Planar nonlinear dynamic analysis of cable-stayed bridge considering support stiffness

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Abstract. Support stiffness is one of important factors on structure dynamics. Considering the vertical support stiffness, a multi-cable stayed shallow arch model of the cable-stayed bridge is established. Its differential equation governing the planar motion of cables and the shallow arch and the corresponding boundary conditions are derived by Hamilton's principle. Firstly, the in-plane free vibration of the system is explored in order to find the modal functions and the possible internal resonances of nonlinear dynamics. Then, the 1:2:2 internal resonance among the first modes of the shallow arch and two cables are investigated by the multiple time scale method and pseudo arclength algorithm. Meanwhile, the frequency-/force-response curves are used to explore the nonlinear behaviours of the system, especially the influence of vertical support stiffness, excitation frequency and amplitude on the internal resonance of the system is considered. To a certain extent, the support stiffness can reduce the response amplitudes of members by absorbing some energy from excitation.

Introduction

As one of the popular bridges, cable-stayed bridge is of the large spanning ability, elegant appearance and mature method of construction. However, it is sensitive to external load due to its lower stiffness and the complex environments, which has been attracting many researchers. In order to understand its internal mechanism of dynamics and find method to control its large vibration, many scholars have been devoted to the study on dynamics of the cable-stayed bridge. Fujino et al. [1] established a three-degree-of freedom model of a cable-stayed beam and studied its dynamic properties. Based on a cable-stayed beam model, Gattulli et al.[2] investigated the parametric influence on linear and nonlinear behaviors of the cable-stayed bridge. Lenci and Ruzziconi [3] investigated the nonlinear vibrations in the single-mode dynamics of a cable-supported beam. In order to study the interaction among members of cable-stayed bridge, especially among cables, Kang et al. [4] established a double cable-stayed shallow arch model of the cable-stayed bridge and studied 1:1:1 the internal resonance analysis among the shallow arch and two cables. It is observed that there is no work on effect of support stiffness on nonlinear dynamics of the cable-stayed bridge because that the boundary condition is considered ideally. Hence, the support elasticity should be considered when the dynamics of cable-stayed bridge is concerned, especially for nonlinear dynamics, which is our motivation in this work. In order to explore the effect of elasticity of support on the nonlinear dynamics of cable-stayed bridge, a multi-cable stayed shallow arch model with vertically elastic support as shown in Fig.1 will be proposed and its dynamic theory and properties will be examined systematically.

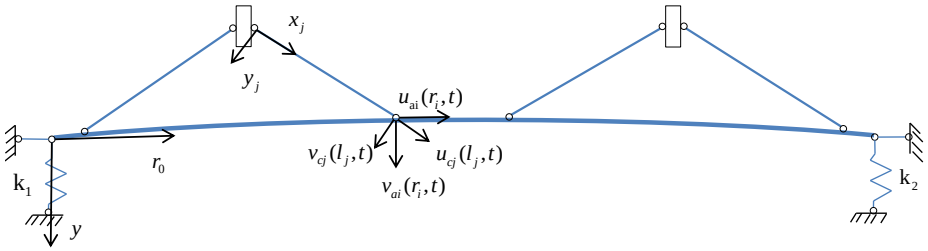

Figure 1: Multi-cable stayed shallow arch model with vertical elastic support of cable-stayed bridge.

Results and conclusions

The linear eigenvalue problem is solved to find the effect of elastic support on the natural frequencies and corresponding modes. The possible internal resonance among these modes of members is also examined, especially for the case of 1:2:2 internal resonance. It is found that with decreasing of the support stiffness, its displacement increases and more energy is absorbed, which results in less energy transferred to the shallow arch and cable, and the vibration amplitude of the cable and the shallow arch decreases.

References

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