Finite element analysis of square ring shape force transducer

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Abstract: Force transducer is an important component used for force measurement in many industrial applications. A unique material PC – ABS by 3-D printing is used for numerical investigation for square ring force transducer. This study elaborated the procedure of FEA for a force transducer of 3-D printed material with 1750 N nominal capacity.

Keyword: Finite element analysis (FEA), Square Ring Force Transducer (SRFT)

1. INTRODUCTION

Force transducer play a vital role force measurement. Various force measurement technologies are in use to measure the forces in tension as well as compression mode. There are several industrial applications like torque measurement of engines, gearboxes, pumps, measurement of thrust force in gas turbine and rocket engine, verification of material testing machine (H Kumar, C Sharma and A Kumar, 2013). Also, there are many other applications like measurement of cutting forces in machining process such as milling, drilling, turning, rolling mills, weighing of aircrafts, high capacity hydraulic press machines, automobile industry hardness blocks calibration at different scales such as Brinell, Vickers and Rockwell, microhardness atomic force microscopy, etc. (R Kumar, S Rab, B D Pant and S Maji, 2018, A P Singh, S K Ghoshal and H Kumar 2019). There are many industrial applications described in the previous related to a variation of force transducers, i.e., from dynamic to static force (E Soleman 2015, RKumar, S Rab, B D Pant and S Maji, 2016).

There are several engineering uses which need scientific applications, dynamic force measurement, including metrological uses, frequently need static force measurement (A P Singh, S K Ghoshal and H Kumar 2018,).

In previous investigation carried out by various researchers used metal alloys to simulate and fabricate force transducer [B Cheng, X Wu, X Peng 2007, A P Singh, S K Ghoshal, H Kumar and R Rai 2019, R Saxena, S K Ghoshal and H Kumar 2019, JN Libii 2006]. There is no such literature available with thermoplastic/3-D printed in used for force sensors. Therefore, in the present investigation a computational investigation of square ring shaped force transducer has been carried out on a 3-D printed PC ABS material and proved to be an alternative of metal force transducer.

2. SQUARE RING FORCE TRANSDECER

The force Transducer with Ring shaped is modified to square ring force transducer, having ring shapes internal and square shaped external cross section. The outer surface of square force transducer is
suitable for application of strain gauge and inner circular section is provided for the installation of the dial gauge (Kumar, Sharma and Kumar, 2013). The analog and digital dial gauge are used for deflection measurement and strain the signal is measured by strain gauge.

The external radius, Ro, internal radius, Ri, and the width, b, are 25 mm, 15 mm and 20 mm, respectively and the thickness, t, is 10 mm. All dimensions in mm. The polycarbonate-ABS (PC ABS) material is selected for computational investigation due to its industrial applications like electronics, telecommunications, and automobile. The most appropriate properties of PC are superior strength and heat resistance and the flexibility of ABS. The cross-sectional views shown in Figure 1. Table 1 represents the design parameter of force transducers.

![Figure 1. Schematic diagram of SRFT](image)

| Sr. No | Parameter                              | Symbols |
|--------|----------------------------------------|---------|
| a      | Outer Radius                           | Ro      |
| b      | Inner Radius                           | Ri      |
| c      | Mean Radius                            | R       |
| d      | Thickness                              | t       |
| e      | Cross section width of square ring     | b       |
| f      | Force Applied on transducer            | P       |
| g      | Young’s Modulus of Elasticity          | E       |
| h      | Poisson’s ratio                        | ν       |
| i      | Stress                                 | σ       |

3. COMPUTATIONAL ANALYSIS

The Ansys simulation software is used for numerical investigation. The point load has been applied in compressive mode. The numerical investigation has been conducted with numerous repetition for optimization of design. The optimization of design is used to find out the valuable and exact solutions. The objective of these investigation is to determine the highest deformation point on SRFT.
3.1. Application of numerical investigation
To design any model, the computational investigation is very useful to optimized the design with proper approach and direction. These results also help in validating your results/value with analytical as well as experimental.

3.2. Contemporary Investigation – FEM of 1750 N SRFT
The computational investigation of the SRFT was carried out using computer software, i.e. Ansys, completed. A solid-edge software was used to create a three-dimensional model and the 3D model was exported to Ansys for finite element analysis. The boundary condition was defined according to the analysis method. After meshing is complete, a total of 20530 nodes and 14321 elements are used for further investigations. The networking is shown in Figure 2.

3.2.1 Computational analysis Stress
The present investigation was conducted in compression mode using point load. The compressive load is applied to the top middle and the reaction force to the bottom middle of the square ring force transducer. The stress distribution pattern depicted in Figure 3. The smallest stress of 0.92767 MPa has accumulated on the top of the center of the square ring, and an extreme stress of 17.152 MPa has accumulated on the middle of the ring underside of the square ring.

3.2.2 Computational analysis Strain
The extreme strain 0.0055377 mm/mm is happened on middle of 0°, 90°, 180° and 270° surface of square ring and smallest strain is 0.0004612 mm/mm at 45°, 135°, 225°, 315° square ring. The figure 4 shown the variation of strain. The figure shows the same pattern of strain as it is observing red for stress.
3.2.3 Computational analysis Deflection

For the precise deformation measurement is playing very important role in force measurement. The axial deformation is shown for small force only 1750 N. The figure 5 show the total deformation. The extreme deformation observed on the middle of top square ring force transducer at 0°. The smallest deformation is 0.25515 and the extreme deformation is 0.48029.

3.2.4 Computational analysis Factor of Safety of SRFT

Factor of safety is very important parameter during the design of any component. Figure no 6 shows the factor of safety of square ring force transducer. In case of force transducer factor of safety is always more than unity.
3.2.5 Variation of Angle with fixed load

The variation of angle ie. 0°, 45°, 90°, 135°, 180°, 270° and 360° with constant load 1750 N for deformation, stress and strain. The details graphical representation has been shown in figures 7, 8 and 9 and shows the increase in the angle pattern in all trends, also it is observed that the design is symmetrical which helpsin ease of design and manufacturing.

![Figure 7. Variation of deflation at constant load with variation of angle](image)

![Figure 8. Variation of stress at constant load with variation of angle](image)

![Figure 9. Variation of strain at constant load with variation of angle](image)

4. CONCLUSION

Following are the conclusions drawn from the present study:

a) A unique 3 – D Printed PC ABS material which has never been used previously for numerical
simulation for square ring force transducer is used.

b) A numerical model with 1750 N nominal capacity for square ring force transducer has been proposed.

c) Studied on force transducer for deflection, stress and strain are carried out.

d) The optimal location for strain gauge application are identical by stress distribution studies.

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