Flame Brush Dynamics in an Harmonically Oscillating, Turbulent Jet Flame

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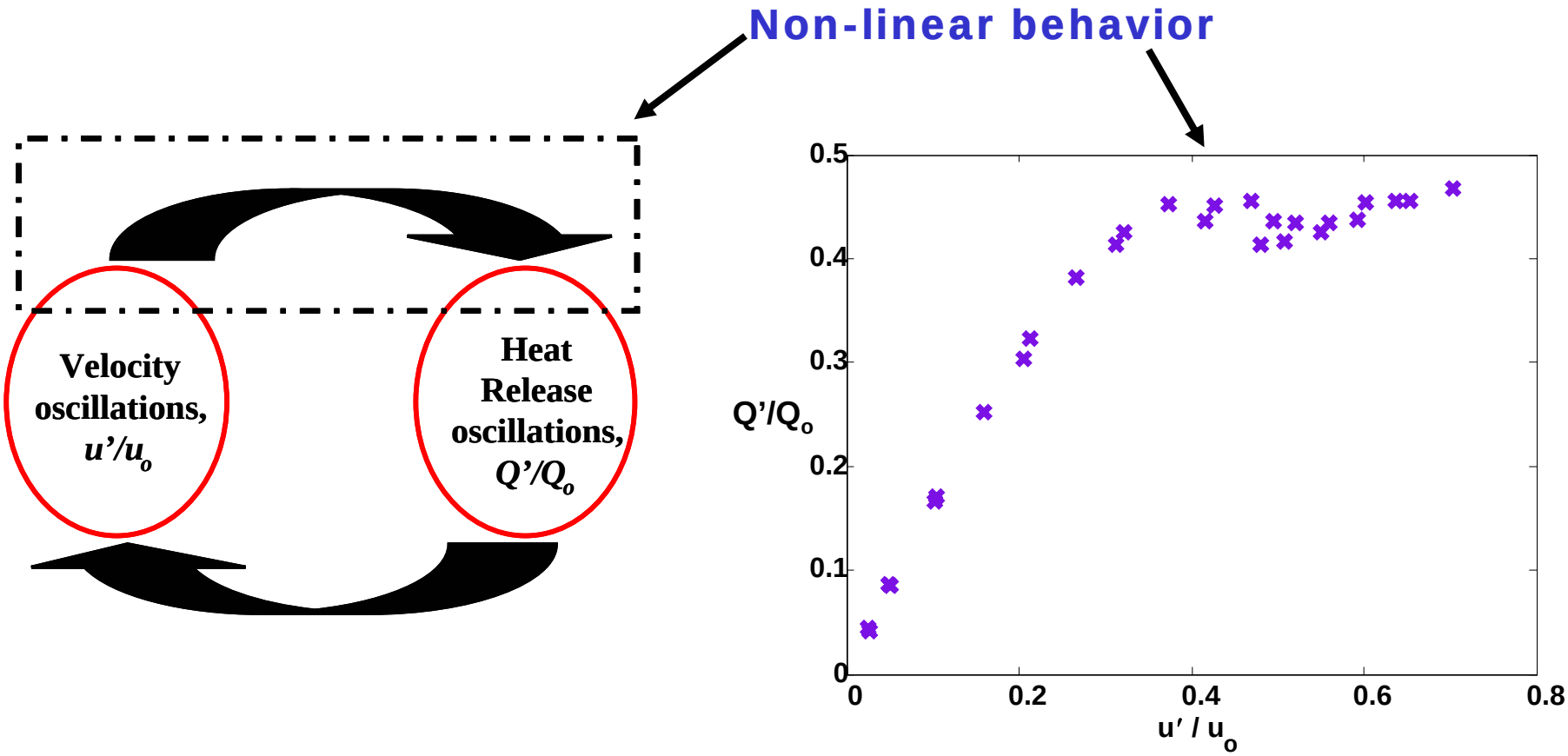
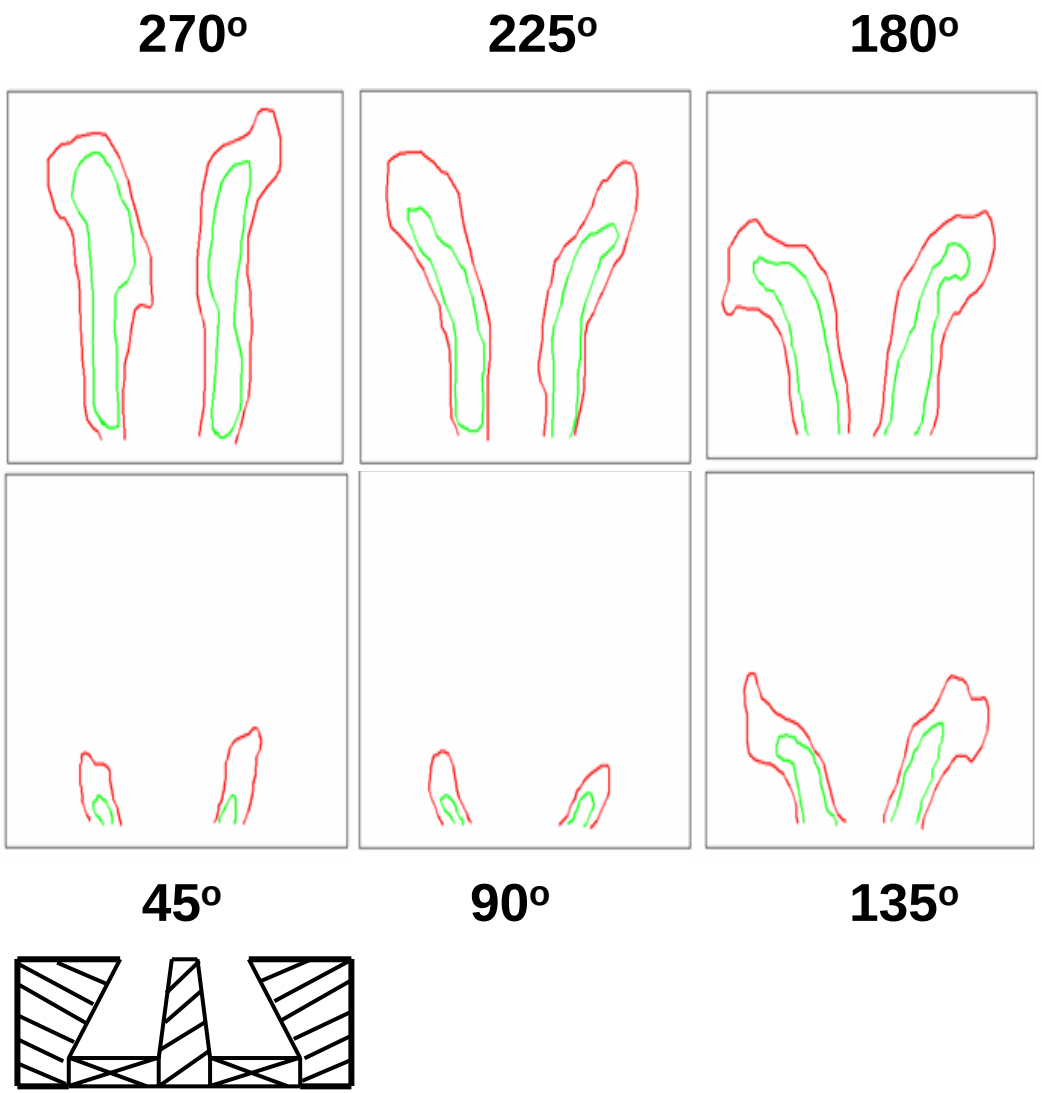
BACKGROUND- Acoustically Forced Flames



