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Multi-Capacity Load Cell Concept

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Abstract: Force measuring systems are usually used to calibrate force generated systems, it is not preferable to use load cells to measure forces less than 10 % of its nominal capacity. Several load cells are required to offer calibration facilities at sites to cover different ranges, this lead to difficulties in handling procedures, through the need for several carrying cases to carry this overweight in addition to the over cost of purchasing several load cells.

This article concerns with introducing a new concept for designing a multi-capacity load cell as a new force standard in the field of measuring the force. This multi-capacity load cell will replace a set of load cells and reflects economically on the total cost and on easiness of handling procedures.

Keywords: Load cell, Build-up system, Dual-range, Sensitivity and conceptual design.

1. Introduction

Force measurement system is made up of a transducer and associated instrumentation. Load cell is the most common commercial force transducer; basically it consists of specially designed structures which perform in a predictable and repeatable manner when a force is applied (elastic element). The force applied is translated into a voltage by the resistance change in strain gages which are intimately bonded to the transducer structure, these gauges are connected in what is known by Wheatstone bridge circuit.

The strain gauges and the elastic element form the heart of load cell. The elastic element may be a column or tension bar of circular, square or octagonal cross section and may be either solid or hollow. The material used for the elastic element is usually a material which exhibits a linear relationship between the stress (force applied) and strain (output) with low hysteresis and low creep in the working range. There also has to be high level of repeatability between force cycles to ensure that the load cell is a reliable measuring device. To achieve these characteristics it is usual to subject the material to a special heat treatment [1].The geometric shape and modulus of elasticity of the elastic element determine the magnitude of the strain field produced by the action of the force.

2. Load Cell Capacity

Stiffness is a governing factor in determining the load capacity. Stiffness is the resistance of an elastic body to deformation by an applied force, It is determined from the equation (1):

$$Stiffness = \frac{Load}{Deformation}$$

Or

$$k = \frac{P}{\Delta L}, \qquad (1)$$

where k is the stiffness, P is the load and ΔL is the deformation.

Stiffness depends on the material, shape and boundary conditions. It is related to the elastic modulus by:

$$k = \frac{EA}{L}, \qquad (2)$$

where E is the modulus of elasticity, A is the cross-sectional area and L is the initial length.

3. Force Build up System

3.1. Build-up Technique

Is a technique on which more than one load cell is arranged in determined positions to withstand a load higher than the nominal capacity per each of them. The force on a build-up system is measured as being the sum of the forces that go by the set of active sensing elements coupled in parallel on the base of the build-up system [2].

This is a method to use the available load cells to measure forces in a new range which is not available to be measured, if each existing load cell is used separately.

3.2. Compression Build-up System

The mechanical arrangement for a build-up system in compression mode could be simply described as in the following Fig. 1, a base plate where three force transducers (sensing elements) are placed at the apexes of an equilateral triangle, each of the force transducers has a loading pad to transmit the forces to the sensors head, the force on the distribution plate is distributed equally on the three reference force transducers (sensing elements) [2].

3.3. Tension Build-up System

The following Fig. 2 [3] shows a typical tensile build-up system, it is more complicated than the compression build-up system. Simply, it comprises of three Z-shaped force transducer mounted parallel in a block. The block consists of two disks between which three force transducers are arranged. A steel sphere is situated between the disks at the center of the conical openings. The sphere enables the disks to interact along their spherical surface.

Tension build-up systems still not widely known as compression build up system for its difficulties.

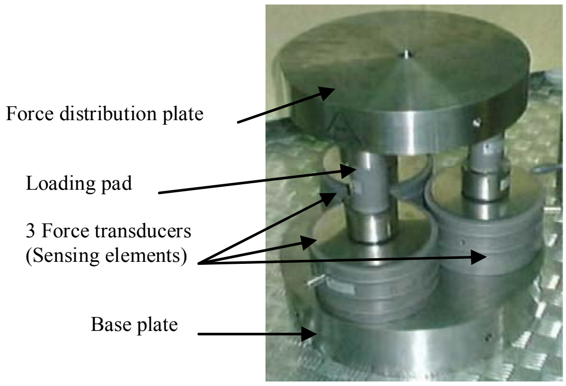

Fig. 1. Compression build up arrangement.

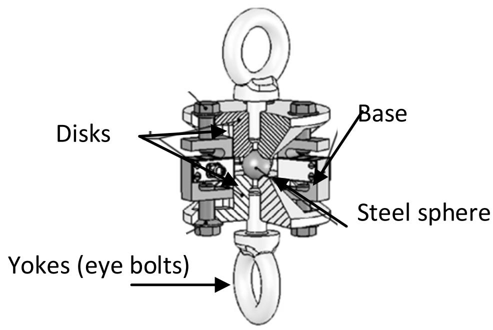

Fig. 2. Tensile build-up setting.

