Mechanical Engineering Doctoral Defense

CAVITATION NUCLEATION AND DYNAMICS IN BIOLOGICAL SYSTEMS

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Abstract

"Cavitation bubbles in the human body, when subjected to rapid mechanical load, are being increasingly considered as a possible brain injury mechanism during contact sports and military operations. Due to this great importance, it is essential to fundamentally understand the cavitation bubble dynamics in varying biological systems. In this dissertation, experimental and theoretical characterization of cavitation dynamics in soft matters from tissue simulant soft gels (e.g., agar, agarose, and gelatin) to actual live cells are performed. First, cavitation nucleation and bubble growth in different types of tissue simulants are studied under translation impact. The critical acceleration that corresponds to onset of cavitation bubble burst is measured in the soft gels and individual gel types indicate significantly different trends in the critical acceleration and bubble shape (e.g., A gel-specific sphere-to-saucer transition) with increasing gel stiffness. Possible underlying mechanisms of the experimental observations are provided in the concepts of a damaged zone and crack propagation. This study sheds light on potential links between traumatic brain injuries and cavitation bubbles induced by translational acceleration, the overlooked mechanism in the literature.

Second, a drop-tower-based repetitive impact tester is newly designed to mimic biological systems under a wide range of impact conditions including high strain rate as well as repeated loadings. Theoretical approach based on a two-degree-of-freedom mass-spring-damper model simulates the transient dynamic response of the system with experimental validations. As one of main implications, a novel noncontact detecting method is developed to capture initial cavitation nucleation during successive drop events. This study also observes impact characteristics dependent cavitation bubble responses, which have not been characterized by other methods (e.g., laser or ultrasound induced cavitation rheology).

Finally, although significant efforts have been made in the dynamic response of tissue simulants, there is a huge knowledge gap between the soft gels and actual live cells due to the lack of the experimental capability and of knowledge for complicated cell responses. Newly designed in vitro experimental setup and systematic characterization of specific cell types, i.e., Hs27 fibroblasts, enable a testing of spatio-temporal responses of cells under mechanical impact by controlling their static and dynamic behaviors. "

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