Damping augmentation of a rotating beam-tendon system via internally placed spring-damper elements

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ABSTRACT

A guided tendon concept in the context of rotating helicopter blades is put forward to modify the dynamics in order to enable the rotorcraft to work in a wider range of working conditions; however, some blade modes are insensitive to the axial force. In this paper, the damping augmentation of a rotating Timoshenko beam axially loaded by a tendon via placing spring-damper elements is studied in the flapping direction, where the spring-damper elements that replace the rigid attachments are placed at some spanwise locations to guide the tendon through the beam. The equations of motion are derived by means of Lagrange’s equation with the energy expressions. In vacuo modal analysis is carried out and the model is validated against the experiment for a non-rotating case with a rigid attachment. A damping model is then proposed and validated against the experiment to characterise the damping properties of the beam-dominated modes. It is found that with the use of spring-damper elements, the damping ratios and damped frequencies of the beam-dominated modes can be increased significantly. With the use of one spring-damper element, the location achieving maximum damping ratio is different for different beam-dominated modes. Adding the number of spring-damper elements only leads to a small increase of the maximum damping ratios for the studied beam-dominated modes. Compared with rigid attachments, the spring-damper elements can realise the same function of increasing the frequencies of the tendon-dominated modes, but decrease the critical force below which the axial force can be applied. By applying spring-damper elements to the active tendon concept, the damping ratios of the blade modes that are insensitive to the axial force can be increased significantly to mitigate the resonant vibration.

1. Introduction

The rotorcraft with variable rotor speed can bring about some benefits, e.g., reduced noise emission and fuel consumption. One of the main drawbacks is the resonant vibration due to insufficient separation between the rotor harmonics and the natural frequencies of the blades. The idea of incorporating a tendon in the rotorcraft blade to control its dynamics was first put forward in [1] and further studied within the SABRE project [2] with the motivation of avoiding and suppressing the resonant vibration.

For the theoretical study, the rotorcraft blade is usually modelled as a beam. By applying a compressive load to the beam (or blade) via an embedded tendon, the natural frequencies of many beam-dominated modes can be reduced so as to increase the separation between the natural frequencies and the rotor harmonics [3]. Because of the incorporation of a tendon in the system, several...