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Contents

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Research Articles

Investigation of Magnetic-field-induced Temperature Error of Pt- 500 <i>Rajinikumar Ramalingam and Michael Schwarz</i>	1
Classification of Unknown Thermocouple Types Using Similarity Factor Measurement <i>Seshu K. Damarla and Palash Kundu</i>	11
The Design of a Novel Flexible Tactile Sensor Based on Pressure-conductive Rubber <i>Fei Xu, Yunjian Ge, Yong Yu, Junxiang Ding, Tao Ju, Shanhong Li</i>	19
Study on the Relative Difference of the Force Transducer Constants in Tensile and Compressive Modes Calibration Equations <i>Ebtisam H. Hasan and Seif. M. Osman</i>	30
Design of a Large-scale Three-dimensional Flexible Arrayed Tactile Sensor <i>Junxiang Ding, Yunjian Ge, Shanhong Li, Fei Xu, Feng Shuang</i>	37
The Activity Airflow Detection of Vehicle Intake System Using Hot-film Anemometry Sensors Instrument <i>Rong-Hua Ma and Chi-Kuen Sung</i>	48
Hardware Developments of an Ultrasonic Tomography Measurement System <i>Hudabiyah Arshad Amari, Ruzairi Abdul Rahim, Mohd Hafiz Fazalul Rahiman, Herlina Abdul Rahim, Muhammad Jaysuman Puspanathan</i>	56
Design and Development of Microcontroller Based Fluoride Meter <i>Bhaskar Reddy S., V. V. Ramana C. H. and Malakondaiah K.</i>	64
Effect of Magnetic Flux Density and Applied Current on Temperature, Velocity and Entropy Generation Distributions in MHD Pumps <i>M. Kiyasatfar, N. Pourmahmoud, M. M. Golzan, M. Eskandarzade</i>	72
Design of a DCS Based Model for Continuous Leakage Monitoring System of Rotary Air Preheater of a Thermal Power Plant <i>Madan Bhowmick and Satish Chandra Bera</i>	83
The Design of a Wireless Monitoring System for Unattended Environmental Applications <i>Ibrahim Al-Bahadly and Victor Mtetwa</i>	101
Performance Measures of Ultra-Wideband Communication System <i>Mrutyunjaya Panda, Sarat Kumar Patra</i>	120
Unspecified Low-Frequency Noise in Chopper Op-Amps <i>Charles Gilbert</i>	127

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- Fundamentals in biotechnologies
- Biodevices
- Biomedical technologies
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Registration	March 5, 2011
Camera ready	March 20, 2011

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Registration	March 5, 2011
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- GOBS: GRID over Optical Burst Switching Networks



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- Complex Systems

Study on the Relative Difference of the Force Transducer Constants in Tensile and Compressive Modes Calibration Equations

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Abstract: Force transducers when calibrated in tension and compression modes an equation is derived to enable the users to interpolate results throughout the entire range. The equation constants derived governs the adequacy of the output of the transducer in relation to the applied load. If users face difficulties in calibrating the transducers in the tension mode they may resort to the use of the calibration equation of the compression mode when they use the transducer in tension measurements. The adverse effect of such act may influence the judgment on the adequacy of the applied force measurements. It is this concept that this paper aims at throwing light on.

The study reveals that different types of transducer to be calibrated in accordance with certain standard specification have little effect on the transducer output in the two modes of calibration. However, such an effect must be taken into consideration in accurate measurements like in the case of inter-comparisons or research work. *Copyright © 2011 IFSA.*

Keywords: Force transducer, Tensile mode, Compressive mode, Performance.

1. Introduction

Characterizing the performance of a force measuring system is commonly based on calculating such a best - fit least - squares line and evaluating the measurement errors with respect to it. Vertical deviation from this line is referred to as non-linearity and generally the largest value is given in the

specifications of a system. The largest value of hysteresis, which is the difference of readings between the increasing and decreasing forces at any given force, is usually at the mid-range of the system.

In general, a force transducer has two interfaces through which a force is applied. These may be the upper and lower loading surfaces of a compression force transducer or the upper and lower screw threads of a tension device. In some force transducers, one or both interfaces are part of the elastic element to which the strain gauges are bonded; in other transducers the interfaces may be remote from the elastic element.

The rated capacity is the maximum force that a force transducer is designed to measure. The full scale output, known as the output at the rated capacity, is the output at rated capacity minus the output at zero applied force. The sensitivity is defined as the full scale output divided by the rated capacity of a given transducer. Depending on the design of the transducer, the change of sensitivity caused by a change of end loading conditions can be quite large. Some precision compression force transducers with low creep, hysteresis and temperature coefficients can show differences of sensitivity in the bearing pad test of 0.3%, other less than 0.05 %. The bearing pad test is the test that a transducer is loaded through flat steel pad and then through each of two steel pads that are conically convex and concave respectively by 1 part in 1000 of the radius [1].

A force sensor is ordinarily used as a part of a large system such as weighing system or process-control system. When a force sensor is calibrated in a standards laboratory and then installed and used in a different system, there may be a significant shift in sensor response due to the differences in many factors such as machine-sensor mechanical interaction, loading sequence, loading rate and environmental conditions. The effect of these differences should be controlled, corrected for, or included in the uncertainty statement for the measurement. [2]. Force transducers are usually calibrated in tension and compression modes. In each case an equation is derived to enable the users to interpolate results throughout the entire range up to the rated capacity. The equation constants derived governs the adequacy of the output of the transducer in relation to the applied load. In some cases users may face difficulties to calibrate the transducers in the tension mode. In such cases they may resort to the use of the calibration equation of the compression mode when they use the transducer in tension measurements. The adverse

effect of such act may influence the judgment on the adequacy of the applied force measurements. It is this concept that this piece of research aims at throwing light on.

2. Experimental Design

Six force transducers were used for this study to compare the transducers performance in tensile and compression modes. Three of them were supplied by one manufacturer referred to hereafter as manufacturer (A) and the others were supplied by another one referred to hereafter as manufacturer (B). The transducers capacities were 5 kN (B), 10 kN (B), 22 kN (A), 100 kN (B), 450 kN (A) and 900 kN (A), all of them were calibrated using different Dead Weight Standard Machines to offer the facility to calibrate the transducers according to their capacities. The calibrations process were carried out according to two standard specification (ISO 376 [3] and ASTM E74 [4]) to obtain the calibration equations for each transducer in both tension and compression modes under controlled environmental conditions (23 ± 1) C° and (45 ± 5) % in order to neglect the effect of the variation in the environmental conditions.

3. Results and Discussion

As mentioned before the calibration were carried for each transducer on both tension and compression modes. As a result for each calibration process an equation is derived. The following results representations based on comparing the values stated from the driven equation in compression mode with that stated from the equation in tension mode. Each Figure from (1) to (7) represents relation between the relative difference in response at each load (Y-axis) and the load (X-axis). The relative difference is calculated from the following equation.

$$R.D. = \frac{\text{compression response} - \text{tension response}}{\text{load}} \quad (1)$$

Figs. 1 and 2 show the relative difference response for 5 kN (A) and 22 kN (B) force transducers, whose calibrations were carried out in compliance with ISO 376 to obtain the governing equation constants in order to evaluate the relative difference at each load.

