Material Properties of Brain Tissue under Blast-Rate Deformations

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ABSTRACT

Traumatic Brain Injury (TBI) is continued to be one of the major causes of fatality and morbidity worldwide. Over the past decade there has been a significant increase in the number of TBI incidents among armed forces and blast injuries, especially Blast-Induced Neurotrauma (BINT), has been called the signature wound of the Iraq war. BINT is a result of large magnitude high frequency pressure wave propagation with the magnitudes reaching 100 kPa at the rate of 0.5-1.5 kHz. Therefore, studying brain tissue at blast-rate deformations requires a test method with loading duration of about 1 ms. In the previous studies concerned with brain material properties, the strain rates were below 10 s-1; making the results unsuitable for BINT modeling purposes. This study aims at addressing the mechanical behavior of brain tissue at strain rates from 100 to 1000 s-1. A high-speed linear impact system was utilized to apply high-rate shear strain to cylindrical brain samples. This device consists of two parallel tracks, one with an active carriage (driven by a servo motor) and the other (passive track) with 2 freely sliding carriages. One free carriage was placed in the middle of the passive track (stationary carriage) where the sample was placed. The other one (impact carriage) was pushed by the active carriage and released to hit the stationary carriage. Using this method, the peak acceleration of the stationary carriage reached about 1200 G in approximately 1 ms. A load cell was placed above the sample on the stationary carriage to measure the shear force and the shear strain was calculated based on the displacement of the stationary carriage determined using a high-speed camera. To determine the tissue material properties, FE models of the tests were developed in LS-Dyna and the material parameters were obtained based on optimization between the experimental and model stresses. In this study, the material properties of fresh bovine brain tissue were determined in strain rates of 100, 500 and 800 s-1. The results of this study suggest that the brain tissue material properties in strain rate levels higher than 100 s-1 do not change with strain rate. The average instantaneous shear modulus is 13.7±1.5 kPa which is significantly higher than most reported values for the brain shear modulus.