MANTECH Publications

Journal of Automotive Engineering & Technology
Volume 6, Issue 1, January-April, 2021

# *Enhancing Sensitivity at Lower Deflection using FEM for Shape Optimization of Ring Shaped Load Cells*

***Lavanya Jha[1], Anshika Kumar[2], Gurpreet Singh[3]***

*Research Scholar[1], Professor[2, 3]*

*Department of Mechanical Engineering*

*Mahendra Engineering College*

***Corresponding Author's E-mail**: lavanya22@gmail.com[1]*

***Abstract***

*Load cells are constructed using thin ring theories and are used in a variety of applications such as material testing machine calibration, force monitoring in various cutting instruments, agricultural applications, and loading in hardness testing machines, among others. Different ring-shaped load cells, such as square, hexagonal, octagonal, and circular load cells, were investigated using finite element analysis in this research. The study allows for the effect of shape over pressure, as well as deflection in the load cell. When strain is induced in different load cell components, the circular load cell is found to be the most responsive. In the octagonal ring, however, less defection is needed to achieve the same strain as in the circular ring. As a result, it is recommended that octagonal rather than circular shapes be used in the construction of load cells.*

***Keywords**: - Ring-shaped load cell, FEM, Shape optimization, Strain, Deflection*

## INTRODUCTION

Various types of load cells, such as proving rings, elliptical dynamometers, strain gauge load cells, and tuning fork style load cells, are used to calculate force in various applications. 1st The precision and loading range of these load cells varies. Because of their ease of machining and simple design considerations, ring-shaped load cells are commonly used. It consists of an elastic steel alloy ring with a deflection measuring device, such as a dial gauge/micrometer/vibrating reed, to measure the deflection [2]. The elastic ring


Page 39-47 © MANTECH PUBLICATIONS 2021. All Rights Reserved

deforms as the force is applied, and the deflection is measured by the measuring device. (3rd). In the past, some researchers studied for the design and development of a ring-shaped load cell, and a number of analytical expressions were generated to measure stress, strain, and deflection using theory of elasticity and numerical methods. Attempts have recently been made to develop ring-shaped force transducers using finite element analysis. [4] The current work entails analysing strain and deflection in ring-shaped load cells using finite element analysis. [5,6,7,8] Formalized paraphrase. The idealized ring-shaped load cells have square, hexagonal, octagonal, and circular cross sections. The work leads to an understanding of the role of finite element analysis in the efficient design of ring-shaped load cells. Finite element analysis was used to recommend suitable locations for strain gauge mounting.

## METHODOLOGY

To achieve the optimized shape of ring shaped load cell structural analysis is carried out using finite element analysis based software method student version Ansys 19.0 as shown in Fig.1. Initially 3d models of ring shaped load cells (square, Hexagonal, Octagonal, and Circular) are prepared and then smart meshing is done.

