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Deployment analysis for space cable net structures with varying topologies and parameters

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Abstract: Cable net structures are widely used in space deployable devices. For truss-mesh reflector antennas, the cable net turns from a relaxed stage to a full tensioned state and forms a required functional surface during the deployment process. The deployment analysis of cable net structures is indispensable to the calculation of the deploying force, and meanwhile, it also provides valuable references for the cable net design. But unfortunately, at present there is still no effective way to analyze the deployment process of space cable net structures with varying topologies and parameters. In this paper, the parameterized deployment analysis for space cable net structures considering geometric nonlinearity, topological diversity and the cable's sag is presented. Firstly, the cable net is discretized into finite cable elements, and serial numbering rule is proposed to obtain the corresponding topological matrix. Then, governing equations are formulated and further assembled by matrix transformation theory, and trust-region algorithm is used to solve the system equations. In the calculating, the cable's stiffness is determined by its slack or tensional state, and the coupling between the deployment of trusses and the deformation of cable nets are considered by updating the coordinate values of boundary nodes in each time step. We use our method to analyze three case studies and the results agree with experiment data in previous literature. The elastic energies of cable nets during the deployment are calculated and the "self-stretching" process is discussed. The deployment analysis in this research is general for space cable net structures used in mesh reflector antennas.

Key words: Cable net structure; Mesh reflector antenna; Geometric nonlinearity; Deployment analysis

1. Introduction

The widespread usage of cable structures in architecture and engineering is not only due to the aesthetic value, but also for their advantages of large spans, light weight, small stowage volumes and high stiffness [1]. Cable nets, as one of the cable structures, have been applied in space devices in recent years [2], such as deployable mesh reflector antennas ETS-VIII [3] and THURAYA 1-3 [4, 5] for satellite communication, MBSAT for global broadcasting [6], NEXRAD in Space (NIS) for remote sensing and climate forecasting, and GEO-mobile satellites by Boeing for mobile communications.

Space cable net structures are mainly used in deployable mesh antennas in many configurations that differ by their supports [7]. A knitted lightweight metallic mesh is attached to the cable net to form the reflector surface. The