Performance Evaluation of Strain Gauge Based Load Cell to Improve Weighing Accuracy

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Abstract:-In market, Many liquid and solid products are available in packing of pouch, packet, bottle or tin. They need to weigh during packing/filling accurately before sale. As the inaccuracy in terms of under filling may loose the trust of customer, over filling may lead to loss on earning. The main factor that governs the accuracy of weighing is load cell accuracy. The other factors like unwanted side load, suddenly applied load, effect of wind, temperature, moisture, noise on the weighing system as well as on the transmission and control system also affect the performance of weighing. Also in practice, certain system accuracy parameters depend considerably on the application of use, physical load introduction to the system, amount of loading and other disturbing factors. This paper includes mechanical design of strain guage based load cell which can satisfy the performance at full load and modeling and finite element analysis of metallic spring element is done to focus on those conditions of load cell use that either compromise, or enhance the actual scale performance. Also weighing scale with multiple load cell is designed to measure the load irrespective to its position on platform.

Key words: Strain Guage, Load Cell, Wheat Stone Bridge.

I. INTRODUCTION

Load cell is the heart of weighing scale. It mainly consists of two parts. A metallic spring element as the primary element to develop strain in it proportional load applied on it, the other is strain gauge as secondary, to sense the strain developed due to loading on the metallic element.

Strain guage: A strain gage is a small wire grid whose electrical resistance changes as it strains. When a gauge is subjected to a positive stress, its length increases while its area of cross section decreases and vice-versa. Since the resistance is directly proportional to length and inversely proportional to area of cross section, the resistance of the gauge increases with positive strain.

The metallic strain guage consists of a very fine wire or metallic foil arranged in a grid pattern. The grid pattern maximizes the amount of metallic wire or foil subjected to strain strain in parallel direction. The cross sectional area of the grid is minimized to reduce the effect of shear strain. The grid is bonded to thin backing called carrier, which is directly attached to the specimen. Therefore the strain experienced by the test specimen is transferred directly to the strain guage, which responds with linear change in electrical resistanc

Strain Guage Based Load cell: The load cell is a piece of machined metal that bends with the load's mechanical force and converts the mechanical force into an electrical signal.

The bend doesn't exceed the metal's elasticity and is measured by strain gauges bonded at points on the cell. As long as the load is applied to the proper spot on the load cell, the strain gauges provide a proportional electrical signal.

It is well known that the accuracy of load cell is one of the key factors for the accuracy of the balance scales. Design and manufacturing technology is not easy to be merged organically and the load cell is extremely sensitive to the material, machining and production process. So it is hard to make good enough load cell meets with the requirement of high accuracy balance. But the load cell can behave accurately when it is used according to its designed criteria.[1]

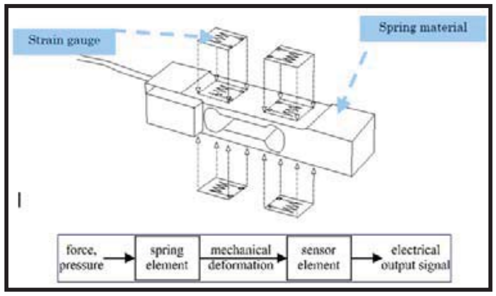

Figure 1. Strain guage based load cell

1.1 Wheatstone bridge

To measure the strain produced due to applied load requires accurate measurement of very small changes in resistance. To measure such small changes in resistance, strain guage are always used in bridge configuration with a voltage excitation source. The general Wheatstone bridge consists of four resistive arms with an excitation across the bridge.

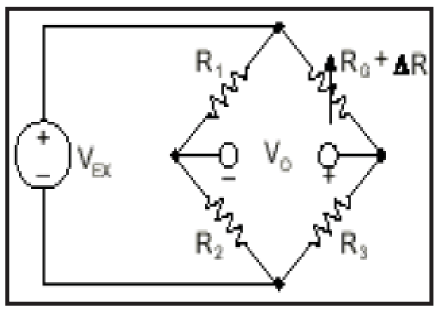

Figure 2: Wheatstone bridge

II. DESIGN OF LOADCELL:

Load cell consist of strain gauges bonded to a suitable 'spring element'. Spring element is the primary element and plays major role in the function of load measurement. It needs to be designed with following criteria for best results.

