PhD Dissertation Defense Announcement
Mechanical and Aerospace Engineering Department
University of Texas at Arlington

ON THE DEVELOPMENT OF A SENSING SYSTEM METHODOLOGY TO EVALUATE THE VISCOELASTIC PROPERTIES OF SOFT TISSUES AS A MEANS OF DISEASE PROGNOSIS

By: Shashank Sanjay Kumat

Supervising Professor: Dr. Panos Shiakolas
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Abstract

Identification of tissue viscoelastic properties could provide valuable information for assessing its healthiness or disease state. Current technologies present challenges to accessing and performing localized tissue assessment in confined spaces in the human body through contact indentation/ palpation. As such, there is a need for a diagnostic system capable of measuring tissue relaxation response at the local site by accessing the tissue through a natural orifice.

This dissertation presents a strain gauge-based uniaxial micro-force sensor, part of the aforementioned system, capable of measuring tissue response data in confined human space environments. A sensing system design methodology is developed and presented. The sensor operational requirements are used to define design specifications and constraints. An exhaustive search discrete optimization approach is formulated, and finite element analysis is employed to identify optimal sensor component design values. A micro-force sensor with an overall diameter of approximately 3.5mm was prototyped and characterized. Characterization test beds were developed in-house to evaluate the performance of the prototyped micro-force sensor using experimentally collected equivalent force data. The performance of the sensor as it relates to its load-bearing capacity, resolution, sensitivity, accuracy, precision, repeatability error, and hysteresis were evaluated to be 1.07N, 0.13mN, \$859.7 με/N, ±28.6mN, 87.2% (23mN), ±3.13% (±25mN), and 118mN respectively.

The characterized micro-force sensor was subsequently employed to perform in vivo tissue characterization experiments on the human forearm through normal contact palpation at different control indentation depths and indentation rates according to approved Institutional Review Board protocol 2023-0306. Tissue characterization experiments were performed on 30+ participants ranging in age (20 to 79 years old), demographics (Asian, Caucasian, Others), gender (male, female), and upper body exercise or not. A three-element Maxwell-Wiechert viscoelastic model, commonly used for soft tissue characterization, was employed to evaluate the viscoelastic parameters of instantaneous shear modulus and relaxation time constant. The analysis of the results showed that the instantaneous shear modulus decreased while the relaxation time constant increased with increasing age. No identifiable differences were observed when comparing gender and/or demographics. The instantaneous shear modulus was larger while the relaxation time constant was smaller for individuals with upper body exercise.

The experimental results provide confidence to employ the sensor to distinguish healthy from diseased tissue in vivo. The dissertation concludes with the importance of this research as a component of a diagnostic system along with a discussion on future research direction.