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Acoustic-induced vibration analysis of glass art object

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Introduction

Why is this important?

- Damage to artifacts has been observed in various museums and has been attributed to some type of vibration
- There are a variety of materials in museums but glass was chosen as the focus for this project
- This project was conducted in service of the Walters Art Museum in Baltimore, Maryland
- Employees at the museum noticed potential effects of this acoustic vibration including but not limited to: opening of cracks, paint chipping, and "walking"
  - Incremental damage may also be observed overtime and is not necessarily obvious

What's being investigated?

- Will vibrations from acoustic noise have negative effects on glass artifacts in museums based on the following variables:
  - Geometry
  - Frequency and intensity of vibrations

Image 1: Before and After of display case; walking can be seen in certain objects

Methodology

Instrumentation

- G-Link ® -LXRS ® wireless accelerometers were used to collect data
- Four tri-axial sensing nodes for collecting data and a base station for receiving data were used as well as the Node Commander ® software
- The nodes were configured to sample acceleration data in the z-direction at a rate of 512 Hz
- The acceleration is plotted in a signal as a function of time

Image 2: One of the accelerometer nodes

Analysis Tools

- Data collected was in the time domain and needed to be transformed to the frequency domain using Fast Fourier Transform (FFT) in Matlab ®

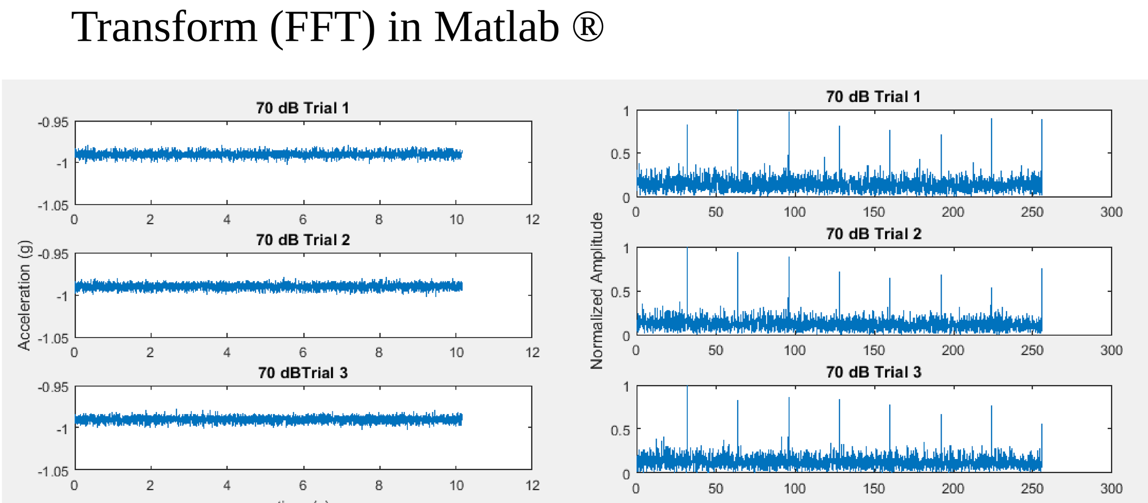


Figure 1: Example transformation between time and frequency domain (FFT)

Methodology Continued

- Audacity ® was also used as an analysis tool during preliminary experiments
- This program records sounds and creates spectrograms
- Data could then be exported and examined in Microsoft Excel ®

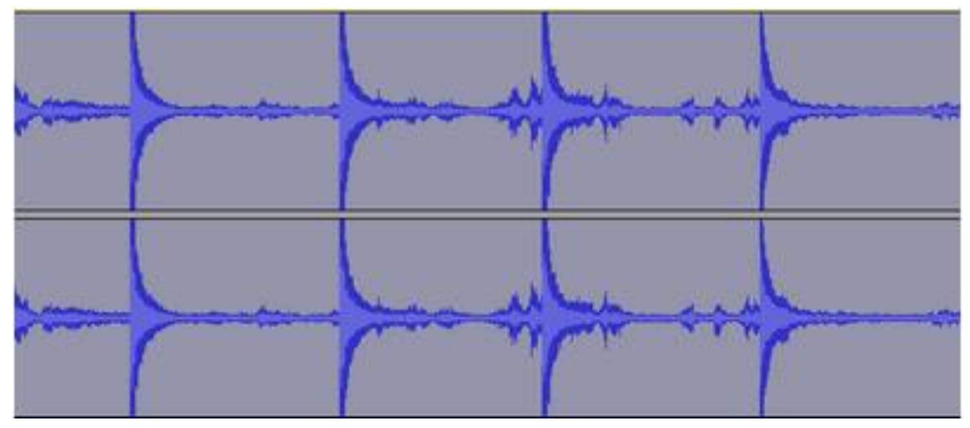


Figure 2: Example of audio recording from Audacity®

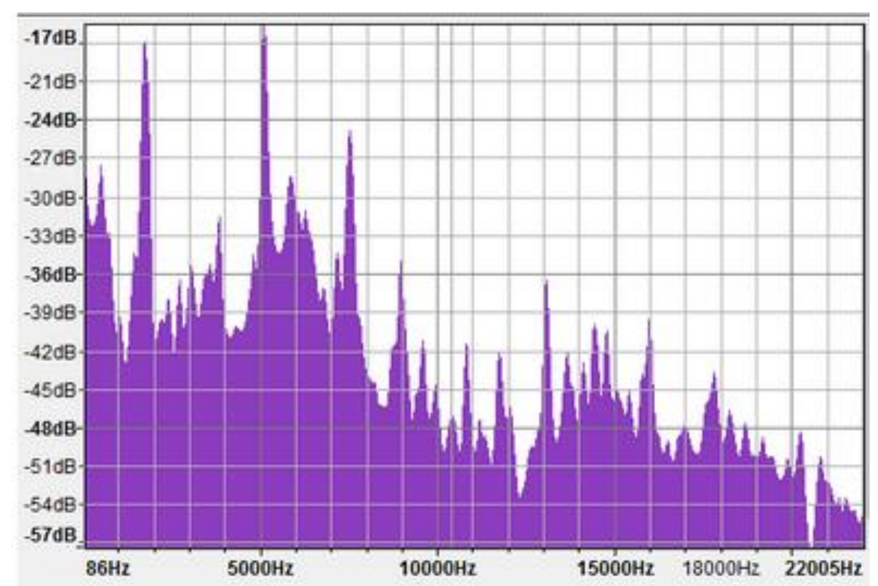


Figure 3: Example of spectrogram from Audacity®

Preliminary Experiments

Resonant Frequencies

- Resonant frequency is the frequency at which an object naturally vibrates
- Audacity® was used to determine preliminary resonant frequencies of all the artifacts provided
- Each object was struck with a ruler multiple times and a spectrogram was created from the recording
- The frequency corresponding to the maximum magnitude was said to be the resonant frequency

Object	Large Glass Bowl	Glass Vase	Small Wine Glasses
Trial 1	689.0625 Hz	4306.641 Hz	1808.789 Hz
Trial 2	689.0625 Hz	4306.641 Hz	1808.789 Hz
Trial 3	689.0625 Hz	5943.164 Hz	5598.633 Hz
Trial 4	N/A	5943.164 Hz	1808.789 Hz
Trial 5	N/A	5943.164 Hz	1808.789 Hz

Figure 4: Resonant frequencies of the glass objects that were provided

- Each object was tested at least 3 times; if the first three frequencies matched the test ended if they did not, 2 more trials were done
  - For example, the large glass bowl only went through 3 trials
  - Additionally, objects have more than one resonant frequency

Decibel Determination Experiment

- For future experiments, it was necessary to determine what source volume corresponded to which decibel (dB) level
- A phone app called Decibel 10th® was used to make this determination
- Music from a phone was amplified by the computer speakers at maximum volume and a dB level was recorded for each phone volume level
  - The numbers were averaged after 3 trials
- The tone middle "C" was used during testing

	Trial 1	Trial 2	Trial 3	Average
Volume Level	dB Output	dB Output	dB Output	dB Output
1	68	68	66	67
2	69	75	68	71
3	70	69	69	69
4	71	71	70	71
5	75	74	74	74
6	77	78	78	78
7	80	80	81	80
8	82	82	84	83
9	85	85	86	85
10	88	88	89	88
11	90	90	91	90
12	93	93	93	93
13	95	96	96	96
14	96	96	96	96
15	97	97	97	97

