Nonlinear dynamics of a base-isolated beam under turbulent wind flow

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Abstract. A homogeneous continuous visco-elastic shear-beam, describing the dynamics of base-isolated tall buildings exposed to a uniformly distributed turbulent wind flow, is studied. The shear beam is constrained at the bottom end by a nonlinear visco-elastic device and free at the top end. Aeroelastic forces are computed by the quasi-static theory. The steady component of wind is responsible for a Hopf bifurcation occurring at a threshold critical value; the turbulent component is responsible for parametric excitation. The interaction between the two bifurcations is studied. Critical and post-critical behaviour is analysed by applying a perturbation scheme. The mechanical performances of the structure are investigated in according to the effectiveness of the visco-elastic isolation system.

Introduction

Tall buildings are very sensitive to dynamic actions induced by wind, which causes a variety of instability phenomena, related to different kind of excitation. Depending on the nature of the loads, the different kinds of excitation can interact. Some attention has been devoted in literature to interactive aeroelastic phenomena, as galloping-parametric excitation [1-2].
In this work, interest is focused on base-isolated tall buildings, under turbulent wind flow, inducing dynamical instability (galloping). The case of steady wind was already studied by the authors [3], considering a continuous visco-elastic shear-beam homogenised model. The quasi-static theory of the aeroelastic forces was applied. By using perturbation methods, the post-critical behaviour of the isolated-beam was analysed. In this paper, the study of [3] is generalized to a turbulent wind flow, by superimposing, to the constant leading velocity, a small harmonic component. Therefore, self-excitation and parametric excitation interact, both in linear and nonlinear fields. The aim is to investigate the new mechanical performances of the structure in according to the effectiveness of the visco-elastic isolation system.

Results and discussion

A tall building of square cross-section, constituted by a multi-story shear-type frame, is isolated to the base via a nonlinear visco-elastic device. The building is modelled by an equivalent homogeneous visco-elastic beam, consisting of a planar shear-beam. The structure is subjected to a turbulent wind flow of velocity $U(t)$, uniformly distributed along its height. A scheme of the model is shown in Fig. 1.

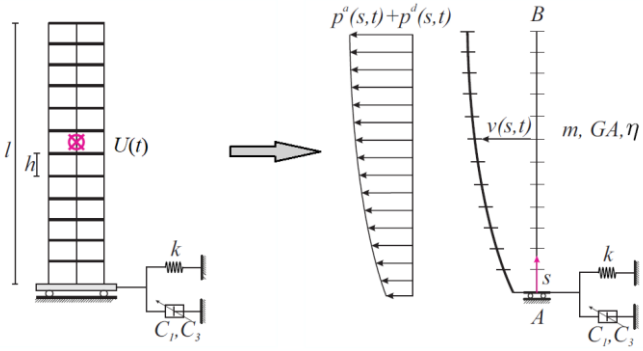

Figure 1: The equivalent base-isolated shear beam model.

Core findings and highlights of the work follow:

- The interaction between the two bifurcations is studied in a three-dimensional parameter space, made of the two wind amplitudes and the frequency of the turbulence;
- Limit-cycles (periodic motions) and tori (quasi-periodic motions) bifurcate from the trivial path;
- The study of the interaction is found to be significant to design an effective passive controller by the visco-elastic isolation system.

References

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