Multi-axial Stress Sensor for Structural Health Monitoring

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All civil structures experience aging and deteriorate with time. To ensure structural integrity, civil structures should thus be equipped with sensors for Structural Health Monitoring (SHM) with the aim of developing automated monitoring systems and facilitate inspections for damage detection. Nowadays, optical sensors and accelerometer are mostly used for SHM [1]. However, it has been shown that stress sensors could improve the reliability of monitoring systems as well as the accuracy of damage identification [2]. Of course, these stress sensors should be low cost to be spread within the structure. MEMS technology is therefore the most promising technology. Existing MEMS stress sensors have very limited full-scale and they are unable to separate the contributions of normal and shear stresses at material-package interface.

This paper presents a multi-axial stress sensor based on thick film piezo-resistive ink [3] that is capable of measuring both the out-of-plane and the in-plane internal stresses of the structures being monitored. By decoupling the two components of stress, the sensor is insensitive with respect to the variation of the surrounding material properties and boundary/installation conditions. The proposed stress sensor consists of three layers of ceramics, two thick protection layers and a thin middle layer bonded together by means of a bonding glass. The top surface of the middle layer contains the piezo-resistive gauges that are connected to form two Wheatstone bridges: one bridge senses in-plane strains and the other one senses both in-plane and out-of-plane strains [4]. The design of the sensor and the position of the sensing elements were optimized by means of a commercial Finite Element software.

A series of prototypes were produced and tested in laboratory by means of compression tests, imposing different boundary conditions and materials, up to a compression force of 5 kN that corresponds to a normal pressure of 10 MPa. Also, the influence of working temperature was assessed. By linearly combining the two bridge outputs, the influence of boundary conditions on the compression stress component can be minimized. Inserting the sensor in standardized concrete samples having size of 15x15x15 cm the influence of inclusions close to the sensor can be also assessed. Again, the influence of inclusions on the compression stress is shown to be negligible unless the inclusion is very close to the 3D resistors.

References

[1] *X. W. Ye, Y. H. Su, and J. P. Han, The Scientific World Journal, vol. 2014, 2014.*
[2] *Nagayama, T., Spencer, B.F, SHM Using Smart Sensors, NSEL, Urbana (2007).*
[3] *Tamborin, M., Piccinini, S., Prudenziati, M. and Morten, B., "Piezoresistive properties of RuO_2-based thick-film resistors" Sensors & Actuators A. 58 (1997) 159-164.*
[4] *Guidetti, E., Abbasi Gavarti, M., Caltabiano, D. and Bertagnoli, G., "Stress Sensor for SHM", Italian Patent 102017000044301 (2017).*