A variable-size iFEM for real time shape sensing of a large honeycomb antenna panel – LATAM-SHM 2023

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ABSTRACT

Spaceborne antennas experience time-varying and substantial thermal excitations while in orbital operation, which leads to unforeseeable deformations. If this deformation is not controlled, it will affect the accuracy of the antenna contour and reduce the efficiency of signal transmission and reception capabilities. Employing deformation monitoring technology that relies on strain information can enable real-time tracking of thermal deformations in large spaceborne antennas while in orbit, ultimately ensuring optimal satellite performance. The inverse finite element method (iFEM) is a popular shape-sensing reconstruction algorithm that is utilized to deduce the continuous displacement field of a structure based on measured discrete strain data. This method is based on the principle of least squares and only requires the measurement of strain, geometric dimensions, and boundary conditions to achieve accurate reconstruction. However, in the context of large-scale structural deformation reconstruction, achieving high accuracy necessitates dividing a substantial number of inverse elements, resulting in computational complexity and low efficiency. In response to the challenges mentioned above, this paper proposed a variable-size iFEM tailored for large-scale antenna structures. According to accuracy requirements, inverse elements are divided according to deformation gradients to control the deformation range in the discrete domain, and optimization of inverse element division based on the structure deformation mode is achieved. In this work, a large honeycomb antenna panel was studied. Firstly, a high-fidelity finite element model of the honeycomb antenna panel was established to calculate the strain and displacement under the uniformly distributed thermal load. Subsequently, iFEM was employed to calculate the reconstruction displacements, utilizing the FEM strain as the algorithm input and the FEM displacement as the reference displacement. The reconstructed deformation of the antenna panel using both uniform-size and variable-size inverse element division based on the displacement gradient was compared. The results show that the presented variable-size iFEM exhibits higher real-time performance than the conventional uniform-size iFEM when they have approximate reconstruction accuracy.