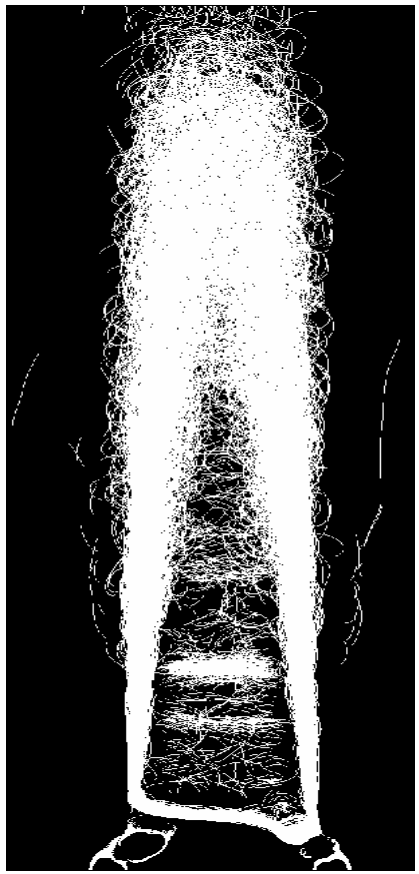
- **Majority of studies - focus on global cause / effect mechanisms.**
- **Very few studies detailing effect on fundamental turbulent flame parameters.**

Huge Variation in Flame Length over Cycle During Large Amplitude Excitation



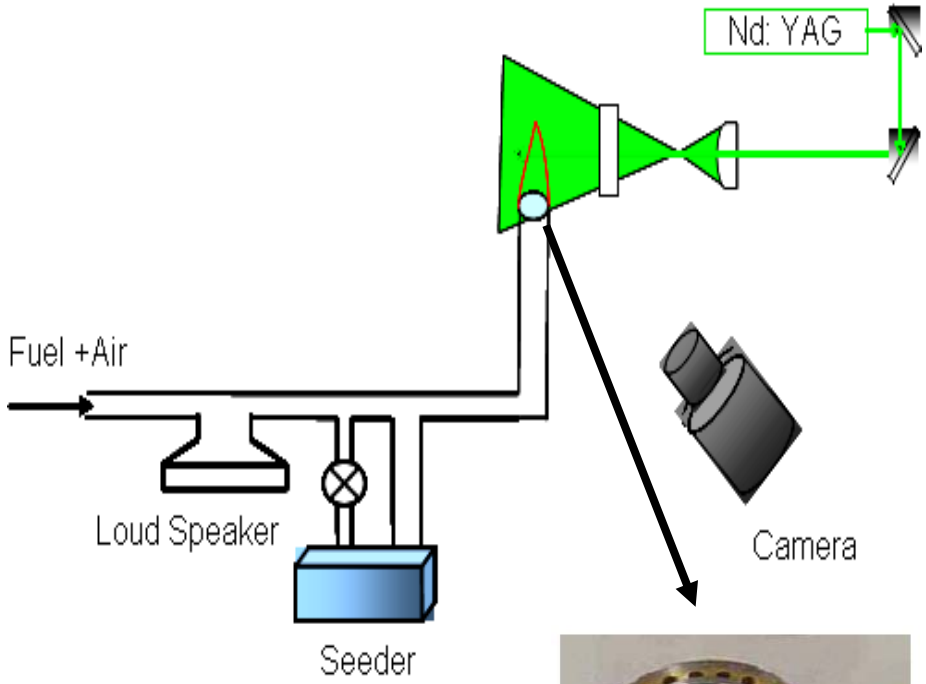
DISCUSSION OBJECTIVES

- **Discuss influence of harmonic forcing upon “nominal” turbulent flame characteristics**
  - **Focus of this study is flame brush**
  - **Lawn & Schefer, Proc. Comb. Inst, 2004**
  - **Sathiah & Lipatnikov (C&F- 2005)**



EXPERIMENTAL FACILITY

- **Axisymmetric Bunsen flame**
  - **Pilot stabilized**
- **Diagnostics:**
  - **Mie scattering**
  - **Hot wire anemometry**



EXPERIMENTAL FACILITY

- **Swirl stabilized burner with centerbody.**
- **Diagnostic techniques:**
  - **OH PLIF**
  - **2 microphone technique for nozzle exit velocity**

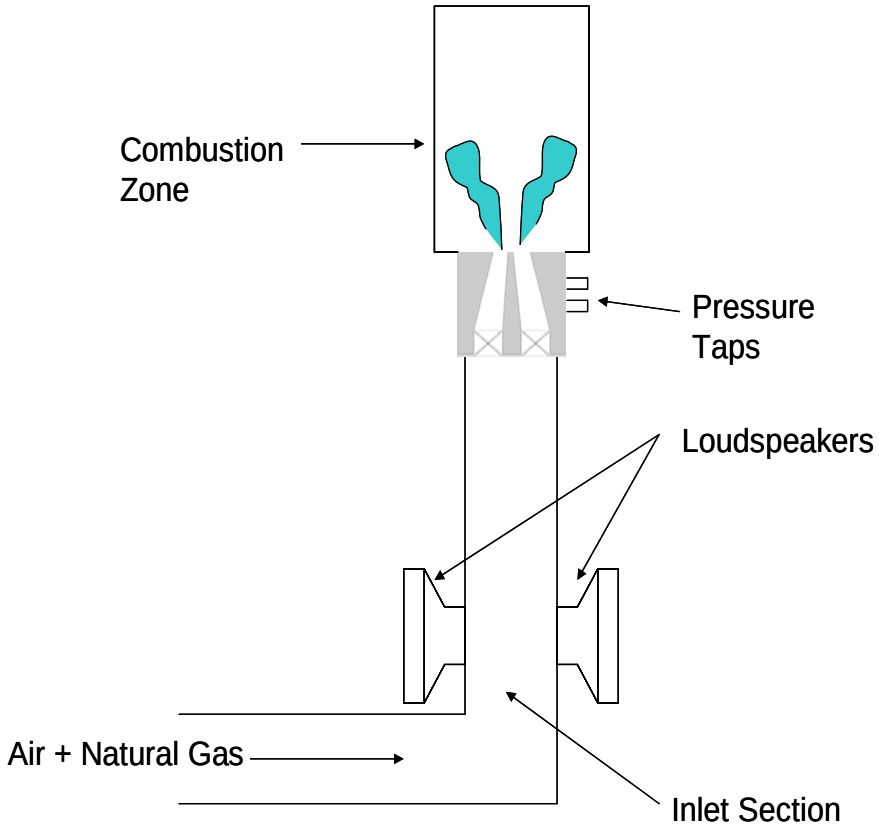
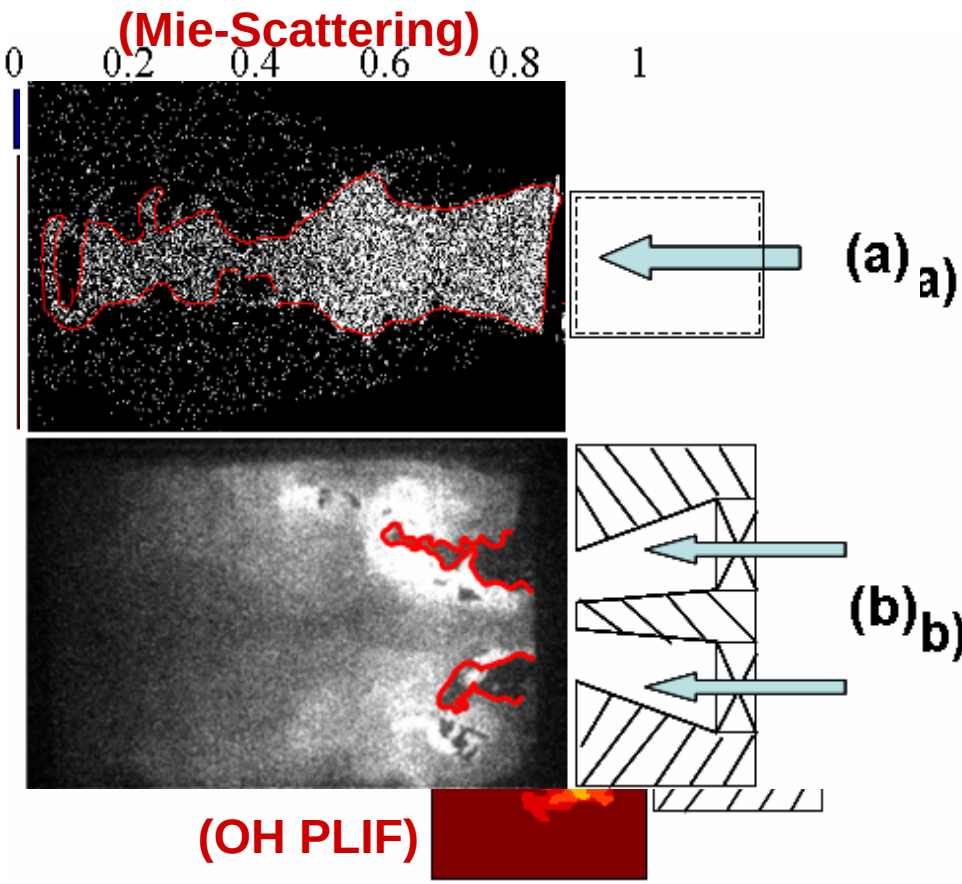


IMAGE ANALYSIS

- **Phase Locked Imaging**
  - **8 phases of an acoustic cycle**
- **Digitized Flame Edge Images.**
- **Progress variable contours : $\overline{c}$**

