Simulation and Experimental Study for Selection of Gauge Area Cross-Section of 'S' Type Load Cell

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Abstract - *A load cell is a transducer used to create an electric signal for force measurement. For the system to behave satisfactorily, the design of a load cell and electrical connections are important. In this study, S type load cell is selected and different shapes viz. rectangular and elliptical gauge areas are used to check the variation of the strain to identify the best shape which gives better accuracy. The designs are modeled using AUTODESK INVENTOR© and simulation study is carried out using ANSYS© Workbench 15. Two gauge area cross sections are analyzed and the optimal positions for strain gauge mounting are obtained. The strain gauges used are of foil type linear. For experimental study, strain gauges are mounted on S type load cell using Wheatstone full bridge network for better acquisition of output voltage. Load cells are tested on UTM for compression loading. The output voltage is measured using a multi-meter. The experimental results are plotted on a graph of output voltage (mV) vs applied load (kg) and the linear best fit is plotted. The experimental study is carried out for rectangular and elliptical gauge areas with EN24 material and results are compared with each other. The comparison study shows that the load cell having rectangular gauge area gives better accuracy.*

***Key Words*: S type load cell, strain gauges, gauge area etc…**

1. INTRODUCTION

A load cell is a transducer that is used to create an electrical signal whose magnitude is directly proportional to the force being measured. This is voltage to load indirect conversion occurs in two stages. Most of today's designs use strain gauges as the sensing element. Foil gauges offer the largest choice of different types and in consequence tend to be the most used in load cell designs. Through a mechanical arrangement, when the force is applied that deforms a strain gauge. The strain gauge converts the deformation (strain) to electrical signals (Voltage). A load cell is a device normally used in weighing industry. One of the most popular types of load cell is an S-type load cell[1]. It is normally used in tension and compression applications. It provides great performance in a compact package. The results obtained by the load cell are dependent on factors like shape and size of load cell structure and electrical components and connections [2]. In order to obtain accurate results, the gauge area selection is very essential. In this study, the S type load cell is considered for compression loading with two different gauge areas viz. Rectangular and Elliptical. The finite element analysis is used as a tool to find the exact location for mounting the strain gauge. The objective of this study is to design and to experimentally test an S-type load cell with different gauge areas for better accuracy under compressive load.

2. FINITE ELEMENT ANALYSIS

The change in resistance of the strain gauges is proportional to the load applied on the load cell structure. Thus, the strain gauges are to be mounted exactly where the strain is more under loading condition. Also, the gauge area plays the most important role on the behavior of load cell. To achieve this, two s type load cells are modeled in AUTODESK INVENTOR© with rectangular and elliptical gauge areas for maximum load carrying capacity of 200Kg. Fig.1 shows basic dimensions of s type load cell for rectangular gauge area. The standard and most widely used gauge area cross-section for S type load is circular cross section. The attempt is made to suggest different gauge area cross-sections in order to satisfy the design criteria and to achieve better force measurement accuracy.

Numbers of iterations are carried out with design modifications to obtain best possible design of S type load cell satisfying the criteria. The dimensions are chosen such that the following acceptance criteria are satisfied.

1. The minimum factor of safety should be around 1.2.
2. There should be uniform strain distribution at the strain gauge locations.
3. The strain distribution at the diagonally opposite gauge locations should be similar.

The basic dimensions of the S type with rectangular gauge area load cell are as follows:

1. H = 76.2 mm
2. L = 50.8 mm
3. W = 19.1 mm

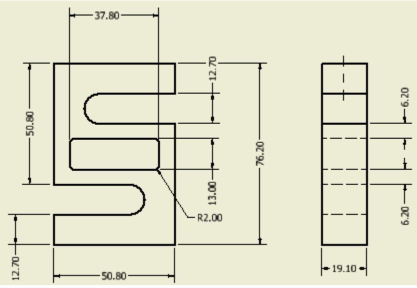

Fig -1: Basic dimensions of S type load cell

The models are saved in IGES format and the load cell structures with two different gauge areas are analyzed in ANSYS© to obtain best mounting position of strain gauges and factor of safety.

The material properties for EN24 are as follows.

Young's modulus: 73100 MPa

Ultimate tensile strength: 469 MPa

Yield strength: 324 MPa

The boundary conditions applied for the analysis are as follows:

1. Fixed Support at the bottom face of the load cell structure.
2. Pressure of magnitude 2 MPa at the top surface of the load cell structure.

Fig. 2 and Fig. 3 show the strain plot and the Factor of safety plot respectively considering the rectangular gauge area for EN 24.

