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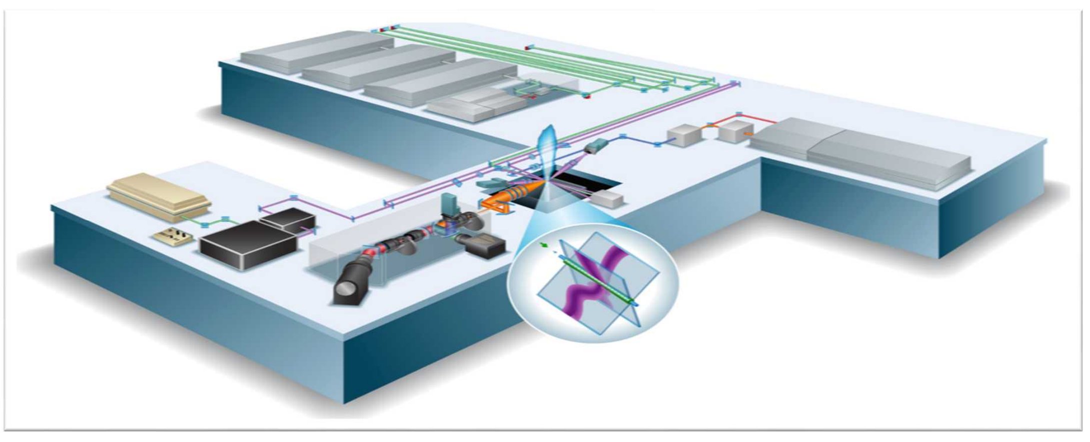

