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Measurement of Stress by Strain Gauge using NI Lab VIEW and its Validation with Simulations

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Abstract: *Mechanical elements are subjected to various stresses due to different loading conditions hence it is necessary to calculate the values in order to avoid failure of the structure. A component fails because of axial stress, bending stress and torsional stress. The work presented here aims at developing a test rig to measure bending stress developed in cantilever beam. The test rig uses strain gauge in Wheatstone full bridge configuration to sense the deformation. Data Acquisition System is used to measure the stress due to point load and is integrated with NI LabVIEW software. Experimental and theoretical results are in close agreement and the Flexural formula was successfully validated*

Keyword: *Bending stress, Data Acquisition System, NI labview, Strain gauge, Wheatstone network*

I. Introduction

In the current era, development of technology has been main aim of mankind. As due to huge advancements in designing area the complexity has arisen in analysing various types of loading. The structures are subjected to various types of stresses developed due to these loadings like Bending stress, Axial Stresses and Torsional Stresses. There are many methods to obtain these stresses. They are theoretical, experimental and Analytical methods. There has been a need to measure actual stresses experimentally because measured experimental stresses do not agree with the theoretically calculated stresses. Experimental stress results are required for further rectification and improvement in design of structures. Bonded electrical metal foil Strain Gauges are considered as the most accepted way to measure strain [1].The Strain gauge gives resistance values and this change of resistance values is converted into differential voltage between two terminals of Wheatstone bridge. Electrical signals'. E. LABAŠOVÁ [2] has calculated the properties of material using strain gauges integrated in Wheatstone bridge along with Data Acquisition system.Strain gauge pasting is a tedious job, the Procedure used for pasting of strain gauge depends on the material to be used. Thomas C. Moore [3] has worked on various strain gauge application procedures.

Strain gauge has many applications; Study of pressure exerted due to internal stresses developed on a soda can by A Ibrahim et al. [4]. L. Ramesh et al.[5] have conducted experiment for crack diagnosis . They have performed vibration analysis using experimental and finite element analysis. Strain gauge has applications in Medical field as well in the form of Strain gauge rosettes in Dental Treatment by A. D. Vardimon et al. [6]. Civil engineering uses strain gauges from building a small foundation slab to building of a bridges, by L. David et al. [7]. Stress strain analysis of an RC Grandstand is done by D. Šimić et al. [8].Analytical simulations are also an ideal way for validating theoretical results. M.D.Yaqoob Mehdi et al. [9] has done simulations on three types of beams i.e. straight, quarter arc and semi arc beams keeping same cross section and same type of loading and concluded that semi arc beam is less stressed than other two beams. Ansys simulations eased the work of analytical complications in calculations.AhmetErklig et al[10] has carried Finite element analysis for the mesh of linear and nonlinear conditions by placing strain gauges at the nodes defining element in FEM i.e. Finite element model, placed strain gauges according to the node defining the elements in Finite element model and concluded that dislocation of strain gauges resulted in error of up to 10%.In this article, experiment was carried out on cantilever beam. Setup was developed for validation of bending stress and flexural formula by comparing Experimental results with theoretical and analytical results.

II. Methodology

The setup was developed to measure the bending stress in cantilever beam for different loading conditions. Fig.1 represents the schematic diagram of cantilever beam. In theoretical method point load is applied at a distance l_2 by calculating the reaction forces moment around the strain gauge is calculated. Bending stress is calculated using flexural formula.

Fig.1.Schematic diagram of cantilever beam

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$$\sigma_{th} = \frac{M \times y}{I} \qquad (1)$$

$where, M(Nmm)$ is moment about strain gauge,
$y(mm)$ is distance from neutral axis,
$I(mm^4)$ is moment of inertia,
$\sigma_{th}\left(\frac{N}{mm^2}\right)$ is theoretical bending stress.

$$M = W(l_2 - l_1)$$

$W(N)$ is the load applied,
L_2 is the distance of load applied from fixed end
L_1 is the distance of the strain gauge from the fixed end

$$y = \frac{t}{2}$$

$$I = \frac{b \times t^3}{12}$$

On substituting above values in equation (1) we get,

$$\sigma_{th} = \frac{W(l_2 - l_1) \times t \times 12}{2 \times b \times t^3}$$

$$\sigma_{th} = \frac{W(l_2 - l_1) \times 6}{b \times t^2} \qquad (2)$$

Thus, equation (2) theoretical value of stress is calculated

Experimentation:

