Strain Measurement and analysis on the load in Universal Testing Machine

Tanay Jani[1], Prof.Manisha Mhetre[2]

[1]B.Tech student, Dept of Instrumentation and Control, Vishwakarama Institute of Technology, Pune

[2]Assistant Professor, Dept of Instrumentation and Control, Vishwakarma Institute of Technology, Pune

ABSTRACT

Strain measurement in a metal provide fatigue analysis of that material upon static and dynamic force application. This analysis gives out important indication about strength of material for the given application. This paper presents the experimentation of measurement of strain of the MS material in a Universal Testing Machine for static and dynamic force upon unloading and loading conditions. Lab view DAQ card and software is used to acquire the signal and its analysis. From the data acquired, MATLAB is used for getting the equation for strain of the given material for unknown force .For strain indication microcontroller based system is built-up. Strain is indicated on LCD.

Keywords:- Universal Testing Machine, dynamic force, loading and unloading conditions

1. INTRODUCTION

1.1What Is Strain?

Strain is the amount of deformation of a body due to an applied force. More specifically, strain (e) is defined as the fractional change in length, as shown in Figure 1.

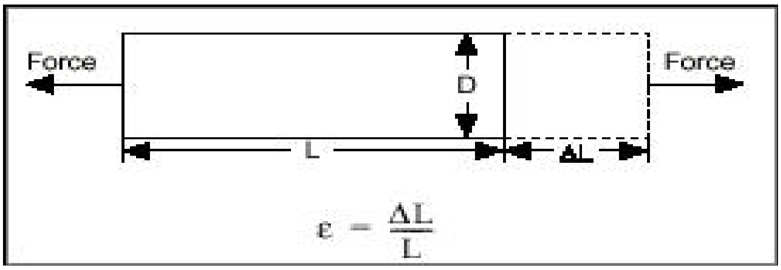

Figure 1. Definition of Strain

Strain can be positive (tensile) or negative (compressive). Although dimensionless, strain is sometimes expressed in units such as in./in. or mm/mm. In practice, the magnitude of measured strain is very small. Therefore, strain is often expressed as micro strain (me), which is e x 10-6. When a bar is strained with a uniaxial force, as in Figure 1, a phenomenon known as Poisson Strain causes the girth of the bar, D, to contract in the transverse, or perpendicular, direction. The Magnitude of this transverse contraction is a material property indicated by its Poisson's Ratio. The Poisson's Ratio n of a material is defined as the negative ratio of the strain in the transverse direction (perpendicular to the force) to the strain in the axial direction (parallel to the force), or n = eT/e. Poisson's Ratio for steel, for example, ranges from 0.25 to 0.3.

Methods to measure Strain:

1. Strain Gauge
2. Hydraulic Load cell
3. Pneumatic Load cell

1.2Strain Gauge:

While there are several methods of measuring strain, the most common is with a strain gauge, a device whose electrical resistance varies in proportion to the amount of strain in the device. The most widely used gauge is the bonded metallic strain gauge. The metallic strain gauge consists of a very fine wire or, more commonly, metallic foil arranged in a grid pattern. The grid pattern maximizes the amount of metallic wire or foil subject to strain in the parallel direction (Figure 2). The cross-sectional area of the grid is minimized to reduce the effect of shear strain and Poisson Strain. The grid is bonded to a thin backing, called the carrier, which is attached directly to the test specimen. Therefore, the strain experienced by the test specimen is transferred directly to the strain gauge, which responds with a linear change in electrical resistance. Strain gauges are available commercially with nominal resistance values from 30 to 3,000 Ω, with 120, 350, and 1,000 Ω being the most common values.

