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Space Structures I Design, Development and Verification (Launch Vehicles and Space Vehicles, including their Mechanical/Thermal/ Fluidic Systems) (1)

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PREDICTION OF THERMO-MECHANICAL STATE OF REENTRY CAPSULE BASED ON LIMITED SENSORS

Abstract

The integration of various novel materials and manufacturing techniques has led to an increased complexity in the structural damage patterns of modern reentry capsules. This complexity becomes particularly evident when considering the structural response states under the extreme thermo-mechanical conditions during reentry. Therefore, an accurate thermo-mechanical state prediction (TMSP) model of the reentry capsules is crucial for its safety. In this study, a coupled thermo-mechanical model of the thermal protection shell and crew cabin structure for a specific reentry capsule is established. Based on the engineering algorithms and finite element methods, the thermo-mechanical response is obtained and used as samples for the establishment of the TMSP model. The Back Propagation Neural Network (BPNN) method is used in this model to establish a mapping from limited sensor data to the stress-temperature field data of the entire structure. To improve the modeling efficiency of BPNN, the Proper Orthogonal Decomposition (POD) method is used to reduce the order of sample data. Additionally, to balance the contradiction between measurement cost and prediction accuracy, an optimization approach for the sensor layout design is proposed. The results show that the thermo-mechanical state of the reentry capsule can be accurately predicted by the TMSP model based on POD and BPNN methods. Furthermore, through an optimized sensor layout scheme, it is possible to achieve a reduction in the number of sensors by approximately 50% with the same level of prediction accuracy.