Study of China Space Station Coupling Dynamics Evolution Under Condition of Large Deformation

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1. Introduction

The concept of "evolution" comes from the field of biology, and usually, it is used to describe the constitution and succession of a community. However, systems describing spacecraft dynamics also have behaviors similar to those in biology, according to previous research. In addition, dynamic evolution of spacecraft has not been previously researched but it is a better way to reveal the essential characteristics of dynamic systems. In this paper, the China Space Station has been taken as an example and coupled-structure vibration-attitude dynamics and control of the spacecraft will be discussed.

Under the condition of large deformation, the spacecraft has a complex interaction between attitude movement and flexible appendage vibration response. On this aspect, many authors devote their time to analysis of the mechanism of coupling dynamics.

2. Body of abstract

In this paper, the dynamics equation of the Spacecraft has been set up using vector mechanics. Later, several equations describing the attitude dynamics of the spacecraft are deduced. Third, simulation of the evolution of the coupled-structure vibration-attitude dynamics of the China Space Station (CSS) has been researched. Simulation results reveal the generating mechanism and the evolutive law of the coupled-structure vibration-attitude dynamics of the spacecraft. Finally, a simplified experimental platform has been set up.

3. Equations, figures, and tables

Rolling Movement

$$\sum_{i,k}\left[m_{ik}\left|\vec{V}_T\right|\left|\dot{\vec{u}}_{ik}\right|+m_{ik}\left|\left(\dot{\vec{u}}_{ik}+\dot{\vec{V}}_T\right)\right|\left|\vec{w}_{ik}\right|\right]+T_s = \left\{\sum_{i,k}m_{ik}\left|\vec{u}_{ik}\right|^2+\vec{I}_T\right\}\ddot{\theta}_x+\sum_{i,k}2m_{ik}\left|\dot{\vec{u}}_{ik}\right|\left|\vec{u}_{ik}\right|\dot{\theta}_x \quad (1)$$

Yawing Movement

$$\sum_{i,k}\left[m_{ik}\left|\vec{V}_T\right|\left|\ddot{\vec{u}}_{ik}\right|\right]+T_s=\left\{\sum_{i,k}m_{ik}\left|\vec{u}_{ik}\right|^2+\vec{I}_T-\sum_{i,k}m_{ik}\left|\vec{l}_{ik}\right|\left|\vec{u}_{ik}\right|\right\}\ddot{\theta}_z+\left\{\sum_{i,k}2m_{ik}\left[\left(\left|\vec{u}_{ik}\right|\left|\dot{\vec{u}}_{ik}\right|\right)\right]-\sum_{i,k}m_{ik}\left|\dot{\vec{u}}_{ik}\right|\left|\vec{w}_{ik}\right|\right\}\dot{\theta}_z \quad (2)$$

Pitching Movement

$$\sum_{i,k}\left[m_{ik}\left|\vec{V}_T\right|\left|\dot{\vec{u}}_{ik}\right|+m_{ik}\left|\left(\dot{\vec{u}}_{ik}+\dot{\vec{V}}_T\right)\right|\left|\vec{w}_{ik}\right|\right]+T_s = \left\{\sum_{i,k}m_{ik}\left|\vec{u}_{ik}\right|^2+\vec{I}_T-\sum_{i,k}m_{ik}\left|\vec{u}_{ik}\right|\left|\vec{w}_{ik}\right|\right\}\ddot{\theta}_y+\sum_{i,k}m_{ik}\left[2\left|\vec{u}_{ik}\right|\left|\dot{\vec{u}}_{ik}\right|-\left|\vec{w}_{ik}\right|\left|\dot{\vec{u}}_{ik}\right|\right]\dot{\theta}_y \quad (3)$$

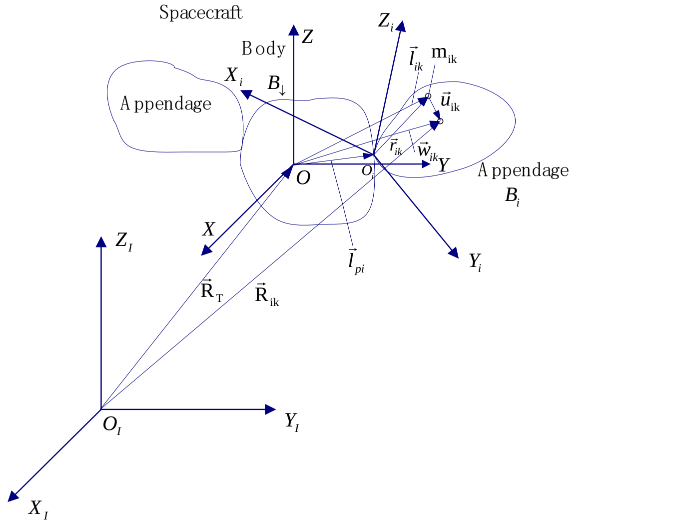

Fig.1 Coordinated frame of spacecraft with central rigid body and several flexible appendages