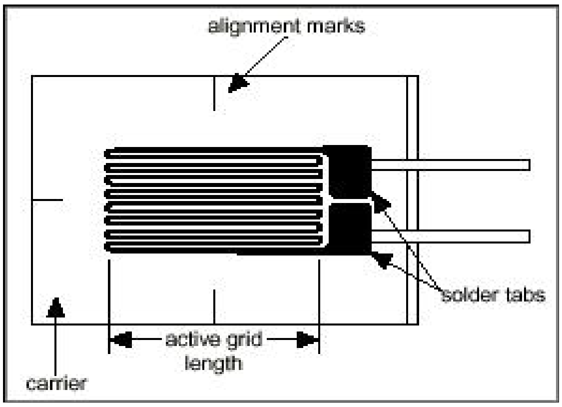

Fig. 2 Strain gauge

t is very important that the strain gauge be properly mounted onto the test specimen so that the strain is accurately transferred from the test specimen, through the adhesive and strain gauge backing, to the foil itself. A fundamental parameter of the strain gauge is its sensitivity to strain, expressed quantitatively as the gauge factor (GF). Gauge factor is defined as the ratio of fractional change in electrical resistance to the fractional change in length (strain).

$$GF = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{\varepsilon}$$

The gauge factor for metallic strain gauges is typically around 2.

1.3Strain Gauge Measurement

In practice, strain measurements rarely involve quantities larger than a few millistrains (e x 10-3). Therefore, to measure the strain requires accurate measurement of very small changes in resistance. For example, suppose a test specimen undergoes a strain of 500 me. A strain gage with a gage factor of 2 will exhibit a change in electrical resistance of only 2 (500 x 10 -6) = 0.1%. For a 120 Ωgage, this is a change of only 0.12 Ω. To measure such small changes in resistance, strain gages are almost always used in a bridge configuration with a voltage excitation source. The general Wheatstone bridge, illustrated in Figure 3,consists of four resistive arms with an excitation voltage, VEX, that is applied across the bridge.

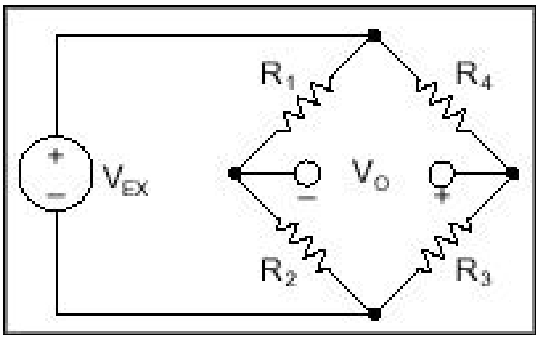

Fig 3 Resistance Bridge using Strain gauges

$$V_O = \left[\frac{R_3}{R_3 + R_4} - \frac{R_2}{R_1 + R_2}\right] \bullet V_{EX}$$

The output voltage of the bridge, VO, is equal to:

From this equation, it is apparent that when R1/R2 = R4/R3, the voltage output VO is zero. Under these conditions, the bridge is said to be balanced. Any change in resistance in any arm of the bridge results in a nonzero output voltage.

Therefore, if you replace R4 in Figure 3 with an active strain gage, any changes in the strain gage resistance will unbalance the bridge and produce a nonzero output voltage. If the nominal resistance of the strain gage is designated as RG, then the strain-induced change in resistance, DR, can be expressed as DR = RG•GF•e, from the previously defined Gage Factor equation. Assuming that R1 = R2 and R3 = RG, the bridge equation above can be rewritten to express VO/VEX as a function of strain (see Figure 4). Note the presence of the 1/(1+GF•e/2) term that indicates the nonlinearity of the quarter-bridge output with respect to strain.

2. HARDWARE DESCRIPTION

Fig 4 Universal Testing Machine

Operation of the Universal Testing Machine (Fig. 4)machine is by hydraulic transmission of load from the test specimen to a separately housed load indicator. The system is ideal since it replaces transmission of load : through levers and knife edges, which are prone to wear and damage due to shock on rupture of test pieces. Load is applied by a hydrostatically lubricated ram. Main cylinder pressure is transmitted to the cylinder of the pendulum dynamometer system housed in the control panel. The cylinder of the dynamometer is also of self - lubricating design. The load transmitted to the cylinder of the dynamometer is transferred through leverage to the pendulum. Displacement of the pendulum actuates the rack and pinion mechanism which operates the load indicator pointer and the autographic recorder. The deflections of the pendulum represent the absolute load applied on the test specimen. Return movement of the pendulum is effectively damped to absorb energy in the event of sudden breakage of the specimen. System Block diagram:

