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Experimental Modal Analysis of a Skateboard

# 1 Introduction

Vibration transmitted through the suspension and deck of a skateboard is a common cause of fatigue among high-frequency riders. In practice, this vibration is reduced by low-durometer wheels and bushings within the truck’s axle hangers. The purpose of this experiment was to examine the vibratory characteristics of the system transmitted to the rider’s body by performing two experimental modal analyses of the system: unweighted, and with a resting foot.

# 1.1 Physical Vibration System

The physical vibration system used in this experiment was an Arbor Skateboards Zeppelin. It is 32 inches (81.28 cm) in length with a maximum width of nine inches (22.86 cm). It is fitted with Gullwing Sidewinder II trucks, which have an axle length of ten inches (25.4 cm).

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| **Figure 1.** Arbor Skateboards Zeppelin (Source: https://images-na.ssl-images-amazon.com/images/I/61PY5srElYL.\_SL1000\_.jpg) |

# 1.2 Experimental Design

Discussion of the choice of response and excitation locations, excitation type, signal processing parameters and boundary conditions. Include drawings with relevant dimensions indicating response and excitation locations, and boundary conditions. Also include clear photographs of the experimental setup.

To test the vibratory characteristics of the system, seven PCB 353B16 accelerometers measured the impact from a PCB 086C01 impact hammer. Figure 2 shows the placement of accelerometers on the board face: the locations were chosen in order to counteract potential node point placement.

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| ../../../Downloads/vibrations_project_photos/accel%20locations%20annotated.png |
| **Figure 2.** Accelerometer placement on skateboard deck. |

The accelerometers and impact hammer were plugged into two National Instruments NI 9234 buses, which interfaced with a MATLAB app via a National Instruments NI cDAQ-9174 compact DAQ USB chassis. Using the hammer to excite the skateboard deck by tapping lightly near accelerometer #3, the MATLAB app recorded the acceleration data of each accelerometer, then displayed graphs of the Fast Fourier Transform of each channel per iteration, as well as the averaged coherence for measurements made during all iterations. To establish initial conditions (resting foot fore of the board centerline). Figure 3 illustrates the initial condition loading.

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| **Figure 3.** Initial conditions: unladen skateboard. |

To test the modal modification, a shoe was placed on the board and loaded with one 35-pound (15.88 kg) kettlebell and one cylindrical [INPUT WEIGHT HERE] weight, and the procedure was repeated. Figure 5 shows the modified weight location.

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| **Figure 4.** Mass-modified condition: weight rearward on the board. |

# 2 Results and Discussion

# 2.1 Unmodified System

Tabulate natural frequencies and damping ratios from Requirement 3 in a single table. Do not tabulate mode shapes. Instead plot the mode shapes one figure per mode. Note that since mode shapes can be 3-dimensional, mode shapes should reflect the physical system’s appearance. Also, superimpose mode shapes over the system’s static shape.

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| **Table 1.** Natural Frequencies and Damping Ratios of Unmodified System | | |
| *Mode* | (Hz) | ζ |
| 1 | 150.5 | 0.0619 |
| 2 | 295.8 | 0.0379 |
| 3 | 451.9 | 0.0263 |

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| **Figure 5.** Unmodified system mode 1 shape. |

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| **Figure 6.** Unmodified system mode 2 shape. |

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| **Figure 7.** Unmodified system mode 3 shape. |

# 2.2 Modified System

Tabulate the natural frequencies predicted from Requirement 5 and from the modal model experimentally determined from Requirement 6. Include percentage errors in this table. Do not tabulate the mode shapes; instead, follow the aforementioned practice and overlay predicted versus measured mode shapes.

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| **Table 2.** Natural Frequencies of the Modified System | | |
| *Mode* | (Hz) | % Error Versus Predicted |
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| 3 |  |  |

# 3 Conclusions

Draw conclusions about discrepancies in the different methods drawing upon assumptions made, data processing and methodology.

# 4 Appendix A—Measured Frequency Response and Coherence Functions

All measured frequency response and coherence functions. Place magnitude of each frequency response and corresponding coherence function on their own page column-wise.

# 4.1 Appendix A1—Unmodified Physical System

Measured FRF and Coherence Functions from original physical system. *(n x m figures)*

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| **Figure 11.** Location 1 Unmodified Response and Coherence |

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| **Figure 12.** Location 2 Unmodified Response and Coherence |

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| **Figure 13.** Location 3 Unmodified Response and Coherence |

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| **Figure 14.** Location 4 Unmodified Response and Coherence |

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| **Figure 15.** Location 5 Unmodified Response and Coherence |

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| **Figure 16.** Location 6 Unmodified Response and Coherence. |

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| **Figure 17.** Location 7 Unmodified Response and Coherence. |

# 4.2 Appendix A2—Modified Physical System

Measured FRF and Coherence Functions from system with added mass. *(n x m figures)*

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# 5 Appendix B—Measured and Synthesized Frequency Response Functions

Magnitude and phase of all synthesized frequency response functions superimposed with corresponding measured frequency response functions. Place magnitude of each frequency response & corresponding phase on their own page column-wise.

# 5.1 Appendix B1—Unmodified Physical System

Measured and synthesized FRFs from original physical system. *(n x m figures)*

# 5.2 Appendix B2—Modified Physical System

Measured and synthesized FRFs from the system with added mass. *(n x m figures)*