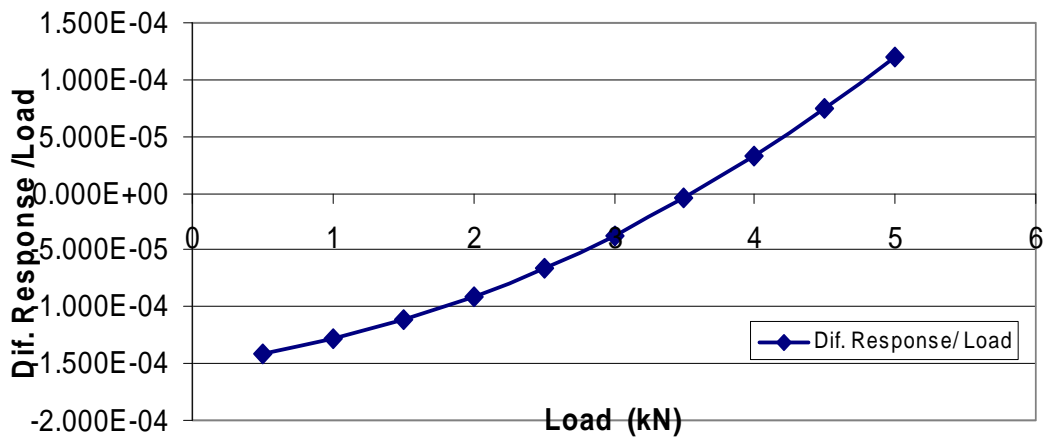


Fig. 1. Relative difference response to applying load for 5 kN transducer.

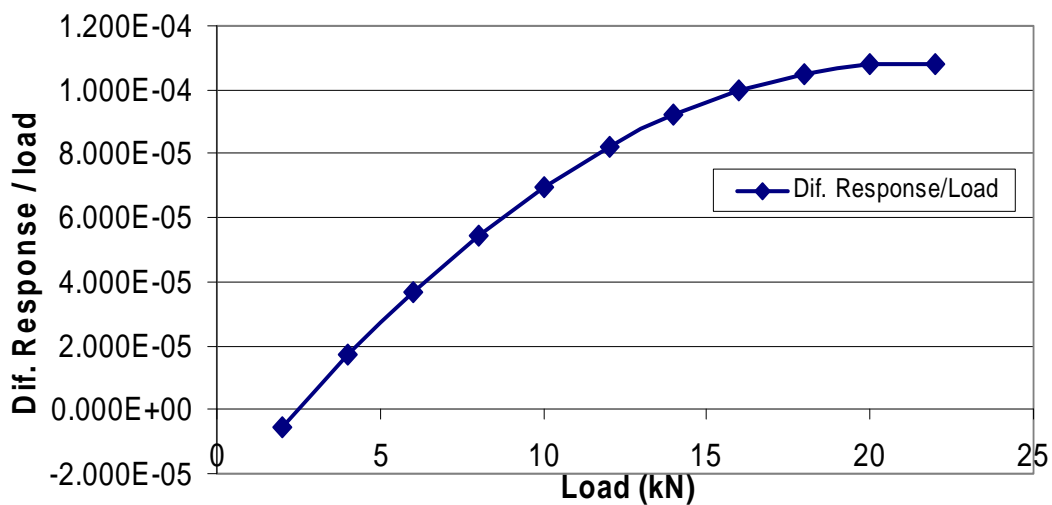


Fig. 2. Relative difference response to applying load for 22 kN transducer.

Figs. 3 to 7 show the relative difference response for 5 kN (A) , 10 kN (B), 100 kN (B), 450 kN (B) and 900 kN (B) force transducers, whose calibrations were carried out in compliance with ASTM E74 to obtain the governing equation constants in order to evaluate the relative difference at each load.

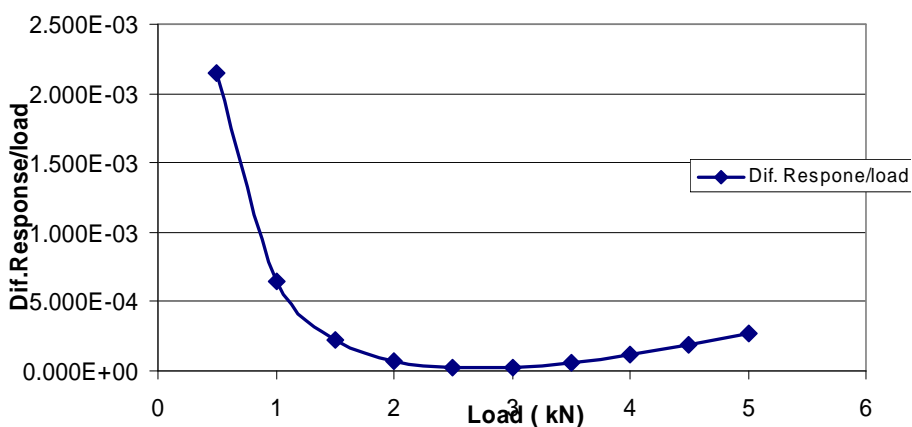


Fig. 3. Relative difference response to applying load for 5 kN transducer.