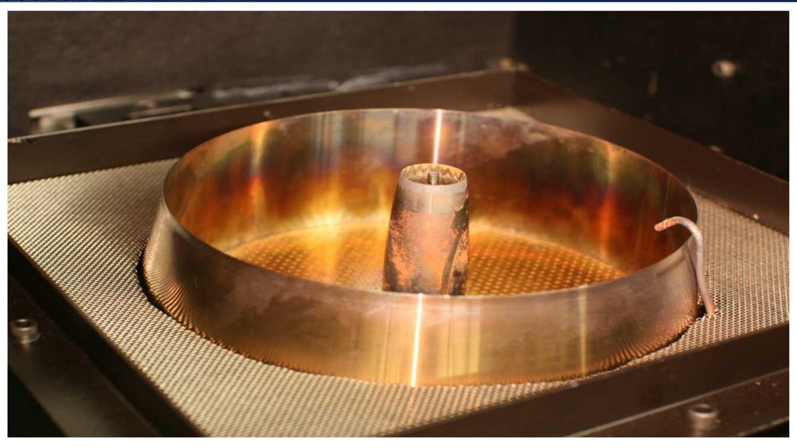

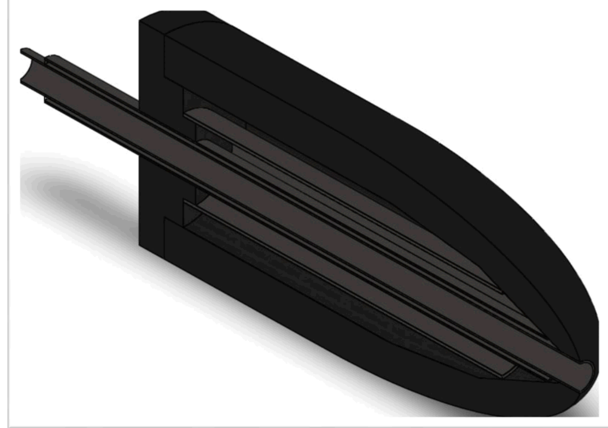

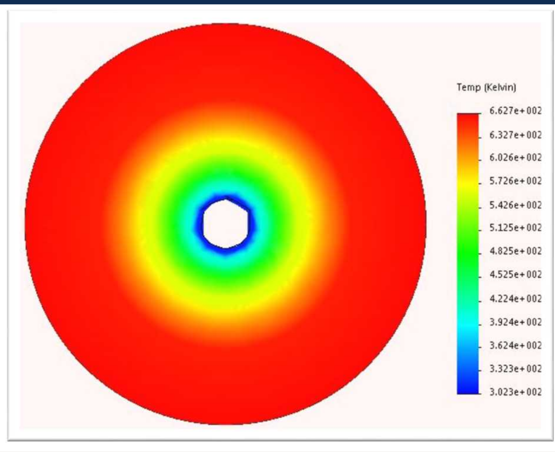

Heat Transfer Analysis of a Modified Premixed Jet Burner

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Abstract

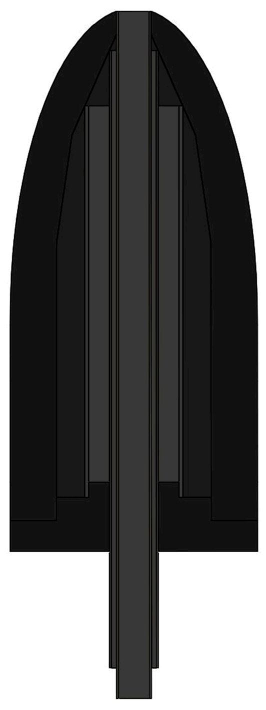
In the present work, a new burner design is proposed to investigate finite-rate chemistry effects in highly sheared turbulent premixed jet flames in a hot (1500 K) coflow. A piloted premixed jet burner (PPJB), used in previous experimental and computational studies, is modified by eliminating the pilot while still achieving thermal isolation of the reactant jet. Doing so reduces the problem to two streams and allows for the stabilization of low Damköhler number (*Da*) premixed flames without the additional complications typically found in gas turbine combustors, such as swirl, recirculation, and complex boundary conditions. The intent of this study is to determine if a passive design is sufficient for computational modeling by ensuring that the heat transfer to the jet is at a minimum, thereby resulting in a burner exit temperature close to room temperature. Toward that goal, a heat transfer analysis is performed on the proposed design. Preliminary results show that conduction across the air gaps dominates. The modified burner will be the target of detailed laser-based measurements of temperature, species, and velocity, allowing for quantitative evaluation of turbulent combustion models.

Introduction

- Most combustion systems involve turbulent flow
- Desirable to make them cleaner and more efficient
- Need to identify and understand controlling basic principles in turbulent combustion
- Experiments that isolate effects of turbulence-chemistry interaction are needed for model validation
- Simple and well-defined BC are essential
  - Heat transfer analysis

Burner Design

- Coflow:
  - 197 mm diameter
  - lean H2/air products
  - 1500 K
  - 0.8 m/s
- Central Jet:
  - 4 mm diameter
  - CH4/air
  - 50-200 m/s
- Thermal Design:
  - Ceramic shroud, Macor or 310M silica foam
  - Air gaps for low conductivity
  - Concentric SS tubes to reduce convection and radiation



Methods

Assumptions

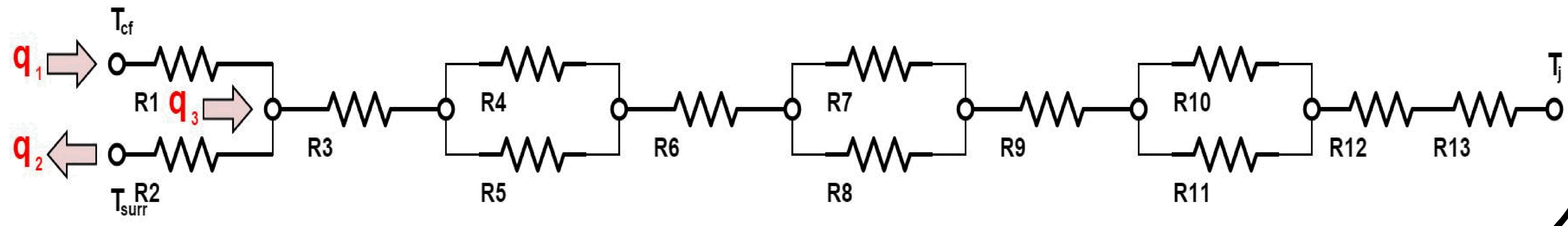
- Steady-state
- 1D and 2D heat transfer
- No fluid motion in air gaps
- Fully developed turbulent pipe flow
- Opaque, diffuse, gray surfaces
- Air does not contribute to radiation

Heat Transfer Mode	Thermal Resistance	
Conduction	$R_3, R_4, R_6, R_7, R_9, R_{10}, R_{12}$	$\frac{ln(r_b/r_a)}{2\pi Lk}$
Convection	R_1, R_{13}	$\frac{1}{2\pi rLh}$
Radiation (surface to surface)	R_5, R_8, R_{11}	$\frac{1}{2\pi r_a L h_r\left[\frac{1}{\varepsilon_a}+\frac{1-\varepsilon_b}{\varepsilon_b}\left(\frac{r_a}{r_b}\right)^2\right]}$
Radiation (surface to surrounding)	R_2	$\frac{1}{2\pi rLh_r}$

$r_b > r_a$, $h_r \equiv \varepsilon\sigma(T_a+T_b)(T_a^2+T_b^2)$, $\sigma = 5.67 \times 10^{-8}\, W/m^2 \cdot K^4$

$$q = \frac{\Delta T}{R} \qquad \Delta T = T_b - T_a,\ T_b > T_a$$

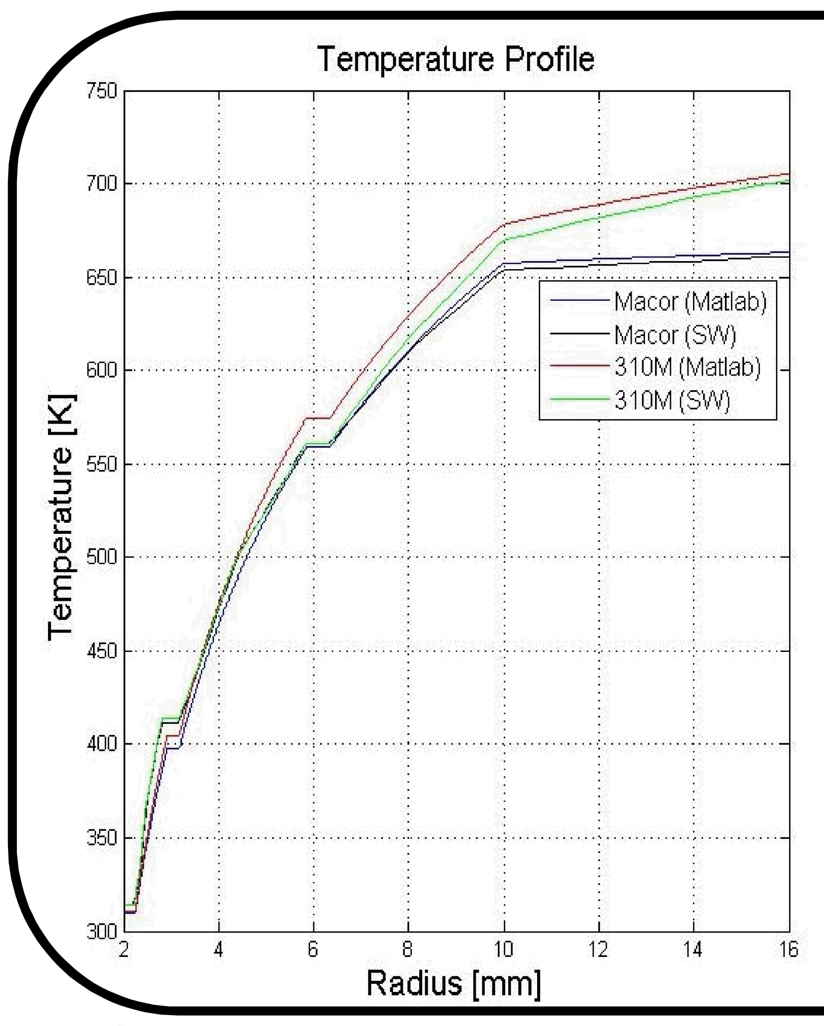
