An Experimental Study on Uncertainties in Strain Measurement of Fixed-Fixed Type Beam

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Abstract— Strain gauges are utilized in many applications like bridges and structural frames for monitoring their health and also monitoring vibrations in rotating elements. Electrical resistance strain-gauge approximately fulfils all of the favourable needs for a strain gauge; therefore it is utilized in stress analysis and as the sensing element. The smallest dimensional change of mechanical elements in response to a mechanical load, pressure, force, and stress causes a change in the resistance of the strain gauge. Wheatstone bridge is commonly employed to convert the resistance change to an output voltage. Most commonly used strain gauge circuit use Quarter bridge, Half bridge and Full bridge orientation. Every strain measuring circuits have some amount of uncertainty linked with it. This research work aims to understand the uncertainties while measuring strain in a fixed-fixed type of beam with static loading conditions. The method adopted for recording the reading experimentally is the deflection method for a Wheatstone bridge circuit.

Key words: Beam, Bridges, Structural Frames

I. INTRODUCTION

The project involves experimentally measuring strain using different Wheatstone bridge orientation. Most commonly used orientations are Quarter bridge, Half bridge and Full bridge. The electronic interface is required for measurement, which helps to process the data accurately and precisely. This entire interfacing requires structural knowledge, Sensors and software's. For this Electronics, Electrical and Instrumentation background is needed which helps in choosing the appropriate tool/element. Therefore the project has much interdisciplinary relevance with mechanical, electrical, computer and instrumentation engineering fields. To develop non-intrusive, affordable technology to monitor the system health, with provision of preventing predicted structural failure. The objective is to do experimental, analytical and simulation study regarding the uncertainties in strain measurement to reduce the uncertainties level using proper Wheatstone bridge orientation. The project will help in obtaining an insight into the various issues related to the operational capabilities and limitations of this system. This setup can be used, to establish and understand the concept of uncertainties in strain measurement along with the conformation of the best possible Wheatstone bridge orientation

II. EXRIMENTAL SET-UP

The experimental setup consists of a Data Logger TDS-530, which is used for data acquisition of the strain values as shown in the Fig. 1. The digital data is saved to a computer for further offline processing. The plate specimen considered in the study is 3 mm thick beam of stainless Steel, 700 mm active length and width of 40mm.The strain gauge used are of the two type, the 5mm length of strain gauge has the specification FLA5-55, the gauge resistance is 120.0 ohms and gauge factor is 2.11 and the 10mm length strain gauge has the specification BF350-10AA (11) N2x, the gauge resistance is 350.0 ohms and gauge factor is 2.11. The overall dimension of the 10mm length strain gauge is 10mm×5mm with 0.5 mm thickness are used for sensing and the overall dimension of the 5mm length strain gauge is 5mm×5mm with 0.5 mm thickness are used for sensing. They were bonded to the beam using "Strain gauge adhesive type: CN", single thumb pressure for one minute, purchased from the company Tokyo Sokki Ken Kyujo Co. Ltd.

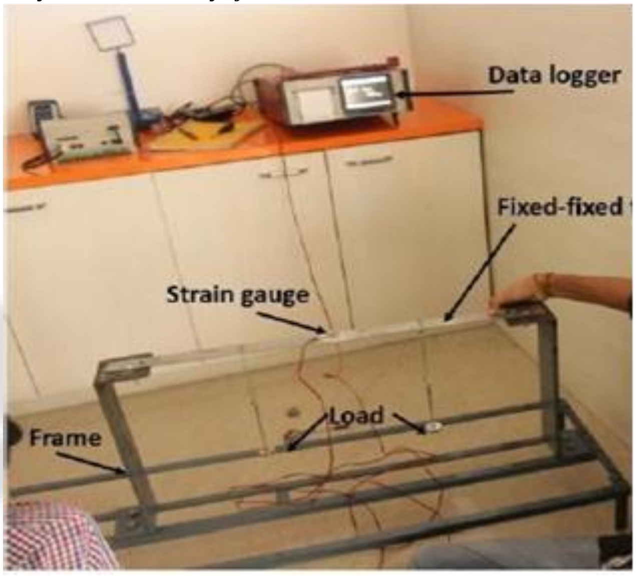

Fig. 1: Various Components used to do Experimental Study on Fixed-Fixed Type Beam

The fixed-fixed beam bolted on both sides. The loads are applied at a distance of length 40mm from each side of the supports, where total active length of the beam is 700mm as shown in figure 2 and 3.