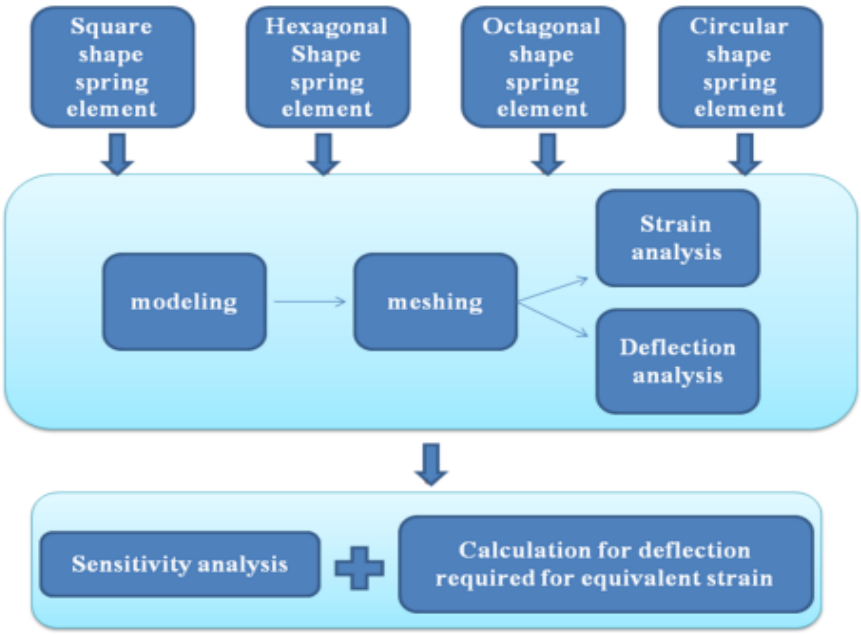



***Fig.1. Methodology for the Shape optimization of ring shaped Load cells***

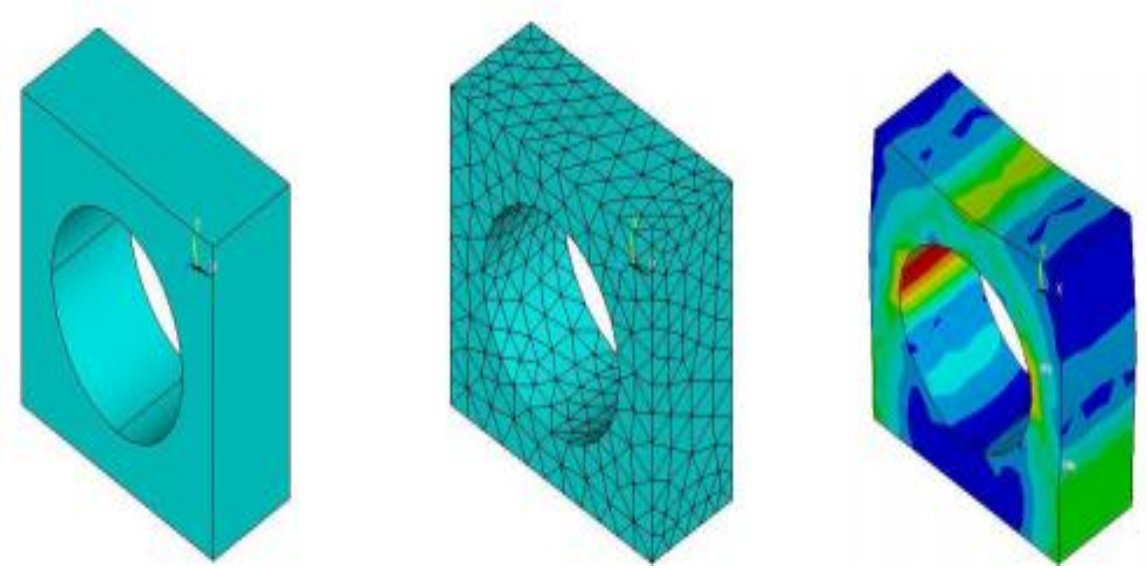

Page 39-47 © MANTECH PUBLICATIONS 2021. All Rights Reserved

Structural analysis is done for strain and deflection computation under same load. Sensitivity of each type of load cell is calculated using the values of load applied and strain induced in the spring elements. Deflection required for equivalent strain in each case is calculated using the values of deflection and strain induced under 100 N loads.

***Square ring shaped spring element***

A square ring shaped spring element is a modification of the ring shaped spring element and it is basically a ring from inside and a square from outer side. The dimensions of the load cell element include inner radii 17 mm, height of the load cell element 50 mm, thickness 8 mm and width 20mm.Three dimensional model is prepared using Ansys software. The material is assumed to be isotropic in nature and the analysis is of linear type.. The modulus of elasticity is 210 GPa and poission ratio 0.3 for EN 24 steel. [9,10] 3-D 10-Node Tetrahedral Structural Solid 92 elements from have been selected and smart meshing is done as shown in Fig.2.

The force is applied on the top surface of load cell elements in compression mode and model is rest on its bottom surface [6] Fig.2 illustrates the strain distribution in the load cell elements under the specific external force 100 kg.



