Material Properties of Brain Tissue under Complex Shear and Compression Loading

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ABSTRACT

A large degree of the variability of brain tissue material properties reported in the literature can be associated partly with the differences in experimental methods. Material properties of brain tissue have been mostly characterized under a specific type of loading, e.g., compression, tension, shear, oscillation, etc. The derived constitutive equations that represent the tissue material properties under one loading condition do not necessarily predict the behavior of tissue under another mode of loading, e.i. it has been hinted that the constitutive model developed based on compression tests can not characterize the behavior of the tissue under shear or tension. In FE simulations of TBI, brain tissue undergoes a complex combination loading modes, which signify the need for a comprehensive constitutive model for brain tissue suitable for multiaxial loading. In this study, a Quasi-Linear Viscoelastic (QLV) constitutive model for brain tissue that is capable of characterizing the tissue behavior under combined modes of loading was developed. 52 cylindrical samples were extracted from fresh bovine brain tissue and tested under compression (n=22) and shear (n=30). A ramp and hold strain with approximate strain rate of 10 s^{-1} *and hold time of 20 s was applied to the samples at different strain levels from 5% to 30%. A QLV model was developed with a 3rd order odd polynomial as the instantaneous elastic response and a Prony series for relaxation function with 4 time constants to cover four experimental time scales. To determine the elastic response and the constants of the relaxation function, the model was fitted to both shear and compression experimental results simultaneously. The results showed that the relaxation function under shear and compression loading is the same and the material parameters were determined to be* C_{10}*=-2.33 kPa,* C_{01}*=2.50 kPa,* C_{11}*=0.04 kPa. The model developed in this study is capable of characterizing the brain tissue behavior under shear and compression in a wide range of strains and can be used in computational modeling of TBI to predict brain deformation that result from falls, sports or automotive accidents.*