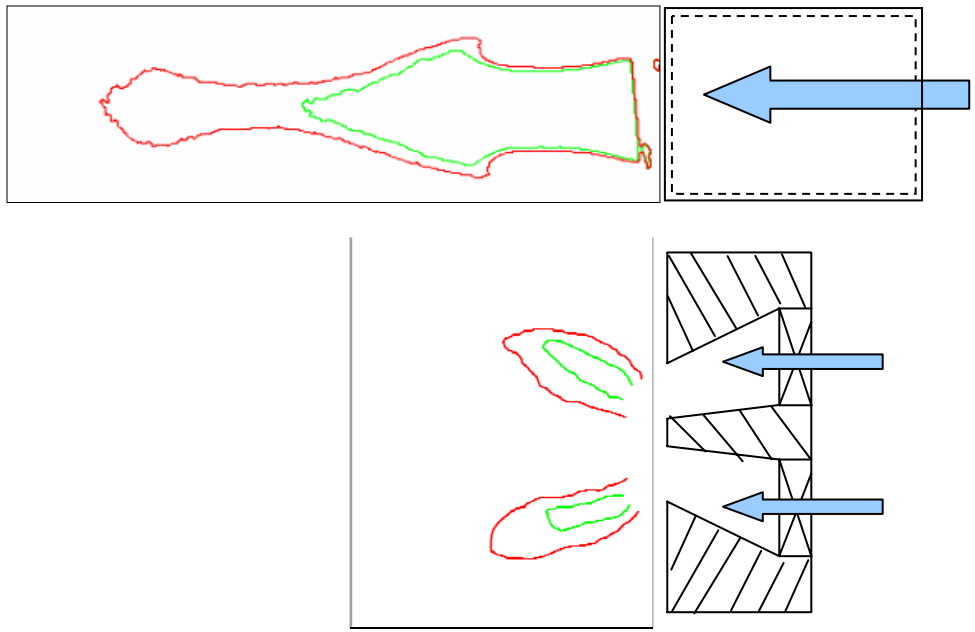


Sample Instantaneous Images

Progress variable contours

IMAGE ANALYSIS

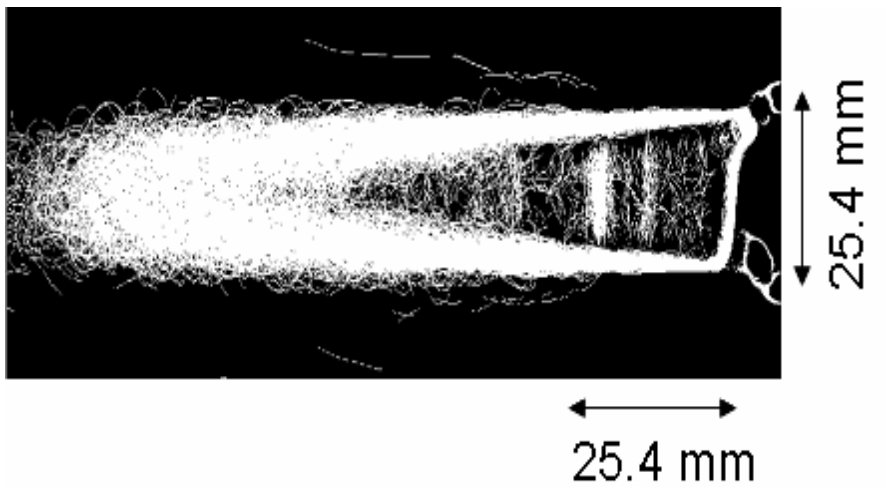
- **Phase Locked Imaging**
  - **8 phases of an acoustic cycle**
- **Digitized Flame Edge Images.**
- **Progress variable contours : $\overline{c}$**
- **Flame brush thickness $(\overline{c} = 0.3 \,\&\, \overline{c} = 0.7)$**

