11th. World Congress on Computational Mechanics (WCCM XI)
5th. European Conference on Computational Mechanics (ECCM V)
6th. European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

OPTIMIZATION OF TORSION TRANSDUCER SENSITIVITY ON LAYERED TISSUE

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Key words: *Inverse Problem, FEM, Non destructive testing, Ultrasonic, POD, Tissular Mechanics*

Introduction

Reliable quantification of the stiffness modulus of soft tissue is an open issue with relevance for the diagnosis of pathologies that manifest as changes in the consistency of the tissue. For this task, we propose to design a piezoelectric transducer for non-invasively sensing them using an identification inverse problem to reconstruct the shear stiffness moduli of the tissue from shear ultrasonic measurements. It is therefore necessary to optimize the piezoelectric transducer model design with respect to two types of parameters. On one hand, the design parameters, and, on the other hand, the mechanical model parameters that characterize the pathology. The forward problem is implemented by performing a three-dimensional finite element simulation. The experimental measurements are simulated by adding a gaussian noise on the numerically predicted signals. In addition, a semi-analytical estimate of the probability of detection (POD) is proposed and developed to provide a rational criterion to optimize the experimental design.

This work aims to (i) evaluate the optimal piezoelectric transducer design of the model-based POD. A second goal is (ii) simulate an experiment based on the three dimensional model of wave propagation generated by the proposed piezoelectric transducer design, and, (iii) carry out a parametric study to extract practical parameters for final clinical applications.

Material and Methods

A parametric finite element model of the ultrasonic torsion piezoelectric sensor is programmed in FEAP, including a new piezoelectric element. An analytical simplified model is formulated and validated with the finite element model, which is aimed at easily predict trends and design parameter dependencies.

The formulation of the POD is derived, and allows to estimate the POD in the sense of a probabilistic signal to noise ratio, by just evaluating the model response dependency on pathology mechanical parameters and to noise by finite differences.

Results

A transducer model with a disk transmitter and a ring receiver for accessibility was designed. The optimization of the design was carried out by combining a piezoelectric finite element model and a analytical estimate of the POD. This allows to estimate the minimum pathology findable given a proposed sensor design, a layered tissue geometry and noise level on measurements.

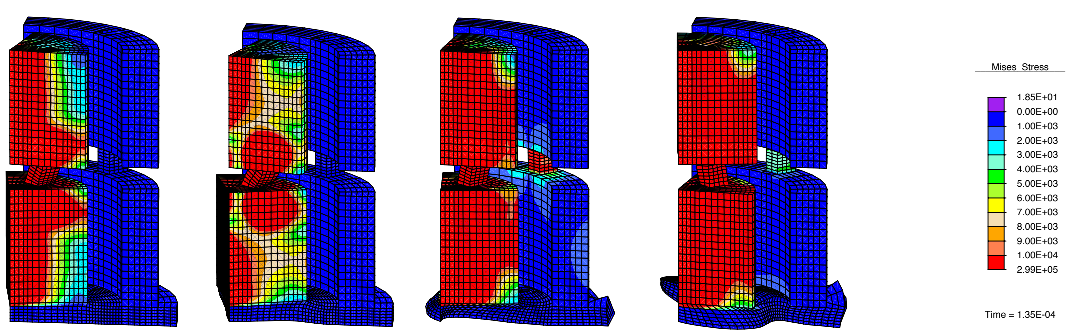

Figure 1: Different states of torsional transducer at instants $t = 9, 18, 117, 135$ μs.

After validation, the POD is used as an optimality criterion to feed the used genetic algorithms. A set of sensitivity tests was performed to validate the robustness of the analytical estimates and verify the feasibility, sensitivity and specificity of the designed transducer by the algorithms above.

The final application will be to anticipate the preterm birth by identifying changes in the consistency of the cervical tissue through the shear modulus measurements.

Acknowledgments: Spanish Ministerio de Economía for project DPI2010-17065, Spanish Junta de Andalucía for projects P11CTS-8089 and GGI3000IDIB, and the European Union for program Programa Operativo FEDER de Andalucía 2007-2013.