Design of Pressure Measuring Cell Using the Uniform Material Law

P. Aguirre[1], F. Figueroa[1]

[1]Sensor Technik Wiedemann GmbH, Kaufbeuren, Bayern, Germany

Abstract

Pressure Sensors (Figure 1) are widely used in the automotive industry. Their main use is the dynamic monitoring of pressure inside combustion engines [1]. Usually the sensor measuring cells are very small up to no more than one centimeter (Figure 2). To achieve a good signal accuracy, the design of pressure sensors can be improved with FEM calculations of stress and strains on the measuring cell depending on their geometry and material properties. The geometry is adapted according to a special nominal pressure and a limit rule of the stresses. The non-linearity can be calculated conforming a use of strain-gages over the membrane surface.

A cylindrical measuring cell is modeled in 2D (Figure 3). The diameter, height, inner contour and membrane thickness are parametrized. Material properties of realistic material model "uniform material law" (UML) [2] [3] for steels is implemented. The cell is fixed on the bottom and forces on the inner surface are defined. Using the Structural Mechanics Module of COMSOL Multiphysics®, is possible to calculate the deformation on the surface of the membrane, and the stresses in the material.Defining a constant maximal limit of allowed stress (Figure 4), and varying the geometry parameters, it is possible to optimize the difference between maximal and minimal strains on the membrane surface.

A plot of the strains on the membrane surface as a function of the distance to its center, shows the surface regions which are compressed or expanded, allowing to determine the best places to locate the strain-gauges for maximal signal sensitivity.

Signals are improved when changing certain geometry parameters. The design with FEM tools allows us to analyze tolerances in the geometry, their effects on the signal and mechanical stability of the sensor. Therefore, non linear effects of each geometry can also be studied.

Burst pressure can be useful estimated with COMSOL Multiphysics® with a user defined nonlinear elastic/plastic material model like UML for steels [4]. By increasing the pressure weak spots in the cell are well represented with a stress plot (Figure 3). Results can be extended with a statistical variation of the modeled geometry parameters and be evaluated to estimate their effects in the calculated burst pressure.

Reference

[1]Ambarish G. Mohapatra, Design and Implementation of Diaphragm Type Pressure Sensor in a Direct Tire Pressure Monitoring System (TPMS) for Automotive Safety Applications, International Journal of Engineering Science and Technology (IJEST), Vol. 3 No. 8 August 2011

[2]: Sinan Korkmaz, Master's Thesis, BAUHAUS UNIVERSITY GRADUATE SCHOOL OF STRUCTURAL ENGINEERING, 2008

[3]: Materials Data for Cyclic Loading, Supplement 1, Bäumel, A., Seeger, T., Elsevier Amsterdam, 1990

[4]: A Stress-Strain Function for the Fatigue of Metals, Smith K. N., Watson P. and Topper T.H., Journal of Materials, Vol. 5, No 4, 1970

Figures used in the abstract

Figure 1: Pressure sensor

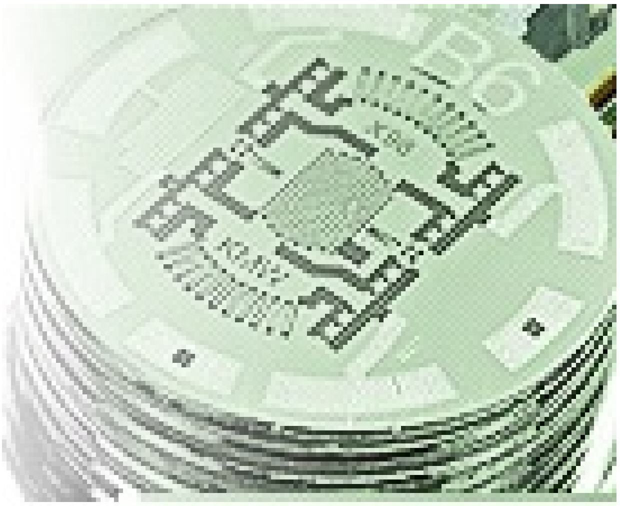

Figure 2: measuring pressure cell

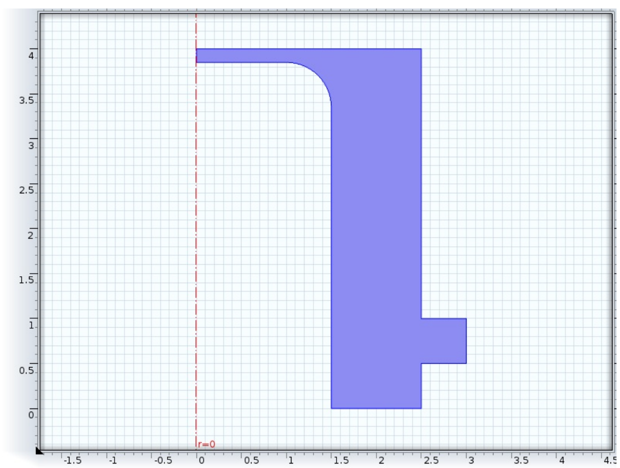

Figure 3: Draw of a pressure cell

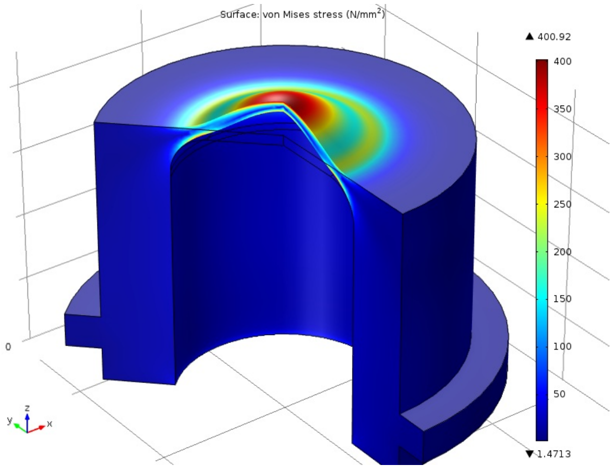

Figure 4: Calculated von Mises stresses for a special geometry