Structural acoustic characterization of a tenor trombone

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Abstract

An analysis of the sound-producing characteristics of a tenor trombone has been initiated at TCU. Focus of the effort will be on the model Conn 44H "Vocabell" tenor trombone due to its unique rimless bell. A numerical model of the instrument using Autodesk Inventor has been created. The model was then analyzed using the built-in finite element analysis tools.

Key areas of focus include understanding the interaction between the instrument's structural vibrations and the sound radiated from the bell. The "Vocabell" design, known for its unique construction and acoustic qualities, will be critically examined to assess how its geometry and material properties influence sound production and associated frequency spectrum. Radiated sound and structural vibration measurements have been conducted on the physical instrument, providing data for model correlation and validation. Once validated, the numerical model will be used to explore more advanced concepts of brass instrument design.

Background

The Tenor Trombone is one of the most commonly seen and known instruments from all types of wind bands[1]. It produces noise via a player buzzing their lips inside the mouthpiece, and that sound travels through the length of the piping to produce its characteristic sound. The slide portion of the trombone serves to change the pitch or note of the horn, while the bell portion amplifies the sound.

The Conn 44H model trombone was selected for its "rimless" design along the end of the bell. Most trombones have a lip along the outer edge, while this model does not. This unique design will allow for easier model validation in later steps of the project.

Structure of the Horn

The Trombone is comprised of two main sections:

Slide

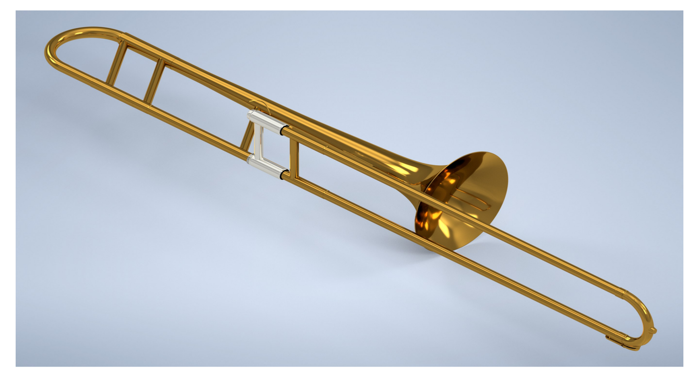
- The slide half of the horn slides outwards to change the note played.
- It has a constant radius and metal thickness throughout.

Bell

- The bell section begins right after the slide section ends, it maintains the same radius as the slide section until the start of the 180° curve.
- At the start of the curve section, the bell begins to expand linearly until five inches from the end where its expansion grows rapidly.

Methodology and Procedure

A model of the Conn 44H "Vocabell" trombone was recreated in CAD using physical measurements on the horn itself, as well as a derived equation defining the radius of the bell from a best-fit curve in excel. The model was created on the horn as-is, with no tuning adjustments made to the model or horn before analysis began.



- Measurements of the "natural" pitches with no slide adjustments were then taken. Recordings were done using a standard iPhone microphone, and specific note and frequency values were interpreted using the Tonal Energy Tuner app.
- A free body modal analysis of the model was then performed using the finite element analysis tool in Autodesk Inventor. The natural frequencies and modes shapes were described and listed for the first 100 modes. For each note played on the horn, the closest matching free body mode to the frequency of the note played was then found.
- An idealized version of the model was used for the modal analysis section due to the thickness of the metal modeled. Intermediary planes were used to construct the mesh for the FEA rather than the volumetric model.

