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A MULTI-SCALE METHOD OF MECHANICAL AND THERMAL COUPLING ANALYSIS FOR THERMAL PROTECTION STRUCTURE

Abstract

The multilayered thermal protection structures are widely used in reusable launch vehicles of space transportation which have multi-scale characteristics in the heat transfer and strength problems. For decreasing the computational scale in the mechanical and thermal coupling analysis, a computationally efficient multi-scale method is proposed to construct complicated boundary conditions based on the sub-structural boundary assumption, which can simplify the complex multilayered thermal protection structure to a reducible beam and plate structure dimensionally. Moreover, the proposed method can construct various boundary conditions flexibly by the transformation matrix, especially the rational higher-order displacement functions with thermal expansion additional degree of freedom in thickness direction, which can be easily extended into the transient analysis by the time integration algorithm. The relationship between the proposed method and the extended multi-scale finite element method (EMsFEM) is also discussed in this paper. Finally, some steady and transient numerical examples are analyzed including multilayered thermal protection structures, which reveal the high accuracy and efficiency of the method.