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Measurement of Load Using Component of the UTM as Load Sensing Member

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Abstract: Measurement of load acting on machines and structures is important from many considerations. Accurate weighing of commodities, applying known load on specimens being tested for strength, safe operation of material handling equipment such as crane are some examples. When the load or forces are to be measured, a load cell is to be placed in the load path. Many times, it is not feasible to insert the load cell in the load path. In such cases, using the machine member themselves for measuring load will be advantageous. This paper involves study of machine members for them to be used for measurement of load and is applied to UTM where load measurement is essential. The load measurement involves identification of critical component in the load path. Once the critical component in the load path is identified, electrical resistance strain gauges are mounted to get maximum output for an applied load. An electronic load meter consisting of amplifier, ADC and display is used to process the electrical signal from the strain gauge to display the load. Load measurement using this load meter compares well (within 6% error) with the existing load measuring device. This method of measurement of load acting on machines and structures is safe, convenient and economical.

Index terms: Load, Strain gauge, UTM, Load meter, Sensor. Electronic components, Critical component.

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1. INTRODUCTION

The load can be measured in different ways and this load may be static or dynamic. Most commonly used method for load measurement is load cells. When loads or forces are to be measured, a load cell is to be placed in the load path. A load cell is a transducer that converts mechanical force into electrical signals. There are many different types of load cells that operate in different ways, but the most commonly used load cell today is the strain gauge based load cell. As their name implies, strain gauge load cells use an array of strain gages to measure the deformation of a structural member and convert it into an electrical signal. Many times, it is not feasible to insert a load cell in the load path. In such cases, using the machine members themselves for measuring load will be advantageous. Many researchers have done work on load measurement in the machine members.

Antti-jussi romppanen investigated the Inverse load sensing method for finding a line load distribution, the feasibility of the method, especially for rotating beams is evaluated. The strain measurement of beam like structures can be utilized in order to solve the actuating line load distribution. The Inverse load sensing method is first verified in two experimental cases of static point forces acting on beam like structure. Finally method is tested on real dynamic application of pilot rolls press,

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Strain gauges are installed on to the inner surface of one of the roller and strain data recorded during run and inverse load sensing the load is estimated [1].

J.F Doyle investigated the determination of impact force for beam and plate type of structures subjected to transverse impacts. Strain gauges were used in his experiment to sense the strain responses at selected locations on the specimens. The force/strain relation for the transverse impact of beam and plate were established in the time domain for beam, and frequency domain for the plates. Inversion by the use of fast Fourier transform (FFT) was shown to determine the force history [2].

S.E.S. Karlsson worked on Identification of external structural load by measuring harmonic responses. In many practical situations, it is difficult to perform direct measurements or calculations of the external forces acting on an existing vibrating structure. Instead, the structural response may be measured and the position and magnitude of the exciting forces be calculated from the measured response [3].

Ravinarayan R.Rao worked on "force estimation on a mechanical member" by inverse finite element approach. During this research, work-study is carried out on a Universal Testing Machine; critical member of the machine is identified and used for measurement of load.

2. LOAD CELL AND ITS LIMITATIONS

A load cell usually consists of a mechanical member such a beam, a circular ring etc. It is properly supported and electrical resistance strain gages are mounted at critical location to get maximum strain output due to the applied load.

The strain gages are connected in a Wheatstone bridge configuration. An instrumentation amplifier, converted to a digital signal using ADC, amplifies the electrical signal output and the output is displayed. The output of the load is calibrated by applying known loads.

2.1 Limitations

- The mounting of load cell in load path is difficult.
- Slightly difference in loading position of load cell platform may give wrong result; the load should be equally distributed on the load cell platform.
- Calibration and Maintenance of load cell is difficult. Cost is more.

3. USE OF MACHINE MEMBERS FOR LOAD MEASUREMENT

Measurement of load acting on machines and structures is important from many considerations. The load cells are difficult to install on load path in some applications for load measurement, this limitation can be overcome by using the machine component itself as load sensor. This method drastically reduces the cost involved in designing the separate load cell and accessories.

In category of problem where the known load cannot be applied on the machines and structures load measurement by using machine member itself as load sensor will be very useful. This involves thorough study of the different members of the machine and identifying the critical member in the load path. Stress analysis of the critical member provides necessary data about the critical location where strain can be measured. By knowing the nature of stress distribution, electrical resistance strain gages can be mounted in such way that maximum strain can be measured. An electronic measuring unit similar to the one used for load measurement in a load cell is used with proper calibration for displaying the load. This approach can be used measuring load acting on any member during actual working of the machine. This data can also be used for optimization redesigning of machine members.

