

OPTIMAL VIBRATION CONTROL OF GUYED MASTS

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Summary Topics considered in this paper include: dynamic properties of the mast and nonlinearities present in the problem, linearized equations governing guyed mast motion, conditions of stability, controllability and observability. Control forces are exerted by an anchored mechanism in such a way, that they change tension in guy cables. A control algorithm ensuring robust optimal control is also proposed. Finally, the paper is verified by a numerical simulation of a vibration control process.

INTRODUCTION

Guyed masts belong to a class of vibration-prone structures. Their location in open spaces together with their height reaching even a few hundred meters, make them exposed to action of strong wind pressure. It often happens, that the time of the strongest windblasts coincides with that of the heaviest icing. For that reason, safety of the structure requires a robust control scheme, which can stabilize the mast under different load configurations. Dynamic analysis of a guyed mast is complex, because of nonlinear behaviour of guy cables [1]. During recent years many control methods have been developed, but their practical application to mast-like structures still remains limited. One of the recent approaches is presented by Preumont [2]. Using massless cables, he proposed integral force feedback controller to reduce vibration of a truss structure. Another control technique of cable structures, called Active Stiffness Control, was proposed by Fujino [3] and was applied to cable-stayed bridges. Recently, the problem of damping cable vibrations by semi-active control was investigated by Spencer [4]. The objective of this paper is a numerical simulation of an active vibration control of a mast, supported by guy cables.

MECHANICAL MODEL OF THE MAST

The guyed mast is discretized, following a three-dimensional finite element approach. The column of the mast is represented by a prismatic truss of a triangular cross section (Fig. 1). A single guy cable consists of a chain of tension-only elements. One cable end is attached to the mast, and the second one to an anchored mechanism, allowing control of tension in the cable. After assembling global stiffness and mass matrix, nonlinear analysis is performed, to find static equilibrium of such a composite structure. Next, for the purpose of dynamic analysis, small amplitudes of vibrations are assumed, to obtain linearized equations of motion including both the mast and guy cables. In practise, the assumption of small vibrations should be satisfied to ensure appropriate serviceability of the structure. Then, modal transformation is used in order to reduce the model of the structure and to retain the most dominant modes only. Mode shapes of the mast are divided into two groups. The first one includes dominant motions of guy cables (symmetrical and anti-symmetrical ones), and the second group includes vibrations of both mast and cables. By using the controllability index concept it is found, that symmetrical mode shapes are very poorly controllable by actuators located at anchor points.

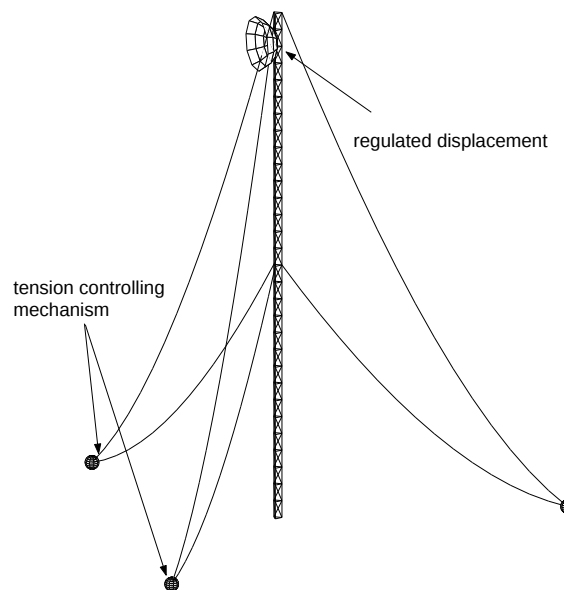


Figure 1. 3D finite element model of a guyed mast.

CONTROL SYSTEM

The designed control system of the mast is operating in varying environmental conditions. For that reason, a controller possessing dissipative properties in all possible weather conditions is chosen. One of control algorithms satisfying this property is Direct Velocity Feedback introduced by Balas [5]. In the paper, the method is applied by measuring velocity of points, at which cables are attached to the mechanism, allowing adjustment of cable tension. A positive definite selection of control gain matrix for such a collocated system is ensuring both optimal performance and robust stability. Another issue is related to external loading. Classical optimal control methods assume, that the loading has the form of an impulse in a deterministic approach, or white noise in stochastic approach. In this study, a disturbing wind force with Davenport's power spectrum is taken into consideration. Finally, the aim of the closed-loop system is to suppress transverse dynamic displacement and slope of the top of the mast.

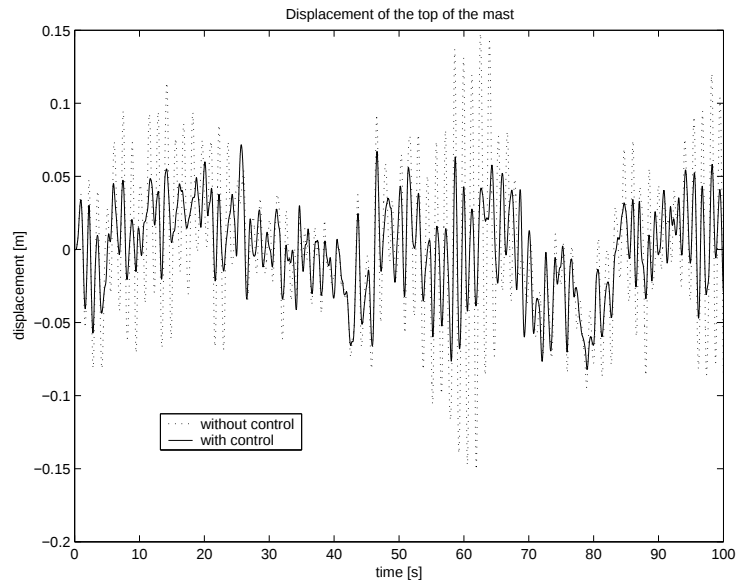


Figure 2. Dynamic response of the top of the guyed mast subjected to wind forces.

CONCLUSIONS

In the paper, a numerical investigation of the robust optimal control of vibrations of a guyed mast is presented. Results indicate, that active control system allowing adjustment of cable tension, can provide significant reduction of vibration amplitudes of the top of the mast (Fig. 2). However, it is recognized that amplitudes of guy cable vibrations are much less controllable than those of the mast.

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