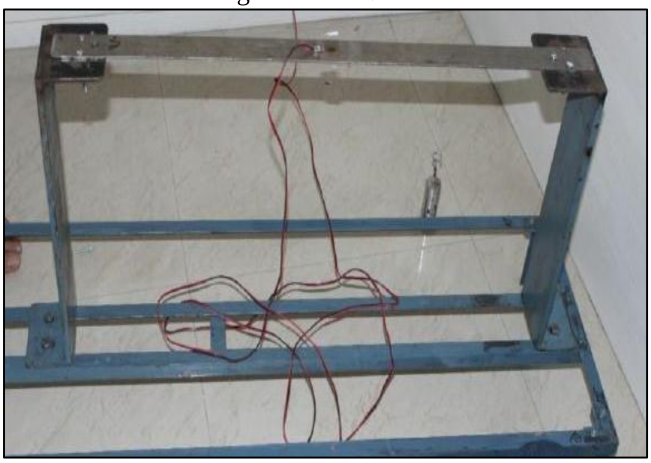

Fig. 2: Experimental Set-Up for Fixed-Fixed Type Beam

The fixed-fixed beam is bolted on both sides. The loads are applied at a distance of length 40mm from each side of the supports, where total active length of the beam is 700 mm.

The strain gauge is placed at the centre, along the direction of the beam. The load added each time is of 50 gram of weight on both the locations, the strain gauge used is of 10mm length, which in turn is connected to the data logger. The soldering terminal is as shown in the fig. 3. It is used for connecting terminals of the strain gauge, i.e. interconnection and also to connect to wire of the data logger. The need for such a terminal mainly arises because the output terminal of the strain gauge is weak and thin. The TDS-530 is an automatic, multi-channel, scanning data logger for reading strain gauges, thermocouples, Pt RTD temperature sensors, strain gauge based (full bridge) transducers dc voltage. New A/D converter technology provides accuracy and stability at very scan rates. The TDS-530 in combination with our new IHW-50G high speed switching boxes can provide up to 1000 channels of data that can be scanned in 0.4 seconds.

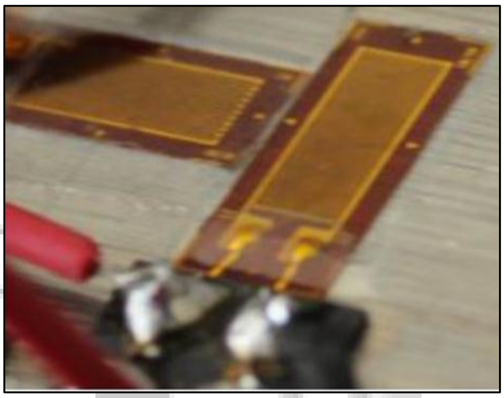

Fig. 3: Strain Gauge with 10 mm Length

The unit features a color LCD display and touch panel channel setup and operation. In addition, the unit may be computer controlled through an RS-232C, USB2.0 or Ethernet Lan connection. The strain gauges used are of the two types, the 5mm length of strain gauge has the specification FLA5-55, the gauge resistance is 120.0 ohms and gauge factor is 2.11 as shown in fig.4 and the 10mm length of strain gauge has the specification BF350-10AA (11) N2x, the gauge resistance is 350 ohms and gauge factor is 2.11 as shown in Fig. 4.. The overall dimension of the 10mm length strain gauge is 10mm×5mm with 0.5 mm thickness are used for sensing and the overall dimension of the 5mm length strain gauge is 5mm×5mm with 0.5 mm thickness are used for sensing

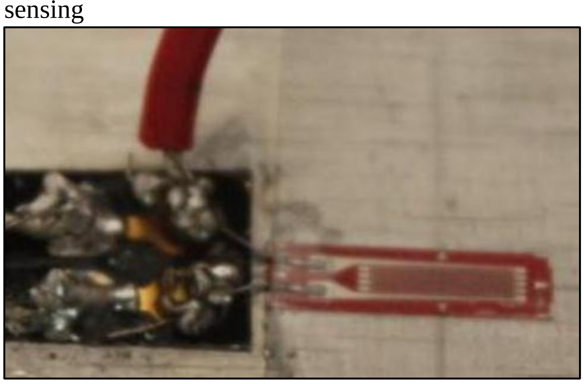

Fig. 4: Strain Gauge with 5mm Length

The test is conducted for full (F. B), half (H. B) and quarter bridge (Q.B) type strain gauge configurations. These configurations have the following characteristics: A single active strain gauge element mounted in the principle direction of axial or bending strain. Temperature variation decreases the accuracy of the measurements. Sensitivity at 1000 με is ~ 0.5mVout / VEX input

III. UNCERTAINTY METHODOLOGY

Calculating standard uncertainty in strain measurement using full, half and quarter bridge for different conditions. When a set of several repeated measured samples of P has been taken, the mean¯ and estimated standard deviation, SP, can be calculated for the set.

$$\bar{P} = \frac{\sum_{i=1}^{T} P}{T} \tag{3.1}$$

$$S_P = \left(\frac{1}{T-1}\sum_{i=1}^{T}(P-\bar{P})^2\right)^{\frac{1}{2}} \tag{3.2}$$

The N is the number of measurements in the set. The estimation of the standard uncertainty, k, of the mean is calculated by

$$k = \frac{S_P}{\sqrt{N}} \tag{3.3}$$

The Combine standard uncertainty is calculated by accounting individual standard uncertainties by taking as ‘root sum of the squares’.

