Introduction

Why account for nonlinear vibration?
- Coupled Nonlinear Dynamics/Aeroelasticity of very Flexible Aircraft
- Vibration-based MicroElectroMechanical Systems (MEMS)
- Long, Light and Flexible Blade of Wind Turbine
- High Speed Compliant Actuator
- Squeal of the Brake System

What is the problem in optimization?
- Today’s design procedures are often based on linear finite element (FE) models.
- High computation costs of nonlinear structural dynamics are prohibitive for iterative optimization.

The goal of this PhD project
- Focus on developing reduced-order models to facilitate efficient analysis and optimization.
- Eliminate the time dimension to compute the steady-state vibration efficiently.
- Do sensitivity analysis and design optimization using reduced-order models.

Examples

Design of nonlinear beam dynamics

The structure is a doubly clamped beam with periodic load applied at the midspan. The design variable is the width w(i). The objective function will be given in each example. The nonlinearity in the model arises from the midplane stretching. The axial strain ε and the curvature κ are defined as

\[ \epsilon = \frac{\partial u}{\partial x}, \quad \kappa = \frac{\partial^2 u}{\partial x^2} \]

Minimize the resonant peak

\[ \min \epsilon (\rho, w(i)) = \epsilon^0 - w^2 \epsilon^0 = w^2 \epsilon^0 + b \]

in which \( \epsilon^0 \) and \( b \) are the coefficients of the fundamental harmonic \( w^0 \cos(\omega t^0) + b \sin(\omega t^0) \) for the deflection at the midspan.

Maximize the super-harmonic resonance

\[ \max \epsilon (\rho, w(i)) = \epsilon^0 - w^2 \epsilon^0 + b \]

in which \( \epsilon^0 \) and \( b \) are the coefficients of the third-order harmonic \( w^3 \cos(3\omega t^0) + b \sin(3\omega t^0) \) for the deflection at the midspan.

Discussion
- Optimized width for minimizing the resonant peak using linear FE model(left top) and using nonlinear FE model (left bottom), and nonlinear frequency-amplitude curves: circles denote optimized width using linear FE model, diamonds denote optimized width using nonlinear FE model and dots denote uniform width.

References