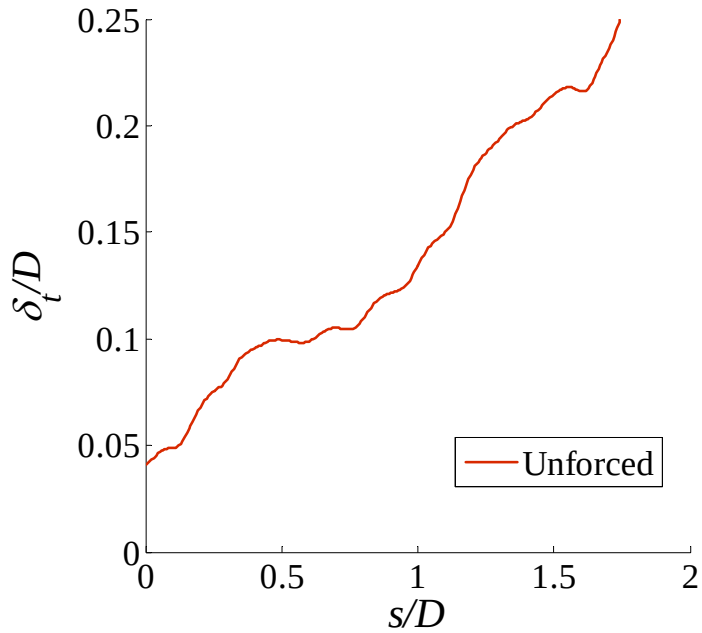


Progress variable contours

RESULTS AND DISCUSSIONS

- **Unforced Bunsen flame**



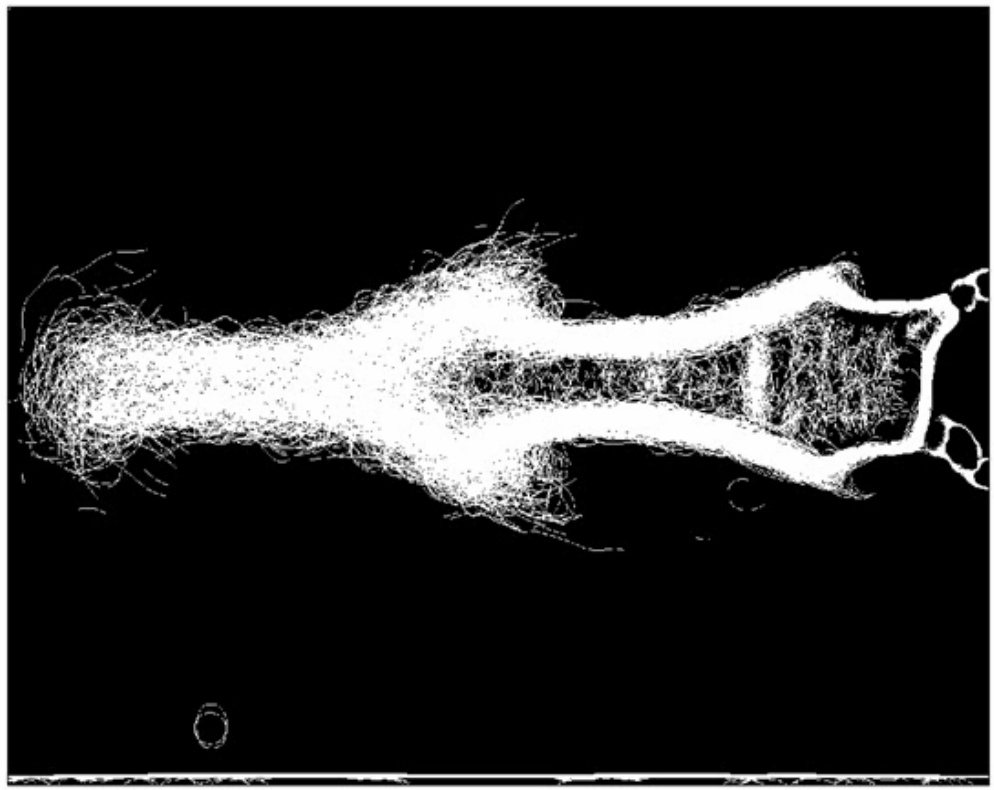


Re =10,200

- **Monotonic growth of flame brush thickness.**

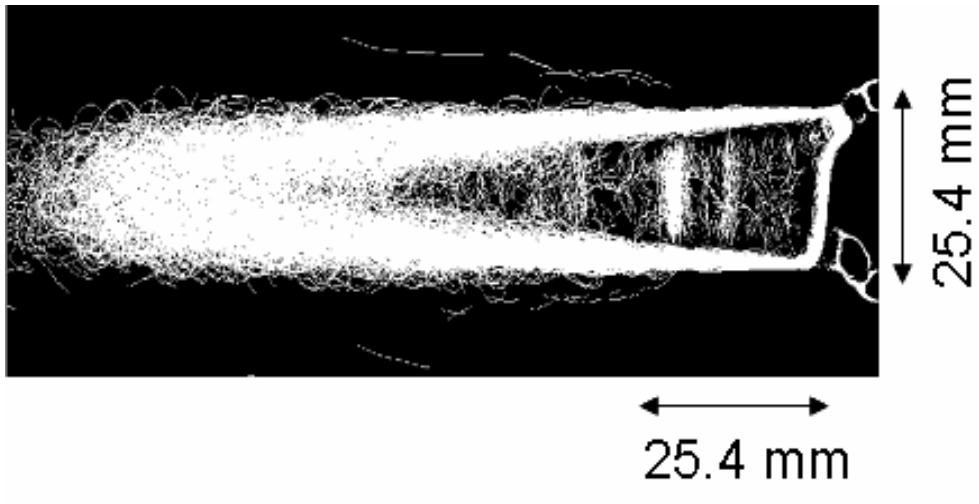
RESULTS AND DISCUSSIONS

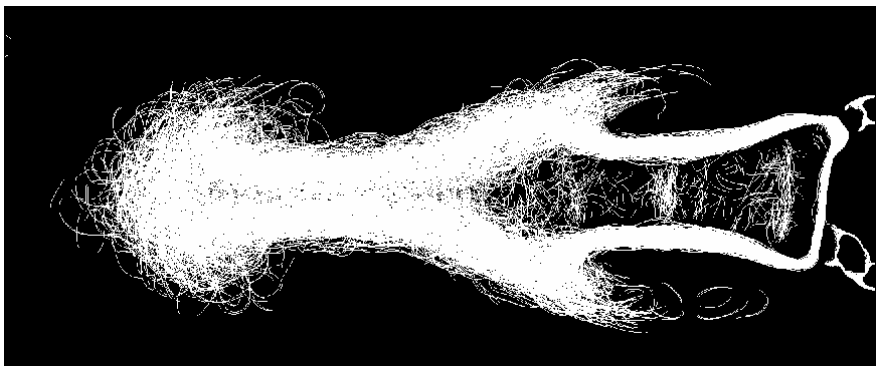
- **Acoustically forced Bunsen flame**
  - **Oscillating flame length**
  - **Convecting ring vortices**