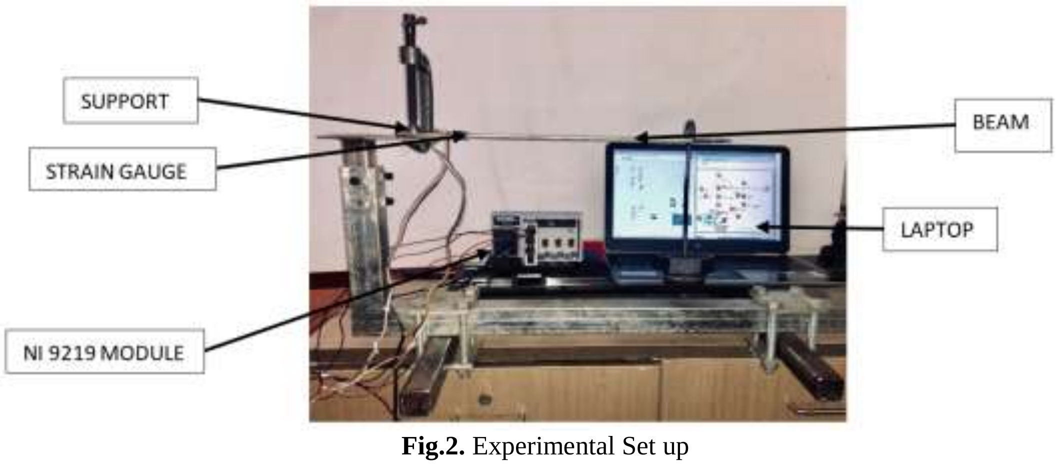

Fig.2. Experimental Set up

III. Experimental Set Up

The instruments used to carry out the experiment are, steel beam, C- clamp, dead weights, NI 9219 Data Acquisition System module, NI-LabView and frame structure.The assumptions made are as follows;

1. Beam is assumed to be isotropic and homogenous.
2. Residual stress are neglected in theoretical calculations and limited by calibration in experimentation.
3. Young's modulus $E = 210GPa$

The beam is fixed at one end by using a C-clamp as shown in Fig.2. The strain gauges are mounted on the beam at a distance of 55mm from the fixed support. Strain gauges are mounted in accordance with Wheatstone bridge by using full bridge circuit.The strain gauges mounted on the upper part give us tensile stress and the strain gauges on the lower part weights.The deflection of the strain gauges is acquired by Data Acquisition System (DAQ) and displayed on the monitor as shown in Fig.3. From the experimental strain values experimental stress is calculated.The experimental and theoretical stress values were validated using Ansys software.

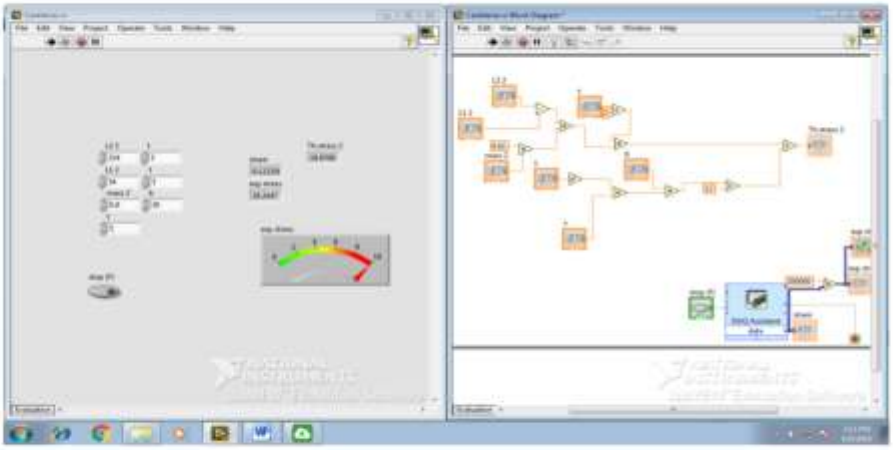

Fig.3. Ni LabView coding

IV. Observation

The experiment was conducted for various loadings and the values of stresses are shown in Table.1 below. Results were compared with analytical (simulations) and theoretical values of stresses and the graph indicating deviation is shown in Fig.5

Table 1

Sr.no	Mass (kg)	Theoretical value ($\frac{N}{mm^2}$)	Experimental value ($\frac{N}{mm^2}$)	Analytical value ($\frac{N}{mm^2}$)	Error between theoretical & experimental (%)	Error between theoretical & analytical (%)
1	0.7	14.8327	13.8012	14.673	6.9542	1.0766
2	0.9	19.0706	18.2447	18.888	4.3307	0.9574
3	1.2	26.3603	25.4096	25.9843	3.6065	1.4263