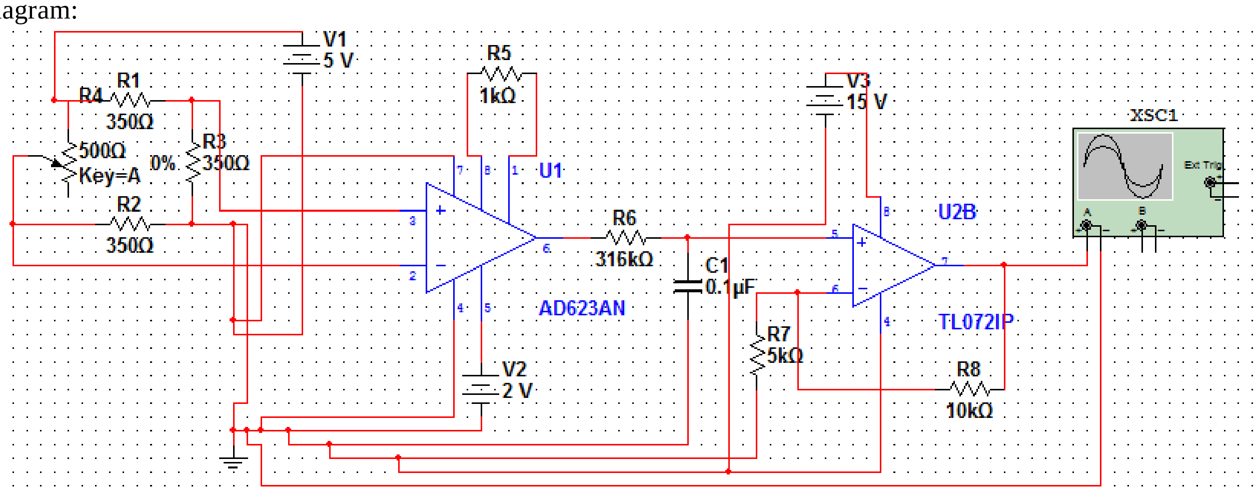

Fig 5 System Block diagram

2.1Signal Conditioning for Strain Gauges:

Sensor is placed in a metallic rod having strain gauge. To increase the accuracy of the output increase the number of strain gauge (fig 5 and fig 6) Strain gage measurement involves sensing extremely small changes in resistance.

Therefore, proper selection and use of the bridge, signal conditioning, wiring, and data acquisition components are required for reliable measurements. To ensure accurate strain measurements, it is important to consider the following: Wheatstone bridge measurement, Bridge Completion, Circuit Excitation, Remote sensing, Amplification, Filtering, Offset, Shunt calibration. We have selected 350Ω resistor in the remaining 3 arms of the Wheatstone bridge as our strain gauge is of 350Ω.Any change in the resistance of the strain gauge will unbalance the bridge and the output of the bridge will be in mV. This output is given to the instrumentation amplifier.

2.2Wheatstone bridge circuit:

The output of strain gages and bridges is relatively small. In practice, most strain gage bridges and strain-based transducers output less than 10 mV/V (10 mV of output per volt of Excitation voltage). With 10 V excitation, the output signal is 100 mV. Therefore, strain gage signal conditioners usually include amplifiers to boost the signal level to increase measurement resolution and improve signal-to-noise ratios. Unless you are using a full-bridge strain gage sensor with four active gages, you need to complete the bridge with reference resistors. Therefore, strain gage signal conditioners typically provide half-bridge completion networks consisting of high-precision reference resistors. Figure 9a shows the wiring of a half-bridge strain gage circuit to a conditioner with completion resistors R1 and R2.

2.3Bridge Completion

Unless you are using a full-bridge strain gage sensor with four active gages, you need to complete the bridge with reference resistors. Therefore, strain gage signal conditioners typically provide half-bridge completion networks consisting of high-precision reference resistors. Figure 9a shows the wiring of a half-bridge strain gage circuit to a conditioner with completion resistors R1 and R2.

2.4 Remote Sensing

If the strain gage circuit is located a distance away from the signal conditioner and excitation source, a possible source of error is voltage drop caused by resistance in the wires connecting the excitation voltage to the bridge. Therefore, some signal conditioners include a feature called remote sensing to compensate for this error. Remote sense wires are connected to the point where the excitation voltage wires connect to the bridge circuit. The extra sense wires serve to regulate the excitation supply through negative feedback amplifiers to compensate for lead losses and deliver the needed voltage at the bridge.