4. APPLICATION TO LOAD MEASUREMENT IN UTM

A universal testing machine is a versatile machine for conducting different tests on material specimens in a laboratory. For determining the strength of the specimen tested, it is essential to accurately measure the load applied. For this purpose, hydraulic oil used in system is used to move mechanical members to display the load on a dial gage. Alternatively, a pressure transducer is used in the hydraulic circuit to electronically display the load. The load applied during testing can be accurately measured using a critical load-bearing member of the machine. This method overcomes the inertia of mechanical members encountered in mechanical method and any scope for leakage in a hydraulic system when pressure transducer is used.

4.1. Identification of Critical Load Bearing Member.

The universal testing machine mainly consisting of a loading frame, hydraulic pumping system, The Loading Frame consists of a central crosshead and a lower bed. Center crosshead is movable. Compression Test is carried out between the central crosshead and the lower bed where as tension test is carried out between center and upper crossheads.

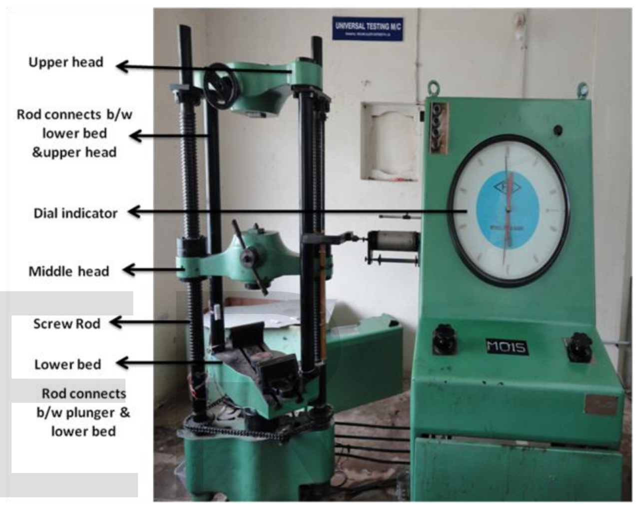

Fig 1. UTM Machine

The components of the UTM are shown in fig 1. These components experience load in tension test as well as compression, therefore the components have been studied for investigating the feasibility of using one of the critical components itself as load sensing member. The three different components have been studied for the Experimental purpose. The UTM critical components have been studied by using the FEM analysis and theoretical method. The three components have been selected for the Experimentation work. The three components are as follows.

- On the rod, which connected to lower bed and the upper bed of the machine, the rod diameter of 65mm
- The threaded rod that is connected between the base of UTM and central movable jaw.
- The rod, which is attached between the top of plunger and the lower bed.

Among three components, the critical component has been decided by FEM analysis. The rod, which is attached between the top of plunger and the lower bed, bears the complete load and this member is used for measuring the load.

4.2. Mounting Strain Gauges.

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, bonded strain gauges in that wire type, foil type gauges. The foil type gauges are more sensitive to the deformation of the materials and they are used for load measurement.

Wheatstone bridge is widely used for measuring the exact output from the strain gauges there are two known resistors, one variable resistor and one unknown resistor connected in bridge. By adjusting the variable resistor, the current through the Galvanometer is made zero. When the current through the galvanometer becomes zero, the ratio of two known resistors is exactly equal to the ratio of adjusted value of variable resistance and the value of unknown resistance. In this way, the value of unknown resistance can easily be measured by using a Wheatstone bridge. The theory of Whetstone Bridge will be,

$$R1R2 = R3R4 \quad (1)$$

The working of UTM was completely studied. The rod, which is attached between the top of plunger and the lower bed, is found to be suitable for the load measurement. When the pressure applied on the plunger, The plunger moves up and the lower bed moves up by applying the force on the specimen.

This condition makes the rod in compression behavior. The four strain gauges are mounted on the threaded rod, two gauges vertical to axis and another two horizontal to axis. The strain gauge resistance used for the Work is 350 ohms with less than 5mm width gauge or miniature gauges. The experiment was conducted for compression test by connecting individual gauges and Wheatstone bridge. The location of strain gauges as shown in the fig 2.

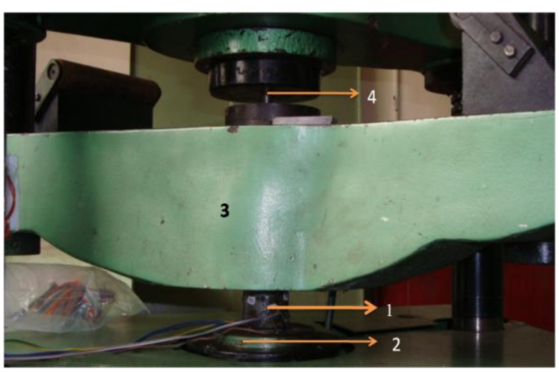

Fig.2. Location of Gauges

1. Gauge location (Rod, which connects plunger and lower bed)
2. Plunger or cylinder.
3. Lower bed
4. Specimen area

The individual readings are taken and the four strain gauges were connected as Whetstone Bridge. Two compression gauges and two tension gauges were used. The bridge constant can be calculated as 2(1+µ), the bridge constant obtained was 2.66.

