Thermally Induced Oscillations of an Inflatable Space Structure with a Repeated Element Pattern

Armaghan Salehian

University of Waterloo, Department Mechanical and Mechatronics Engineering, Waterloo, ON, Canada, N2L 3G1

Daniel J. Inman

Virginia Tech, Department of Mechanical Engineering, Blacksburg, VA, USA, 24061

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Presented here is the analysis of thermally induced vibration of an inflatable space structure using the homogenization method. It is shown that this technique can effectively be used to quantify the thermal oscillations in such structures.

NOMENCLATURE

A_L, A_d, A_b	cross-sectional area of longerons, diagonals, and battens
c_L, c_d, c_b	thermal capacity of longerons, diagonals, and battens
E_L, E_d, E_b	modulus of elasticity of longerons, diagonals, and battens
GJ_{eq}	equivalent product of the shear modulus and moment of inertia of the truss
K	thermal conductivity
KE	kinetic energy of the fundamental element
L_{tot}	total length of the truss
L_L, L_d, L_b	length of longerons, diagonals, battens
m_L, m_d, m_b	mass of longerons, diagonals, and battens
t	time
U	strain energy of the fundamental element
u, v, w	displacement components of the cross-section in (x, y, z) directions
u_0, v_0, w_0	displacement components evaluated at the center of the middle cross-section
x, y, z	Cartesian coordinates
θ, φ, ψ	rotational degrees of freedom of the cross-section along (x, y, z)
$\varepsilon_{x,0}$, $\varepsilon_{y,0}$, $\varepsilon_{z,0}$, $\varepsilon_{xy,0}$, $\varepsilon_{xz,0}$, $\varepsilon_{yz,0}$	strain components evaluated at the center of the cross-section
$\kappa_{x,0}$, $\kappa_{y,0}$, $\kappa_{z,0}$	curvatures evaluated at the center of the cross-section
κ	thermal diffusivity
ρJ_{eq}	equivalent product of the density and moment of inertia of the truss
ρ_L, ρ_d, ρ_b	density of longerons, diagonals, and battens

1. INTRODUCTION

The successful operation of any system requires a precise understanding of the disturbances and its design criteria. For most space structures, the critical loads that the satellites encounter during launch are more important; the smaller loads during the operation are of secondary importance. For inflatable structures, however, which are stowed during launch and deployed upon reaching the destination orbit, the critical loads in the space environment become of particular importance. A complete list of different kinds of disturbances in space environment is given by Davis and Agnes.[1]

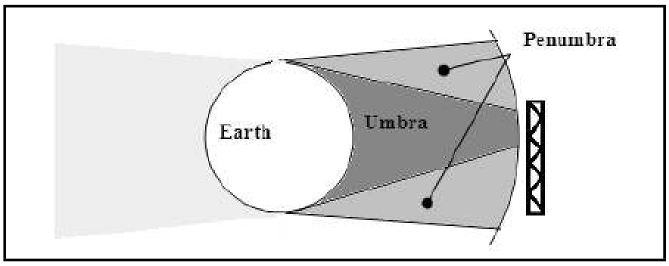

Figure 1. Schematic view of the Earth shadow on the Satellite (full and partial shadows).

One of the most important environmental disturbances is thermal loading. There are three known sources of radiation in space environment: (1) direct solar, (2) earth solar reflection (albedo), and (3) direct earth (infrared). The effects of the last two are less significant for orbits higher than the LEO orbit.[2] When a satellite goes through an eclipse, rapid temperature changes due to direct solar radiation are induced to the system. According to Thornton et. al.[3], the solar heating experienced by a satellite can change up to 95%, dependent upon how long the transitions through the penumbra (partial Earth shadow) and umbra (full Earth shadow) takes (see Fig. 1). As a result, the torques and moments induced in the system can increase the jitter, corrupt the pointing accuracy of the spacecraft, and can cause spacecraft attitude problems, quasi-static deformations, unexpected thermal oscillations, and in some cases even thermal flutter or instability. Figure 2 shows the Solar Array Flight Experiment (SAFE) that had unexpected deflections after its transition thorough the Earth shadow. Some of the problems with solar radiation in space, such as thermally induced vibrations, thermal buckling, surface degradation, and thermal stress, are discussed by Graham, Kraus, and Schmit and Hanawaly.[4–6]

The following literature reveals the previous research and