Amplification Circuit (stage 1):

Rg=100kΩ/G-1

G=Gain

Rg=Gain Resistor

For G=100,

Rg=1kΩ

The reference terminal is also useful when bipolar signals are being amplified because it can be used to provide a virtual ground voltage. We have given reference voltage as 2V.For bridge output of ±10mV o/p of instrumentation amplifier will vary from 1V to 3V with 2V being null position. The output of strain gages and bridges is relatively small. In practice, most strain gage bridges and strain-based transducers output less than 10 mV/V (10 mV of output per volt of excitation voltage).With 10V excitation; the output signal is 100 mV. Therefore, strain gage signal conditioners usually include amplifiers to boost the signal level to increase measurement resolution and improve signal-to-noise ratios.

2.5 Filter

Strain gages are often located in electrically noisy environments. It is therefore essential to be able to eliminate noise that can couple to strain gages. Low pass filters, when used with strain gages, can remove the high-frequency noise prevalent in most environmental settings. Output of instrumentation amplifier is passed to low pass RC filter which has cutoff frequency of 5Hz.The value of the resistance is calculated by the formula:

Cutoff Frequency=1/2πRC

We have taken C=0.1µF

Hence we get the value of the resistance as 318kΩ. The filtered signal is given to the non inverting amplifier. Amplification (stage II) Non Inverting Amplifier (TL072):

Gain of non inverting amplifier is given by

$$G=1+Rf/R1$$

By taking RF =10KΩ, R1=5KΩ From this we get G=3.Thats why we get output in the range of 3-9 V.

2.6 Excitation

Strain gage signal conditioners typically provide a constant voltage source to power the bridge. While there is nostandard voltage level that is recognized industry wide, excitation Voltage levels of around 3 and 10 V are common. While a higher excitation voltage generates a proportionately higher output voltage, the higher voltage can also cause larger errors because of Self-heating.

3. SOFTWARE DESCRIPTION

Figure 7 represents the program in Labview.Figure 8 represents the simulation of the signal in Labview.It represents the change in resistance with the input force. Observations are given below.

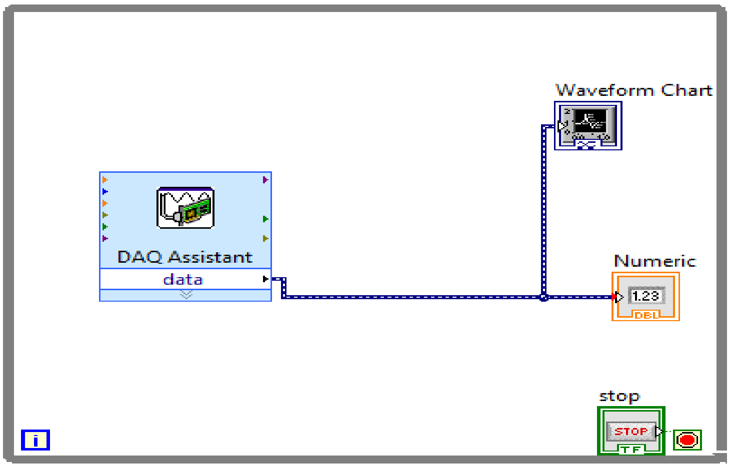

Figure 7 Labview functional diagram

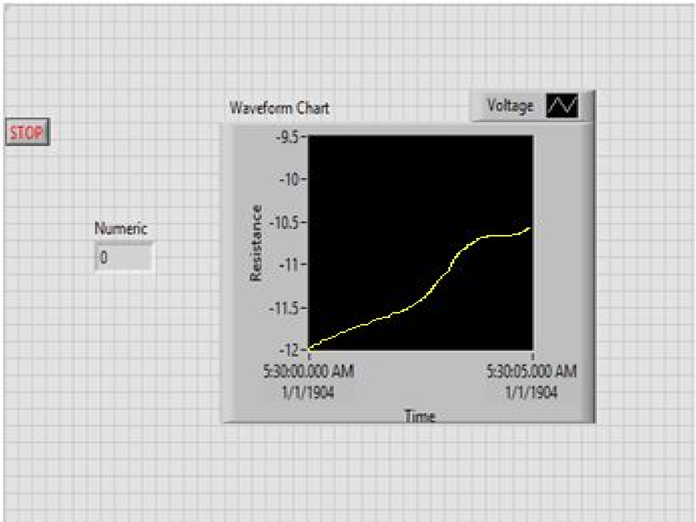

Figure 8: Graph of resistance and time

3.1Algorithm for the micro-controller

1. Get the signal from the Labview.
2. Use ADC commands in PIC for communication of signal with micro-controller.
3. Store the required signal in a register.
4. Initialize LCD.
5. Built up a look-up table for respected value of the signal
6. Send the required bits in the look up table to the LCD.
7. Check for the future signal from Labview
8. End