Output of bridge or voltage is $V_o = V_{ex} \times \varepsilon \times GF$

VO = output voltage

Vex = excitation voltage= 12V

GF = gauge factor = 2

5. LOAD METER

The load meter is designed and developed for measuring the load. The load cells are restricted to use for some of the application due to their limitations towards placing and maintenance. In these cases, the gauges mounted directly on the machine members to estimate the load by the sensor strain gauge, which converts mechanical input into electrical output by using Wheatstone bridge, the output from the bridge V0 is to be connected to load meter.

The load meter has a number of stages to convert the strain gauge output into load. The strain gauge output is interface with the electronic circuit to convert the analog output.

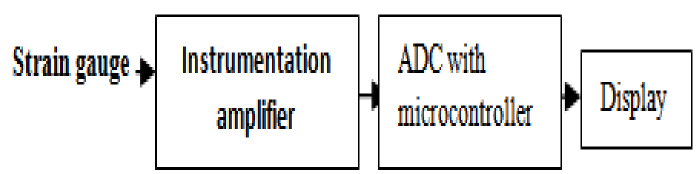

Fig.3.Block Diagram.

5.1. Strain gauge output

The strain gauge is a load sensor, which converts mechanical input into electrical output. The strain gauge has resistance copper wires, which are sensitive to deformation of the material. In case of load meter, the input and output of the bridge is connected to the load meter to measure the load, initially the load meter has facility to balance the bridge.

The output of the full bridge can be calculated by using the mathematical relation.

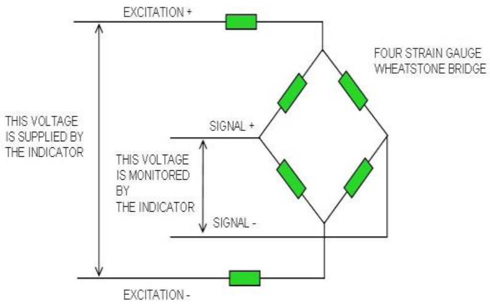

Fig.4. Bridge Configuration

$$V_0/V_{ex} = N \times \varepsilon \times GF/4$$

V_0 = Output voltage of bridge
V_{ex} = Excitation voltage
N = Number of active gauges in bridge
GF = Gauge factor
ε = strain

5.2. Signal amplification.

The output of the strain gauge bridge is relatively small. In practice, the output of the bridge output less than five mV/V (5 mV of output per volt of excitation voltage). With a five volts excitation voltage, the output signal is 50 mV. Therefore, the load meter signal conditioners usually include amplifiers to boost the signal level, to increase measurement resolution and improve signal-to-noise ratios.

The instrumentation amplifier is used for boosting the output of the bridge. The two-stage amplification is designed for the purpose of amplification of bridge output. The output of the bridge will be in few microvolt's so the amplification is necessary.

5.3. Microcontroller with ADC

The output of the amplification unit will be analog signal, it is difficult process the analog signals further, so it is necessary to convert this analog signal into digital form. For this purpose, the analog to digital converter is used in load meter. The 24-bit microcontroller with ADC is used to enhance the efficiency of device. The very low output from the bridge can also be identified and converted in to readable output. The output from the controller will be display as load.

5.4. Load Meter Instrument

The load meter is shown in fig 5. Load meter has a bridge balancing pot to balance bridge initially and tare button to make the values zero or for new load measurement. In addition, the load meter has different load setting. The load measurement in the load meter is in the range of 3000, 10000, 20000kg. The range can be selected by using the central button. The digits can also be shift in the range of loading; this can be done by operating the last button. By operating another two pots, the gain of the load meter can be set. The maximum output of the load meter is 0.22V. The 0.22 Volts in the load meter will display maximum ranges of load.

Fig.5. Load Meter

1. Tare button.
2. Range selection
3. Digit selection
4. Gain setting

6. EXPERIMENTATION

The measurement of load in static condition, where the known load can be applied on the machine is studied on universal testing machine (UTM). It is multipurpose machine with the different operations. The load measurement in the UTM will be very important. The different component of UTM has been studied for load measurement but the results.

