数学与系统科学研究院

计算数学所定期学术报告

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报告题目：

Shock-induced micro-spalling: multiscale modeling and simulations

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报告地点： 数学院南楼二层

204 教室

Abstract:

Micro-spalling is a shock-induced fragmentation phenomenon which has been observed in several important modern industrial applications such as inertial confinement fusion and laser-shock surface micromachining. The distinct feature of micro-spalling is that it involves not only mechanical deformation and damage but also dynamical melting. These complex processes occur simultaneously and couple witheach other in characteristic time-scales less than sub-microseconds. Modeling micro-spalling is beyond the scope of traditional damage mechanics which ignores the kinetics of solid-liquid transformation.

In this talk, we introduce a powerful spalling model that covers transition from classical solid spalling to melting-related micro-spalling, through explicitly coupling hydro-elastic-plastic-damage mechanics with high-pressure melting kinetics. A novel adaptive mean-field homogenization theory is developed to evaluate the influences of (partial) melting and damage on macroscopic mechanical properties. Melting kinetics under transient conditions is developed by generalizing the isothermal coupled-homogeneous-heterogeneous melting kinetics model. Damage evolution law involving temperature effects and melting effects is established by extending the nucleation-and-growth model. Grain-size effects on melting and damage kinetics are incorporated.

Numerical algorithms for the complex model are designed and implemented into a finite element code. After that, the model is firstly tested under uniaxial deformation at constant strain rates. The tests confirm the capabilities of the model for capturing complex mechanical and physical processes and their coupling effects involved in micro-spalling. Then simulations of plate impact tests are carried out and compared to spalling experiments on aluminum. The simulations reproduce experimental measurements of spall strengths at a wide range of initial temperature covering the melting temperature in both single-crystal and polycrystalline aluminum. In particular, it naturally predicts the experiment-detected anomalous high spall strength of single-crystals as the initial temperature approaches the melting point.

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