22nd IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Impact-Induced Mission Effects and Risk Assessments (3)

Author: Dr. Changfang Zhao
Tsinghua University, China

Dr. Hao Liu
Tsinghua University, China
Dr. Chen Liu
Harbin Institute of Technology, China
Dr. Kebin Zhang
China
Prof. Jianlin Zhong
Nanjing University of Science and Technology, China
Prof. Guigao Le
Nanjing University of Science and Technology, China

CFRP CONSTITUTIVE MODEL CONSIDERING THE IMPACT ADIABATIC AND ITS EXTREME IMPACT BEHAVIOR IN THE SPACE ENVIRONMENT

Abstract

At any time, the pace of space exploration has never stopped. In recent years, thanks to the rapid progress of space science and technology, satellites, probes, stations and other man-made equipment have been launched into space one after another, and manned space activities have become frequent. It is important to note that lightweight is still a major requirement for these equipment, as a lower launch weight allows more loads to be carried. Carbon fiber reinforced plastic (CFRP) is one of the lightweight, high strength materials commonly used in space. As a key component of spacecraft, it will inevitably experience high-speed collision events with space debris and waste recycling during operation in space, leading to more complex thermodynamic problems. In this study, a method to construct the CFRP constitutive under ultra-high strain rate impact was reported by identifying the strain rate state, generating the adiabatic temperature and modifying the stiffness matrix. In the low strain rate compression state, the initial nonlinearity caused by material defects was described by introducing the initial nonlinear modulus increasing factor. In the high strain rate impact state, the nonlinear high strain rate strengthening effect was described by introducing the stress and strain dynamic strengthening factors based on the mechanical behavior under the reference strain rate. Based on the instantaneous temperature rise obtained from the impact adiabatic equation, the mechanical-thermal coupling effect was described by considering the influence of temperature on modulus and strength. Under the ultra-high strain rate impact state, the mechanical behavior of non-progressive damage and adiabatic shear failure was described by introducing the equation of state and the wave motion dependent failure criterion. Using incremental constitutive logic, a user-defined material subroutine was developed and feasibility verification was performed in conjunction with the experiment. The subroutine was then used to predict the high-speed impact of space fragments on the CFRP structure and the results show that the distribution of adiabatic temperature and damage varies with strain rate. The failure mode of CFRP is related to the size of the fragment, and its shear fracture and impact crushing have critical dimensions. This research work includes the establishment method of the constitutive of CFRP under high and low strain rate states, which provides a design reference for some extreme space collision events.