IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 15, Issue 2 Ver. IV (Mar. - Apr. 2018), PP 49-59
www.iosrjournals.org

Design and Construction of Indigenous Strain Gauge Equipment

*Ejiko, S.O. and Olakolegun O. D.
Department of Mechanical Engineering, Federal Polytechnic, Ado-Ekiti
Correspondence Author: Ejiko, S.O

Abstract: *Strain is an important factor that establishes the mechanical behavior of varieties of metal used in machine development. The strain experienced in a metal is directly proportional to the stress. Equipment such as resistance strain gauge, piezoelectric strain gauge and extensometer are used for measuring strain. These devices are expensive and the costs of maintenance are high, hence the need to develop an indigenous strain gauge that is affordable. This device is simply design for easy application in carrying out materials' strength experiment by student. The developed indigenous strain gauge has a height of 1.22m and could accommodate samples of 5 to 10 mm diameters with a gauge length of 200mm; couple to it is a transducer to magnify the strain signal for efficient strain calibration. The equipment was able to withstand a load of 1000N. The ratio of deformation (Strain) with reference to load increment correlates with theoretical response.*

Keyword; Design, Equipment, Experiment Indigenous, Strain and Stress

---

Date of Submission: 10-04-2018 Date of acceptance: 24-04-2018

I. Introduction

Strain gauge equipment is a device used to measure strain on an object, it also help to understand the force being applied to an object (Perry, 1984). In most applications, indigenous strain gauges are use to study the effect of forces on an object, also used to quantify other value such as pressure. It consists of frame pan, string and specimen. This design is required to carry out experiment on the properties of a

given material. Strain is a measure of the amount of stretch of compression along a material (normal strain), or amount of distortion associated with the sliding of layers within a material (shear strain) (Middlehoek and Audet, 1994). Strain measurement is a key element of materials testing. The physical properties of materials are usually represented by stress-strain curve and knowledge of the stress-strain curve allows engineers to compare different materials and predict the behavior of a part or structure made from a particular material (e.g. stiffness and failure strength) during processing operations, (e.g pressing, forging and during design). Strain measurement also play a vital role in low-cycle fatigue testing that is used to determine the durability of materials subjected to alternating strains during service, examples include parts of an engine (Azom, 2017). With today's emphasis on product liability and energy efficiency design must not only be lighter and stronger, but also need thoroughly tested than ever before, this place new importance on the subject of experimental stress analysis and the techniques for measuring strain(Spark, 2006). This research is aimed at the application of strain and the ways it can be determined using indigenous strain gauge equipment.

Stress in a material cannot be computed from other measurable parameters, therefore, the stress analyses use measured strains in conjunction with other properties of the material to calculate the stresses for a given loading condition. The application in measuring strain is based on the following; contacting, non contacting and bonded strain technique. In contacting technique the strain measurement in material testing is traditionally carried out using some form of contacting extensometer. In bonded strain technique a length of a very fine wire is bonded to a structure so that any and all signal that comes in contact with the surface of the strain was directly transmitted to the wire for onward detection. The developed strain gauge should have features such as accommodation in narrow portion of the specimen of small size and mass, easy attachment, high sensitivity to strain, low cost and low sensitivity to temperature and other ambient condition (Hannah and Reed, 1992).

Practical strain gage measurement is purely mechanical devices. The addition of a light beam and minor arrangement to extensometer improve resolution and shorten gage length allowing the reduction of resolution and gage lengths. Still another type of device is the photoelectric gage, it uses a combination of mechanical, optical and electrical amplifications to measure strain, this is done by using a light beam, to fine grating and a photocell detector to generate an electrical current that is proportional to strain. This device comes in gage lengths as short as 1/16 inch, but it is costly and delicate. All mechanical devices tend to be bulky and cumbersome to use, and most are suitable only for state strain measurement (Richard and Donald, 2011).

The optical method for these are several optical methods used for strain measurement on these techniques uses the interference fringes produced by optical plates to measure strain. This device is sensitive and accurate but the technique is more delicate than that of laboratory condition required for it's use. Electrical device is another class of strain measuring devices, it depends on electrical characteristic which vary in proportion to the strain in the body to which the device is attached. Capacitance and inductance strain gages have been constructed, the sensitivity to vibration mounting difficulties and complex circuit requirement keep them from being very practical for stress analysis work (Hilal and Mohamend, 2011).

