Dynamic analysis of transmission line cables using nonlinear 3d frame element

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Abstract.

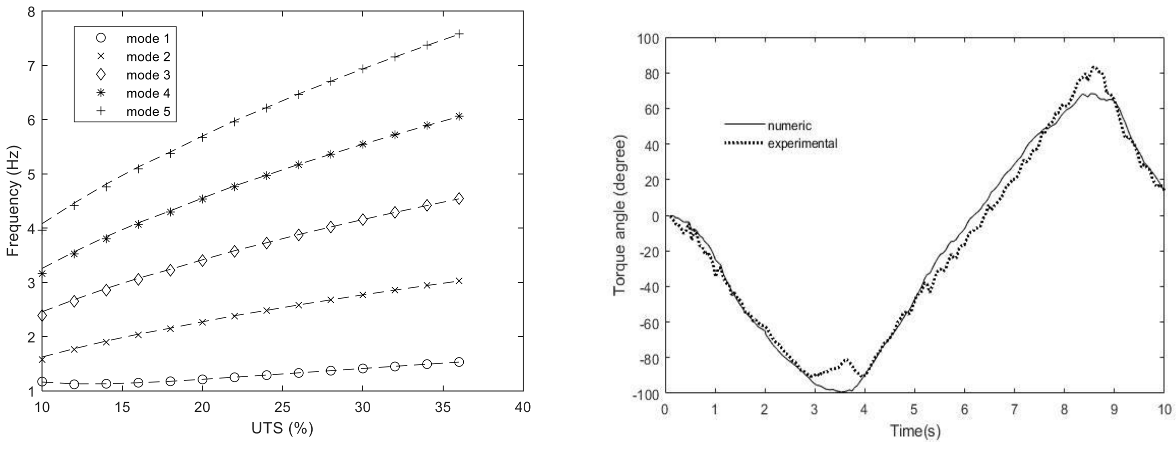
The 3D frame finite element is used in this work to investigate the nonlinear dynamic behavior of electrical transmission line cables. The elastic stiffness matrices (small displacements) and the geometric stiffness matrix (large displacements) are obtained through Timoshenko's beam theory. The mathematical model is validated by comparing numerical and experimental natural frequencies. The experimental modal behavior is obtained using three different cables with approximate lengths of 54m. The experimental data are obtained through accelerometers arranged along half of the sample and the system is excited using an impact hammer. The same mathematical model is used to validate the torsional behavior by adjusting the angle of twist. In this case, another test bench was used, varying the position of a lever. Excitation was obtained by manually moving the lever clockwise and counterclockwise.

Introduction

The mathematical model is obtained using the 3d non-linear frame element. The used element has 2 nodes and 12 degrees of freedom (Timoshenko 3d beam element). The stiffness matrix is composed of two parts: elastic stiffness matrix (small displacements) and geometric stiffness matrix (large displacements). The differential equation of motion has the following form [1]:

$$\boldsymbol{M}\ddot{\boldsymbol{u}}(t) + \boldsymbol{K_E}\boldsymbol{u}(t) + \boldsymbol{K_G}(\boldsymbol{u})\,\boldsymbol{u}(t) = \boldsymbol{f}(t)$$

where: $\boldsymbol{M}$ is the mass matrix; $\boldsymbol{K_E}$ and $\boldsymbol{K_G}(\boldsymbol{u})$ are the elastic and geometric stiffness matrices; $\boldsymbol{f}(t)$ is the external excitation vector; $\ddot{\boldsymbol{u}}, \boldsymbol{u}$ are the acceleration and displacement vectors. Figure 1(a) shows the experimental data (symbols) and numeric values (dashed lines) for the variation of the first five natural frequencies in relation to the variation of the percentage of the ultimate tensile strength (mechanical load). Figure (1b) shows the experimental (symbol) and adjusted numeric (dotted line) of the torque angle [2].



(a) (b)

Figure 1: Variation of natural frequencies (a) e torque angle (b).

It is noted that the adjustments of natural frequencies and torque angle had good agreement between numerical and experimental values.

References

[1] Chandrupatla T. R., Belegundu A. D. (2002) *Introduction to finite elements in engineering*. Prentice Hall, Upper Saddle River, New Jersey.

[2] McConnell K.G., Zemke W.P. (1982) A Model to Predict the Coupled Axial Torsion Properties of ACSR Electrical Conductors. *Experimental Mechanics* 237-244.