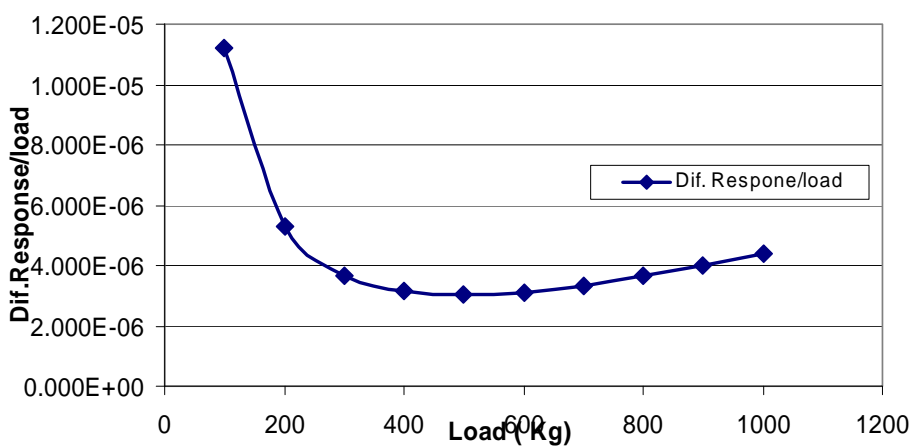


Fig. 4. Relative difference response to applying load for 10 kN transducer.

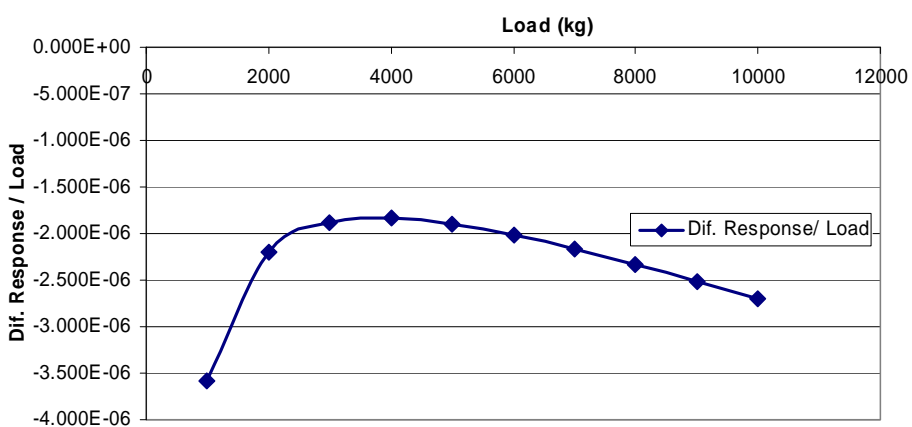


Fig. 5. Relative difference response to applying load for 100 kN transducer.

