THE LARGE STRAIN RESPONSE AND CONSTITUTIVE MODELING OF BRAIN TISSUE

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Annually, motor vehicle crashes world wide cause over a million fatalities and over a hundred million injuries. Of all body parts, the head is identified as the body region most frequently involved in life-threatening injury. Numerical Finite Element (FE) modelling is often used to predict the mechanical response of the contents of the head during impact. Current FE head models contain a detailed geometrical description of anatomical components inside the head but lack accurate descriptions of the material behavior of the brain. No consensus exists on the exact nature of the non-linear behavior [1]. Furthermore, results reported in literature show a large scatter [2,3]. Accurate representations of the constitutive behavior of the various components are crucial for the reliability and predictive capabilities of numerical head models.

The objective of this work is to determine the non-linear mechanical behavior of brain tissue and to develop a constitutive model for this behavior. The mechanical response of brain tissue to high loading rates is characterized using porcine brain tissue. A combination of both shear and compression experiments is used to characterize the three-dimensional behavior. Moreover, the material response during complex loading histories (loading-unloading, as is relevant for impact situations) is determined. An improved method for rotational shear experiments is used, producing a homogeneous strain field and leading to an enhanced accuracy. Furthermore, the immediate loss of structural integrity, at the time scale of impact, due to large deformations, is investigated. No significant mechanical damage is observed for shear deformations up to 45 %. A new differential non-linear material model for brain tissue is developed. The model is formulated in terms of a large strain viscoelastic framework and considers non-linear inelastic deformations in combination with non-linear elastic behavior, which is particularly suited to model the material in different deformation modes.

Experimental data on the mechanical response of brain tissue subjected to large deformations for different deformation modes is presented. A new differential viscoelastic model is used to model the response of brain tissue. This constitutive model is implemented in a three-dimensional head model in order to predict the mechanical response of the intra-cranial contents due to an impact.

References

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