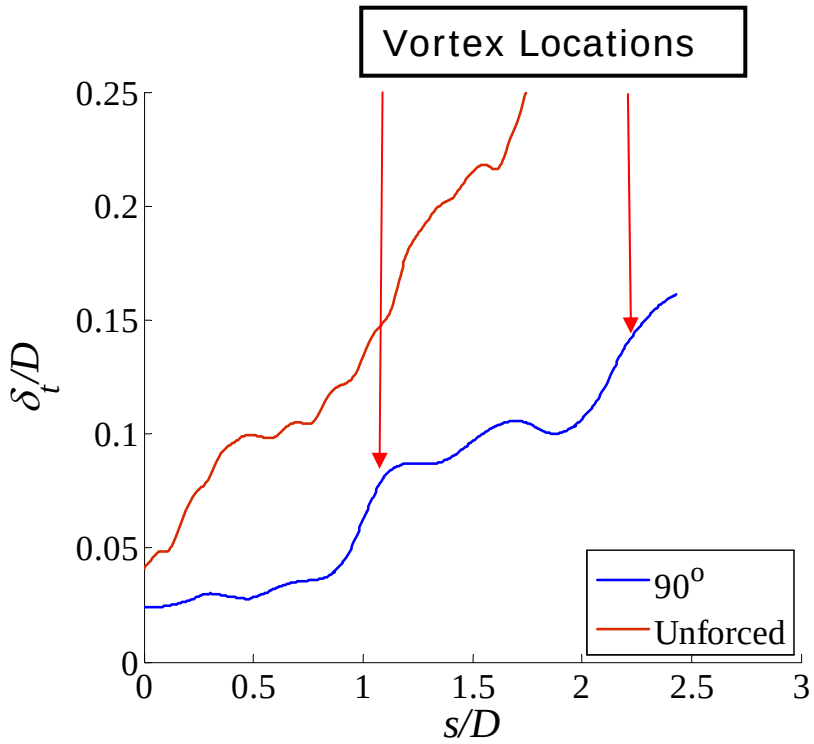


Re =10,200, u'/u_o =0.2

Results -Acoustically forced Bunsen flame



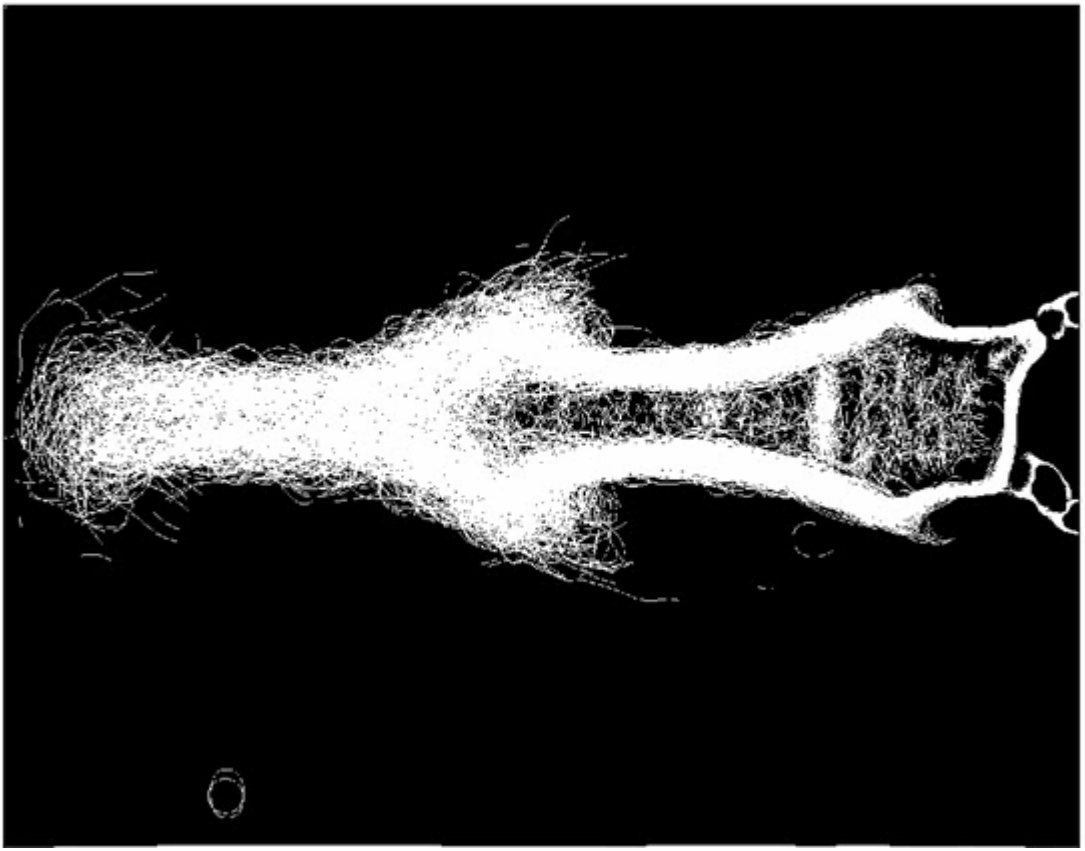


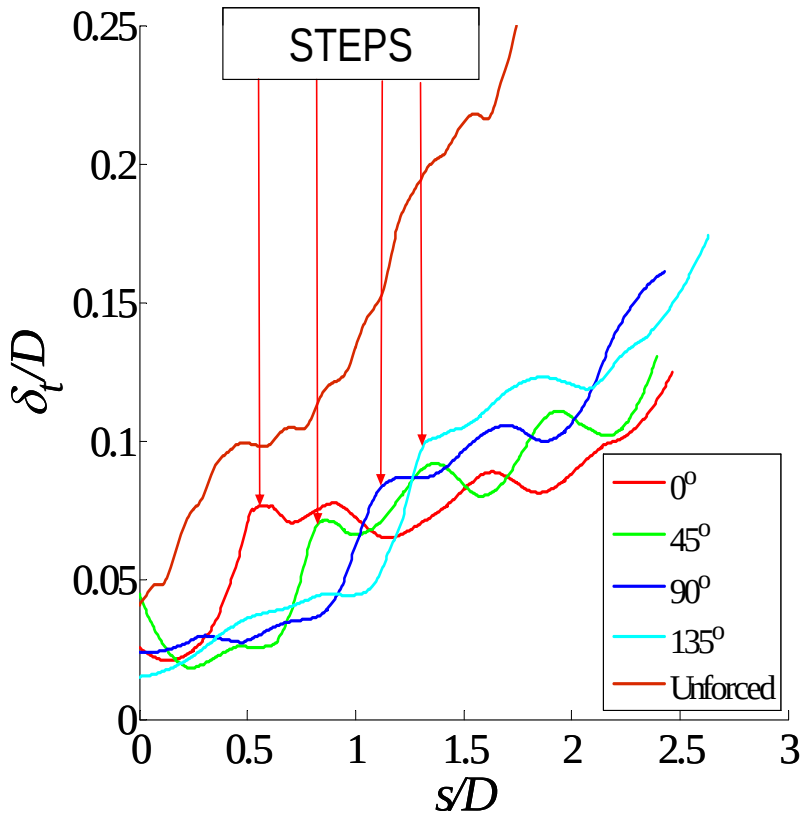


Re =10,200, u'/u_o =0.2

- **Two behaviors exhibited by flame brush:**
  - **Slow growth relative to unforced case**
  - **Rapid growth across convecting vortex**

