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Title: Measurement of Chladni Mode Shapes with an Optical Lever Method

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Author Questionnaire

1. Microscopy: Does your protocol involve video microscopy, such as filming a complex dissection or microinjection technique? **N**

2. Software: Does the part of your protocol being filmed demonstrate software usage? **N**

3. Filming location: Will the filming need to take place in multiple locations (greater than walking distance)? **N**

Introduction

1. Introductory Interview Statements

REQUIRED:

1.1. **Mengke Ma**: This protocol can provide a clear guidance for determining the Chladni mode shape using the optical lever method **[1]**.

1.1.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

REQUIRED:

1.2. **Mengke Ma**: The proposed method is a rather simple approach to quantitatively determining the Chladni mode shape at a very low cost **[1]**.

1.2.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

OPTIONAL:

1.3. **Yuqi Wang**: Knowledge of the partial differential equation and the finite element method is important for a successful execution of the procedure **[1]**.

1.3.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

Protocol

2. Vibration System Preparation

2.1. To set up the vibration system, acquire two 1-millimeter-thick, mirrored circular acrylic plates with 150-millimeter and 200-millimeter diameters, respectively **[1]**.

2.1.1. WIDE: Talent selecting plate(s)

2.2. Drill a 3-millimeter-diameter hole in the center of each plate and mark several points every 5 millimeters along an arbitrary radius **[2]**.

~~2.2.1.~~

2.2.2. Black point(s) being marked

2.3. Attach each plate to the actuate bar of the vibrator with a bolt in the middle point **[1]** and use a waveform generator to drive the vibrator with a sine wave **[2-TXT]**.

2.3.1. Talent attaching plate to middle point

2.3.2. Talent driving vibrator **TEXT: Default setting enough for resonance experiment**

3. Resonance Frequency Acquisition

3.1. To acquire the resonance frequency, use the laser pen to perpendicularly project the laser beam from a 120-millimeter distance onto the vibrating plate **[1]** such that the beam is reflected to the light screen 500 millimeters in the distance **[2]**.

3.1.1. WIDE: Talent pointing pen at plate

3.1.2. Shot of reflected beam

3.2. Quickly move the laser pen along the direction perpendicular to its length to scan over the diameter **[1]** while the signal generator continuously changes its frequency **[2]**.

3.2.1. Pen being moved/incident point scanning over diameter *Videographer: Important step*

3.2.2. Shot of changing frequency *Videographer: Important step*

3.3. When the spot length is significantly stretched along the diameter and some spots with almost no expansion appear **[1]**, begin scanning this certain frequency range slowly **[2]** and determine the frequency at which the spot expands most obviously **[3]**.

3.3.1. Shot of significantly stretched diameter w/ spots w/ no expansion *Videographer: Important step*

3.3.2. Frequency being scanned slowly *Videographer: Important step*

3.3.3. Shot of frequency at which spot expands most obviously *Videographer: Important step* NOTE: Steps 3.3.2 and 3.3.3 are shot simultaneously, so these two steps are merged.

4. Light Path and Measurement System Preparation

4.1. To prepare the light path and measurement system, place the light screen parallel to the vibrating plate **[1]** and mark the distance with a meter ruler **[2]**.

4.1.1. WIDE: Talent placing light screen parallel to vibrating plate

4.1.2. Talent marking distance

4.2. Then, using 500 millimeters as the starting distance, place the laser pen to project the beam perpendicularly on the plate such that the beam is reflected to the light screen in the distance **[1]**, making sure that the previously made mark can be scanned while the laser pen is moving **[2]**.

4.2.1. Talent placing pen/beam being project perpendicularly

4.2.2. Mark(s) being scanned with moving laser pen

5. Experimental Measurement

5.1. To obtain an experimental measurement, turn on the signal generator **[1]** and set the excitation frequency to the resonance frequency at which the spot expanded most obviously **[2]**.

5.1.1. WIDE: Talent turning on generator *Videographer: Important step*

5.1.2. Talent setting frequency *Videographer: Important step*

5.2. The signal intensity should be as small as possible once the light spot on the light screen is large enough to be recorded **[1]**.

5.2.1. Shot of the intensity and large enough spot to be recorded

5.3. Adjust the laser pen such that the incident point coincides with the first marker, that is, with the nearest marker to the fixed point of the plate **[1]**, and move the screen from 500 to 1000 millimeters **[2]**, measuring the spot length on the screen every 50 millimeters **[3]**.

5.3.1. Talent adjusting pen *Videographer: Important/difficult step*

5.3.2. Talent moving screen *Videographer: Important/difficult step*

5.3.3. Talent measuring spot length *Videographer: Important/difficult step*

5.4. Then adjust the laser pen to make the incident point adjacent to the next marker **[1]** and repeat the measurements from 500 to 1000 millimeters as just demonstrated **[2]**.

5.4.1. Talent adjusting pen to adjacent point

5.4.2. Talent moving screen and/or measuring spot length

5.5. When all of the incident points have been measured, repeat the measurement with the acrylic plate of the next largest diameter **[1]**.

5.5.1. Talent replacing plate

Protocol Script Questions

A. Which steps from the protocol are the most important for viewers to see?
3.2., 3.3., 5.1., 5.3.

B. What is the single most difficult aspect of this procedure and what do you do to ensure success?
5.3.

Results

6. Results: Representative Mode Shaper Measurement and Analysis

6.1. The excitation frequency that can excite an axisymmetric Chladni pattern is determined through the frequency sweeping test **[1]**.

6.1.1. LAB MEDIA: Figure 3b

6.2. A larger plate diameter correlates with a higher plate flexibility **[1]**.

6.2.1. LAB MEDIA: Figure 3b *Video Editor: please add arrows and texts as in original Figure 3*

6.3. Under the corresponding resonant frequency, the length of the light spot on the light screen of different plates can be measured and recorded **[1]**.

6.3.1. LAB MEDIA: Table 1 *Video Editor: please emphasize Revised slope data columns*

6.4. Plotting this data allows comparison of the mode shapes of different plates **[1]**.

6.4.1. LAB MEDIA: Figure 4 *Video Editor: please sequentially emphasize data lines in Figures 4A, 4B, and 4C*

Conclusion

7. Conclusion Interview Statements

7.1. **Mengke Ma**: The most important aspect of this procedure is obtaining accurate data when measuring the spot length, as these data determine the accuracy of the entire experiment **[1]**.

7.1.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera (5.3.)

7.2. **Yuqi Wang**: This method can also be used to determine non-axisymmetric mode shapes in a forward manner to demonstrate the beauty of Chladni patterns **[1]**.

7.2.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera