REMOTELY CONTROLLED DATA – ACQUISITION EXPERIMENTAL SETUP FOR STRESS-STRAIN MEASUREMENT

Sunil .S. Pansare[a*], Anirban .C. Mitra[b*], Shubham Varal[c], Gunjan Malgundkar[d], Dipesh Kavankar[e]

Modern Education Society's College of Engineering, Pune- 411001, Maharashtra, India.

Received: February 02, 2019 Accepted: March 19, 2019

ABSTRACT: *In engineering sciences, measurement of mechanical quantities in electrical can be found frequently, It is also generally utilized in designing applications for example, force estimations, especially in machine apparatuses. In mechanical engineering research, they frequently used load sensors which consist of strain gauges, to measure bidirectional force, they are bonded to a metal beam. The force applied, generates very small variations in the resistance of strain gauges. To measure strain with strain gauge, they are connected in electrical bridge measuring circuit. The electrical structure consist of four strain gauge elements, forms a Wheatstone bridge circuit. Also it requires signal conditioning for further process. The aim of this paper is to measure the stress developed on various materials and monitor it from remote location on remote device through web or cloud . Also the model will atomised to develop an application of testing equipment in industry.*

Key Words: *Stress, strain gauge, measurement, Wheatstone bridge, signal conditioning, remote monitoring and controlling, Automation*

A. Introduction

In today's world due to increase in complexity of designs, there has been an increase in need for measurement and analysis of stresses and strain developed in the components, also needs to monitor from remote location. In many industrial sectors for such measurements Strain gauges has an important consideration. Systems with correct measurements can define the strain level generating on various construction such as from civil to biomechanics engineering. Specific construction's life time and threat can be measured based on strain measurement. Strain is nothing but the deformation caused due to stress. The most standard and reliable method to measure strain is using Bonded electrical strain gauge. Upon deformation. the conductive grid changes electrical resistance of strain gauge The Strain gauge gives readings in terms of resistance, so the Wheatstone Bridge is used to convert change of resistance into electrical signals i.e., in terms of electrical voltage. But this difference voltage is very small so it need to amplify to certain level so as to understand by controller. Strain gauge is mounted as one of the four legs of the Wheatstone bridge circuit designing a full bridge circuit which amplifies the micro strain values from each strain gauge and gives the sensitivity about two times & four times higher than Half Bridge and Quarter Bridge configuration respectively. The resultant Output value is the difference voltage between two output terminal.

In this article, Stress measurement and analysis has been done on a Simply Supported beam, a setup was designed and fabricated for the experiment and readings were taken, the obtained experimental results were validated with Theoretical results & NI-DAQ module.

B Literature Survey

The relation between Strain and electrical resistance variation is almost linear and the constant of proportionality is called sensitivity factor [6]. The orientation of Strain gauge on the material defines the type of stress to be calculated, in case of bending and axial stress[6], In case of torsional stress [6]. The material properties of a material are sometimes unknown. Strain gauge can also be used to measure residual Stresses as in work done by H.Eisazadeh et al [7], they have found Residual stresses in dissimilar welds using Nondestructive. Strain gauge are also used in Medical field as used in Strain gauge rosettes in Dental Treatment by A. D. Vardimon et al. [8]. A product design will fail if the stresses generated are more than the products bearing capacity and also depends on the point of Stress applied, F. Giubilato et al [9], has applied strain gauge on cycle saddle and found that mass of cyclist does not affect the stresses on the cycle rather the rider's postures which affect the way in which the stress is applied affects the rate of damage to the vehicle.

From building of a bridge to small foundation slab, strain gauge can be used in civil engineering applications as by L. David et al. [10] and also analysis of stress and strain on RC Granstand of a sports hall by D. Šimić et al [13]. A safety margin should follow in High pressure boilers and are dangerous if gone out of control, strain gauges can be used to determine stresses developed to high pressure, its application ranges from High pressure boilers to stress analysis of a small soda can, A Ibrahim et al [11], has done stress analysis of a soda can by measuring the elastic strains generates due to internal pressure developed. Strain gauge also has applications in space technology . In paper published by J. Shen et al [12], shows one of the key element in maintaining the health condition of the Chinese space station by precise measurement of strain for the bulkhead. It is of great importance to carryout real-time health assessment for the bulkhead of space station