The simplest case is where the result is the sum of a series of measured values (either subtracted together or added). For example, you might need to find the total length of a wall made up of different width wall panels. If the standard uncertainty (in metres) in the length of each wall panel is given by Z1, Z2, Z3, etc., then the combined standard uncertainty (in metres) for the whole wall would be found by squaring the uncertainties, adding them all together, and then taking the square root of the total. The Combined Uncertainty Y(c) is given as

$$Y(c) = \sqrt{z_1^2 + z_2^2 + z_3^2 + z_4^2 \ldots\ldots + Z_n^2} \tag{3.4}$$

IV. RESULTS

To validate experimental measured results the testing is done by using two different types of Strain gauges a FLA5-55 and BF350-10AA (11) N2x. A plot with load on x-axis and strain on y-axis is plotted as shown in the figure 7 and both of which are Q.B. configuration, the results shows both cure follows the same trend.

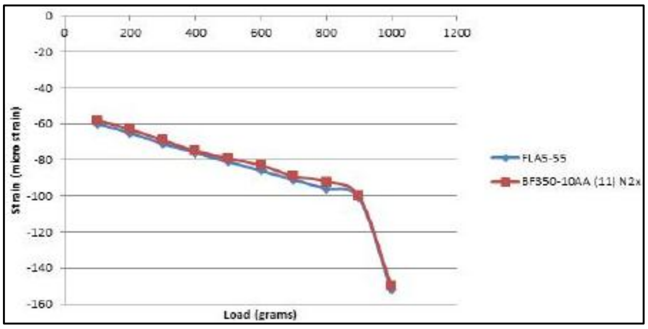

Fig. 6: Load Vs strain plot of two strain gauges with quarter bridge arrangement

The tables 1 and 2 show that the number of strain attached to the strain gauge attached to the fixed-fixed type beam, which in turn depends on the bridge configuration is affecting the strain measurement.

Fixed –Fixed type beam (FLA5-55)					
No.	Load (grams)		Q.B. (Micro strain)	H. B. (Micro strain)	F.B. (Micro strain)
	P1	P2			
1	500	500	-152	-104	-23
2	450	450	-101	-93	-20
3	400	400	-96	-82	-18
4	350	350	-91	-72	-16
5	300	300	-86	-62	-13
6	250	250	-81	-51	-11
7	200	200	-76	-41	-20
8	150	150	-71	-30	-23
9	100	100	-65	-20	-24
10	50	50	-60	-11	-23

Table 1: Observations of Strain Gauge Fla5-55 for Various Bridge Configurations

Fixed –Fixed type beam (BF350-10AA (11) N2x)					
No.	Load (grams)		Q.B. (Micro strain)	H. B. (Micro strain)	F.B. (Micro strain)
	P1	P2			
1	500	500	-150	-102	-21
2	450	450	-100	-91	-19
3	400	400	-92	-79	-16
4	350	350	-89	-69	-15
5	300	300	-83	-67	-11
6	250	250	-79	-50	-10
7	200	200	-75	-37	-17
8	150	150	-69	-27	-21
9	100	100	-63	-18	-23
10	50	50	-58	-10	-22

Table 2: Observations of Strain Gauge Bf350-10aa(11)N2x For Various Bridge Configurations

V. Conclusion

The numerical value for combined uncertainty is calculated for fixed-fixed type of beam for bridge orientation like quarter Bridge, Half bridge and Full Bridge as shown I the table 1 and 2. The uncertainty analysis is carried out for strain values obtained by experiments with different bridge configurations. The result of uncertainty analysis shows uncertainty value is more in case of Quarter Bridge, observing that, as this bridge configuration makes use of a single active gauge for strain measurement. Thus this study concludes quarter bridge increases error and the full bridge reduces the error with respect to strain measurement. It is observes that uncertainty is little more in 10mm length of strain gauge than in 5mm of length of strain gauge for fixed-fixed type of beam for all the three configuration. These aspect of the measurement needs to be further investigated

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