Importance of Strain Gauge

Product such as the strain gauge that measure fatigues in metals plays a vital role in productivity and safety. There are many categories of measuring instruments and many more if the products within each category are counted. For example, within the category of strain gauges there are seven sub-categories including accessories such as cleaning agents and solder terminals. Such products are of vital significance in a world, which is increasingly dependent on high-tech equipment (Karl, 2012).

As the world, revolve a myriad of machines work smoothly to keep things going. Massive planes take to the skies in tremendous bursts of power, and at a different level, coal power and nuclear turbines keep the electricity flowing into domestic kitchens. The stresses impose by heat and movement upon the material components of all the machines that power our lives do not in themselves causes break down but are the causes that will inevitably result in effects. Engineers measure stress in mechanical components using a variety of means.

A strain gauge is a resistance-based sensor used by mechanical engineers, strain does not officially have a unit of measurement, but for reference purposes, a special unit of measurement is used. Because the changes in length often very small, the unit of change employed is express as 10 to the power of six to provide meaningful readings (Hilal and Mohamend, 2011).

There are various types and configurations of sensors. The metal foil gauge consists of a length of thin metal wire wound around a grid called a matrix; this is stock to a metal backing and then bonded to the object where measurement is required. The gauge is aligned with the line in which stress will occur. As the wire lengthen or compresses, so measurements are taken.

Optical sensors are made of glass of varying thickness; fibers with a core of micrometers are surrounded by a layer of pure glass with a diameter of 125 micrometers. Different reflection points create optical effect, as these gauges are insensitive to electromagnetic fields; they are useful in explosive atmosphere.

Configurations of gauges can be designed to measure various strains that might apply to objects of different sizes and components. For example, the bi-axial configuration can measure along different planes as in a hole or cutting instrument. Here two different appliances are aligned at right angles to a common point in order to measure along different axes. In addition to measuring mechanically, instrument can be designed to measure thermally. The forces applied to continuously welded railway lines occur vertically, longitudinally and laterally. Configurations of different instruments provide important data for maintenance crews, helps to ensure the safety of long distance and high speed trains. It is clear that the strain gauge play an important role across the gamut of industrial activities. In mining, agriculture, architecture construction and road building, there are obvious applications. Less obvious, but equally important are the uses in the media, medicine and legal services. Engineers engage across all these fields do well to choose the products of reputable manufacturers who can be relied upon to produce accurate measuring instruments (Karl, 2012).

II. Literature Review

Until recent times one most difficult problem facing engineering had been to find the stresses acting upon a body by the direct application of measuring devices. Before the invention of the electrical resistance strain gauge the most important means available for this purpose was the extensometer in its various forms (mechanical, optical, etc) but these have a number of disadvantages, the most important of which are their relative bulk, which makes application impossible in conditions of limited space, and the gauge length required for application, usually not less than 12mm. Thus engineering stress problems formerly were solved on a purely theoretical basis coupled with trial and error tests and large factors of safety which were introduced to allow for the lack of precise knowledge of stress conditions at a particular point or points in the structure (Oluwole *et. al.*, 2015).

The principle on which electrical resistance strain gauges based was established by Lord Kelvin in 1856 when he showed that a stress applied to a metal wire, besides changing its length and diameter, also change its electrical resistance (Collet and Hope, 2001).

In the 1930's this effect was used by American workers to develop independently the bonded wire electrical resistance strain gauge which is attached by means of a suitable cement to the surface under test and subjected to the same strain. Since this type of gauge was developed a number of gauges have become available based on effects other than change of electrical resistance but the resistance gauge is still by far the most widely used. The most important gauges used for strain determination are as follow; Bonded wire, Bonded foil, Semiconductor, Photoelectric, Extensometer (Collett and Hope, 2001).

2.1 Strain

A body subjected to external forces is in a condition of both stress and strain. Stress cannot be directly measured but its effect, i.e. change of shape of the body, involves change in the fundamental quantity, length, which can be measure; thus, provided there is a known relationship between stress and strain, the stresses occurring in a body can be computed if sufficient strain information is available.