From the components were nonlinear, finally the working of UTM was completely studied. The rod, which is attached between the top of plunger and the lower bed, is found to be suitable for the load measurement. When the pressure applied on the plunger, the plunger moves up and the lower bed also moves up by applying the force on the specimen. This condition makes the rod in compression behavior. The components of the UTM parts, which experience the load in both compression test and tension test.

The individual readings are taken and the four strain gauges were connected as Whetstone Bridge. Two compression gauges and two tension gauges were used.

The bridge constant can be calculated as 2(1+µ), the bridge constant obtained was 2.66. The voltage linearly increases with the increase in load. The output voltage can be easily monitored by load meter device.

The output of the bridge is connected to the load meter, the gain set by the gain buttons and the load is measured. The load display with respect to the load applied on the UTM is tabulated. The experimental set up is as shown in fig.6.

Fig 6. Experiment Setup

To check the efficiency of the load meter the experiment has been carried out by using load meter as well as the Computer interface facility of UTM. The readings are recorded from mechanical dial gauge of UTM, computer-interfacing unit and load meter. The results have been compared and the errors from the three different readings were studied, for the purpose of cost minimization and minimize the difficulty in load measurement.

7. RESULTS AND DISCUSSION

The individual readings are taken and the four strain gauges were connected as Whetstone Bridge. Two compression gauges and two tension gauges were used. The results obtained are linear then the bridge output connected to load meter to measure the load with respect to the dial gauge reading. The load display of both load meter and dial gauge readings are tabulated and compared. The results are shown in fig 6.

The experimental results for all three cases, mechanical gauge reading, computer interface load reading and load meter reading are given in fig 7 Pressure transducer may interface with the computer for the display of load. All three load values are compared each other and the error also calculated and the analysis made for best load result. The results shows that the computer interface reading has more error compare to reading of load meter, so it is advantageous to use the load meter for the load measurement by using the machine member as load sensing member.

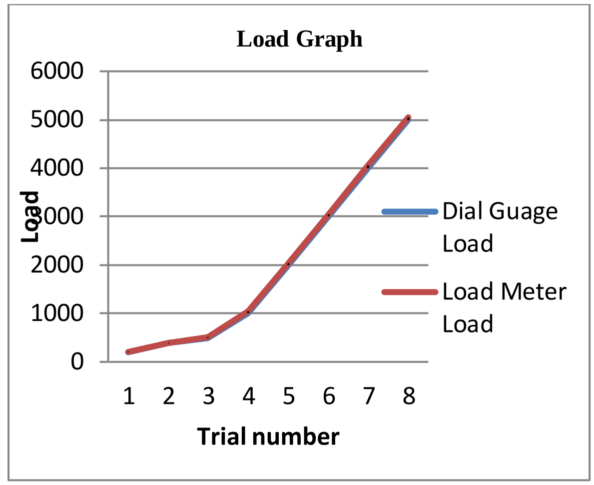

Fig.7.Trial Load Graph

The comparison of the load graph is plotted as shown in the fig.7 the graph shows that the computer interface result is deviated more from the conventional load and a load meter result, the error in the computer interface load display is more. Therefore, the load meter readings are better when compare to computer interface readings for computerizing the test data in UTM.

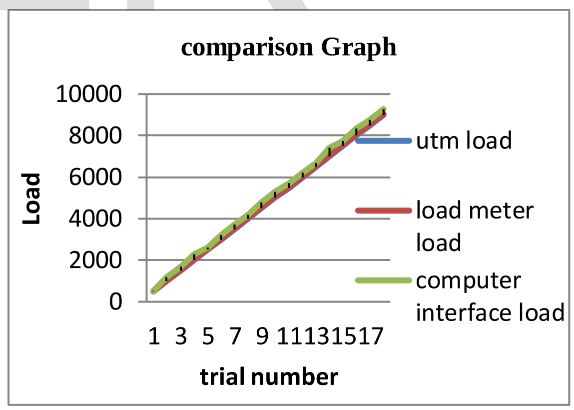

Fig.8. Comparison Graph

8. CONCLUSION

Measurement of load acting on machines and structures is important from many considerations. Inserting a load cell in the load path is difficult and sometimes may not be feasible. In such cases it is advantageous to use member of the machine itself as load sensor. During this research work, Universal testing machine used for testing specimens in the laboratory is taken for the investigation.

In case of UTM, the difficulty from the present load measurement by using the conventional method and the pressure transducer can be resolved by using the machine component itself as load sensing member with the load meter. The rod that transfers load from lower bed of the machine to the plunger in the hydraulic cylinder is the critical load-bearing member and this member is used as the load sensor. Strain gages mounted on this rod are used for measuring the load using an electronic load meter. The error in load measurement using this method is about 3 to 4%, the error is lesser when compared to the existing load measurement in UTM machine. By using component of UTM gives better results for the load measurement.

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