Numerical Investigation of Square Ring Shape Force Transducer

Ajay PratapSingh, Sanjoy Kumar Ghoshal, Harish Kumar, Ajay Kumar Rai*

*Mechanical Engineering Department, Indian Institute of Technology - ISM, Dhanbad 826 004, India
Mechanical Engineering Department, Ajay Kumar Garg Engineering College, Ghaziabad 201 009, India
Department of Mechanical Engineering, National Institute of Technology Delhi, Delhi 110 040, India

E-mail: *ajay.pratap.singh.86@gmail.com

Abstract:
With growing industrial needs, there has been consistent thrust over the development of simple shaped force transducers. Some of the shapes designed may be analyzed through the analytical methods or conventional theorems. But, some of the newer shaped developed recently or proposed are not been able to analyzed through analytical methods, insist the application of modern computational tools like finite element analysis to be implied and applied in rationalized manner to have effective outcome regarding design analysis and other parameters. The present study attempts to discuss the procedure and outcome of finite element analysis for a square ring shaped force transducer for the material Al 7075 with a nominal capacity of 5 kN. The paper discusses details of the approach and salient outcome. The paper further cites the implications of the finite element analysis in design and development of the force transducer. The software ANSYS has been used to carry out the present study.

Keywords: Square ring force transducer, Computational analysis, deflection, stress, strain

1. Introduction:
Force measurement has been playing very vital role in measurement and metrological systems for a very long period of time. Force, being very important parameter in technical field having different applications in functional areas has been measured by a various types of sensors capacities ranging from few Newton’s to mega Newton’s. The contemporary development of force measurement technology is credited to Sir Isaac Newton, who did a lot of work for force measurement technology by framing laws related to force measurement. He has developed definite systematic expressions, which are still acting as a structure for modern development in the field of research. In the force metrology dimension, precision, accuracy and metrological characterization are the play a vital role when a designing new instruments(Kumar, Pant and Maji, 2016). Numerous Force Measurement using force transducers are required in different industrial applications like weighing of aircrafts, installation of big and heavy machinery, verification of material testing machine, thrust force measurement in gas turbine or jet engine or rocket engine, torque measurement on engines, electronic weighing scales, or pumps and gearboxes, measurement of different machining process like milling, turning, rolling mills, drilling, high capacity hydraulic press machines and morphological study etc. (Kumar, Sharma and Kumar, 2011).Further for industrial manufacturing application, where the force transducer are used, where the critical force measurements are strictly needed (Aydemir, Kaluc and Fank, 2006). Further for dynamic force measurement correction method for measuring dynamic force applied to force transducer is required. Levitation Mass Method is usually used for correcting the force measured by force transducer in a dynamic system(Takita, Ono and Fujii, 2014)(Fank and Demirkol, 2006).Further forbiomechanics field application, novel force transducer measure with the functional grip forces (Chadwick and Nicol, 2001).
2. Square Ring Shaped Force Transducer:
Square ring force transducer is a modification of ring shaped force transducer. External cross section is look like a square and internal cross section is look like a ring. Outer surface of square force transducer offers suitability for application of strain gauge and inner circle to installed the dial gauge (Kumar, Sharma and Kumar, 2013). For the deflection, measurement to use the analog and digital dial gauge are used and for precise measurement measure signal with strain gauge. The outer diameter (Do), inner diameter (Di) and width (b), and are 192 mm, 172 mm and 35 mm, respectively. The thickness (t) is the difference between outer diameter and inner diameter. The properties of Aluminum 7075 (AL7075T6) have taken for designs as per standard. The details of figure shown in figure 1.

![5 KN Axial](image)

Figure 1. Square ring force transducer

2.1 Design parameters

| S. No. | Symbol | Parameter                               |
|-------|--------|-----------------------------------------|
| 1     | D_o    | Outer Diameter (mm)                     |
| 2     | D_i    | Inner Diameter (mm)                     |
| 3     | R      | Mean Radius (mm)                        |
| 4     | t      | thickness of cross section of square ring (mm) |
| 5     | b      | width of cross section of square ring (mm) |
| 6     | P      | Applied Force                            |
| 7     | E      | Young’s Modulus of Elasticity (GPa)      |
| 8     | σ      | Stress (N mm²)                          |
| 9     | ε      | Strain (mm/mm)                          |
| 10    | δ      | Deflection of square ring (mm)           |

3. Computational Analysis:
The computational analysis was performing with Ansys software. The load was applied of only in compression mode. The computational study can be performing for various iterations comprising of various designing parameters. It would also help us to find out the various desired and valuable results. The aim of this analysis to find out the maximum deformation point on square ring force transducer.