Professor Arthur Rouge invented the strain gauge device in 1938 to help his student John Meier to complete his investigation of earthquake stress on elevated water tanks. It was simple: a tiny piece of high resistance filament was bend in an zigzag pattern and fixed in rigid base (glue). The gauge was applied to the surface and these could be easily detected by measuring the changes in the electrical resistance of the current running through the wires of the gauge. Having been granted full rights to his invention, Rouge began the patent application process. When he discovering that E.E, Simmons of Caltech had invented the same device a year earlier. They both applied for the patent. In 1939, Rouge started a business with MIT Professor Alfred to manufacture the SR-4 gauge (Initial S and R honor the inventors), a device use in virtually all commercial weighing scales. In every structural stress test and it even allowed astronaut Neil Armstrong to declare: "The Eagle has landed" (Karl, 2012).

The electrical resistance strain gauge in the basic form know today was first used in 1936. The discovery of the principle upon which electrical resistance strain gauge is based was made in 1856 by Lord Kelvin , who loaded copper and iron wire in tension and noted that their resistance increased with the applied strain to the wire. Furthermore, he observed that the iron wire showed a greater increase in resistance that the copper wire when they were both subjected to the same strain. Lord Kelvin also employed the Wheatstone bridge to measure the resistance change. In that classical experiment, He established three very important facts which helped further development of electrical resistance strain gages; the resistances of the wire changes strain gauge, different materials have different sensitivity and Wheatstone bridge can be employed to accurately measure these resistances changes (Karl, 2012).

Types of Strain Gauges

Strain gauge types include; mechanical, optical, acoustical, pneumatic and electric based technique (Neubert, 2000).

Mechanical Strain gauges

They can measure the surface strains in any direction. The gauge is placed parallel to the surface in which direction the strain can be measured. It can measure static strains only (Neubert, 2000).

Optical Strain Gauges

In these gauges, the measurement and magnification are done optically. A system of mirrors may be used to produce large displacement on scale. It is suitable for measuring dynamic strains with a photographic recording system. It is difficult to handle and is a heavy instrument (Neubert, 2000).

Vibrating Wire Type Gauges

When wire is stretched between two clamps the natural frequency will change. This principle is used to measure the strains in vibrating wire type gauges. A gauge containing the wire is clamped into the test pieces and frequency of vibration is measured. Then it is compared with the standard known frequency. Easy and rapid measurement of strains can be done by this type of gauge (Neubert, 2000).

Pneumatic Strain Gauges

This type of strain gauges is widely used in precise engineering measurement to measure the micro strains. These gauges have very little application in civil engineering. Working principle of pneumatic gauges is that pressure drop is directly proportional to amount of fluid passing through the orifice (Neubert, 2000).

Electrical Resistance Strain Gauges

It is a very fine metal grid that is cemented in paper base material on the surface of any structural component to measure the surface normal strains in any desired direction. Lord Kelvin (1856) first gives the principle of working strain gauges. He proved that the resistance of conductor changes with the change in length. The idea was used measure the strain first in 1936 by US defense department (Neubert, 2000).

The Requirement for Accurate Strain Measurement

Ideally, gauges used for measuring strain should conform to the following requirements; the gauge should be small in size and easy to attach to the specimen or component, its profile should be as low as possible so that it will respond in unison with the changes in the surface to which it is fixed, the gauge should be highly sensitive in the direction of the measured strain but of low sensitivity in the transverse plane (cross-sensitivity), the strain resistance characteristics should be linear. Stiffness in all directions should not be such that the stiffness of the tested surface is modified and calibration should be easy and, once made, should remain stable with time, dynamic loading, and change of temperature, pressure or humidity. Speed of response should be high so that time lag is negligible. Remote indication should not present difficulties. The evaluation of complex strain patterns should be obtainable from as small a number of strain measurements as possible. Gauges should be inexpensive, reliable and readily available. There should be a variety of types and sizes suited to a wide range of applications. Immersion in liquids should not modify performance. Bonded resistance strain gauges fulfill many of these requirements. There are different types of commercial strain gauges; these are: unbonded wire gages, bonded wire gages, bonded foil gages, Piezo-resistance gages and Semi-conductive gages. The first three of these types are very similar and they are based on Lord Kelvin`s findings The major differences between then are based on the design concepts rather than the principles. The last two are entirely new concepts and are based on the use of a semiconductor as the strain sensing element. Bonded strain gages are the very common type (Enzine, 2017).

III. Methodology

One of the materials used in this work is mild steel which contains 0.15% to 0.3% of carbon. It has moderate strength, toughness, ductile and easy to machine. It is used for construction of building pillars, beams, metal rafters, bolts and nuts (Oluwayose, 2001). Other materials utilize in this work are bronze and brass based on their elastic properties. The application of theories and analysis based on sample size assumption were utilize to establish the developed device part specification.