C. Strain gauge

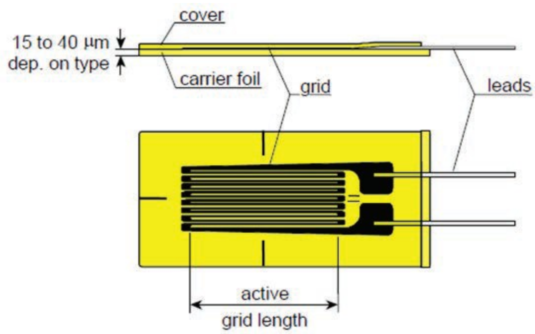

Fig. 1. Stain gauge construction

A Strain gauge (Fig. 1) is a transducer used to measure strain. When it is deformed, electrical resistance of a conductive grid changes. Grid deformation causes due to forces generating from object that is loaded to which strain gauge is mounted by bonding. Strain gauge gives output as resistance change depending on a physical change of the test object. The operating principle of strain gauge is based on Equation (1). When the strain gauge is subjected to tensile or compressive forces, it's length changes and hence cross-section which affects in resistance change.

R=ρ l/s (1)

Where,
R –electrical resistance [Ω]
ρ –electrical resistivity [Ω·m]
l – length [m]
s – cross section area[m^2]

The change of resistance is proportional to the change of the length, Equation (2).

ΔR/R ~ ΔL/L0 (2)

D. Wheatstone bridge circuit

The Wheatstone network with full bridge configuration has four legs consist of strain gauges. Full bridge configuration amplifies the output & gives sensitivity about four times than quarter bridge configuration.

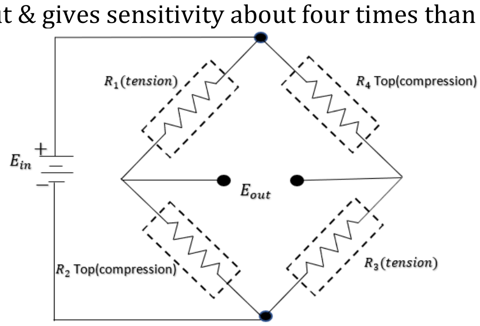

Fig. 2. Wheatstone Full Bridge Configuration

(3)

The equation (3) gives the value of strain using Wheatstone bridge refer Fig. 2, where n represents the number of strain gauges. The value of n is equal to four for full bridge network. Therefore equation (1) becomes,

(4)

The stress is calculated by multiplying the strain from equation (4) with modulus of elasticity (E).

$\sigma\_exp=\varepsilon\times E$ (5)

Thus, above equation (5), gives us the experimental value of bending stress.

To measure infinitesimal changes in the resistance, arrangement of strain gauges has different Wheatstone bridge configuration as shown in Fig.2. Two strain gauges are mounted on the top and two are mounted on the lower surface of the beam. This configuration is highly sensitive to bending strain only. Strain gauges R1 and R3 measures compressive strain and strain gauges R2 and R4 measures the tensile strain.

E. Data Acquisition System

In this we are using arduino to measure strain and stress from Wheatstone bridge and signal conditioning circuit output voltage.

i. Signal conditioning circuit:

The conditions where high sensitivity, accuracy and stability are required, the instrumentation amplifier is used. Additional characteristics include

DC offset is very low,

low drift & low noise,

Open-loop gain is very high,

very high common-mode rejection ratio,

very high input and Low output impedance.

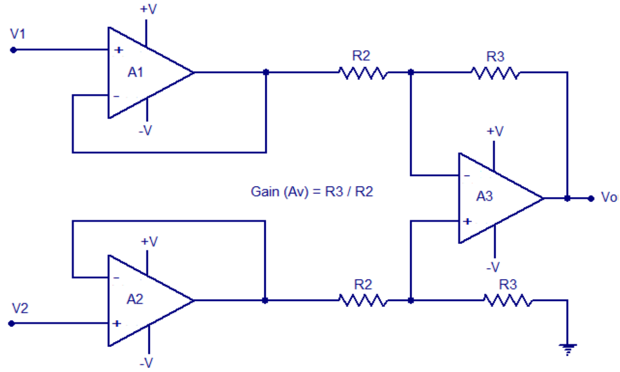

Fig. 3. Instrumentation Amplifier Circuit

This circuit implements a full series negative feedback path and the gain of A1 and A2 will be unity. The overall gain is

$$Av = R3/R2$$

ii. Arduino Board (Controller)

