Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 199 (2017) 516–521

Procedia Engineering

www.elsevier.com/locate/procedia

X International Conference on Structural Dynamics, EURODYN 2017

Dynamical analysis of various transmission line cables

Nilson Barbieri[a,b,*], Mayara Kelly Tenório Calado [a], Marcos José Mannala[c], Key Fonseca de Lima[a], Gabriel de Sant'Anna Vitor Barbieri[a]

[a] *Pontifícia Universidade Católica do Paraná, Rua Imaculada Conceição, 1155, CEP:80215-901, Curitiba-PR, Brasil*
[b] *Universidade Tecnológica Federal do Paraná, Avenida Sete de Setembro, 3165, CEP: 80230-901, Curitiba-PR, Brasil*
[c] *Institutos Lactec, Rodovia BR 116, km 98, 8813, CEP: 81530-180, Curitiba-PR, Brasil*

Abstract

The main objective of this work is the analysis of the dynamic behavior of new transmission line cables: Tern (CAA), CA 1120 and CA 6201 (alloy); with mechanical tension variable (7 to 36% of the ultimate tensile strength (UTS)) with and without the inclusion of Stockbridge dampers. In order to achieve these objectives a procedure is used based on experimental data obtained by dynamic tests and numerical data obtained through computer simulation of mathematical models (linear and nonlinear) obtained by the finite element method. For low cable load, the nonlinear behavior is accentuated and the results obtained by nonlinear modeling exhibit good accord with the experimental modal data. With an increased cable load, numeric data obtained through the linear and non-linear models are close.

Keywords: Cable, nonlinear model, vibration, modal analysis

1. Introduction

A recent survey of the cable dynamics can be found in [1]. The authors reviewed models of helical cable behavior with an emphasis on recent models and they concluded that damping through inclusion of friction forces, viscoelastic shear effects, or bending stiffness, as a function of cable curvature and wire properties, must be included to produce a realistic cable model.

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
E-mail address: nilson.barbieri@pucpr.br

1877-7058 © 2017 The Authors. Published by Elsevier Ltd.
Peer-review under responsibility of the organizing committee of EURODYN 2017.
10.1016/j.proeng.2017.09.143

Xiang et al. [2] presented a new model to analyze the dynamic response of a multi-strand wire rope subjected to axial tension and axial torque. The model takes into account the double-helix structure in a multi-strand configuration. The different friction of the adjacent wires influences the bending and torsion deformation of the double-helix wire.
Ghoreishi et al. [3] investigated the validity and limitation of linear models to describe de behavior of simple straight strands under axial loading. According to the authors, the validity domain of these models has not been evaluated yet because the experimental results reported in the literature are very limited.
Zhu and Meguid [4-6] presented nonlinear models for dynamic cable behavior analysis. Some analyses were restricted to cable models considering new curved beam element and subject to low axial loads.
Qiu and Maji [7] investigated, experimentally and analytically, the vibration damping behavior of a carbon fiber cable.
Barbieri et al. [8-10] developed and applied linear and nonlinear models obtained through the finite element method for dynamic analysis of transmission line cables. In order to validate the models, experimental data were obtained in an automatic test bench for electrical transmission line cables. The modal analyses took into account the variation of the first five vibration modes for different axial loads and sample lengths.
When the internal damping is insufficient to minimize the vibration levels, Stockbridge type vibration absorbers are commonly installed along the cable. The Stockbridge damper is presently the most common type of transmission line damper. In general, the absorber consists of two weights attached to the end of stranded cables, which are known as *messenger wires*. In transmission lines with Stockbridge dampers, mechanical energy is dissipated in wire cables. Sophisticated research has been developed [11-13] to analyze the non-linear behavior of Stockbridge.
In this work, the dynamic analysis of new transmission line cables: Tern (CAA), 1120 and 6201 (alloy); with mechanical tension variable (7 to 36% of the ultimate tensile strength (UTS)), with and without the inclusion of Stockbridge dampers, is performed. A procedure based on experimental data obtained by dynamic tests and numerical data obtained through computer simulation of mathematical models (linear and nonlinear) obtained by the finite element method is developed. For low cable load, the nonlinear behavior is accentuated and the results obtained by nonlinear modeling exhibit good accord with the experimental modal data. With increased load cable, numeric data obtained through the linear and non-linear models are close.

2. Mathematical models

The linear physical model [8] is similar to a beam under the action of an axial load. This model is usually used to evaluate the behavior of the cable submitted to the action of an external load (such as the excitation due to the wind) and to an axial load (mechanical tension of project). The differential equation of cable dynamics is:

$$EI\frac{\partial^4 w(x,t)}{\partial x^4}+\rho A\frac{\partial^2 w(x,t)}{\partial t^2}-P\frac{\partial^2 w(x,t)}{\partial x^2}=f(x,t) \tag{1}$$

where $f(x,t)$ is the external load, $P(x,t)$ the axial load, ρ the specific mass, A the cross-sectional area, w the transversal displacement, x the position along the sample, t the time variable and EI the flexural stiffness.
Even for geometrically non-linear problems with large displacements, the equilibrium conditions between internal and external forces have to be satisfied. If the displacements are approximated with the conventional finite element method by a finite number of nodal values, $q=\{q_1,q_2,\ldots\ldots q_n\}^t$, the equilibrium equations are obtained by using the principle of virtual works [10].

If $\psi(q)$ represents the sum of the internal and external generalized forces, the equilibrium can be expressed as being:

$$\psi(q)=\int_V B^t\sigma dV-f=0 \tag{2}$$

where the matrix B is defined from the strain definition as;

$$d\varepsilon=Bdq \tag{3}$$