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Nonlinear Dynamics and Control of Moving Slender Continua Subject to Periodic Excitations

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Abstract: Tall structures often sway with large amplitude and low frequency due to resonance conditions induced by wind loads and long-period seismic excitations. These sources of excitation affect the performance of vertical transportation systems (VTS) deployed in these structures. The fundamental natural frequencies of tall buildings fall within the frequency range of the wind and seismic excitations and the sway motions form the excitation mechanism which acts upon the VTS. Particularly affected are long moving slender structural components such as the suspension ropes, compensating cables and travelling cables. Complex nonlinear resonance interactions arise in the system when the frequency of the excitation is tuned to the natural frequencies of those elements. The methods to mitigate the effects of dynamic interactions in a high-rise VTS involve the application of passive and active control devices attached at the compensation sheave assembly. In this paper a numerical simulation model is presented to predict and analyse the resonance behaviour of the system equipped with a nonlinear damper-actuator system. The performance and characteristics of this device can then be optimized and adjusted to minimize the effects of adverse dynamic responses of the system.

Keywords: tall structure, slender continua, nonlinear vibration, control

1. Multibody dynamics model

Fig. 1 shows a dynamic model of a high-rise VTS system deployed within a vertical cantilever host structure subject to ground motions $s_r(t)$, $r = 1,2$ in the in-plane and out-of-plane directions, respectively [1]. The structure undergoes bending elastic deformations with the in-plane and out-of-plane displacements at the top end ($z = z_0$) denoted as $w_r(t)$, where $r = 1,2$, respectively. The equations of motion of the system are formed a system of nonlinear partial differential equations. The dynamic response of the system is defined in terms of lateral displacements of the slender continua elements denoted as $v_i\left(x_i,t\right), w_i\left(x_i,t\right)$, i = 1,2..., 4, the longitudinal displacements of the dicrete massess represented by q_{M1}, q_{M2} and q_{M3}, with the corresponding rotations θ_{M3}.

2. Results and Conclusions

The results presented in the paper demonstrate the resonance behaviour of the system [2,3]. The resonance frequencies of the slender continua can be shifted / changed by the use of different masses of the compensating sheave assembly. The frequencies of the suspension ropes depend on the mass/ weight of the car (and the corresponding mass of the counterweight) as well as on the car loading conditions. The characteristics of the damping -actuator device can be optimised and adjusted to minimize the effects of adverse dynamic responses of the system.

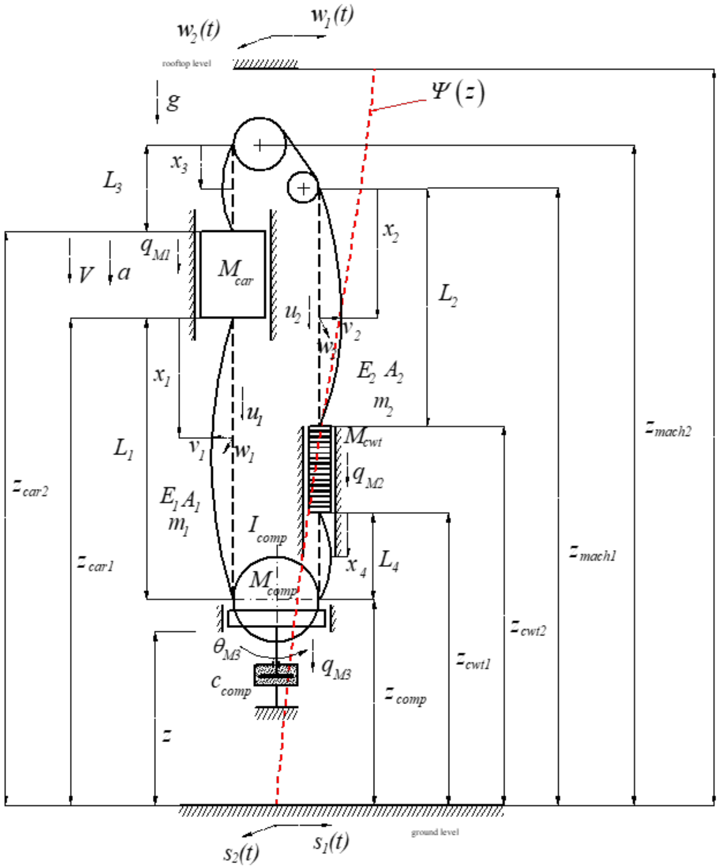

Fig. 1. Dynamic model

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