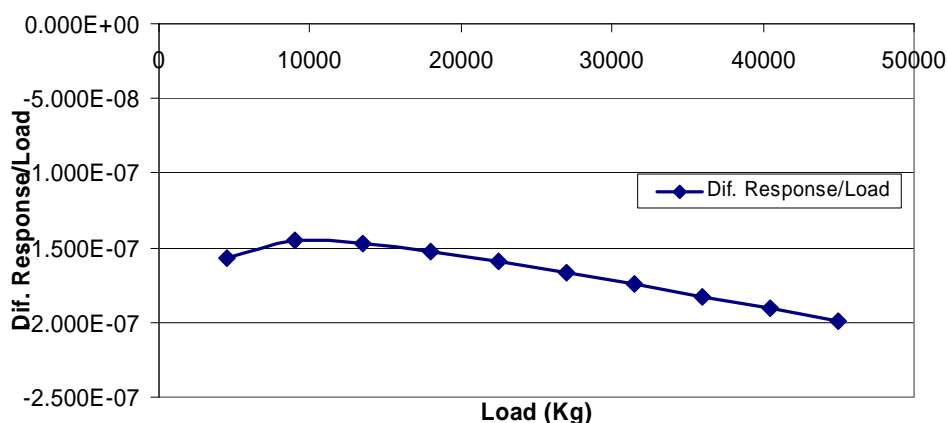


Fig. 6. Relative difference response to applying load for 450 kN transducer.

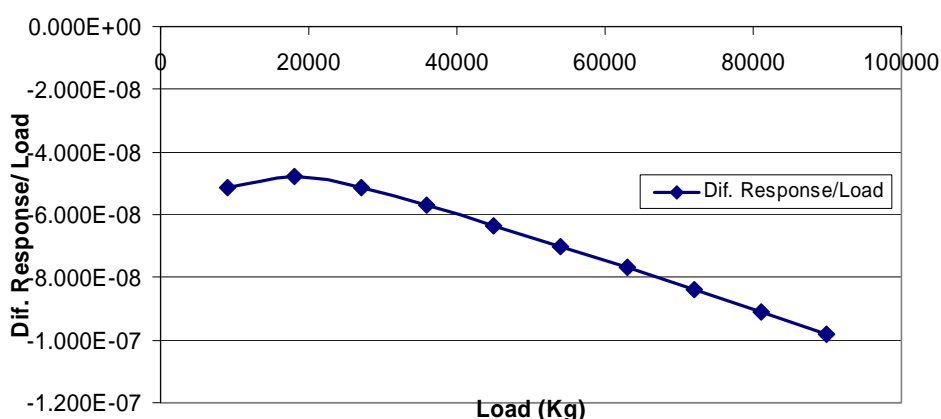


Fig. 7. Relative difference response to applying load for 900 kN transducer.

The following table (Table 1) summarizes the maximum relative difference response for the different force transducers used. The results indicate that the maximum relative difference response in case of using ISO 376 for the majority of transducer calibration is higher than in case of using ASTM E74 in the calibration procedures to determine the transducer constants. This may be due to rotating the force transducers - a must in ISO 376, not a must in ASTM E74- which introduces the contribution of rotational effect in 120° and 240° positions on the calibration results. On using the ISO 376, reversibility also has an effect of the results.

Also the table shows that the type of the transducer has an influence effect on the relative difference, this could be due to using different conceptual design and manufacturing techniques in manufacturing the force transducer. This is shown when comparing the results using the same standard specification in calibrating the force transducers. For example, the maximum relative difference for the 5 kN force transducer type B is greater than the max relative difference for the 22 kN force transducer type A under the use of the same calibration procedures (ISO 376).

From the Table 1, it is noted that for the force transducers calibrated according to ISO 376 the relative difference is increased from the lower loads up to the higher loads due to the rotational position effect for the calibration when using the ISO 376 standard for transducer calibration. But in case of the force transducers calibrated according to ASTM E74, the relative difference behavior between tensile and compression decreased from the lower loads up to the maximum load (except for the first beginning lower loads).

Table 1. Relative difference response to the applying load.

Transducer Capacity	Transducer Type	Std. Method for Calibration	Max. Relative Difference Bet. Ten. & Comp. Response
5 kN	B	ISO 376	+1.202E-4
10 kN	B	ASTM E74	+1.122E-5
22 kN	A	ISO 376	+1.083E-4
100 kN	B	ASTM E74	-1.839E-6
450 kN	A	ASTM E74	-1.467E-7
900 kN	A	ASTM E74	-4.781E-8

In general, uncertainty calculation in the standard specification ASTM E74 covers wide range of the factors that are taken into consideration in the ISO 376 standard. Hence, dividing the uncertainty estimated using ASTM E74 by 2.4 will yield a value that nearly cover the uncertainty estimated by ISO 376 satisfactorily.