RESULTS AND DISCUSSIONS



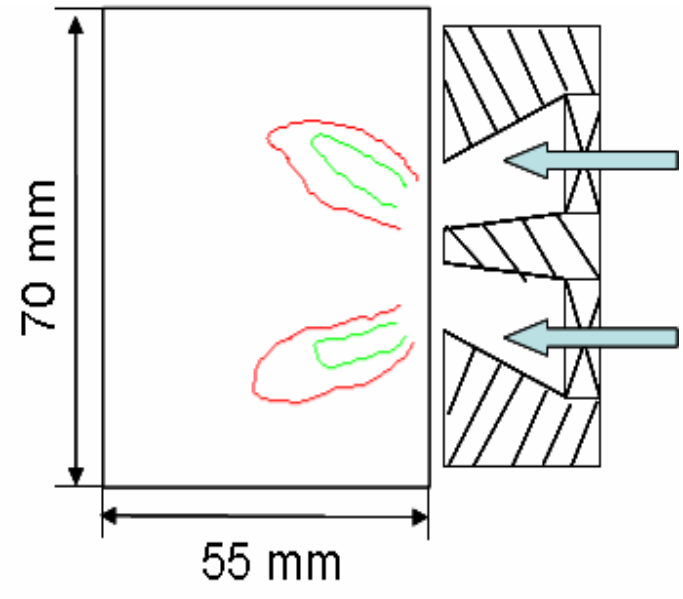


***Re* =10,200, u'/u_o= 0.2**

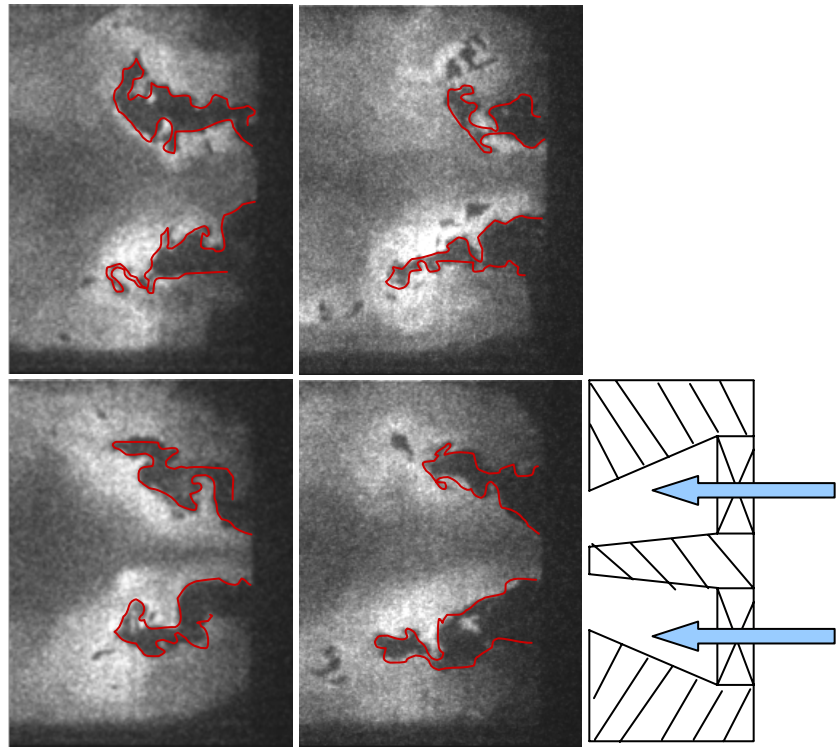
- **Very slow growth relative to unforced case**
- **Step like increases across vortical structures**

RESULTS AND DISCUSSIONS (Swirl Flame)

***Re* =21,000 (Unforced)**



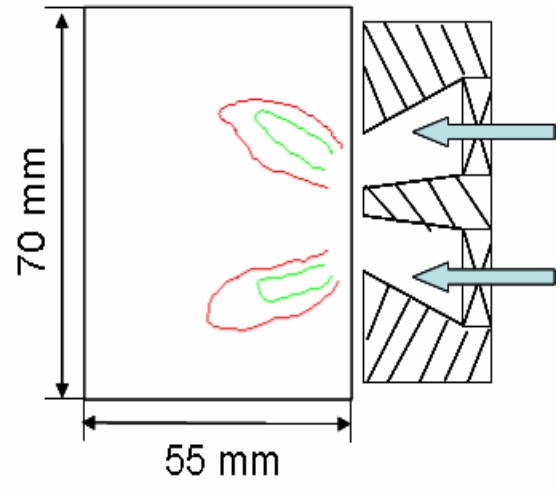
Progress variable contours

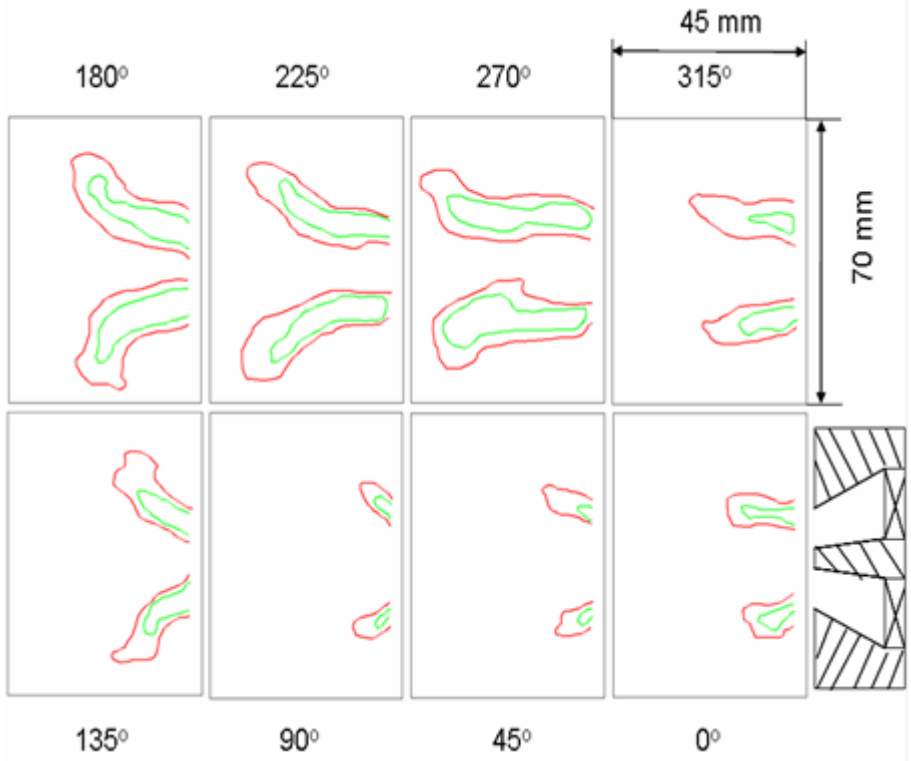


Instantaneous OH PLIF images

- **Gradual growth in flame brush thickness**

RESULTS AND DISCUSSIONS (Swirl Flame)