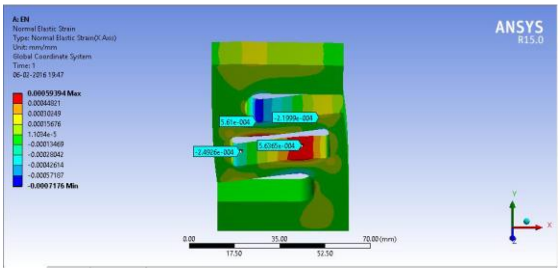

Fig -2: Strain plot considering rectangular gauge area for EN24

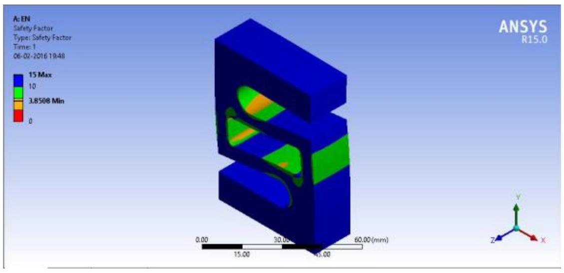

Fig -3: Factor of safety plot considering rectangular gauge area for EN24

Fig. 4 and Fig.5 shows the strain plot and Factor of safety plot respectively considering the elliptical gauge area for EN24.

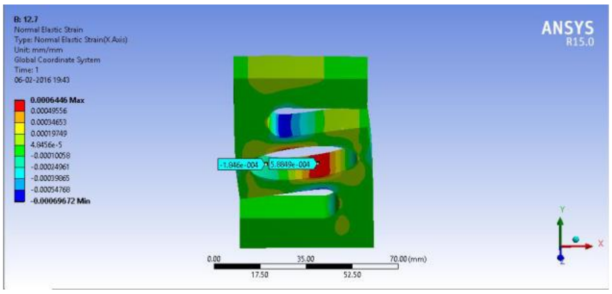

Fig -4: Strain plot considering elliptical gauge area for EN24

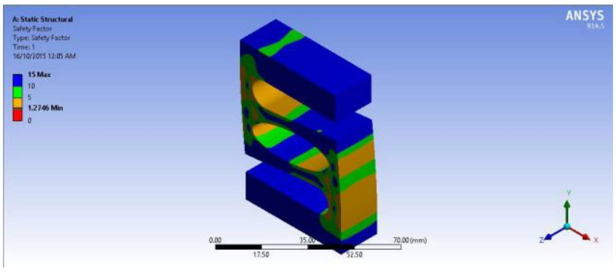

Fig -4: Factor of safety plot considering elliptical gauge area for EN24

3. EXPERIMENTAL STUDY

The two S type load cells with exactly same dimensions as modeled are fabricated. The load cells are fabricated using VNC machine with tolerance of 0.5 mm. For the force measurement, foil type linear strain gauges of resistance value 350Ω and gauge factor of 2 are selected as

transducers. The grid pattern maximizes the amount of metallic wire or foil subjected to strain in the parallel direction. It 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 carrier, to the foil itself.
To measure the strain, accurate measurement of very small changes in resistance is required. To measure such small changes in resistance, strain gauges are used in a bridge configuration with a voltage excitation (VEX) source of 9 V. Ideally, the resistance of strain gauge changes only in response to applied strain. However, the strain gauge material, as well as the specimen material to which the gauge is applied, also responds to changes in temperature. By using strain gauges in the bridge, the effect of temperature can be minimized. The foil type strain gauges are mounted in whetstone's full bridge ,on the locations where the strain is maximum under loading condition is shown in Fig.5. These positions are obtained by simulation study.

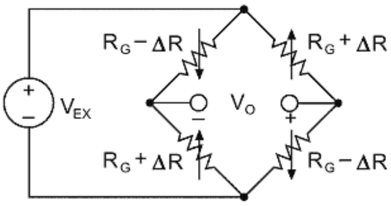

Fig -5: Full bridge Wheatstone circuit arrangement [7]

The strain gauges with pre soldered lead wires are used. A smooth and uniform layer of Cyanoacrylate adhesive is prepared on the test specimen where the strain gauge is to be mounted. The strain gauge with the adhesive tape is then mounted on the test specimen with a single wipe. The load cells are now ready for the electrical connections.

The lead wires are soldered to the strain relief terminal. The single strand connecting wires each of 0.5 m length are soldered to each of the strain gauge terminals. The full bridge Wheatstone circuit with excitation and output terminals is made on the bread board. The excitation voltage is provided by 9 V, DC battery. The output terminals are connected to multimeter to measure the output voltage in mV. Fig.6 shows the strain gauges mounted on elliptical gauge area specimen.