***a. 3 D Solid model  b. Meshed model  c. Strain distribution***

***Fig.2. Square shaped ring load cell spring element***


Page 39-47 © MANTECH PUBLICATIONS 2021. All Rights Reserved

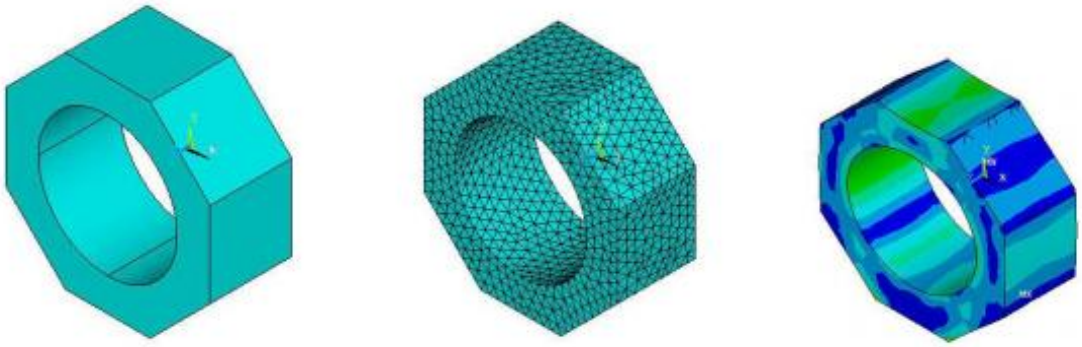
***Hexagonal ring shaped spring element***

Hexagonal ring shaped spring element of equal sides having height of 50 mm, internal hole of size 17 mm radius,8 mm thickness, and 20 mm width is modeled and smart meshed. Following above same boundary conditions structural analysis for strain and deflection is worked as shown in Fig.3.

***a. 3 D Solid model  b. Meshed model  c. Strain distribution***

***Fig.3. Hexagonal ring load cell spring element***

Octagonal ring shaped spring element Octagonal ring shaped spring element of equal sides is modeled using dimensions as height of 50 mm, internal hole of size 17 mm radius,8 mm thickness, and 20 mm width and smart meshed. Structural analysis for strain computation and deflection is worked following same boundary conditions as previous research as shown in Fig.4



***a. 3 D Solid model  b. Meshed model  c. Strain distribution***

***Fig.4. Octagonal ring load cell spring element***


Page 39-47 © MANTECH PUBLICATIONS 2021. All Rights Reserved

***Circular ring shaped spring element***

A circular ring shaped spring element is thin ring of 8 mm thickness, width of 20 mm, inner and outer radii of 17 mm and 25 mm respectively. Strain distribution of circular ring is shown as in Fig.5 below

***a. 3 D Solid Model*** ***b. Meshed Model*** ***c. Strain Distribution***

***Fig.5. Circular ring load cell spring element***

**RESULTS AND DISCUSSIONS**

***The finite element analysis has exposed the following results:***

- Maximum strain occurs at up to an angle of about 10oon upper side of horizontal axis in each type of spring elements and it starts to decrease along the internal periphery of the load cell elements

- The stress distribution for the load cell elements follows the similar trend like the strain distribution.

- The deflection for the load cell element is maximum at an angle about 900 under axial compressive load but tends to decrease along the internal periphery and is just about in significant at about 00 .The strain induced in the load cell elements for forces 10 N to 100N at a step of 10N have been computed and summarized in Table 1.

Graphical representation between loads applied on each shape load cell spring element and strain induced in it is as shown in Fig 6. It shows that circular shaped load cell element is most sensitive as its slope is steeper.


Page 39-47 © MANTECH PUBLICATIONS 2021. All Rights Reserved

***Table 1 Strain in load cell elements (εstrain)***

| Load (N) | Strain in load cell spring elements (εstrain) | | | |
|---|---|---|---|---|
| | Square shape | Hexagonal shape | Octagonal shape | Circular shape |
| 10 | 4.14 | 8.67 | 13.38 | 15.43 |
| 20 | 8.29 | 17.34 | 26.75 | 30.86 |
| 30 | 12.43 | 26 | 40.13 | 46.28 |
| 40 | 16.57 | 34.68 | 53.51 | 61.71 |
| 50 | 20.72 | 43.35 | 66.88 | 77.14 |
| 60 | 24.86 | 52.01 | 80.26 | 92.57 |
| 70 | 29.01 | 60.68 | 93.64 | 107.99 |
| 80 | 33.15 | 69.35 | 107.01 | 123.42 |
| 90 | 37.29 | 78.01 | 120.39 | 138.85 |
| 100 | 41.43 | 86.68 | 133.77 | 154.3 |