Theoretical Background

Whenever some system of forces acts on a body, it undergoes some deformation. As the body undergoes deformation, their molecules setup some resistance to deformation. The resistance per unit area to deformation is known as stress.

Mathematically, stress may be defined as the force per unit area as given in equation 1 by Khurmi, (2000).

Stress ($(\sigma)= \frac{P}{A}$ (1)

where P= Load or force acting on the body, and A= Cross-sectional area of the body

Strain

Whenever a single force acts on a body, it undergoes some deformation. This deformation per unit length is known as strain. Mathematically, strain may be defined as deformation per unit length as given in equation 2 as given by Khurmi, (2000).

Strain $(\varepsilon)=\frac{\delta l}{l}$ or $\delta l = \varepsilon l$ (2)

where $\delta l =$ Change in length of the body, and

$l =$ Original length of the body.

Type of Stresses

There are many types of stresses, yet tensile stress is important due to the application of forces on various machine members.

Tensile Stress:

When a section is subjected to two equal and opposite pull and the body tend to increase its length as shown in fig. 3.1, the stress induced is called tensile stress. The corresponding strain is called tensile strain.

Hooke's Law: states that when a material is loaded, within its elastic limit, the stress is directly proportional to the strain which is in line with equation 3 as given by Khurmi, (2000).

$\frac{Stress}{Strain}=\frac{\sigma}{\varepsilon}=E=$ constant (3)

Deformation of Body Due to Force Acting on it (A body subjected to tensile stress) Using Superposition Principles which state that when a body is subjected to a number of forces acting on the outer edge as well as some other sections, along the length of the body. In such a case, the forces are splinted up and

their effects are considered on individual section. The resulting deformation of the body is equal to the algebraic sum of the deformation of the individual section as given in equation 4 by Khurmi, (2000).
The relation for the resulting deformation may be modified as;

$$\delta l = \frac{Pl}{AE} = \frac{P}{E}\left(\frac{l_1}{A_1} + \frac{l_2}{A_2}\right) \quad (4)$$

where P = Force acting on section 1
L_1= Length of section 1
L_2= Length of section 2
A_1= Cross-sectional Area 1
A_2= Cross-sectional Area 2

and Strain for Material Subjected to Tensile Stress

Stress on an oblique section of a body subjected to a direct stress in one plane. Oblique section AB inclined with the x-x axis with the line of action of the tensile stress on which it is expected to find out the stresses as shown in Fig. 1.

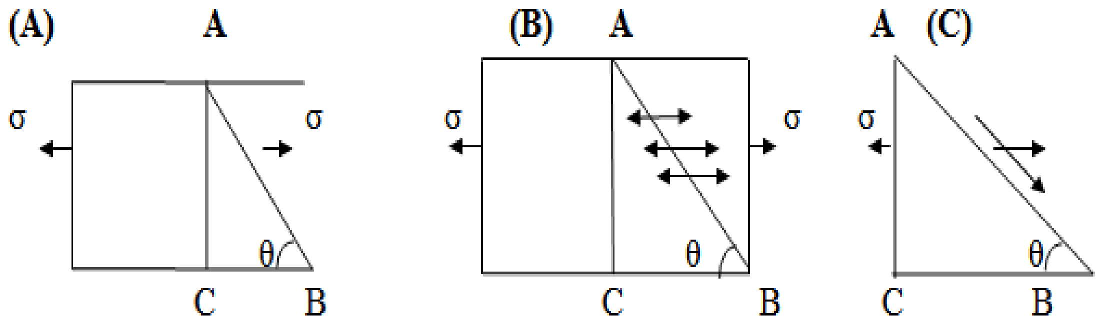

Fig. 1: Stress and strain for material subjected to tensile stress

where
σ = Tensile stress across the face AC and
θ = Angle which the oblique section AB makes with BC with the x-x axis in the clockwise direction (Khurmi, 2000).
Considering Fig. 1 B and C, the horizontal force acting on the face AC

$$\mathrm{P} = \theta.\,\mathrm{AC}\ (\longleftarrow)$$

Resolving the force perpendicular or normal to the section AB

$$\mathrm{Pn} = \mathrm{P}\sin\theta = \theta.\,\mathrm{AC}\ (\longleftarrow) \quad (5)$$

