**MARMARA UNIVERSITY**

**FACULTY OF ENGINEERING**

**DEPARTMENT OF MECHANICAL ENGINEERING**

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

**EXPERIMENT NO. 1**

**DESIGN OF AN EXPERIMENT FOR DETERMINING THE FLEXURAL RIGIDITY AND MODULUS OF ELASTICITY OF A CANTILEVER BEAM**

1. **Objective**

In this experiment, the flexural rigidity and modulus of elasticity of a cantilever beam are aimed to be determined by using a strain gage.

1. **Introduction**

There are basically two types of strain gages – mechanical and electrical resistance strain gages. In this experiment, an electrical resistance strain gage will be used to measure strain under a known load. Once the strain is measured, the flexural rigidity and modulus of elasticity of the beam can be calculated by using 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 used in the calculations of this experiment. 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. Recall also that 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.

***3.2. Wheatstone bridge***

The Wheatstone bridge circuits are used in strain gage measurements. Depending on the number of active strain gages to be employed, they can be configured as quarter-, half- or full-bridges. Since single active strain gage will 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.

1. **Experimental procedure**
* Measure and record the distance *d*, beam thickness *h* and beam width *b*.
* Apply the given known load to the beam.
* Measure and record the voltage output of the bridge.
1. **Required calculations**
* Calculate the strain by using the provided gage factor.
* Calculate the flexural rigidity of the beam (i.e. *EI*) by a combined use of Hooke’s law and bending stress formulas.
* Calculate the modulus of elasticity of the beam.
1. **Required report format**
* The report should be organized as follows: Title Page, Introduction, Theoretical Background and Calculations, Discussions, Conclusion, Appendix (if any).
* Measured and calculated quantities should be presented in tabular form.
* Show all details of your calculations.
* Discuss the possible sources of errors.
* 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