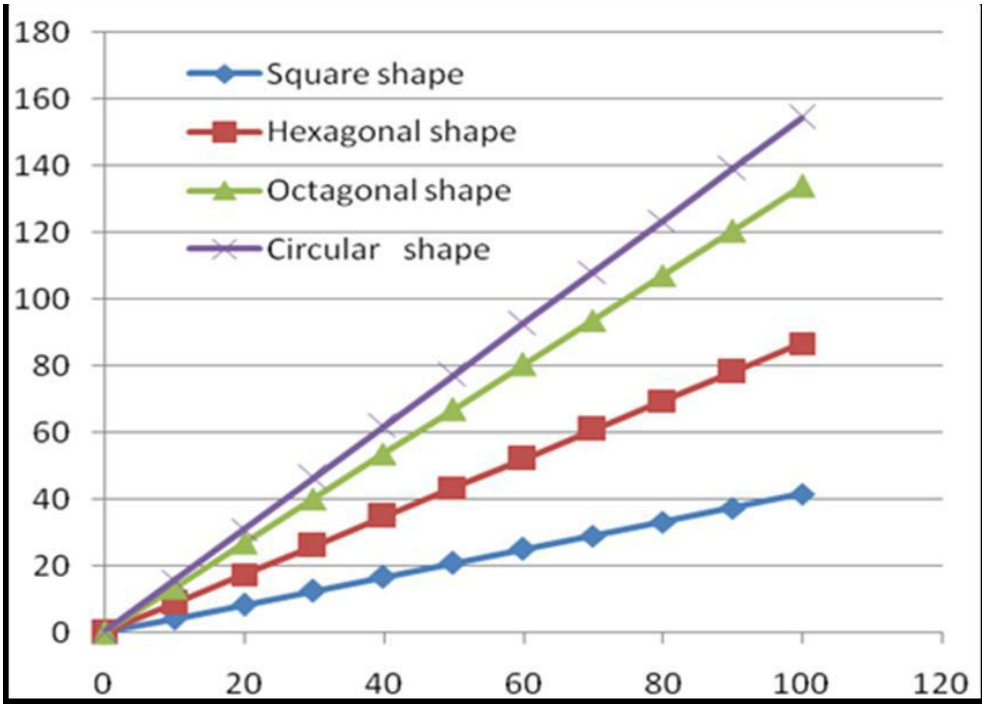



***Fig. 6.Graphical representation between loads applied and strain induced***


Page 39-47 © MANTECH PUBLICATIONS 2021. All Rights Reserved

The deflection and maximum strain induced in the octagonal and circular ring load cell elements for force 100N have been computed and summarized in Table 3.Deflection required for the unit strain measured is calculated and listed in the table. It shows that less deflection is required for equivalent measured strain in case of octagonal shape rather than circular shape. So an octagonal ring load cell spring element should be preferred for the manufacturing of load cell.

## CONCLUSION

Finite element analysis of the square, hexagonal, octagonal and circular ring shaped load cell spring elements is discussed. The results have been focused on stress, strain and deflection. The stress –strain pattern guide the method for effectual location for mounting of strain gauges for developing the load cell. It showed that at 0 to 100 to the either horizontal axis of the considered load cell spring elements, the stress – strain values are moderate and are appropriate places for locating the strain gauges. Comparison of strain induced in different load cell spring elements results that circular ring load cell spring element is most sensitive. But less deflection is required to get equivalent strain in octagonal ring than the circular ring. So it is advisable that for the development of load cells, an octagonal ring spring element should be preferred than circular ring. This study may be used to determine the dimensions of the load cell and to study the effect of different design factors of load cell. The study can be used in the improvement of the load cells.

