The Effect of "Fixed" Joint Uncertainty on Dynamic Properties

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1. Abstract

The object of this summer school project is to quantify uncertainty introduced by a variety of boundary conditions that may nominally be thought of as "fixed" on dynamic properties of a structure. Students will test variations of the same structure with different joining mechanisms; these could be welded, bolted, monolithic, and/or press-fit. The method of dynamic testing will be through use of PZT or MFC patches using wave propagation measures (lamb wave, time reversal, etc.). Students will also model their simple structure and the dynamic excitation using a commercially available finite element package.

2. Project Outline

a. Goal: The goal of this project is to isolate and quantify one major source of uncertainty in dynamics testing, that due to joints in a system. For simplicity only joints that might be thought of as fixed will be examined. All other factors will be controlled as closely as possible, such that variability found in the dynamic features is attributable to variation in the joints of the simple structure examined. A secondary goal of the project is to be able to model the wave propagation features of interest in a commercially available finite element code.

b. Motivation: Quantification of uncertainty is an important part of any structural dynamics investigation and especially damage identification. It is important to know whether variations in measured data are caused by damage to the structure, or inherent variability. Uncertainty due to joints is of particular interest because interfaces between mechanical parts are notoriously difficult to model. If uncertainty due to the interfaces could be quantified experimentally, it might mitigate the fact that we almost always do a poor job of modeling them physically.

c. Procedure: The project will have three distinct parts:

- (i) Analytical calculations of uncertainty introduced by boundary conditions using beam/plate deflection formulas.
- (ii) Testing of simple structure (this will likely be a plate or a beam) – Dynamic features of interest should relate to wave propagation features (lamb wave, time reversal, etc.)
- (iii) Modeling of the structure and its wave propagation features. Incorporation of joint uncertainty in the model (either physically or empirically).

3. Background Literature

French, A.P. *Vibrations and Waves*. W.W. Norton and Company. 1971.

Wait, Park, Sohn, Farrar, "Plate Damage Identification Using Wave Propagation and Impedance Methods." Procedings of SPIE, v. 5394, 2004.

Sohn, Park, Wait, Limback, Farrar, "Wavelet-based active sensing for delamination detection in composite structures." Smart Materials and Structures, V. 13 (2004) pp. 153-160.

Ang and Tang, Probability Concepts in Engineering Planning and Design, v1 – Basic Principles, Wiley and Sons, 1975.

4. Week by Week Plan

Week 1 – Literature search/Analytical problem setup

Week 2 - Lit review/Analytical problem solving – displacement/mode shapes/wave equations (?)

Week 3-5 - Finite element model development and testing of structure with different connections, definition of dynamic features of interest

Week 6 - Post-processing of test data, feature extraction, quantification of uncertainty due to joints on dynamic features of interest

Week 7 - Implementation of uncertainty in FE model (empirically and/or physically)

Week 8 - Report and present.

5. Real World Design Issues as a Project Consideration.

When damage detection is performed on real world structures results are often influenced by variability in the environment and variability inherent in the structure. This variability influences the ability to accurately assess the health of the structure in question. If the preceding set of experiments is carefully carried out, results may be applicable to larger structures using the same kinds of connection mechanisms.

6. Equipment Requirements.

a. Test structure (plate or beam, likely using uni-strut and off the shelf connection components).
b. Data Acquisition Hardware compatible with PZT/MFC wave propagation measurements.
c. Modal DAQ toolkit (modal hammer, accels, MEScope or equivalent)

7. **Software Requirements.**

a. Standard DAQ software, compatible with PZT/MFC measurements
b. ABAQUS finite element software or similar
c. Matlab
d. Mathematica/Maple (possibly)
e. JMP (possibly)