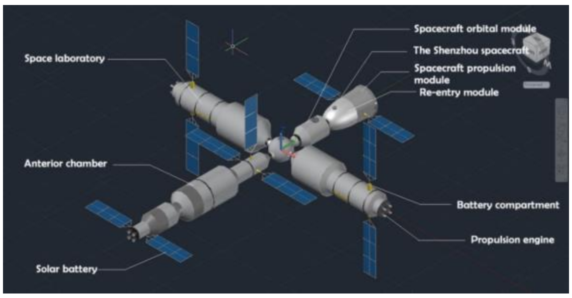

Figure 2 China Space Station (CSS)

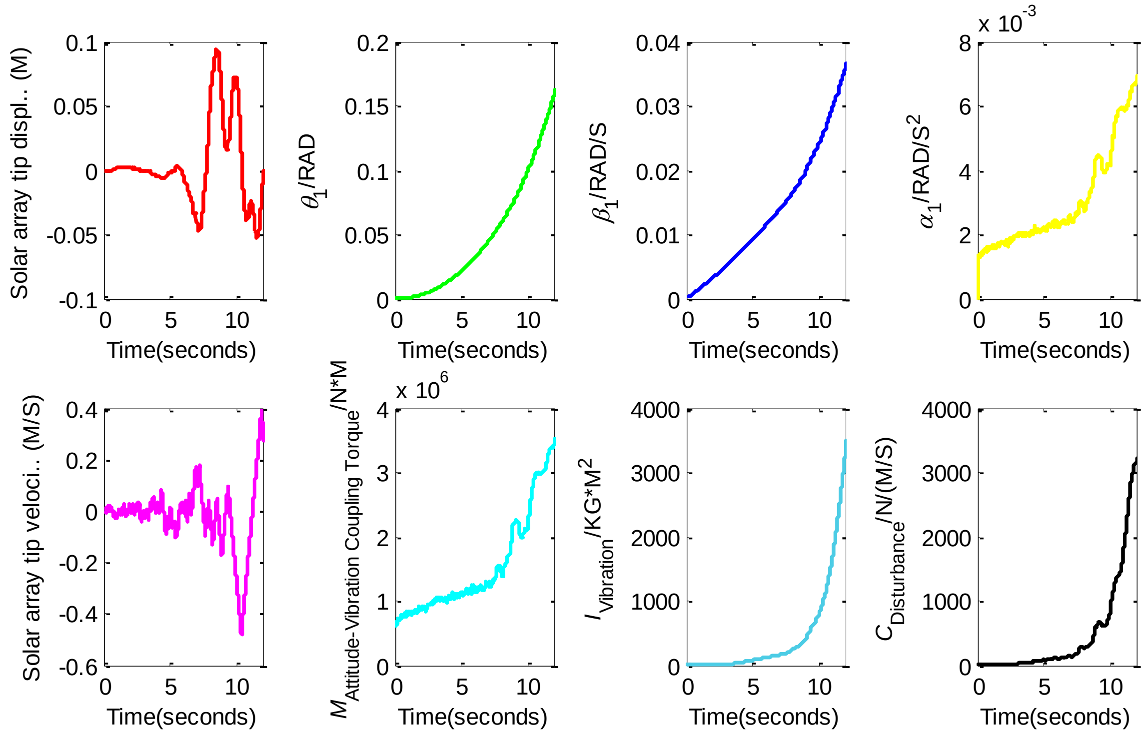

Figure 3 Coupled structure vibration-attitude dynamics evolution of China Space Station (CSS-Rolling)