4. Dual Range Load Cell

It is a new introduced arrangement which offers carrying out force measurements in two different ranges [4]. This arrangement is formed of two load cell based on bending principle located over each other as shown in the diagram Fig. 3, the smaller load cell is placed on the larger load cell and are coupled together using an elastic coupling joint.

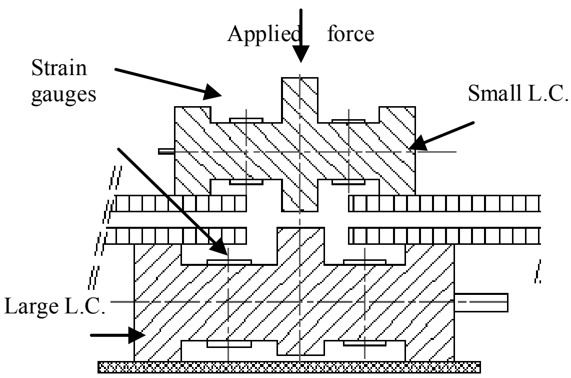

Fig. 3. Schematic diagram of Dual range load cell.

As the load is applied the smaller load cell sense the load until the load reaches its maximum capacity and the upper flange of the coupling joint bends until touch the lower flange in the coupling joint, at this instance the two load cells are coupled together and the load applied on the smaller load cell is transferred to the larger load cell without any more effect on the strain gauges of the smaller load cell. This could be considered as two range multi-capacity load cell. This design is mainly designed to be used in secondary standards calibrations but it can be used also as a movable standard.

5. Multi-capacity Concept

The concept of the multi-capacity load cell is introduced depending on using strain gauges load cell as it is the most common commercially available type of force transducers.

The concept mainly is based on increasing the stiffness (k) for each range [5], increasing the stiffness require using harder elastic element while decreasing the stiffness requires using softer elastic element. Building a multi-capacity load cell require different values of stiffness, these different stiffness could be applicable through using different elastic elements. Load cell capacity can be changed by using a new elastic element for each range or combining more than one elastic element together for each range.

5.1. Concept of Three Range Multi-capacity Load Cell

Building a three range multi-capacity load cell requires the ability to offer three values of stiffness, one for each range. Simply for the load cell first capacity an elastic element nominated for the working range is loaded (see Fig. 4).

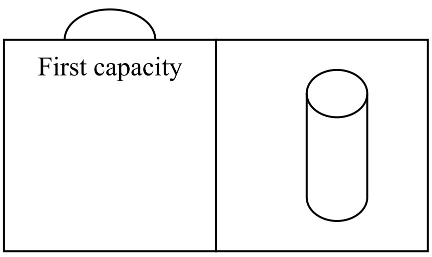

Fig. 4. Elastic element for first capacity.

For the second capacity of the load cell either a new element is loaded separately with different stiffness – without any loading on the first element- or a new introduced element is loaded with the first element to withstand the load together. The new stiffness is the resultant of the combination of the first and second element stiffness (see Fig. 5).

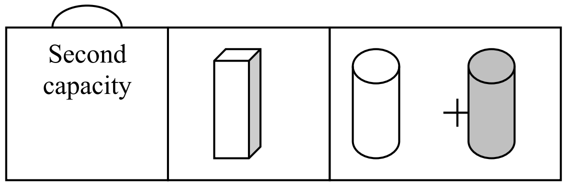

Fig. 5. Elastic elements for second capacity.

For the third capacity the same concept applies (see Fig. 6); new element replaces those used for the second capacity or is added to them.

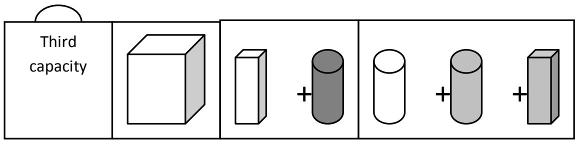

Fig. 6. Elastic elements for third capacity.

6. Effect of Using More than One Elastic Element on Stiffness

Using more than one elastic element to establish a multi capacity load cell will directly reflect on the stiffness. A new value of stiffness will arise in case of using more than one elastic element depends on the way in which the elastic elements are added. A new elastic element could be coupled in series or in parallel.

6.1. Elastic Elements in Series

A new element can be added in series as shown in Fig. 7. The new stiffness resulted from this arrangement (Ks) is calculated from equation (3):

$$\frac{1}{K_s} = \frac{1}{K_1} + \frac{1}{K_2}, \quad (3)$$

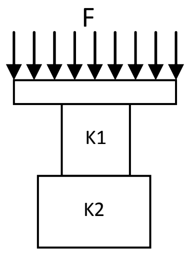

Fig. 7. Elastic element in series.