- Strain level induced in the gauge(s) at maximum rated load, usually design for 500 to 1000 με in the gauge area. This maintains high gauge linearity and fatigue life.
- Uniform strain distribution over the gauge area with the gauges mounted at the maximum strain locations. This is to ensure the highest possible output

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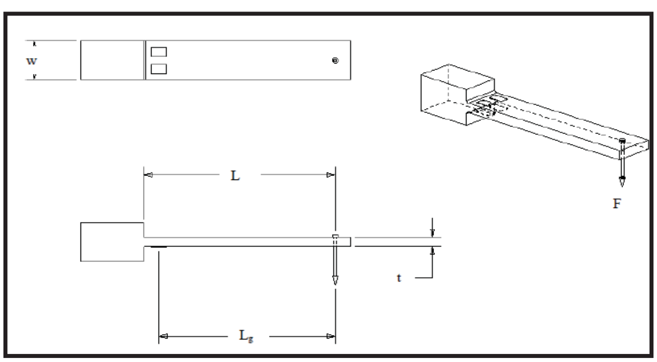

Figure 3: Design Of Load cell

- Keep strain (and, hence, stress) levels as low as possible throughout the rest of the spring element. This also minimizes the deflection of the load cell.
- Natural frequency of the spring element must be much greater than the highest frequency components that need to be measured.
- Monolithic construction to improve repeatability and minimize hysteresis.
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2.1Design Specification

- Material : Steel
- Young's Modulus E = 207 Gpa.
- Length of bar element L=125mm.
- Dist between gauge position & point of load application . L_g = 115 mm.
- Width of element w = 25mm.
- Thickness of the element t = 3mm.
- Guage Factor G= 2.15.
- Max. Loading capacity: 50 N.

2.2 Check max. Stress (at fillet)

Moment of Inertia I: $wt^3/12$
$= 5.625 \times 10^{-11}\ m^4$.

$I / c = 3.75 \times 10^{-8}\ m^3$.

Bending moment M = 50 * 0.125
= 6.25 Nm.

Stresses in bar σ = Mc/I = 166.5 Mpa.

Factor of Safety : 4.2

Which is more than satisfactory.
At the gauges,

Stress s= 166.5* 0.115/0.125.
= 153.2 Mpa.
Strain ε = s / E
$= 153.2/207000 * 10^6$
= 740 µe
This is reasonable value.

The above design is safe to measure the Load up in the range 0 N to 50 N. [2]

But for a given application……

- If the load cell utilization range is high compared to its maximum capacity (used with small factor of safety), the "signal level" is high (a large microvolt output), but the load cell(s) is subject to mechanical overloads and load cell failures.
- If the load cell(s) capacity utilization is too small (used with large factor of safety), the signal level is low (a low microvolt output) and the weigh meter reading will tend to drift because sensed value is to small and the system may have an unstable zero (the zero reading drifts too much).

While designing, both above factors needs to be focused for its optimum performance. **[**3]

III. FINITE ELEMENT ANALYSIS OF LOAD CELL**:**

- load cell needs to be used according to its designed criteria to behave accurately. If load applied is to high compare to its capacity the load cell, it may be subjected to mechanical overloads that may result in permanent changes in linear behavior and further excessive overloading may lead to load cell failures so load cell should not be used with lower range of safety factor. If load applied is two small compare to its capacity, the signal level is low, and the weigh meter reading will tend to drift and the system may have an unstable zero so load cell should not be used with upper range of safety factor.[4]

- Load cell need to be designed for factor of safety higher than one to avoid the accidental failure due to over load or shock load, same can not be kept to high as it will increase the material cost as well as effect of property of

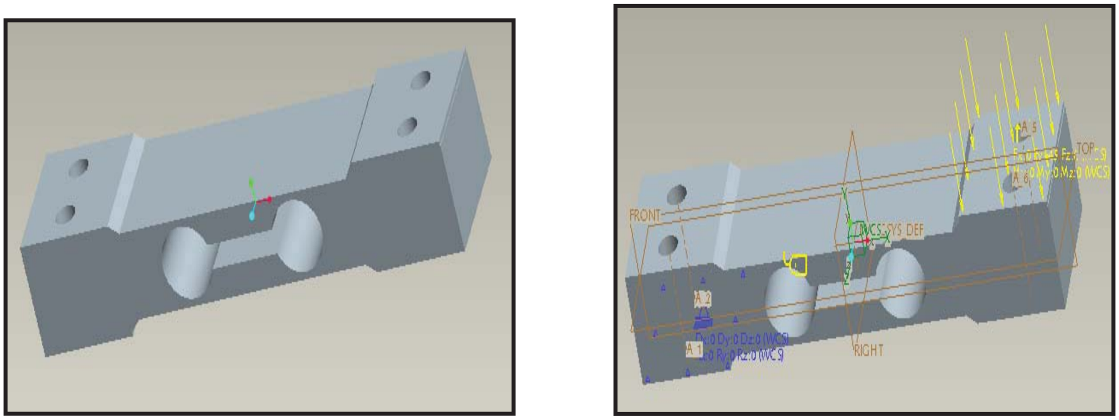

Figure 4. Modeling of Load cell

- Single point beam type load cell with capacity of 60N is modeled using Pro- Engineer software. Load is applied at one end and the other end is constrained.
- Stress in the load cell should be near to 15% of the yield stress of the material to guarantee that its behavior is linear. That means load cell will behave accurately near to factor of safety 6.
- For the present analysis metallic spring element of the load cell is selected to study the amount of stresses generated on different value of loading up to its full capacity.[5]

