Unsteady Combustion Response of a Ducted Non-premixed Flame and Acoustic Coupling
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Introduction

Objectives

- Model and simulate a ducted non-premixed flame in uniform flow field.
- Examine the unsteady response and acoustic instability characteristics of a ducted non-premixed flame.
Duct Model

- Consists of a long duct with open ends.
- The acoustic zone is modeled as the length of the duct.
- The combustion zone is a small volume located along the x axis.
Combustion Zone Modeling

Finite-rate chemistry

- Considers two types of non-linearity, due to convection and reaction rate

Infinite-rate chemistry

- Considers only the reaction rate as non-linearity
Coupling Flame and Sound

How do flames generate sound?

- **Heat release fluctuations** act as source of acoustic energy, cause velocity and pressure fluctuations
- **Rayleigh Criterion**
  - Phase difference \(+/- 90^\circ\)
Rayleigh Criterion

Notice Phase Difference of Heat Release Rate and Pressure Fluctuations
Combustion Instability

- Acoustic oscillations can lead to flame “blow off”
- Indicated by drop of heat release rate
- Reveals the non-linear nature of the response of the flame to acoustic fluctuations
Conclusions

- Phase relationships between combustion heat release and acoustic pressures help develop an understanding of flame behavior in ducts.

- Non-linearity in combustion dynamics lead to non-exponential growth rates of acoustic oscillations ➔ instability.