University Consortium on Instructional Shake Tables

SDOF System: Obtaining the Frequency Response Function

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Objective

Observe transient and forced vibrations in a simple, single degree of freedom system.

Additional Learning Objectives

- Understand the concept of natural frequency
- Know how to determine system frequency and damping experimentally
- Use the shake table to obtain a system transfer function
- Operate data acquisition and instrumentation for measuring system responses
- Use teleoperation to remotely perform an experiment

Experiment Background Information

A single degree of freedom, SDOF, system consists of a mass-spring system, or a one story building, which is driven by an instructional shake table. The shake table provides an acceleration input to the structural system. An accelerometer is placed on the moving surface of the shake table to measure the input forcing function, and another accelerometer is attached to the building mass to measure the output response function.

Read your textbook regarding single degree of freedom systems for a more thorough explanation of the mathematical model.

UCIST Background Information

This experiment is to be conducted using several cyberinfrastructure tools designed by the Network for Earthquake Engineering Simulation, NEES (http://nees.org). You will have the ability to control the instructional shake table remotely, view the experiment in real time through a webcam, and collect the resulting data for analysis.

A Graphical User Interface, GUI, will enable you to select the frequency and amplitude of the motion of the shake table, and then to start the motion. The video of the resulting motion and the data obtained from the two integrated circuit DC accelerometers will then be automatically streamed from the server to your remote computer using the Ring Buffered Network Bus, RBNB. The video and data will then be available for you to store through the use of the real-time data viewer, RDV.

Procedure

1. Follow the instructions provided in the Appendix to open the RDV client from your computer.

2. From the video, sketch the experimental apparatus, test specimen and location of the sensors. Plan on including a clean version of this schematic diagram in your report.

3. Set the ground motion parameters to a frequency of **2.5 Hz** and amplitude of **0.001 m**. Run the excitation.

4. Observe the responses from the initial few seconds of the response. In your report, describe qualitatively the transient response at the beginning of the excitation.

5. Save the data. See the Appendix for help.

6. In this same manner, you will run a series of harmonic input motions in order to obtain the frequency response function, FRF. To do this, select 12-15 different values of frequencies between **0.5-4.5 Hz**. For each frequency, keep the amplitude at **0.001 m**. Save the data for each run. You should begin each test with the structure at rest. Note: Please limit the input motions to the specified values to avoid damaging the equipment.

7. Disconnect the RDV client so that the next user will be able to connect.

Report

The lab report should be a formal report. Organize your report into sections (e.g. Abstract, Introduction, Procedure, Theory, Results, Discussion, Conclusions, References, and Appendices as needed). Write concisely and clearly, and use MATLAB for your plots.

The mass, m, and stiffness, k, of the structure will be provided by your instructor.

Remember to include the following:

Procedure
- A schematic diagram and description of the apparatus

Theory
- A mathematical model of the system (Consider a simple spring-mass-damper system.)
- Free-body diagrams
- Equations of motion (Base the parameters of your model in terms of physical properties that you were given, but leave your equations in simple symbolic form.)
- Plots of the FRF based on this theoretical model, with and without damping (Estimate the damping of the system, c, and show your work.)

Results
- A plot of the transient response recorded during the first run of the experiment.
- Representative plots of the output response for a few select harmonic motions.
- Estimates of the natural frequency and damping ratio from the experimental data using the half-power bandwidth method described in your textbook.
- Plot of the FRF based on the experimental data. It would be helpful to include the theoretical FRFs on the same plot.

Discussion
- Assumptions.
- Comparison between your theoretical FRFs to the experimental FRF.
- Possible explanations for differences between theory and observation.

Appendix

Setting up the Experiment

1. Open the Teleoperation Control Panel at: http://mase.wustl.edu/wusceel/UCIST/MASE431/lab2_page.htm

2. Click on "Click Here to Launch Experiment" and choose "Open." A window containing Figure 1 will open, indicating everything is working properly.

3. If you cannot view the video and vibration data simultaneously, try manually changing the "Time Scale" from the drop down menu to a larger number.
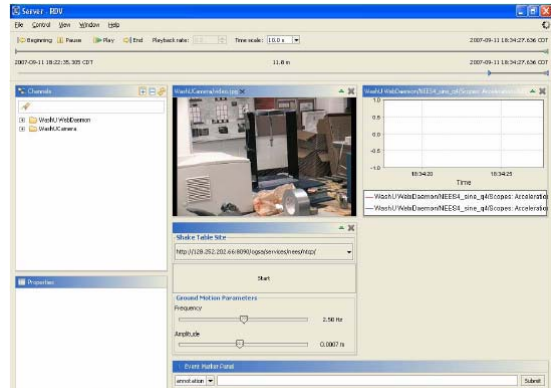

Figure 1 View of the RDV window in operation.

Saving Data

Note: The red data corresponds to accelerometer placed on the shake table. The blue data corresponds to the accelerometer placed at the top of the building.

1. To export the data as a file, follow the path File > Export > Export Data Channels. A window called "Export Data to Disk" will appear.

2. Choose the desired time and select the desired channels. Check only the channels labeled "...a_tbl(g)/1" and "…f1(g)/0."

3. Select the location to send the obtained data by using the "Browse" button and click on "Export."

4. A "data.dat" file will be created at the location that you choose containing the data for that run.