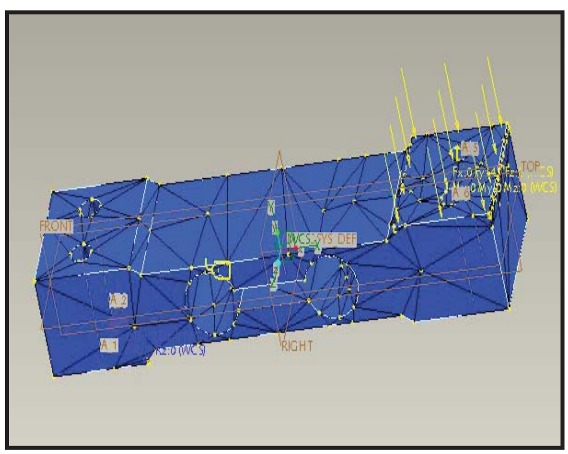

Figure. 5 Meshing of load cell

- Load cell is loaded with different amount of loading and stresses generated are tabulated in result table to calculate the factor of safety at which it operates.

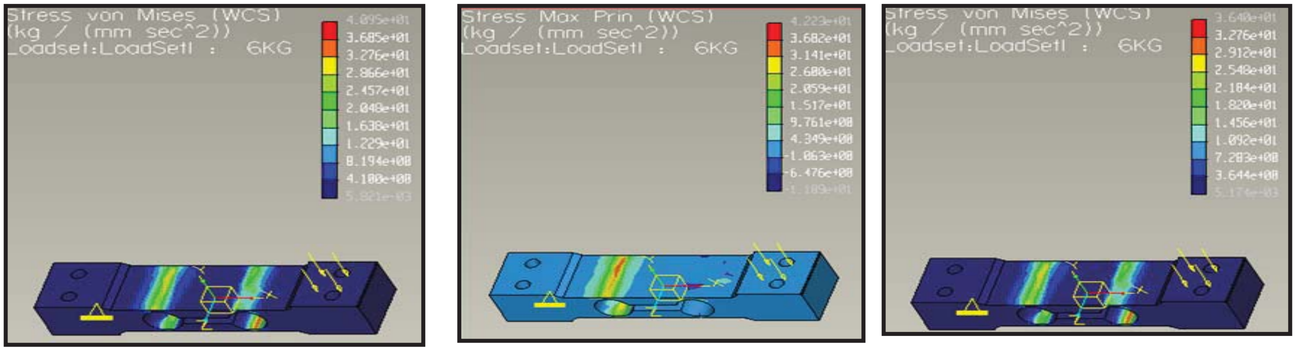

Figure:6. Analysis of load cell loaded at 40 N

IV. ANALYSIS RESULT OF LOAD CELL:

Load cell is loaded with different amount of loading and stresses generated are tabulated in result table to calculate the factor of safety at which it operates

Table 1 : Analysis of load cell loaded by different amount of load:

Sr No.	Load Cell Capacity	Load (N)	Max. Principal Stress	Von mises stress (Mpa)	Yield Strength(MPa)	F.O.S
1	**60 N**	**5**	**4.73**	**4.36**	**250**	**52.89**
2		**10**	**5.57**	**5.14**	**250**	**44.92**
3		**15**	**14.25**	**12.95**	**250**	**17.53**
4		**20**	**18.93**	**18.71**	**250**	**13.21**
5		**25**	**23.46**	**22.75**	**250**	**10.66**
6		**30**	**28.16**	**27.30**	**250**	**8.88**
7		**35**	**32.85**	**31.85**	**250**	**7.61**
8		**40**	**37.54**	**36.40**	**250**	**6.66**
9		**45**	**42.23**	**40.96**	**250**	**5.92**
10		**50**	**46.93**	**45.50**	**250**	**5.33**
11		**55**	**51.62**	**50.85**	**250**	**4.86**
12		**60**	**56.31**	**54.60**	**250**	**4.48**

From the above result table we can conclude that if present load cell is operated to measure 40N to 45N it can behave accurately.

V.CONCLUSION

The performance in terms of weighing accuracy of the system can enhanced by designing the weighing load cell which can measure the load accurately up to its full load capacity with no failure even with shock loading. As well as for long life and consistent performance of weighing cell can be achieved by optimizing its utilization range.

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