And now resolving the force tangential to the section AB,

$$\mathrm{Pt} = \mathrm{P}\cos\theta = \theta.\,\mathrm{AC}\cos\theta \quad (6)$$

And the normal stress across the section AB

$$\sigma_n = \frac{P_n}{AB} = \frac{\sigma AC\sin\theta}{AB} = \frac{\sigma.AC\sin\theta}{AC} = \sigma\sin^2\theta$$

$$= \frac{\sigma}{2}(1-\cos 2\theta) = \frac{\sigma}{2} - \frac{\sigma}{2}\cos 2\theta \quad (7)$$

And shear stress (tangential stress) cross the section AB,

$$\tau = \frac{P_t}{AB} = \frac{\sigma.AC\cos\theta}{AB} = \frac{\sigma.AC\cos\theta}{\frac{AC}{\sin\theta}} = \sigma\sin\theta\cos\theta$$

$$\tau = \frac{\sigma}{2}\sin 2\theta \quad (8)$$

In equation 7, the normal stress across the section AB will be maximum, when $\sin^2\theta = 1$ or $\sin\theta = 1$, or $\theta = 90^0$, or in order words, the face AC will carry the maximum stress. Similarly, the shear stress across section AB will be maximum when $\sin 2\theta = 1$ or $2\theta = 90^0$ or 270^0, or in other words, the shear stress will be maximum or the planes inclined at 45^0 and 135^0 with the line of action of tensile stress.
Therefore maximum shear stress when θ is equal to 45^0,

$$\tau_{\max} = \frac{\sigma}{2}\sin 90^0 = \frac{\sigma}{2}\times 1 = \frac{\sigma}{2}$$

Maximum shear stress, when θ is equal to 135^0,

$\tau_{\max} = \frac{\sigma}{2}\sin 270^0 = \frac{\sigma}{2}(-1) = \frac{\sigma}{2}$ It is thus obvious that the magnitude of maximum shear stress is half of the tensile stress (Khurmi, 2000).

The resultant stress $(\sigma_R) = \sqrt{\sigma_n^2 + \tau^2}$

Design Calculations by Applying Modulus of Elasticity of Material Specimen in Table 3.1

Table 3.1: Young Modulus of Selected Material

S/n	Material	Young Modulus (Gpa)
1	Brass	112.5
2	Bronze	108
3	Mild Steel	210

Equation 9 to 15 where utilize to established the above parameters as given by Khurmi, (2000)
Force (F) = mass x acceleration due to gravity and Modulus of Elasticity

$$E = \frac{\sigma}{\varepsilon} \qquad (9)$$

$$\text{Stress } (\sigma) = \frac{P}{A} \qquad (10)$$

$$\text{Strain } (\varepsilon) = \frac{\delta l}{L} \qquad (11)$$

where,
E = modulus of elasticity,
A = Area of material,
σ = stress, ε = strain,
δl = change in length,
L = Original length
Also,

$$\varepsilon = \frac{\sigma}{E} = \frac{P}{AE} \qquad (12)$$

$$\frac{\delta l}{L} = \frac{P}{AE} \qquad (13)$$

$$\delta l = \frac{Pl}{AE} \qquad (14)$$

$$\delta l = \frac{P}{E}\left[\frac{L_1}{A_1} + \frac{L_2}{A_2}\right] \qquad (15)$$

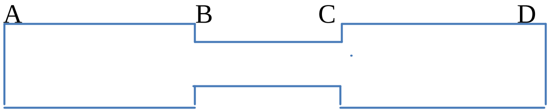

Fig. 2: Sample

Assumption of Material and the Sample

The following assumptions were made during design analysis for the sample shape as presented in Fig. 2, which includes; Having a diameter of 10mm at the middle (section B to C), Section AB and CD has the same diameter of 20mm, Materials to be tested are Brass, Bronze and Mild steel with their modulus of elasticity been known. Maximum load applied on the specimen is 1000 N and they are applied gradually. The original length must not exceed 200mm (total length of specimen). The length of section BC should not exceed 100mm. Having known the diameter of specimen or sample. The strains gauge whose front and side views are shown in Fig 3 and 4 was designed.