Ansys simulations: The beam of actual dimensions used in experiment was modelled in ANSYS using workbench. After meshing to refined size point load was applied at the same distance as of the experiment. The stress developed due to loading was calculated. Total deformation, Von mises stress and bending stress at the Strain gauge point was calculated using probe. As shown in Fig.3 Shear moment diagram was plotted as shown in Fig.5

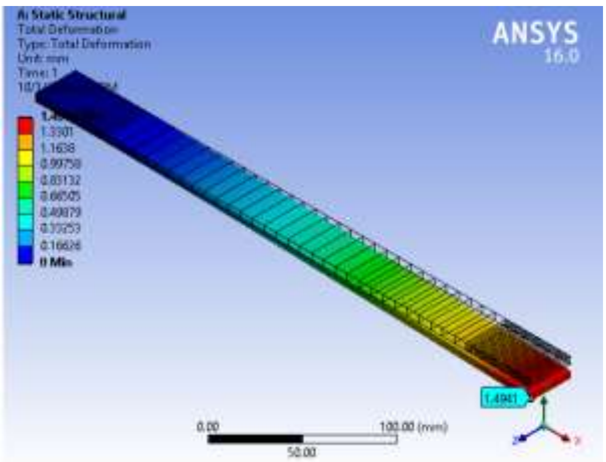

Fig. 4. Ansys simulation

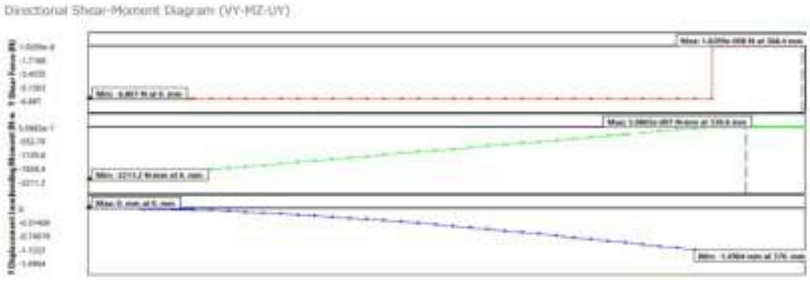

Fig.5. Shear- moment diagram

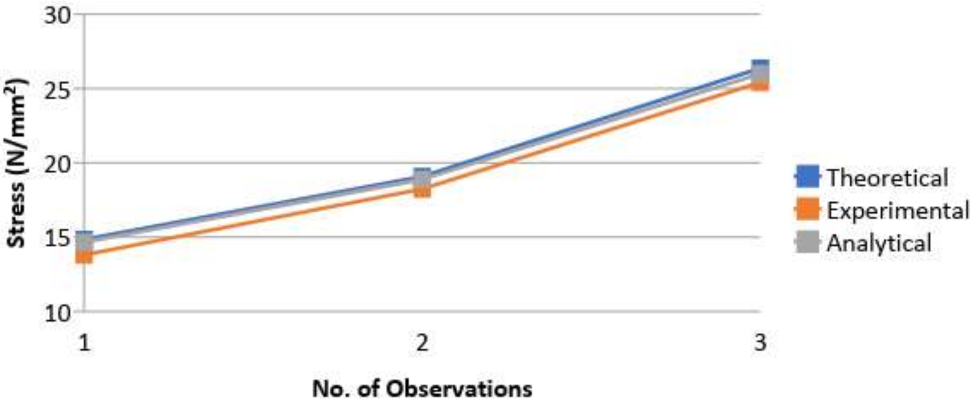

Fig. 6. Graphical representation

V. Conclusion

The theoretical, analytical and experimental values are in close agreement with each other. For load of 0.9kg the theoretical stress value was 19.0706 $\frac{N}{mm^2}$and experimental value measured was 18.2447 $\frac{N}{mm^2}$and the error calculated was 4.3307 %. The variations in the values were due to assumptions. The beam was assumed to be isotropic and homogenous. The average % error was calculated up to 4.96%. The residual stress in the beam was nullified by calibration process. The temperature compensation was attained by Wheatstone full bridge configuration.

Future Scope

The setup can be integrated with microcontrollers to perform real time experimentation.

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Conflict of interest The authors declare that there is no conflict of interests regarding the publication of this paper.

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