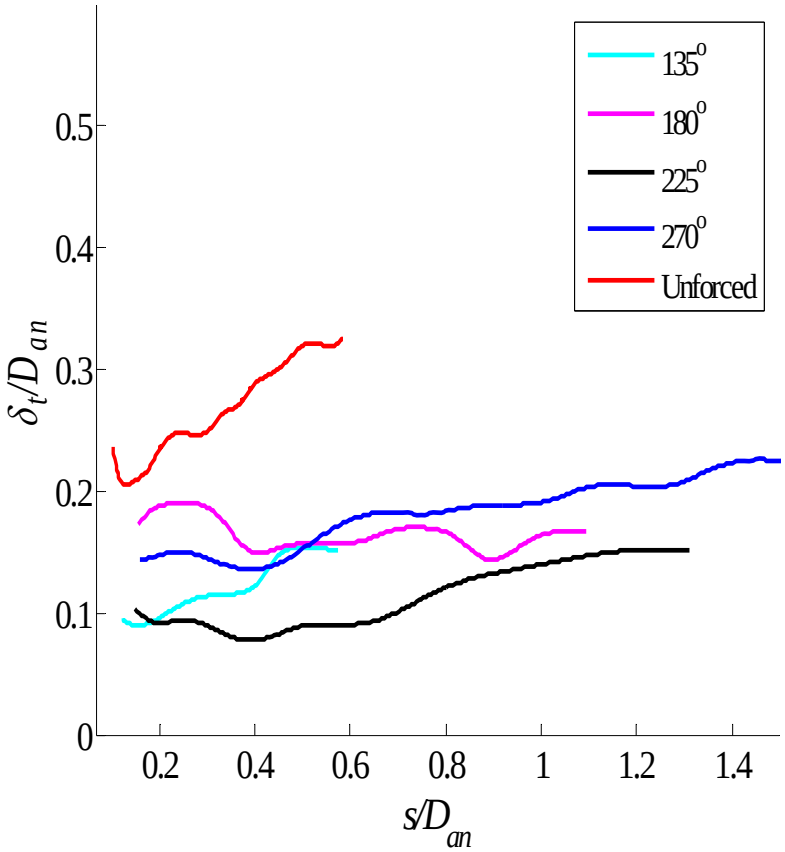


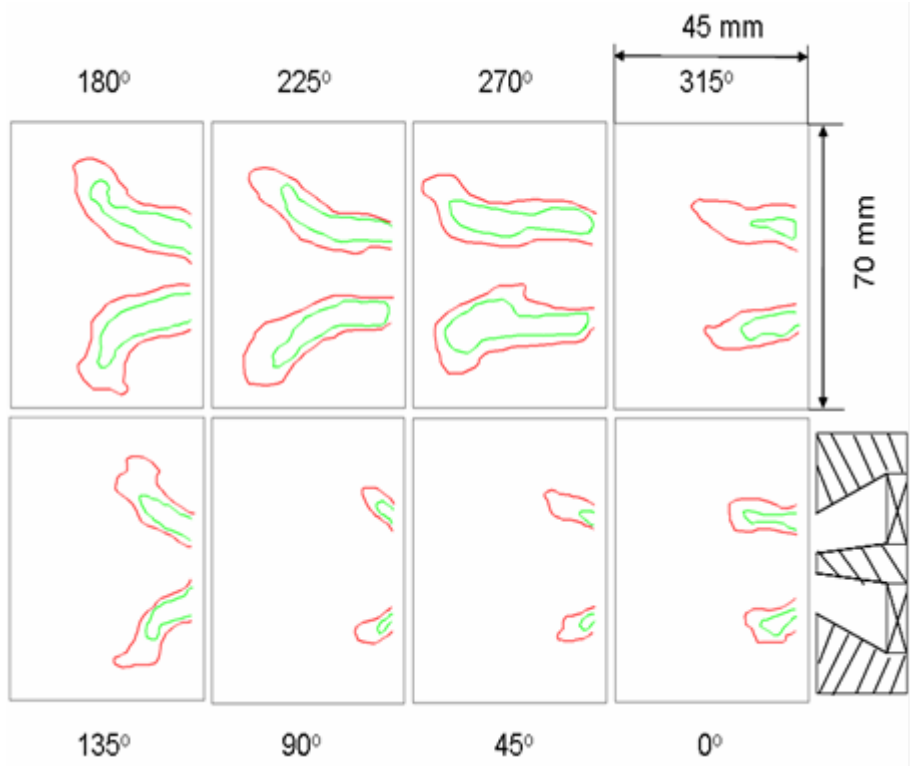
***Re* =21,000 (Unforced)**

***Re* =21,000, f= 130 Hz, u'/u_o = 0.6**

- **Gradual growth in flame brush thickness**
- **Modulations in flame length.**

RESULTS AND DISCUSSIONS (Swirl Flame)





***Re* =21,000, f= 130 Hz, u'/u$_o$ = 0.6**

- **Flame brush growth suppressed / inhibited in forced case**
- **Modulations in flame length.**

CLOSING REMARKS

- ✓ **Flame brush growth suppressed substantially in presence of harmonic forcing**
- ✓ **Flame brush grows in step-wise fashion across vortices**
- ➢ **Discussion, ideas on what is controlling the observed behavior?**
  - **Flame brush evolution known to be substantially altered in flow with pressure gradients, mean strain**