6.2. Elastic Elements in Parallel

Another way to add a new element- to an existing one- is adding them in parallel as shown in Fig. 8. The new stiffness resulted from this arrangement (K_p) is calculated from equation (4) [6]:

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$$K_p = K_3 + K_4 , \qquad (4)$$

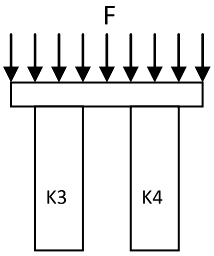

Fig. 8. Elastic element in parallel.

The new stiffness values resulted from adding elements either in series or in parallel shows that using more than one element in series decreases the stiffness (equation 3), while using more than one element in parallel increases the stiffness (equation 4). Adding elastic elements in parallel is recommended for the multi-capacity load cell.

7. Effect of Using More than One Elastic Element on Sensitivity

Sensitivity is one of the most important factors in characterizing load cells. It is defined as the ratio of the output signal variation to force variation [7]. The load cell response is proportional to the applied load. Normally their relation is directly proportional to each other and can be plotted as a straight line as shown in the following graph Fig. 9, this graph represents an ideal expected the relation for a 50 kN normal load cell with maximum output of 2 mV/V. Adding an elastic element to change load cell capacity may occur during loading process or before starting loading process.

7.1. Adding Element During Loading

As discussed previously changing the capacity of the multi-capacity load cell could occur by using different element or adding a new element. The following graph Fig. 10 represents the expected response of a multi-capacity load cell (5 kN, 25 kN & 50 kN) assuming the new elastic elements are added to each other during loading process.

7.2. Adding Element Before Loading

The following graph Fig. 11 represents the expected response of a multi-capacity load cell (5 kN, 25 kN & 50 kN). This load cell design is based on using a new elastic element or adding a new element to the previous one before loading process.

The previous graphs Fig. 9-11 show that adding a new element increase the sensitivity either it is added during loading process Fig. 10 or before starting of loading process Fig. 11 but it is significant that adding the new element before the loading process starts leads to higher sensitivity for each range.

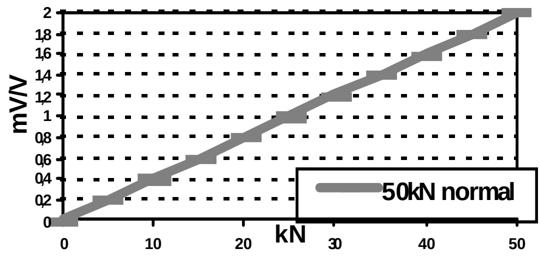

Fig. 9. A representing graph for a 50kN load cell.

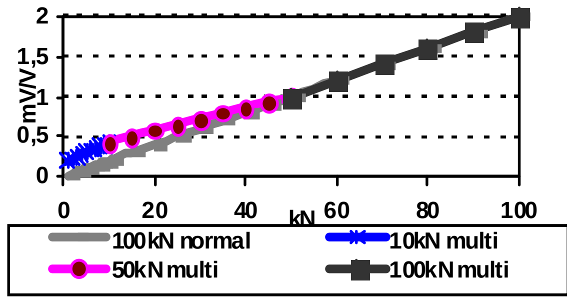

Fig. 10. A representing graph for a 100 kN multi-range L.C. with consequent loading principle.

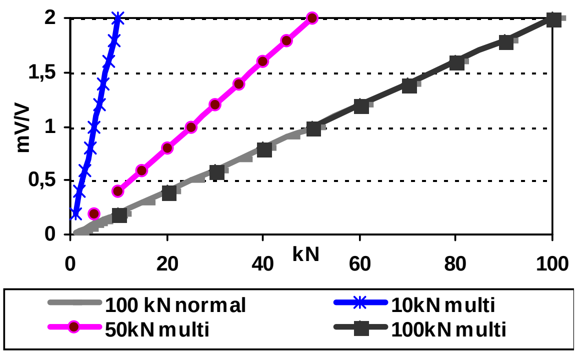

Fig. 11. A representing graph for a 100 kN multi-range L.C. with initial loading principle.

8. Conclusions

This multi-capacity load cell concept is based on using different elastic element together to each other in parallel before beginning of loading process to change the stiffness of the load cell which reflects on its maximum capacity.

This multi-capacity load cell could be considered as an innovation in force measuring field, it will open a new research fields concerning establishment and characterization of measurement standards in the field of measuring the force.

The introduced concept can be used to manufacture a multi-capacity load cell with infinite number of capacity ranges. Number of capacity ranges will depend on the detailed design and the number of the elastic elements.

9. Future Work

It is planned to propose a detailed design for a three range multi-capacity load cell works in compression mode. The detailed design will be used to manufacture a prototype to examine the efficiency of the concept and realize more efficient force standard.

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