4. OBSERVATION

Diameter of rod – 20cm
Area – 314.16
Material – MS
E, Gpa – 200
R0 (Initial Resistance) – 350 Ω
Gauge Factor – 2.11

Table 1: Observation table for Load change and strain developed

Curve-Fitting:
1) Loading:
Linear model Poly1:
f(x) = p1*x + p2
Where x is normalized by mean 30 and std 18.61
Coefficients (with 95% confidence bounds):
p1 = 0.3264 (0.2073, 0.4454)
p2 = 350.5 (350.4, 350.6)
Goodness of fit:
SSE: 1.23
R-square: 0.634
Adjusted R-square: 0.6147
RMSE: 0.2544
2) Unloading:
Linear model Poly1:
f(x) = p1*x + p2
where x is normalized by mean 30 and std 18.61
Coefficients (with 95% confidence bounds):
p1 = 0.307 (0.2644, 0.3496)
p2 = 350.5 (350.4, 350.5)
Goodness of fit:
SSE: 0.1576
R-square: 0.9228
Adjusted R-square: 0.9188
RMSE: 0.09109
After getting the linear equation of the signal we implemented the equation in the micro-controller and made the look-up table.

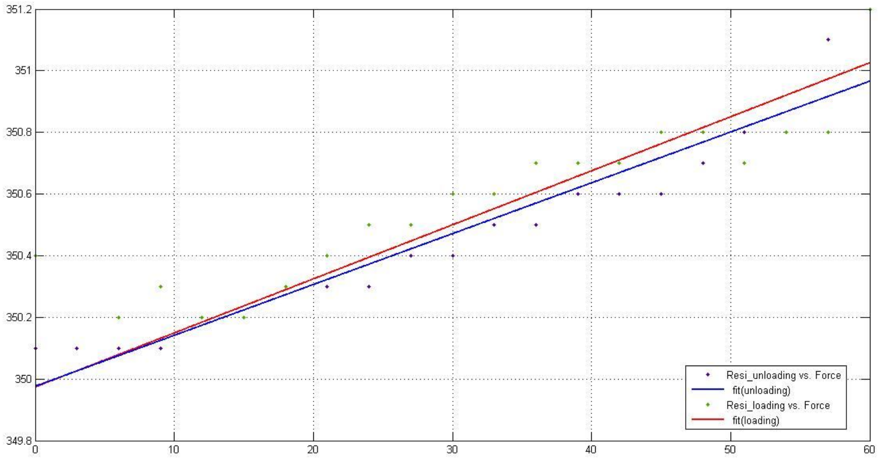

Fig.9. Graph showing force and resistance change (Loading and unloading)

5. CONCLUSION

Thus the system allows us to continuously monitor the strain change from the load of the Universal Testing Machine and get using appropriate algorithm, the system will have much higher accuracy output and can effectively store data for future use**.**

REFERENCES

[1]. PIC Micro-controller-Mazidi
[2]. Electrical and Electronic Instrumentation-A.K.Shawney
[3]. Labview manual
[4]. Industrial Automation-Krisnaswamy
[5].MATLAB help

Authors Profile

Name: Tanay Jani, BTECH, Dept of Instrumentation and control , Vishwakarma Institute of Technology, Pune, Maharashtra

Name: Prof M.R.Mhetre, Assistant Professor, Dept of Instrumentation and control, Vishwakarma Institute of Technology, Pune, Maharashtra. B.E(Instrumentation and Control),M.E.(Electronics),PhD(pursuing, Biomedical Energy harvesting).She is having 2years of Industrial experience and 17 years of Teaching experience. Many Publications in National ,International conference and International refereed Journals with two patents filed.