In the case of using the compression constants to determine loads in tensile mode, the uncertainty calculated in compression mode could be multiplied by certain factor determined for each transducer to obtain the uncertainty in tensile mode. In such case, the compression readings could be used with the tensile estimated uncertainty to calculate the tensile loads. However, it must be emphasized that this factor is differ from transducer to another. It is therefore necessary to calibrate the transducer at least once in compression and in tension to estimate this conversion factor. If it is not possible to apply the calibration in tensile mode for some transducers, it is possible to do this for a wider range of transducer capacities and estimate the factor for a certain range within these capacities.

The results of transducers calibrated in accordance with ASTM E74 and ISO 376 standards reveal no big difference in the beginning of the transducer capacity range between the actual load value determined by tensile experiment and the estimated tensile load from the compression results (difference is around 2%). In the middle range of the maximum capacity the difference reached 0.09% while at the maximum capacity the difference reached 0.02% between the estimated tensile load and actual values determined.

4. Conclusion

The previous experimental work shows that the force transducer conceptual design and manufacturing techniques used during manufacturer, beside the methods used for obtaining the calibration equation constants may affect the behavior of force transducer in tension and compression modes. The study reveals that different types of force transducer to be calibrated in accordance with certain standard specification have little effect on the transducer output in the two modes of calibration. This goes also when calibrating the transducer with other standard specification. So, it couldn't be harmful to use the calibration equation results from calibrating a force transducer in compression mode to correct its output values in tension mode for the routine work and field usage only. But, in case of accurate measurements such as research work and inter-laboratory comparisons, it is recommended to take this difference into consideration.

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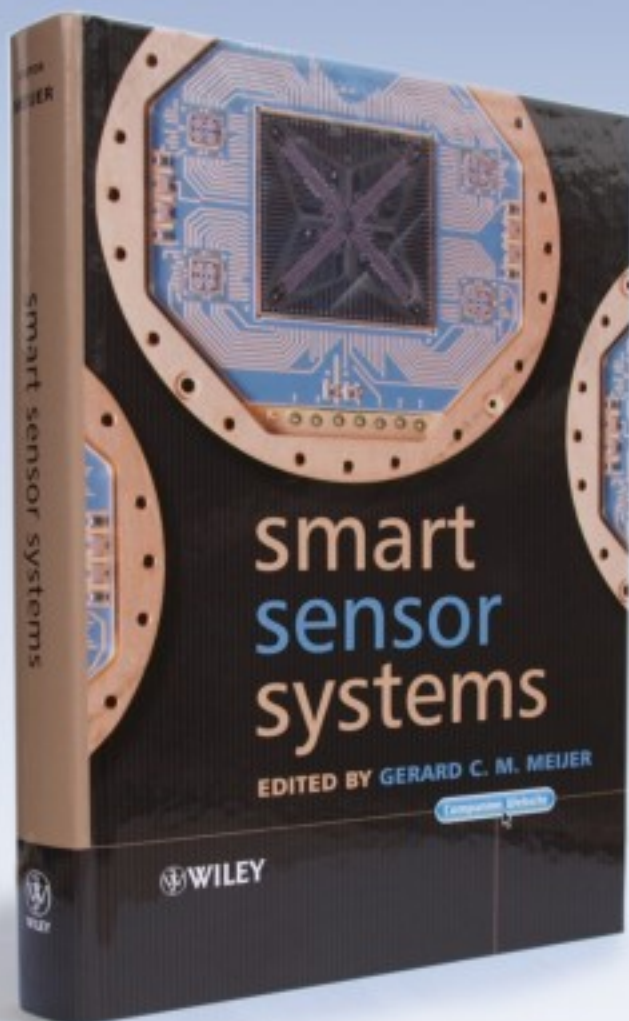
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