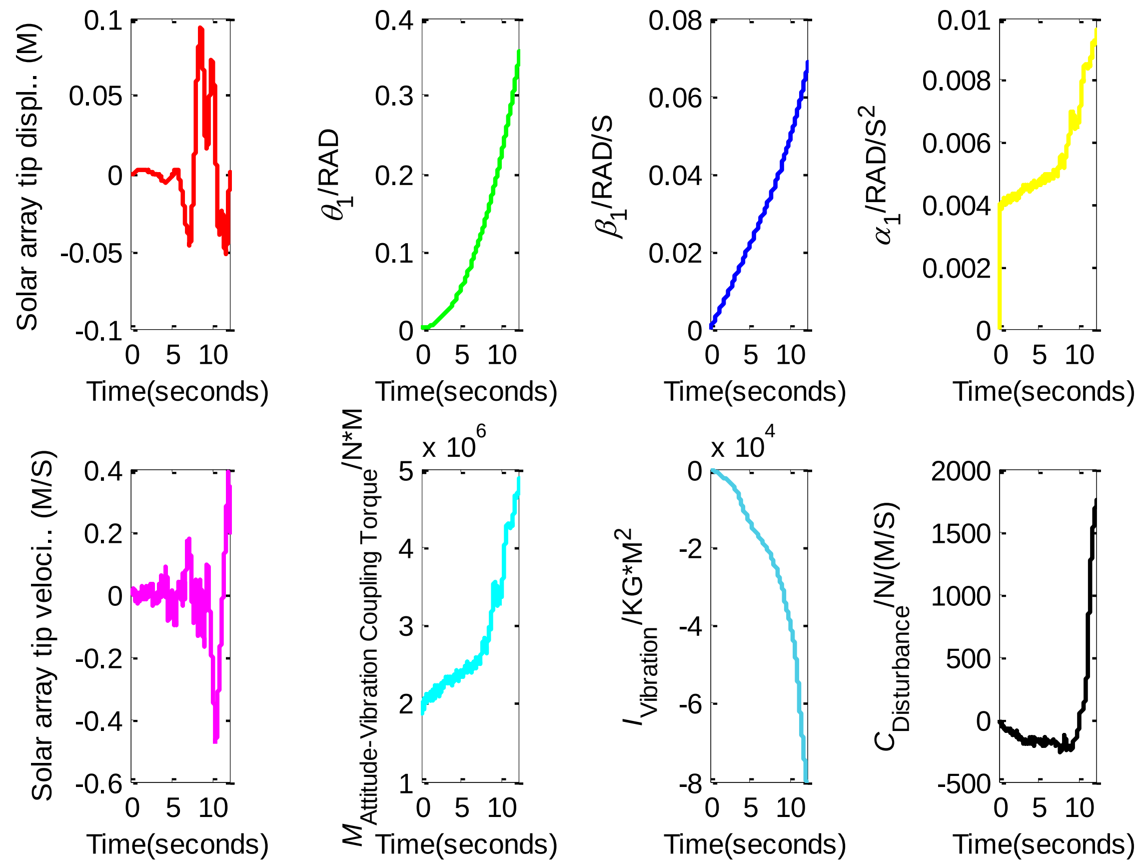

Figure 4 Coupled structure vibration-attitude dynamics evolution of China Space Station (CSS-Pitching)