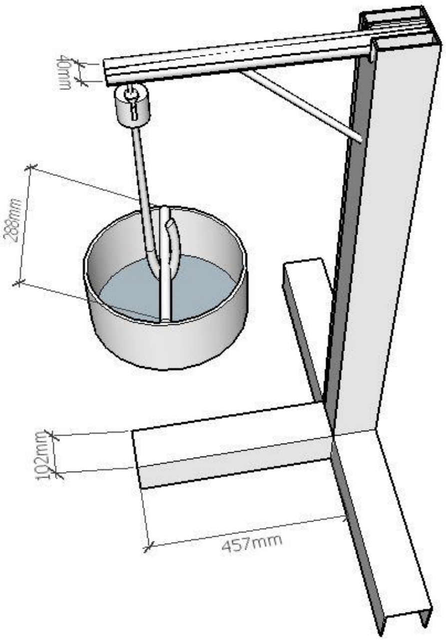

Fig. 3: Strain gauge with dimensions

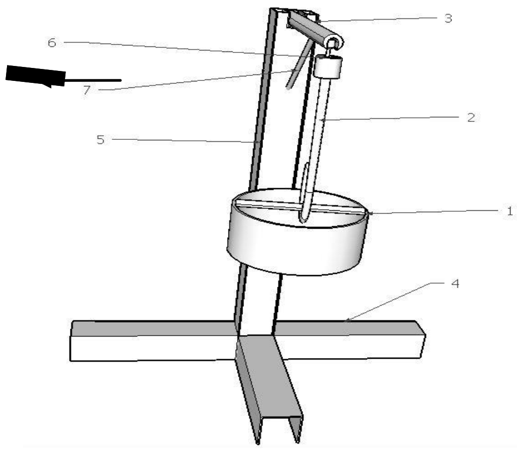

Fig. 4: Strain gauge equipment

Table 2: Part list

ITEMS	QTY	PART NAMES	DISCRIPTION
1	1	Loading pan	
2	1	Load hanger	
3	1	Suspended overhanging rod	
4	1	Frame base	
5	1	Main frame	
6	2	Dogbone specimen	
7	1	Frame support	
8	1	Sensing unit	

Design Calculations Mild Steel Specimen:
At 1kg of load;
Load (P) = 1kg = $1 \times 9.81K = 9.81KN$

Area of specimen at original dia. is,

$$Area = \frac{\lambda d^2}{4} = \frac{3.142 \times 10}{4}$$

= 78.55 mm
Change in length is given as;

$$\delta l_1 = \frac{Pl}{EA} = \frac{9.81 \times 10^3 \times 100}{210 \times 10^3 \times 78.55}$$

$$= \frac{981}{16495.5} = 0.0595mm$$

$$Stress(\sigma_1) = \frac{P}{A} = \frac{9.81 \times 10^3}{78.55}$$

= 124.9 N/mm^2

$$Strain(\varepsilon_2) = \frac{\sigma}{E} = \frac{124.9}{210 \times 10^3}$$

= 0.000595

The summary of the theoretical stress and strain are tabulated in table 3 to 5, where table 3.2, 3.3 and 3.4 gives the outcome of mild steel, brass and bronze respectively; Their strain in term of length, diameter and also their stress at different loading intervals were establish.cx

TABLE 3: STRAIN **RESULT PARAMETERS FOR MILD STEEL**

S/N	Load KN	**Modulus of Elasticity Nmm^2**	Area (A) mm^2	Change in length (δl)mm	Change in diameter (δd)mm	Poisson ratio	Stress (σ)Nmm^2	Strain (ε) %
1	9.81	**210**	78.55	0.0595	0.0018	-	124.9	0.10
2	19.62	**210**	78.52	0.1191	0.00361	0.303	249.9	0.119
3	29.43	**210**	78.47	0.1789	0.0054	0.303	375.0	0.179
4	39.24	**210**	78.37	0.2392	0.00720	0.303	500.7	0.238
5	49.05	**210**	78.27	0.3083	0.0090	0.303	626.7	0.298

TABLE 4: STRAIN RESULT PARAMETERS FOR BRASS

S/N	Load KN	Modulus of Elasticity Nmm^2	Area (A) mm^2	Change in length (δl)mm	Change in diameter (δd)mm	Poisson ratio	Stress (σ)Nmm^2	Strain (ε) %
1	9.81	112.5	78.55	0.1110	0.0037	-	124.9	0.111
2	19.62	112.5	78.49	0.2224	0.0073	0.33	249.9	0.222
3	29.43	112.5	78.38	0.3342	0.0110	0.33	375.5	0.334
4	39.24	112.5	78.20	0.4482	0.0148	0.33	501.8	0.447
5	49.05	112.5	77.96	0.5649	0.0184	0.33	629.2	0.559

