Effects of Forcing on Synchronized Rijke Tubes

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Motivation

- Relation between Rijke tube and general combustion
Objectives

- Examine 2 things:
  1. Examine how Rijke tubes synchronize when coupled together.
  2. Examine how forcing affects that synchronization.
Synchronization Regions

- To traverse the synchronization diagram vertically (i.e., reduce coupling strength), the transmission coefficient of the coupler would be reduced by packing it with sound damping material.

- To traverse the synchronization diagram horizontally, the ratios of the lengths of the Rijke tubes would be varied.

- For each of the four test cases, the forcing frequency and amplitude would be varied to determine the effects.
Similar to the image on the right, with a few differences:

- Tubes made out of steel.
- Tubes connected with small coupler pipe.

Image Source: https://www.researchgate.net/figure/a-The-Rijke-tube-shown-with-a-heating-element-placed-toward-the-bottom-suspension_fig1_273706574
Gas Torch Tubes

Acrylic tube

Metal Gauze

Propane torch
Electric Heater

Hair-Dryer

Variac

Mica Tiles

Nichrome Wire
Electric Heater
Experimental Setup
Experimental Setup
T-joints & Coupler Lengths
Experimental Setup
Different Tubes & Length Extenders
Forcing Tube (Not Used)
Microphones & DAQ Setup

Mic

Acquisition System
Synchronization
Results & Discussion

Relevant Theory

- Synchronization can be detected by visually inspecting the time variation of the phase difference:
  \[ \Delta \phi = \phi_1 - \phi_2 \]

- Alternatively, one can compute the phase-locking value (PLV):
  \[ PLV = \frac{1}{T} \left| \sum_{t=1}^{T} e^{i \Delta \phi} \right| \]
  - PLV \approx 1 => phase-locked.
  - PLV \approx 0 => no synchronization.
Results & Discussion

Time Series

Before instability starts.

Overshot voltage on variac.
Results & Discussion
Time Series (Zoomed In)

A = Noise

B = Thermoacoustic Oscillation
Results & Discussion

Frequency Spectra

- Operating with a 15 cm long coupler produced the same frequency tones for each case.

Increase in frequency for shorter tube is expected.

![Long Tube Fourier Spectrum](image1.png)

![Short Tube Fourier Spectrum](image2.png)
Results & Discussion
Phase Difference & Phase-Locking Value

PLV ≈ 0.0347
PLV ≈ 0.9979
PLV ≈ 0.1902
PLV ≈ 0.9928
Results & Discussion
Ambient Data

- Collected without running the Rijke tubes.
- Illustrates the presence of a low frequency ambient pressure oscillation in the room.
  - Caused by ventilation system in the room.
- This tone was removed via a high-pass filter applied to the data (cut-off = 100 Hz).
Conclusions

▸ What have we actually observed?
  ▸ Normal synchronization, but seen through the lens of Rijke Tubes
  ▸ What this means we accomplished

▸ What do we want to do from here?
Issues with Setup

- Steel gets really hot, so limited to 1 minute.

- Forcing tube altered the acoustics, preventing the formation of the thermoacoustic instability.

- Adding packing peanuts to the coupler stopped all oscillations from occurring.

- Leakage issues at joints.