3.1 Use of computational analysis:
Now a day the use of computational analysis is very important to design any model. It is an approach to find the approximate results and validate with experimental as well as analytical. Computational analysis is a base of development of model and concepts also.

3.2 Present Study – FEM of 5kN Square ring transducer
The numerical investigation of square ring force transducer has been completed with computational software i.e. Ansys. A three dimensional model has been created on solid edge software and export the
3D model in Ansys for finite element analysis. The boundary condition has been defined as per analytical method. After meshing has been completed total 41680 nodes and 26702 elements taken for further studies. The meshing has shown in figure 2.

![Figure 2. Meshing of Square Ring Force Transducer](image)

3.2.1 Deflection
In a force measurement dimension deformation is playing a vital role for precise measurement. In figure 3 the total deformation has shown. The axial deformation is shown only for 5kN. The maximum deformation is 1.6797 and minimum deformation is 0.04807. The maximum deformation has been found on middle of top of square ring force transducer at 0°.

![Figure 3. Deflection of square ring force transducer](image)

3.2.2 Stress:
The analysis has been completed only in compressive mode. The compressive force is applied on center of top and reaction force is applied on center of bottom of square ring force transducer respectively. For the finite element analysis point load has been taken for better results. The variation of stress is shown in figure 4. The maximum stress 230.99 MPa has occur on center of bottom surface of square ring and minimum stress 1.7967 MPa has been occur on center of top surface of square ring.

3.2.3 Strain:
The variation of strain is shown in figure 4. The maximum strain 0.0032227 mm/mm has occurred on center of bottom surface of square ring and minimum strain 2.5565e-5 mm/mm has been occurring on center of top surface of square ring. The results of stress and strain are same patter.
3.2.4 Variation of Mesh Size with Stress, Strain and Deformation:
The variation of mesh size ie 2, 4, 6, and 8 with load variation 1kN, 2 kN, 3 kN and 5 kN for stress, strain and deformation. The pattern is shown on below with graphical representation and found that If the load is increase stress, strain and deflection are also increased with respect to mesh size.

**Figure 5.** Variation of mesh size and load with stress

**Figure 6.** Variation of mesh size and load with deflection
4. Conclusion:
Following conclusions may be drawn from the presented investigation:

a) Finite element analysis is very important tool for verification and validation of analytical findings.

b) A square ring shaped force transducer for 5 kN nominal capacity has been proposed herewith and evaluated for its design features.

c) The force transducer studied for stress-strain and deflection.

d) The stress distribution helps in locating optimal locations for application of strain gauges.

e) The force transducer fabrication is underway and will be characterized as per standard calibration procedure for its metrological features.

Acknowledgement:
Authors express their sincere thanks to Director and Head, CORE, Ajay Kumar Garg Engineering College, Ghaziabad. Author also great full thanks to Head of Department, Mechanical Engineering and Dean Academic, Indian Institute of Technology (ISM) Dhanbad.

References:

1. Aydemir, B., Kaluc, E. and Fank, S. (2006) ‘Influence of heat treatment on hysteresis error of force transducers manufactured from 17-4PH stainless steel’, Measurement: Journal of the International Measurement Confederation, 39(10), pp. 892–900. doi: 10.1016/j.measurement.2006.03.014.

2. Chadwick, E. K. J. and Nicol, A. C. (2001) ‘A novel force transducer for the measurement of grip force’, Journal of Biomechanics, 34(1), pp. 125–128. doi: 10.1016/S0021-9290(00)00168-8.

3. Fank, S. and Demirkol, M. (2006) ‘Effect of microstructure on the hysteresis performance of force transducers using AISI 4340 steel spring material’, Sensors and Actuators, A: Physical, 126(1), pp. 25–32. doi: 10.1016/j.sna.2005.09.007.

4. Kumar, H., Sharma, C. and Kumar, A. (2011) ‘Design and development of precision force transducers’, Journal of Scientific and Industrial Research, 70(7), pp. 519–524.
5]. Kumar, H., Sharma, C. and Kumar, A. (2013) ‘The development and characterization of a square ring shaped force transducer’, Measurement Science and Technology, 24(9), p. 095007. doi: 10.1088/0957-0233/24/9/095007.

6]. Kumar, R., Pant, B. D. and Maji, S. (2016) ‘Design, development and metrological characterization of a force transducer’, Journal of Scientific and Industrial Research, 75(5), pp. 320–321.

7]. Takita, A., Ono, Y. and Fujii, Y. (2014) ‘Review of dynamic-force correction method for a force transducer with the Levitation Mass Method’, Information (Japan), 17(2), pp. 539–544. doi: 10.12792/iaic2013.039.