ex}}{4}F\_{g}ε$ (3)

where *Fg* is the gage factor. The value of *Fg* for the particular gage to be applied in this experiment will be provided in the laboratory session.

***3.3. Experimental uncertainty analysis***

In this section, some useful formulas are recalled. Sample standard deviation *s* is given by

 (4)

where  is the number of measurements, and  is the sample mean given by

 (5)

The standard error of the mean (SEM) can be interpreted as a measure of the uncertainty of the mean. It is given as

 (6)

1. **Experimental procedure**
* Measure and record the distance *d*, beam thickness *h* and beam width *b*.
* Repeat the above step two more times.
* Apply the given unknown load *P* to the beam.
* Measure and record the voltage output of the bridge (i.e. *Vout*).
* Remove the load from the beam.
* Repeat the previous three steps two more times.
1. **Required calculations**
* Express the measurements of the distance *d*, beam thickness *h*, beam width *b*, and the voltage output *Vout* as Mean ± SEM.
* Analytically, show that



* Find the nominal value of the unknown load *P* using the mean values of the measurements of the corresponding quantities.
* Calculate the expected uncertainty and the maximum uncertainty associated with the estimated nominal value of the unknown load *P*.
1. **Required report format**
* The report should be organized as follows: Title Page, Introduction, Experimental Setup and Procedure, Theoretical Background and Calculation Details, Results and Discussion, Conclusions, References and Appendices (if any).
* Measured and calculated quantities should be presented in tabular form.
* Show all details of your calculations.
* Make recommendations for improving the experimental procedure.

**References**

1. J.G. Webster and H. Eren (2014) *Measurement, Instrumentation, and Sensors Handbook, Second Edition: Spatial, Mechanical, Thermal, and Radiation Measurement*. CRC Press, Taylor & Francis Group
2. T.R. Padmanabhan (2000) *Industrial Instrumentation: Principles and Design*. Springer
3. N. Mathivanan (2007) *PC-based Instrumentation: Concepts and Practice*. Prentice-Hall of India
4. M. Kutz (2013) *Handbook of Measurement in Science and Engineering, Volume 1*. Wiley