$$q_3 = q_1 - q_2$$

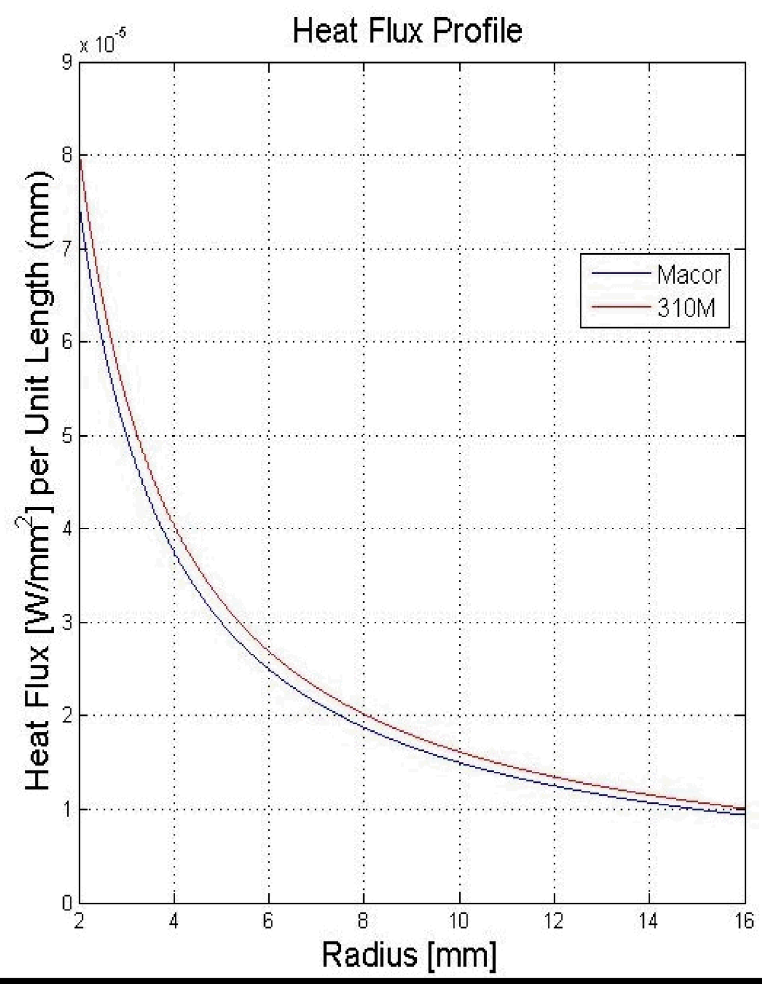


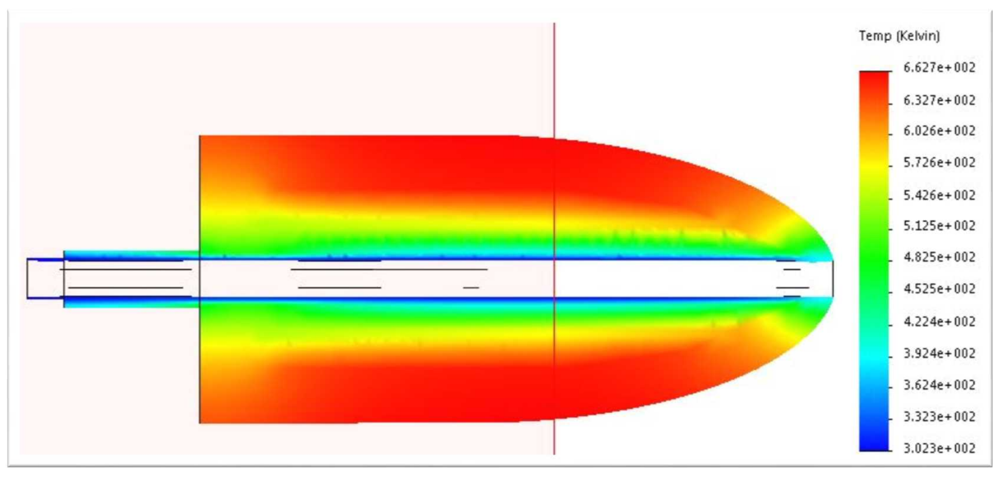
Approach

- MATLAB
  - Thermal circuit
  - Discretization (air gaps)
  - Simplified geometry
- SolidWorks Thermal Simulation
  - Finite Element Analysis

Preliminary Results/Discussion







Summary

- Radiation across air gaps shown to be negligible
- Air gaps provide effective insulation

Future Work

- 3D heat transfer
- Burner exit temperature calculation
- Evaluation of active cooling design
- Final design and construction

Acknowledgements

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