***Table 2 The deflection and maximum strain induced***

| Octagonal shape | | | Circular shape | | |
|---|---|---|---|---|---|
| Strain (εstrain) | Deflection (mm) | Deflection/strain mm /(εstrains) | Strain (εstrain) | Deflection (mm) | Deflection/strain mm /(εstrains) |
| 133.77 | 0.0049215 | 3.66 e-5 | 54.05 | 0.0058041 | 1.07 e-4 |


Page 39-47 © MANTECH PUBLICATIONS 2021. All Rights Reserved

**REFERENCES**

1. Kuhnel M. , Hilbrunner F., Buchner H. , Jager G .,Manske E., Frohlich T. (2014) "Traceable measurement of mechanical parameters of double bending beam force transducers according to EN ISO 376", Measurement, 51, 336-342.

2. Kim J.D., Kim D.S. (1997) Development of a combined-type tool dynamometer with a piezo-film accelerometer for an ultra-precision lathe, Journal of Materials Processing Technology, 71 360–366.

3. Chang Y.S., Lin T.C., (2013) "An optimal G-shaped load cell for two-range loading", Engineering in Agriculture Environment and Food, 6, 4, 172-176.

4. Ferreira H P (2009), "Force Measurement", NRCS – Legal Metrology Division (Technical Report).

5. Kluger J. M., Sapsis T. P., Slocum A.H., (2016) "A high-resolution and large force-range load cell by means of nonlinear cantilever beams", Precision Engineering, 43, 241-256.

6. Uchimura M and Masuyama T, "Multi-range load cell scales," United States Patent, 4,660,667, Apr. 28, 1987.

7. Karabay S (2007), "Analysis of drill dynamometer with octagonal ring type transducers for monitoring of cutting forces in drilling and allied process", Materials and Design, Vol. 28, pp. 673-685.

8. Uchimura M. and Masuyama T., "Multi-range load cell weighing instrument," United States Patent, 4,690,230, Sep. 1, 1987.

9. Yalof S. and Doren L., "Wide range load cell", United States Patent, 4491027, Jan. 1, 1985.

10. Yaldiz S and Unsacar F (2006), "A dynamometer design for measurement of cutting forces on turning", Measurement, Vol. 39, pp. 80-89.

11. Mole P, "Variable range load cell system and method of application",


Page 39-47 © MANTECH PUBLICATIONS 2021. All Rights Reserved

United States Patent, 5,257,549.Nov. 2, 1993.

12. Libii J N (2004), "Design Analysis and testing of a force sensor for use in teaching and research", World Transaction on Engineering and Technology Education, Vol. 5, pp. 175-178.

13. Karabay S. (2007) "Analysis of drill dynamometer with octagonal ring type transducers for monitoring of cutting forces in drilling and allied process", Journal of Materials and Design. 28, 673-685.

14. Osman S.M.,Kumme R., Hakeem M, Hasan E.,Rashad. M., Kouta F.(2015) "Force transducer with different capacities", XXI IMEKO World Congress "Measurement in Research and Industry" August 30 -September 4, , Prague, Czech Republic

15. Budynas, R. G., Nisbett, J. K., Shigley, J. E. (2011), Shigley's Mechanical engineering design, New York: McGraw-Hill.

16. Kolhapure R.R., ShindeV.D.,Kamble V.A.,(2017) "Geometrical optimization of strain gauge force transducer using GRA Method", Measurement,101, 111-117.

17. Shivade A.S., Shinde V.D.(2014) "Multi-objective optimization in WEDM of D3 tool steel using integrated approach of Taguchi method and grey relation analysis", Journal of Industrial Engineering International, 10 149–162.

18. HBM catalogue (2019) "Strain gauges and accessories" https://www.hbm.cz/wp-content/uploads/s3996.pdf

19. Karl Hoffmann, (2011) "Applying the Wheatstone Bridge Circuit", eln.teilam.gr/sites/default/files/Wheatstone%20bridge.pdf


Page 39-47 © MANTECH PUBLICATIONS 2021. All Rights Reserved