Figure 5: Phone volumes and their corresponding decibel levels

Modeling

SolidWorks®

- This software was used to model the three glass objects
- Each object was measured using a micrometer and a caliper and these measurements were used in the program
- The models were then exported to COMSOL Multiphysics ® for further analysis

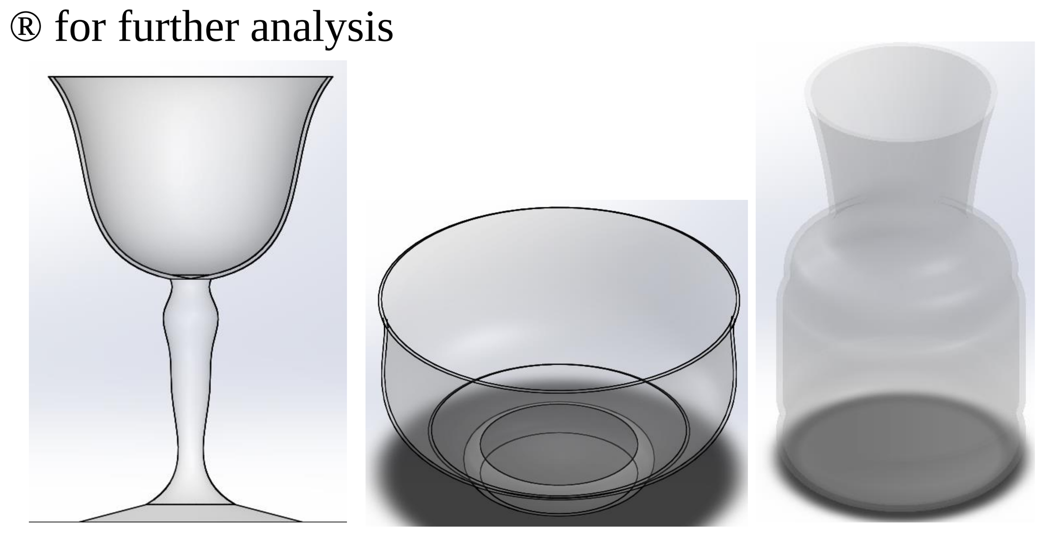


Image 3: Models of glass objects created in SolidWorks®

COMSOL Multiphysics®

- Using the eigenfrequency study, we were able to model the vibration of the objects at the different modes or resonant frequencies