Fig -6: Strain gauge mounted on elliptical load cell

3.1 Experimental Procedure

The sensitivity of the circuit is increased by making all four of the arms of the Wheatstone's bridge active strain gauges in a full-bridge configuration. The S type load cell having strain gauges mounted in the gauge area is subjected to compressive type of force using UTM. The bottom flat surface of the load cell rests on the flat plate mounted on the bed of the UTM.
The load cell held between the two flat plates mounted on UTM is subjected to compressive load. The force input through the flat plate mounted on cross slide is varied on the UTM. The strain gauges at the opposite arms of the bridge configuration undergo compression and tension respectively. The induced strain causes the change in the value of resistance of each strain gauge. Hence, the initially balanced bridge configuration is now unbalanced and the voltage at the output can be measured (V0). Fig.5 shows the full bridge Wheatstone circuit with strain gauges under tension and compression and the mathematical relationship for the output voltage. Provided the excitation voltage and the gauge factor of strain gauges remains constant, the output voltage is directly proportional to the strain developed in the strain gauges.
The strain is directly proportional to the applied force. Hence, the output voltage is directly proportional to the applied force. As a result, there is linear relationship between the applied force and the output voltage.

First, S type load cell with elliptical gauge area is mounted on UTM(Shown in Fig.7) and a gradually increasing force (in kg) is applied at a step of 10 kg starting from no load condition. The output voltage at each load step is recorded. The voltage output at no load condition is expected to be zero as the bridge is balanced. Practically, the non-zero output voltage is recorded at no load condition due to pre strained strain gauge during mounted. The linear equation is developed using the recorded data to generalize the load cell behavior under loaded condition. The accuracy of the load cell designs for force measurement is compared on the basis of standard deviation and variance of the recorded data from the linear behaviour. The same procedure is followed to test another load cell with rectangular gauge area.

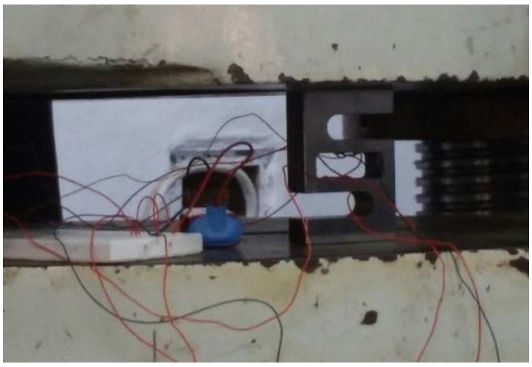

Fig -7: Load cell testing on UTM machine

3.1 Experimental Results

The output voltage data recorded by two different designs of the S type load cells are mentioned below. The best fit equations from recorded data to denote the load cell behavior under compressive loading conditions are obtained. The output voltage values obtained for known load are plotted against the recorded values of voltage and the straight line equation is obtained as a best fit curve. Variance of the values is calculated. The variance values of two designs are compared to suggest the best design in terms of force measuring accuracy.

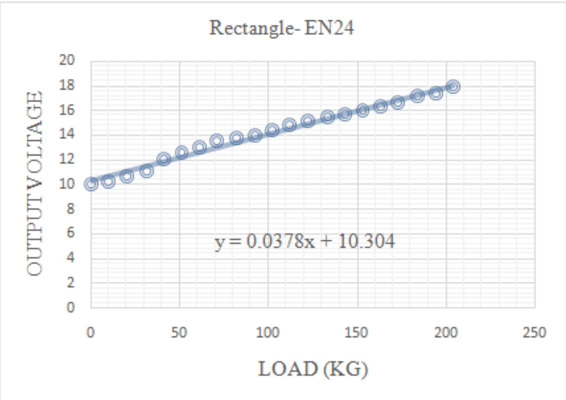

Fig -8: Output voltage vs load plot for S type load cell of EN24 with rectangular gauge area

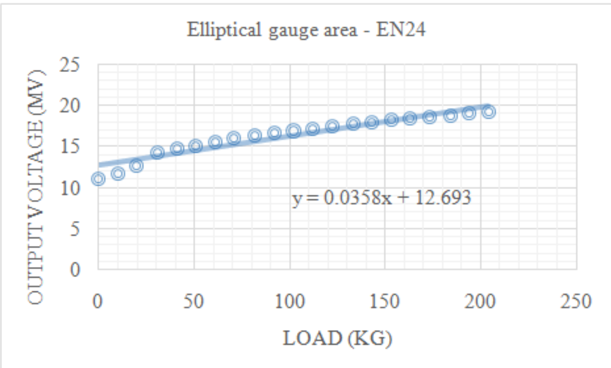

Fig -9: Output voltage vs load plot for S type load cell of EN24 with elliptical gauge area

Fig.8 and fig.9 shows the graph of applied load vs output voltage for rectangular and elliptical gauge area S type load cell under compression loading. The variance values calculated for fig.8 and 9 are 0.0869559 and 0.371016 respectively.

3. CONCLUSION

From the experimental results it is observed that the variance value for s type load cell with rectangular gauge area is 0.0869559 which is less as compared to S type load cell with elliptical gauge area. Therefore, it can be concluded that the s type load cell with rectangular area gives better accuracy. This study focuses on the effect of gauge area shape on the accuracy of the load cell. Further study can be carried out to analyze the effect of material on the accuracy of load cell.

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