Suspension nonlinear analysis and active vibration control of an aerospace structure

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Abstract. Aerospace structure is multi degree of freedom system, which contains complex dynamic characteristics such as time-varying parameters, geometric nonlinearity, gap nonlinearity and so on. According to the law of motion of nonlinear pendulum and considering the influence of geometric nonlinearity of medium swing angle, the relationship between vibration frequency and nonlinear term is obtained by perturbation method, and the influence of parameters on vibration characteristics is studied. Then, the active vibration control system of aerospace structure is established. Variable step size LMS adaptive filtering algorithm or T-S fuzzy control algorithm are used to calculate the control signal, and considering the influence of geometric nonlinearity, the actuator is used to suppress the vibration of the suspended structure. Finally, the amplitude of vibration response decreases by more than 75% under transient excitation and steady-state excitation.

Introduction

Gravity makes the hoop antenna produce serious static deformation, which increases the difficulty of mechanical test and affects the accuracy of vibration control. In order to simulate low gravity environment, suspension method is applied to gravity unloading. Rope suspension has the advantages of large simulation range and no additional inertia[1]. However, the nonlinearity of the suspension cable interferes with the vibration characteristics. Under the premise that the hoop antenna has complex multi-mode and nonlinear factors[2], whether it can effectively suppress the vibration is a mechanical problem.

The advantages of hanging the spacecraft by ropes are simple, reliable and small additional stiffness. If the rope length is long enough, low gravity or even zero gravity simulation of the spacecraft can be realized in both active and passive ways. However, the rope used in the suspension device is slender and soft, and the mechanical model is simplified as a string. In order to realize gravity unloading and follow-up movement, the suspension device inevitably produces vibration problems. As the rope (string) vibrates laterally, the nonlinear parameters significantly affect the dynamic characteristics of the rope (string)[3]. Therefore, according to the law of motion of nonlinear pendulum and considering the influence of geometric nonlinearity of medium swing angle, the oscillation equation with nonlinear term is established.

$$ml\ddot{\theta}\left(t^*\right)+mg\sin\theta\left(t^*\right)+T\cos\theta\left(t^*\right)=0 \tag{1}$$

Assuming a small swing angle motion, sin θ ≈ θ, it is simplified to a linear system,

$$\ddot{\theta}\left(t\right)+\frac{g}{l}\theta\left(t\right)-\frac{g}{6l}\theta^3\left(t\right)=0 \tag{2}$$

If the swing angle is medium, Taylor expansion is used,

$$\ddot{\theta}\left(t^*\right)+\frac{g}{l}\theta\left(t^*\right)-\frac{T}{2ml}\theta^2\left(t^*\right)-\frac{g}{6l}\theta^3\left(t^*\right)=-\frac{T}{ml} \tag{3}$$

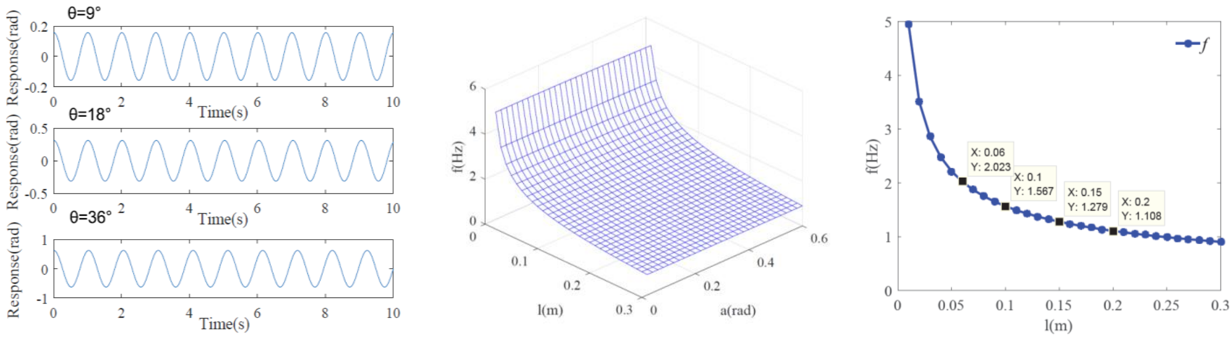

Figure 1: Relationship between vibration frequency, swing angle and rope length

References

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