TABLE 5: STRAIN RESULT PARAMETERS FOR BRONZE

S/N	Load KN	Modulus of Elasticity Nmm^2	Area (A) mm^2	Change in length (δl)mm	Change in diameter (δd)mm	Poisson ratio	Stress (σ)Nmm^2	Strain (ε) %
1	9.81	108	78.55	0.1156	0.00393	-	124.9	0.12
2	19.62	108	78.49	0.2317	0.00787	0.34	149.9	0.232
3	29.43	108	78.36	0.3489	0.0118	0.34	0375.6	0.348
4	39.24	108	78.17	0.4694	0.0158	0.34	501.9	0.965
5	49.05	108	77.92	0.5916	0.0197	0.34	629.5	0.583

FINISHING

Process involved, cleaning, smoothing and painting of the component to provide an attractive surface required of the product; Slag remover

GRINDING: Grinding is a process of removing burnt carbon formation on the surface of the welding joint. This gives the job an attractive appearance and removed the blunt edge of the weld. This process can be done using hand grinding machine.

Cleaning and Smoothing: This is the removal of rust and dust from the surface of the component.

Painting: It is the coating of surface of the component with paint, the process make the component more attractive and also prevent it from rusting and corrosion. Brush is used to apply the paint, red oxide and green paint is used for painting.

Plate 1: Developed Indigenous Strain Gauge

During practical experiment, it was observed that the load applied on the specimen is directly proportional to the elongation of the specimen which actuates the transducer while the indicator read the strain in the specimen under load.

Sensing Element

The sensing system and its component parts are power unit, oscillator, amplifier, detector or demodulator, buffer, crystal and I
Indicator

IV. Results and Discussion

Practical Result of Strain Gauge

Theoretical and practical result of strain measured with specimen of mild steel material having original length of 200mm and diameter of 5mm are reflected in Table 6: Practical result and theoretical result

Load (N)	Theoretical Strain	Practical Strain
50	0.0000120	0.0000124
100	0.0000240	0.0000248
150	0.0000360	0.0000373
200	0.0000490	0.0000497
240	0.0000608	0.0000591
250	0.0000610	0.0000622
300	0.0000730	0.0000746
350	0.0000850	0.0000871
400	0.0000970	0.0000995

Fig. 5 and Fig. 6 are the graphical representation of load against practical strain and theoretical strain respectively, which shows that the load is directly proportional to the strain. While Fig. 7 is the graphical presentation of load against practical strain and the theoretical strain

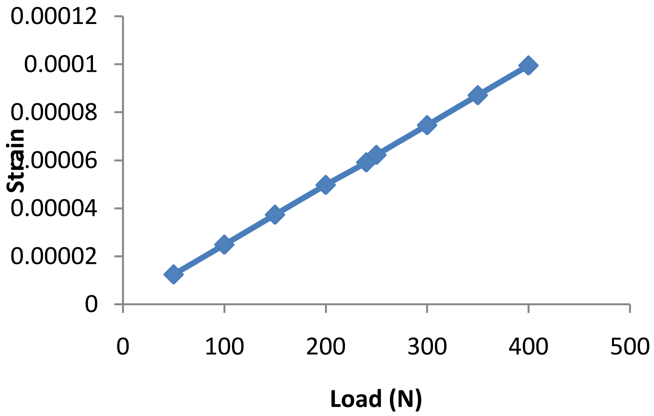

Fig. 5: Pract. strain against Load

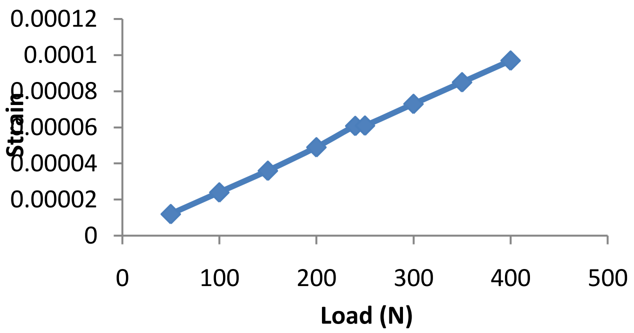

Fig. 6: Theoretical Strain against Load

V. Conclusion

Indigenous strain gauge equipment can be used to determine strain measurement, the energy stored when load is gradually applied and mechanical properties (Modulus of elasticity, Yield strength, Tensile strength, percentage elongation at maximum force) of various structural materials. The fabrication was excellent having reliable strength to withstand maximum load of 1000N without bending. The rigidity of the design is dependable and the equipment performed effectively, the strain measured with the equipment was directly proportional to the theoretical strain.