Data and Results

Note:	Pitch Played: (Hz)	Nearest FEA mode: (Hz)	% Difference:	Mode Description
B flat 2	117	111.33	5.0%	Breathing
F3	179	185.53	3.6%	Breathing
B flat 3	237	249.97	5.3%	Breathing
F4	357	375.25	5.0%	Breathing
B flat 4	476	477.47	0.3%	Circumferential
C5	540	567.99	5.1%	Breathing
D5	594	586.26	1.3%	Breathing
F5	720	731.68	1.6%	Circumferential
G5	775	753.11	2.9%	Circumferential
		average:	3.3%	

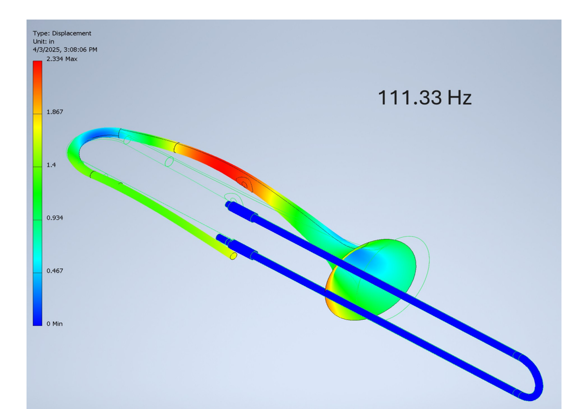


Figure 1: Example of Longitudinal Breathing Mode

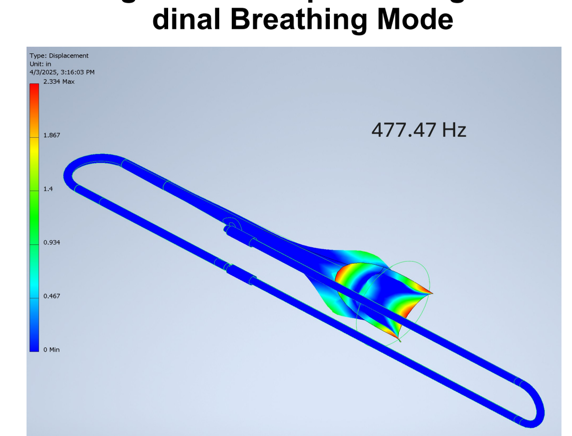


Figure 2: Example of Circumferential Bell Modes

- Two types of modes were observed being near the radiated pitches, both being located within the bell structure. These compared well to previous work[2,3].
- One type was Longitudinal breathing modes of the bell section where as the length undergoes symmetrical expansion and contraction.
- The second type was Circumferential modes of the radius of the expanding portion of the bell structure.
- Modes located in the slide section of the instrument did not appear to correlate to the notes played. These accounted for most of the remaining modes not attached to a playing frequency.
- An average of 3.3% separated the model's free body modes and the played frequencies, with a maximum of 5.3%. This error can most likely be attributed to the idealizations made when forming the mesh and player influences while using the horn.

Conclusions

The results of the research so far indicate an interesting relationship between the modes in the bell of the trombone, and the frequencies of the notes the horn produces in its fully closed position. The model separated from real-life measurements on average of 3.3%, noting good representation of the model to playing tests. However, the contributions of the vibrating air column would be present in the radiated noise measurement, but not the existing FEA results. The influence of the rimless design of our model of trombone as compared to a standard model, with respect to structural modes, needs further refinement. The structural modes of the slide in our model is do not appear to be related to the frequencies of the notes produced, however it does have a significant real-life impact to the notes being played. This is assumed to be due to the changing air volume of the slide change. The thin-bodied approximations used when creating the mesh for our FEA analysis should be revisited to see it solid elements and more elaborate meshing results in increased accuracy.

Future Progression / Recommendations

1. Experimental measurement of the modes in a free boundary condition for model validation.
2. Real-life measurement of the modes on the horns surface while being played with human hand support boundary conditions.
3. More representative model of the horn using volumetric data as opposed to the thin-body approximations used, increased geometrical accuracies using 3D laser scanner device.
4. Incorporation of modeling the air column within the instrument.
5. Understanding the impact the slide has on the modes produced by the horn by producing a more developed model with variable slide length and impact on the full body mesh.
6. Understanding of what changes to the structural modes occur when the trombone has a rim along the edge of the bell.

References

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