Finding the Wolf Tone: Acoustic analysis of the resonance properties of the violoncello

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This project aims to perform analysis on the acoustic resonance properties of the cello with the goal of detecting, isolating, and counteracting the wolf tone frequency. The wolf tone is a consequence of interference between sound waves traveling along the string and vibrations of the cello body. Specifically at resonance frequencies of the cello body, the amplified vibrations are strong enough to cause audible variations. These tones commonly occur around F$\#_3$ on a cello, roughly 185Hz, and can be counteracted by placing a small weight on the string between the bridge and tailpiece. Using scanning laser doppler vibrometry (SLDV), three resonance modes were found in this range: 163.75, 168.25, and 173.00 Hz. 173.00 Hz had the greatest resonance within the frequency range of 100 - 300 Hz and will therefore be assumed as the wolf frequency. Two detailed measurements were taken with the SLDV yielding nearly identical results. Both scans entailed a full body analysis minus the bridge, neck, and tailpiece. The first scan didn't include the strings region and had a wider frequency range of 0 - 500 Hz with 800 frequency divisions compared to 0 - 400 Hz and 1600 frequency divisions in the second scan. Both used 3-sample complex averaging to reduce effects of vibration from noise and 1V speaker amplification for greater displacements at the lower frequency measurements required for our instrument. However, the first scan used a triangular mesh while the second used an "irregular mesh." The irregular mesh proved to be more efficient with greater field density and lower border density compared to the triangular mesh resulting in significantly less points while maintaining high interior density. While the resonant frequencies were lower than expected, this may be due to the cello characteristics. Next steps include a holographic interferometry measurement, placement of the tuned mass damper, and retaking measurements with both SLDV and interferometry. Originally, holographic interferometry should have already taken place; however, conflicts between cello availability and mentor availability resulted in its postponement. Using the resonant frequency of 173.00 Hz, the placement of the damper can be determined based on the string tension and linear mass density. After calculating the frequency modes at 173.00 Hz, the damper will be placed at an antinode between the bridge and tailpiece. Upon placing the damper, measurements will need to be retaken. Ideally, the resonance of the body shouldn't change while the vibration of the string at 173.00 Hz will experience damping resulting in the removal of the wolf tone. However, additional weight may result in shifts of body or bridge resonant frequency requiring additional experiments to ensure correct placement of the damper. In conclusion, progress has included taking a detailed secondary SLDV measurement and identifying resonance as well as correlating resonant frequency to damper position. Next steps include taking an interferometry scan, placing the damper, and retaking measurements.