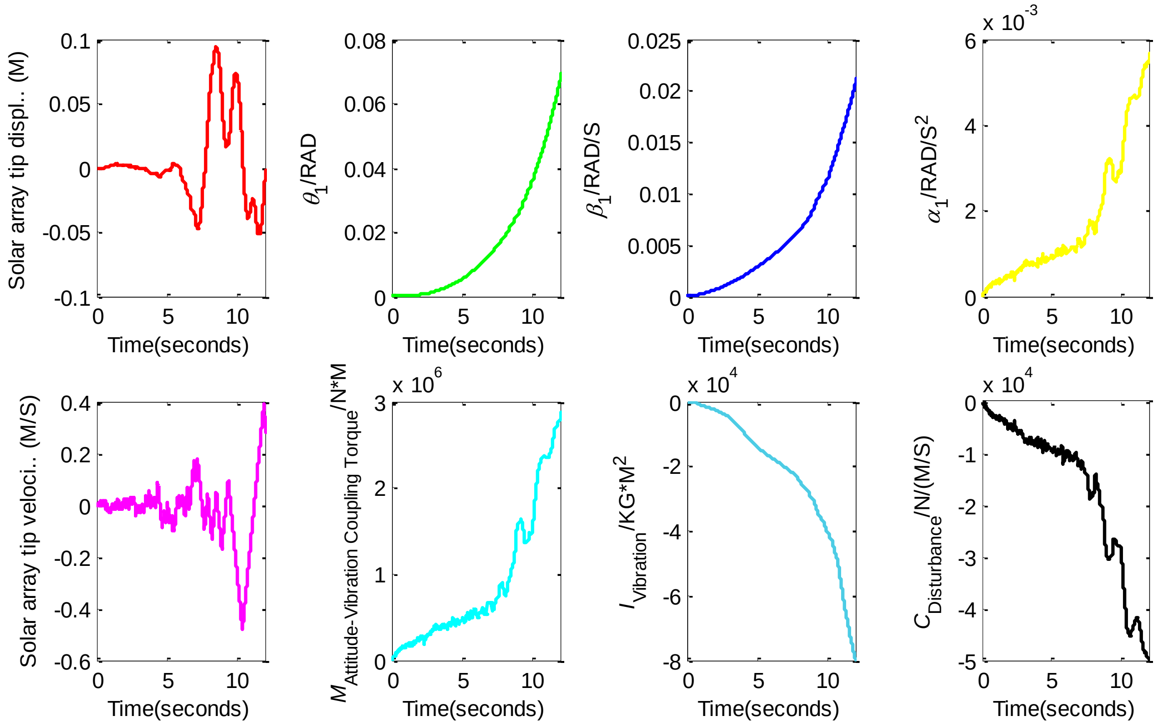

Figure 5 Coupled structure vibration-attitude dynamics evolution of China Space Station (CSS-Yawing)

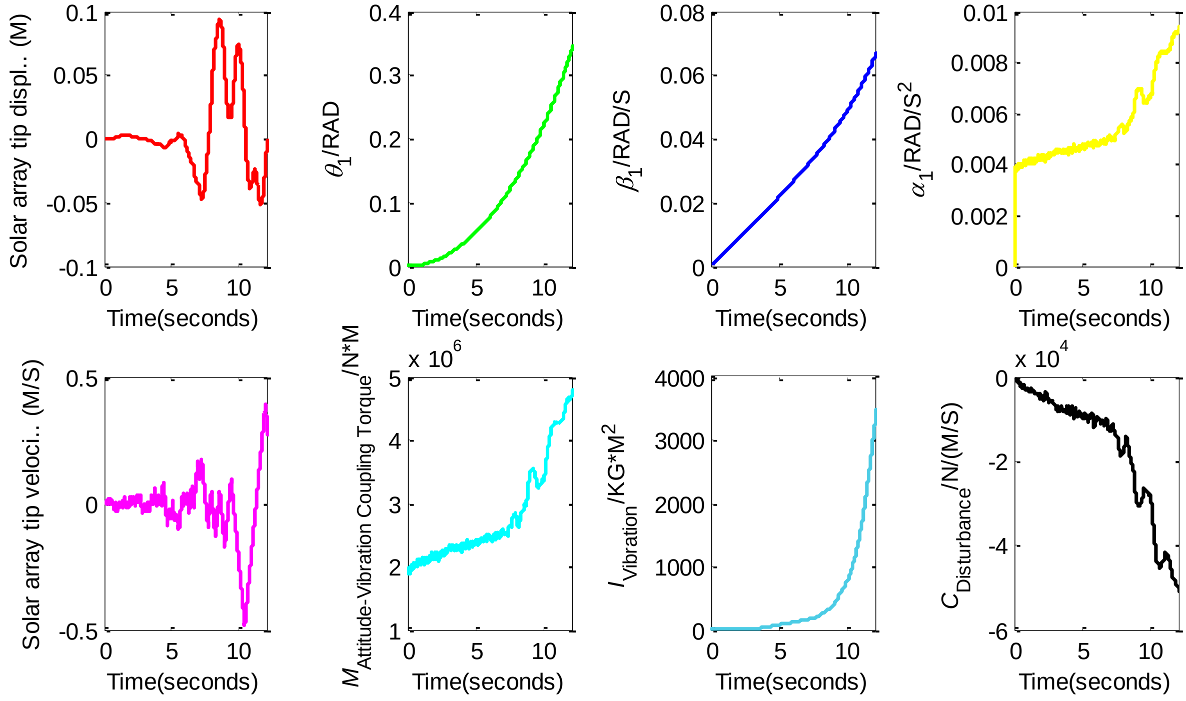

Figure 6 Coupled structure vibration-attitude dynamics evolution of China Space Station (CSS-Transitions)

4. Results and Discussion

From Fig. 7-10, the dynamical evolution of spacecraft has been revealed, and essential characteristics of dynamics systems have been shown. In this paper, the China Space Station has been taken as an example, and coupled-structure vibration-attitude dynamics and control of spacecraft have been discussed. Under the condition of large degrees of deformation, it has been shown that spacecraft have a complex interaction between attitudinal movement and flexible-appendage vibration response.

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