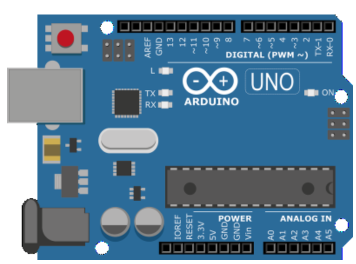

Fig.4. Arduino board

Arduino hardware and software is an open-source that helps to use single-board microcontrollers and microcontroller kits for designing digital devices and interactive objects that can senses and controls both manually and electronically or digitally. It operates with clock speed of 16 MHz The boards are containing number of digital and analog input/output (I/O) pins that are used to interface the various external circuitary and devices, sensors, switches, displays etc.. The boards also supports serial communications interfaces, including Universal Serial Bus (USB) , which are also used for loading programs from computers.

F. NI-LabVIEW

LabVIEW offers graphical programming platform that helps to analyze every aspect of the application. LabVIEW provides ease to integrate the hardware and acts as an interface.

The stress was calculated theoretically. The equation for calculating theoretical stress was programmed in NI LabVIEW software. The equations are developed by Boolean and logical operators provided by the LabVIEW software. The values of load and lengths entered on the front panel gives the theoretical stress directly.

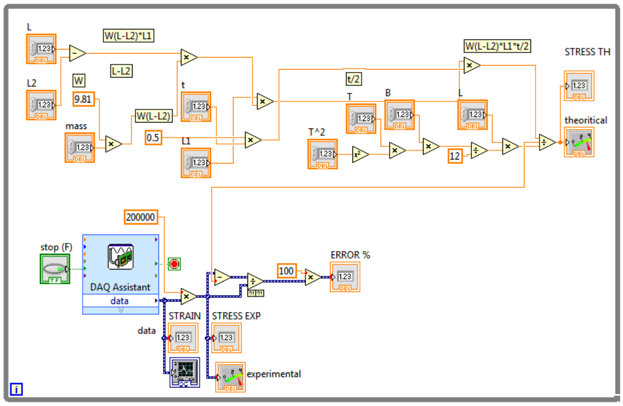

Fig. 4. Block diagram of NI LabVIEW coding

The experimental values of strain are obtained from the input of the DAQ assistant. The value of stress is calculated by multiplying the obtained strain value by modulus of elasticity. The values are displayed on the front panel. Theoretical and experimental values of stresses are validated and displayed using a graphical indicator.

G. Methodology

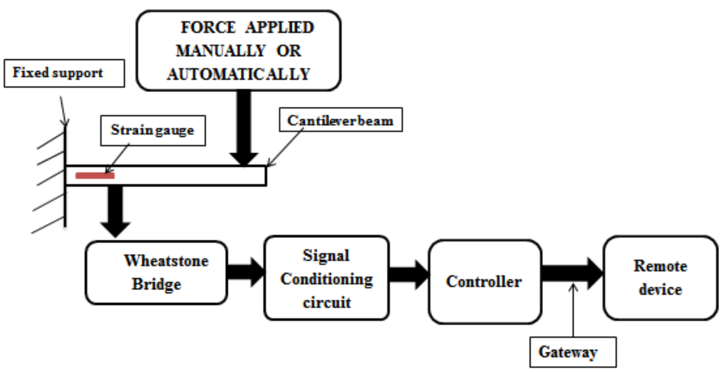

Fig. 5. Methodology of design

H. Experimental setup

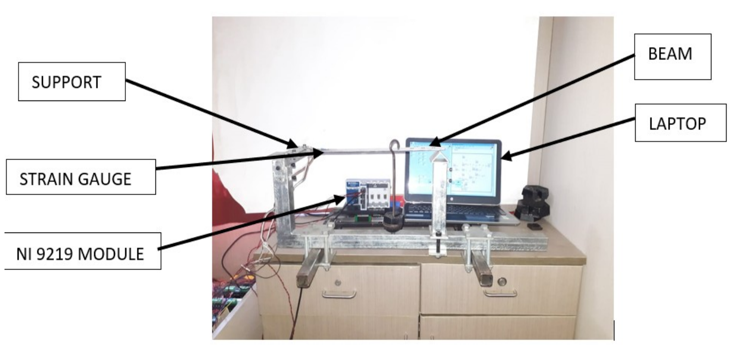

Fig.6. Experimental Setup for simply supported beam

Table 1: Observation and Results:

Sr No	Mass (Kg)	l_1 (mm)	l_2 (mm)	L (mm)	Stress $\frac{N}{mm^2}$		
					Theoretical	Experimental	
						NI9219DAQ	Arduino
1	1.2	55	235	355	1.750	1.634	1.713
2	1.7	55	235	355	2.480	2.294	2.694
3	2.2	55	235	355	3.209	2.937	3.668

By carrying out experiment for different loads using NI-9219 DAQ and Arduino uno , Experimental values of stress are obtained as shown in the Table 1.
Theoretical and simulation results were compared and error measured is very much small and Table 1. indicating theoretical and experimental stress for different loads in Kg .

J. Conclusions

Experimental setup for simply supported beam was designed and executed using DAQ module and NI LabVIEW and using Arduino. The theoretical and experimental values were in close agreement and hence stress measurement is done. The error during the experimentation was restricted below 10%. The difference between the theoretical and experimental values was present because of the assumption made. The experimental values were calculated using DAQ module and arduino. The theoretical & experimental values are displayed simultaneously, hence providing an easy access to user

K. Future scope

The setup will be automated to make it remotely accessible and implemented on IOT platform. The developed stress on any complex design and material can be accessed remotely so that design and material health can be determined.

L. References

1. Brent Maundy, Stephan J. G. Gift, "Strain Gauge Amplifier Circuits", 2013 IEEE, 0018-9456.
2. Anirban C. Mitra, Akshata Jagtap, Sphurti Kachare, Development and Validation of Experimental Setup for Flexural Formula of Cantilever Beam Using NI-LabVIEW . Materials Today: Proceedings 5 (2018) 20326–20335, ICMPC_201
3. Priyanka Singh, Chaturi Singh, Rishi Raj Singh, "LabVIEW-Based Cost Effective Multi-Axis Motion Control System".
4. Piotr Tutak "Application of strain gauges in measurements of strain distribution in complex object" JACSM 2014, Vol. 6, No. 2, pp. 135-145, IT Institute, University of Social Sciences, Łódź, Poland
5. Jelena Manojlović, Predrag Janković "Bridge measuring circuits in the strain gauge sensor configuration", Mechanical Engineering Vol. 11, No 1, 2013, pp. 75 - 84
6. Experimental Stress analysis by Dr. Sadhu Singh,pg 103-110.
7. Hamid Eisazadeh, Daryush K. Aidun, Investigation of transient/residual strain and stress in dissimilar weld, Journal of Manufacturing Processes 26(2017)372-381.
8. Alexander D. Vardimon, Daniel Robbins and Tamar Brosh, In-vivo vonMises strains during Invisalign treatment, American Association of Orthodontists, November 2008, doi:10.1016/j.ajodo.2008.11.027.pp.399-409.
9. Federico Giubilatoa, Nicola Petronea, Stress analysis of bicycle saddles structural components during different cycling conditions, The 2014 conference of the International Sports Engineering Association, Procedia Engineering 72 (2014) 636 – 641.
10. Litvan David, Mateckova Pavlina and Smirakova Martina, Analysis of model foundation slab focused on strain gauge measurement, International Journal of Theoretical and Applied Mechanics, Volume 1, 2016,292-296.
11. Ahmed Ibrahim, Yeong Ryu, Mir Saidpour, Stress Analysis of Thin-Walled Pressure Vessels, Modern Mechanical Engineering, 2015, 5, 1-9.
12. Jingshi Shen, Xiaodong Zeng, Yuxiang Luo, Changqing Cao and Ting Wang, Research on Strain Measurements of Core Positions for the Chinese Space Station, Sensors 2018, 18, 1834.
13. Diana Šimić and Marina Frančić, analysis of stress and strain in the reinforced concrete structure of a sports hall grandstand, Broj 6, godina 2013,pg.81-95.