MS Seminar Talk

Speaker: Vaidya Yagnik Kalpeshkumar (ME22S019)
Biography of the Speaker:
M.S. Research Scholar in Department of Mechanical Engineering, IIT Madras

1. Title of the seminar: An Analytical Inverse Technique to Construct Stored Energy Potential for Brain Tissue and its Finite Element Implementation

2. Date and time: Thursday, 3rd April at 3:30 PM

3. Venue: Seminar Hall, Room 412, Machine Design Section

4. Affiliation of the Speaker:

Guide: Dr. Krishna Kannan (ME Dept.)

GTC Members:

Dr. Prabhu Rajagopal - Chairperson (ME Dept)

Dr. Luoyi Tao (AE Dept)

Dr. Parag Ravindran (ME Dept)

Dr. Sundararajan Natarajan (ME Dept)

4. Abstract:

The human brain is an essential and highly complex organ, and understanding its biomechanical behaviour is crucial in the study of the impact of tumour growth on surrounding healthy tissues, as well as in surgical interventions that involve brain tissue deformation. Accurately modelling the mechanical response of brain tissue is particularly challenging due to its highly nonlinear and strongly mode-dependent mechanical behaviour. One of the significant challenges in brain tissue modelling within the framework of hyperelasticity is deriving the Cauchy stress from the stored energy potential that can describe such sophisticated mechanical behaviour. The use of conventional methodologies often results in excessively intricate formulations.

To address these limitations, we have developed a novel approach, namely, the analytical inverse procedure, which enables the determination of the potential energy from the shear stress measurements in shear-superposed on uniaxial deformations. The potential energy function is analytically derived by invoking the universal relation, ensuring the necessary existence conditions for the stored energy potential, and incorporating the boundary conditions associated with the prescribed motion. The use of Lode invariants of Hencky strain is well-suited for this procedure. The resulting four-parameter constitutive model demonstrates a better description of the mechanical response than existing models, including the widely used Mihai- Ogden model. The model parameters were optimized using the differential evolution algorithm in Mathematica. To enable the practical application of the model in finite element simulations, we have integrated this model into ABAQUS® using a custom UHYPER subroutine scripted in Fortran. The accuracy of the implementation was further verified through quantitative comparisons with the analytical computations of the stress in certain homogeneous deformations.

Since real-world tissue deformation is inherently non-homogeneous, a critical next step in our research was to evaluate the model's performance under non-homogeneous deformation conditions. We observed that the parameters optimized for homogeneous deformation did not provide an adequate description for non-homogeneous scenarios, thereby necessitating further refinement. This optimization process was particularly complex, requiring the coupling of ABAQUS® with ISight® software to refine the model parameters based on non-homogeneous deformation. The updated parameters yielded significantly improved agreement with experimental data on human brain tissue reported by Budday et al. (2017), validating the robustness of our model.

The proposed constitutive model has significant implications for computational simulations of brain biomechanics, including applications in surgical planning and investigations of brain tissue behaviour under various conditions, such as external forces and disease progression. Additionally, they will contribute to a deeper understanding of soft tissue mechanics, supporting advancements in biomechanics, computational modelling, and medical science.