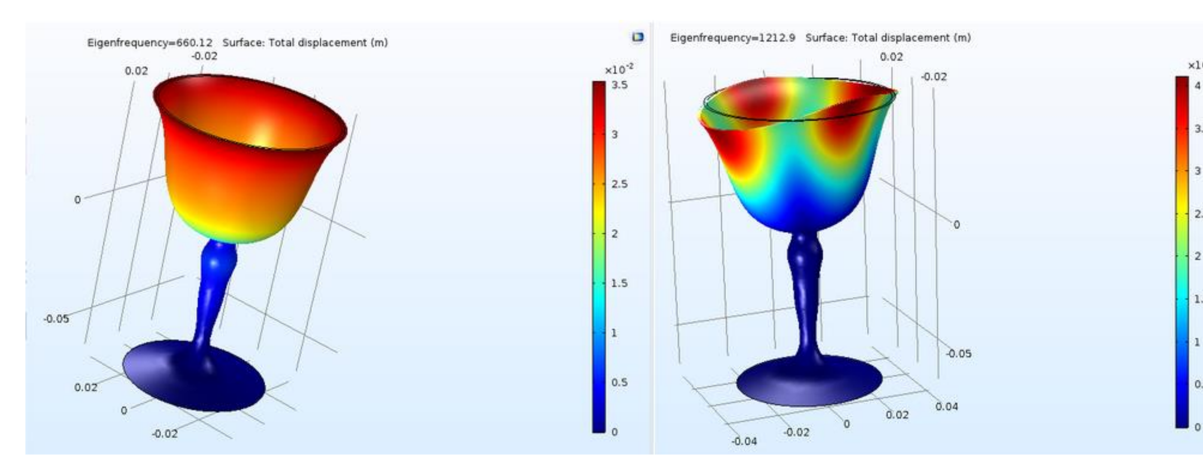
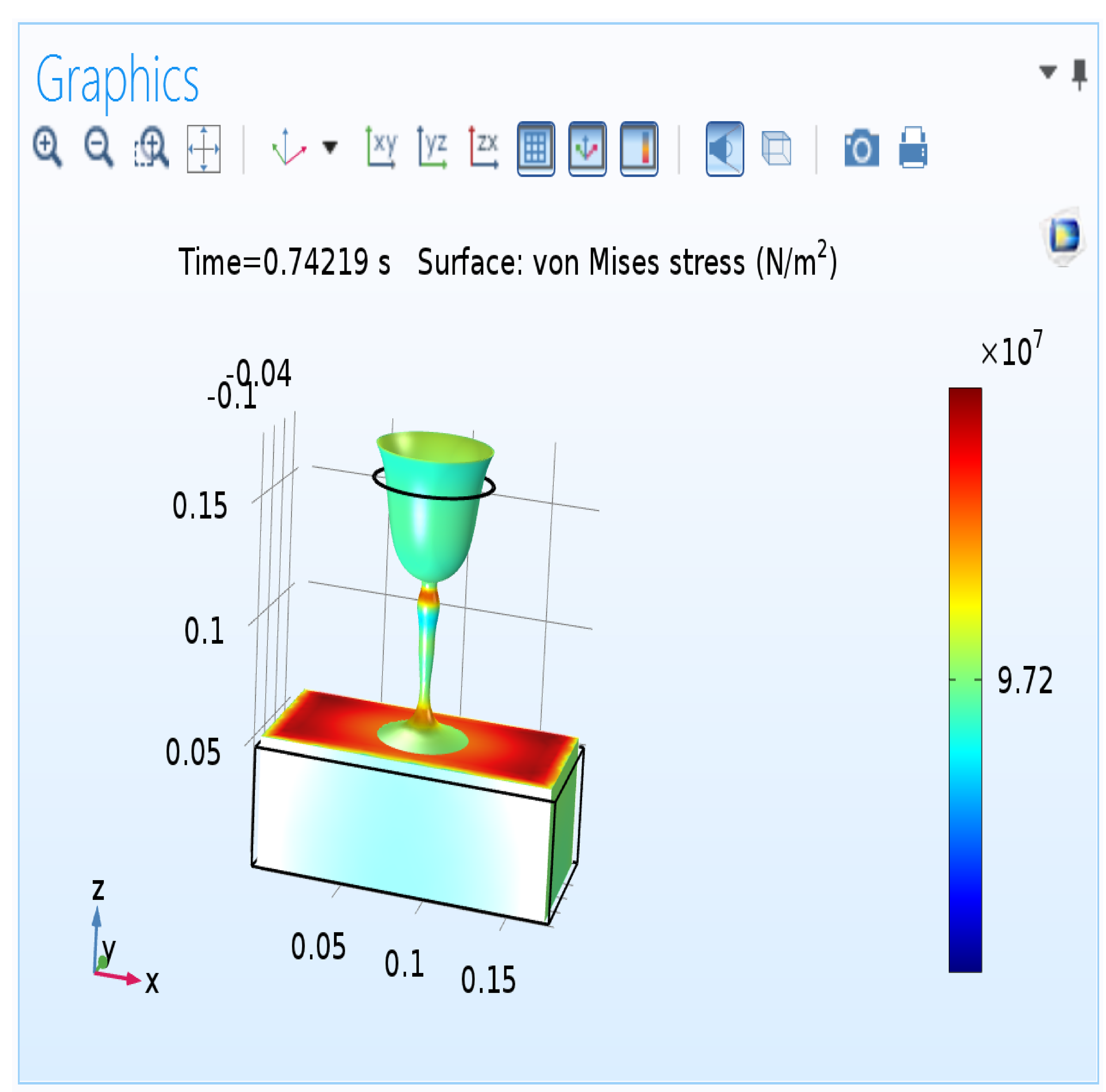


Image 4: 2nd and 3rd modes in COMSOL Multiphysics® Modal Analysis

- In each mode, the cup moves in a different way depending on the frequency
- Some frequencies may cause motion in multiple directions
- The frequencies given in COMSOL Multiphysics® were close to those from the audacity experiment

Results and Conclusions



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