VI. Recommendation

Regard to the rigidity, durability and economical use of the project and the undisputable response of the transducer due to the load applied, and the determination of the strain measurement. This project is recommended for experimental analysis of stress-strain of ductile materials. Students in engineering department most especially, Mechanical and Civil engineering can use this equipment for practical purposes on strain measurement. Modification of the loading pan to have a tripod handle will enable the pan to accommodate more loads and ensure stability of the loads. The strain gauge should be done with a reliable and standard strain gauge equipment to ascertain the reliability of the sensing unit in respect to calibration.

References

[1] Amos, S.W and Roger Amos (2002); Newnes Dictionary of Electronics, 4th Ed, US. Newnes Pp.76
[2] Collet C. V and Hope A. D (1987); Engineering Measurements. Vol. Mag.-16, No. 5 pp 907-909.
[3] Dally, J. W., Rilley, W. F., Mc Connell and Kenneth G. (1993); "Instrumentation for Engineering measurements" 2nd Ed., John Wiley &Son,
[4] Elinger, F. (2008); "Radio frequency integrated circuits and Technologies" USA singer. Pp. 391-394
[5] Elvenspoek, M. (2001); "Mechanical Microsensors", Springer.
[6] Hannah R. L., Reed, S.E. (1992); "Strain Gage users Manual" Society for Experimental Mechanics. P. 122.
[7] Holister G. S. (1967); " Experimental Stress Analysis" (C.V.P) 63rd yr. No. 2 (2001), pp 33-41,
[8] Neubert H.K.P. (2000); "Strain Guages: Kinds and Uses" (Macmillian, 1968).
[9] Hilal, M. M and Mohamed, S. H (2011); "A Strain Gauge Based System For Measuring Dynamic Loading on a Rotating Shaft," International Journal Of Mechanics, Issue 1, Vol.5, 2011. Pp. 7-38
[10] Karl, H (2000); "An Introduction to Measurements using strain gauges," Germany: Druckerei Drach Press, Alsbach. Pp.1-32
[11] Khumi R. S. (2000); "Strength of Materials" S. chard & company Limited
[12] Middelhoek, S. and Audet, S. A (1994); "Silicon Sensors," Delft University of Technology, Department of Electrical Engineering. (Delft: Delft University Press) Lecture et 05-31
[13] " MIT". Cee.mit.edu. 2011-05-01. Retrieved 2011-09-29.
[14] Oluwayose, J. O (2001); " machine and workshop practice". Adelog printing and publishing lagos
[15] Oluwole O. O., Olanipekun A. T. and Ajide O. O (2015); "Design, Construction and Testing of a Strain Guage"; InternationJournal of Scientific & Engineering Research, Volume 6, Issue 4, April- 2015 1825
[16] Patronis and Gene (1987); "Amplifier". In Glen Ballou. Handbook for SoundEngineers.The New AudioCyclopedia. Howard W. Sams & Co. P. 493.
[17] Richard, S. F and Donald, E. B (2011); "Theory and Design for Mechanical Measurements," 5th ed. John Wiley & Sons, Inc. Chapter 11: pp. 466, 2011.
[18] Snelgrove F. R. and Martin G. H. (2011); "Oscillator" Mc Graw – Hill Encyclopedia of science and technology, 10th Ed, science and online service. Mc Grew –Hill. Retrieved March 1, 2012. www.hbm.com
[19] Spark. N (2006); "A History of Murphy's law". Periscope Film.ISBN 978-0-9786388- 9-4.Washington. edu> chap5
[20] "Working Committee on the Safety of Bridges (1980); ASCE. A Guide For Field Testing of Bridges," New York: ASCE. (Delft: Delft University Press) Lecture 08-27.

Ejiko, S.O. "Design and Construction of Indigenous Strain Gauge Equipment." IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) , vol. 15, no. 2, 2018, pp. 49-59