

Design, Development and Metrological Characterization of a Force Transducer

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The present paper discusses the design and development of a force transducer. The force transducer has been developed for a nominal capacity of 5 kN and strain gauges have been applied at suitable locations over it to form a Wheatstone bridge. The force transducer has been metrologically investigated according to the standard calibration procedures based on standards ISO 376-2011.

Keywords: force transducer, ISO 376-2011, uncertainty of measurement.

Introduction

Strain gauged force transducers offers better resolution and interpolation for measurement of in-between step forces. In addition, the digital indicator helps in remote operation of force transducers also. Some commercial strain gauged force transducers are available, but they are of very complex shape and their strain gauging is a difficult task. The present work aims to demonstrate the force transducers with simple design and manufacturing considerations [1-3].

Computational Investigations

In the present paper the design and simulation of a force transducer made up of EN 24 steel for the measurement of medium forces up to 5 kN has been presented. The force sensors for medium range of forces are quite useful for Indian industry. The force is applied to the sensing element through a hardened steel ball over a hemispherical slot at the center of the diaphragm. Simulations have been carried out using an FEA software tool COMSOL MultiphysicsTM. Von Mises Stress as well as displacement of the diaphragm has been simulated for the forces from 0 to 5000 N at the intervals of 500 N (Figure 1). The maximum stressed areas have been determined for the optimal placement of strain gauges to get the highest sensitivity.

Metrological Characterization of Force Transducers

The force transducer has been calibrated according to the calibration procedures using the 50 kN dead weight force machines as discussed earlier. The 50 kN dead weight force machine employs dead weights with denominations from 0.5 kN to 5 kN to realize precisely known force in the range from 0.5 kN to 50 kN [4]. The dead weight force machine is able to apply the force in ascending or descending order according to the calibration procedures based on standards ISO 376-2011) [5-6]. A very high resolution digital indicator (DK 38 of HBM, Germany) of resolution 0.00001 mV/V has been used for taking the

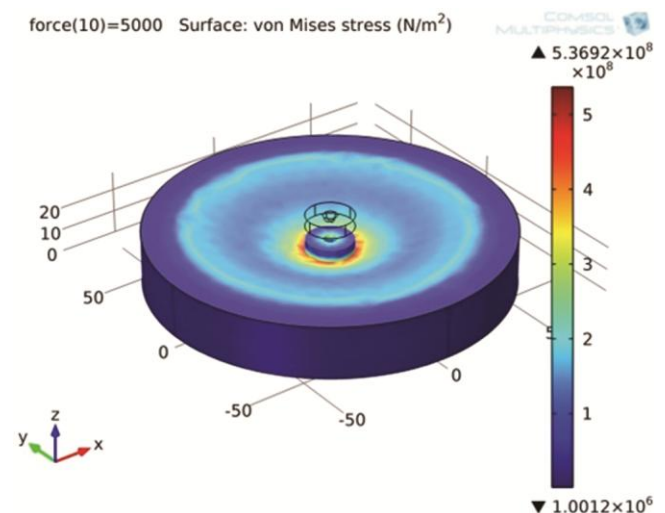


Fig. 1- Stress of the diaphragm at 5000 N force

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Table 1—Uncertainty of measurement of force transducer in accordance to ISO 376-2011

Force (kN)	Relative deviation (%) due to						W (%) (<i>k</i> =2)
	Zer.	Rep.	Rpr.	Res.	Int.	Hys.	
0.5	0.007	0.028	0.042	0.014	0.012	0.063	0.04
1.0	0.007	0.014	0.057	0.007	0.012	0.070	0.04
1.5	0.007	0.014	0.047	0.005	0.001	0.059	0.03
2.0	0.007	0.011	0.057	0.004	0.001	0.051	0.04
2.5	0.007	0.009	0.046	0.003	0.008	0.065	0.03
3.0	0.007	0.007	0.031	0.002	0.003	0.074	0.02
3.5	0.007	0.014	0.053	0.002	0.012	0.053	0.04
4.0	0.007	0.021	0.043	0.002	0.000	0.071	0.03
4.5	0.007	0.021	0.027	0.002	0.008	0.071	0.02
5.0	0.007	0.017	0.043	0.001	0.003	0.000	0.03

observations. Relative uncertainty due to repeatability (rep), reproducibility (rpr), hysteresis (hys), zero (zer), interpolation (int) and resolution (res) has been calculated to evaluate uncertainty of measurement of force transducer (Equations (1-2)).

$$W_{c(tra)} = W_{rep}^2 + W_{rpr}^2 + W_{int}^2 + W_{hys}^2 + W_{zer}^2 + W_{res}^2 \dots (1)$$

$$W_{(tra)} = k \cdot W_{c(tra)} \dots (2)$$

The relative uncertainty of calibration, *W* shall be determined by the Equation (3), considering the best measurement capability (bmc) or uncertainty of force measurement by force machine of the force standard machine (Table 1).

$$W = [W_{(tra)}^2 + W_{(bmc)}^2]^{1/2} \dots (3)$$

Results and Discussions

The present investigation results in the development of a 5 kN force transducer. The strain gauges of nominal resistance $350 \pm 0.3 \Omega$ have been applied at suitable locations to make a Wheatstone bridge.

The force transducer has been metrologically studied on the basis of calibration procedure according to ISO 376-2011. The relative uncertainty due to the factors contributing to the uncertainty of measurement of force transducers have been evaluated according the calibration procedures based on the standard ISO 376-2011. The uncertainty of measurement is better than 0.05 % (*k* = 2) for overall range of the rated capacity of the force transducer.

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