CFD Analysis of a Lean Premixed Gas Turbine Combustor for H2 Applications

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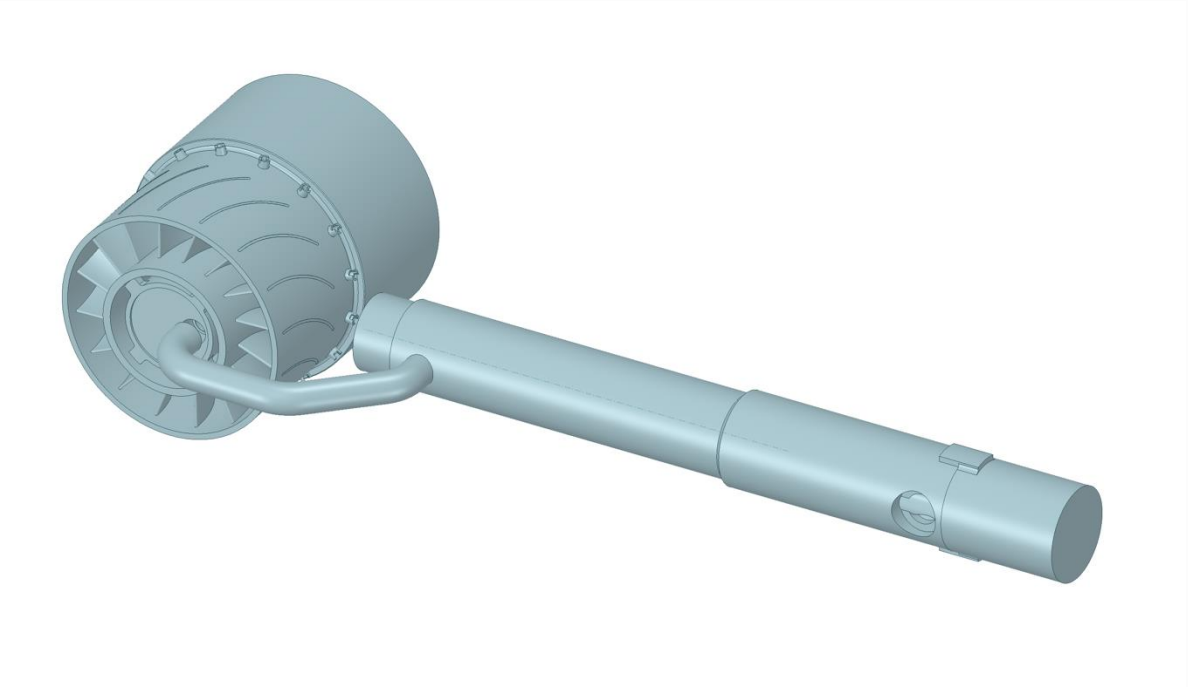
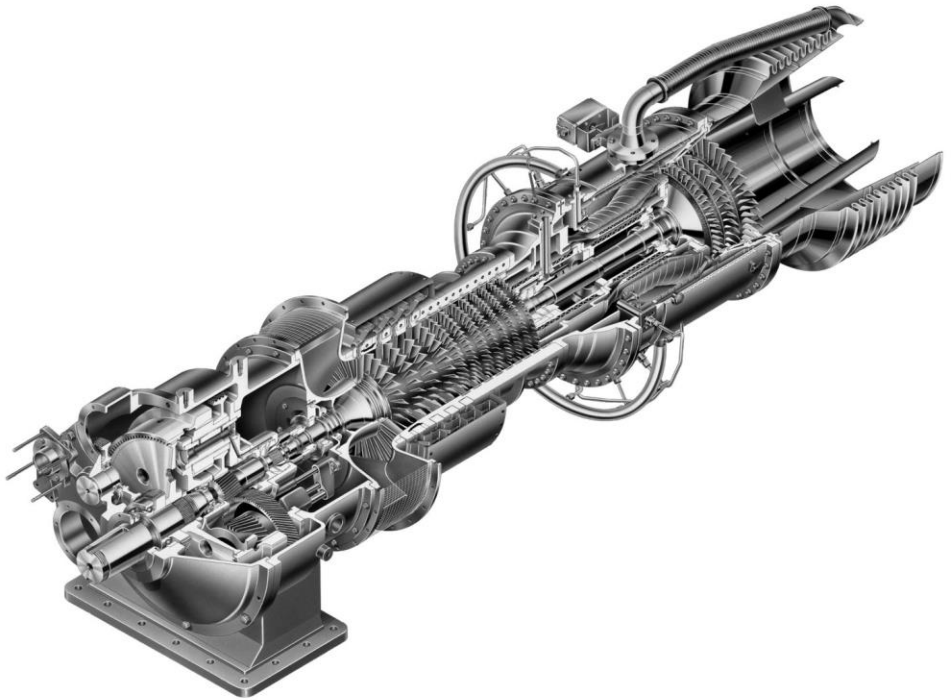
EthosEnergy

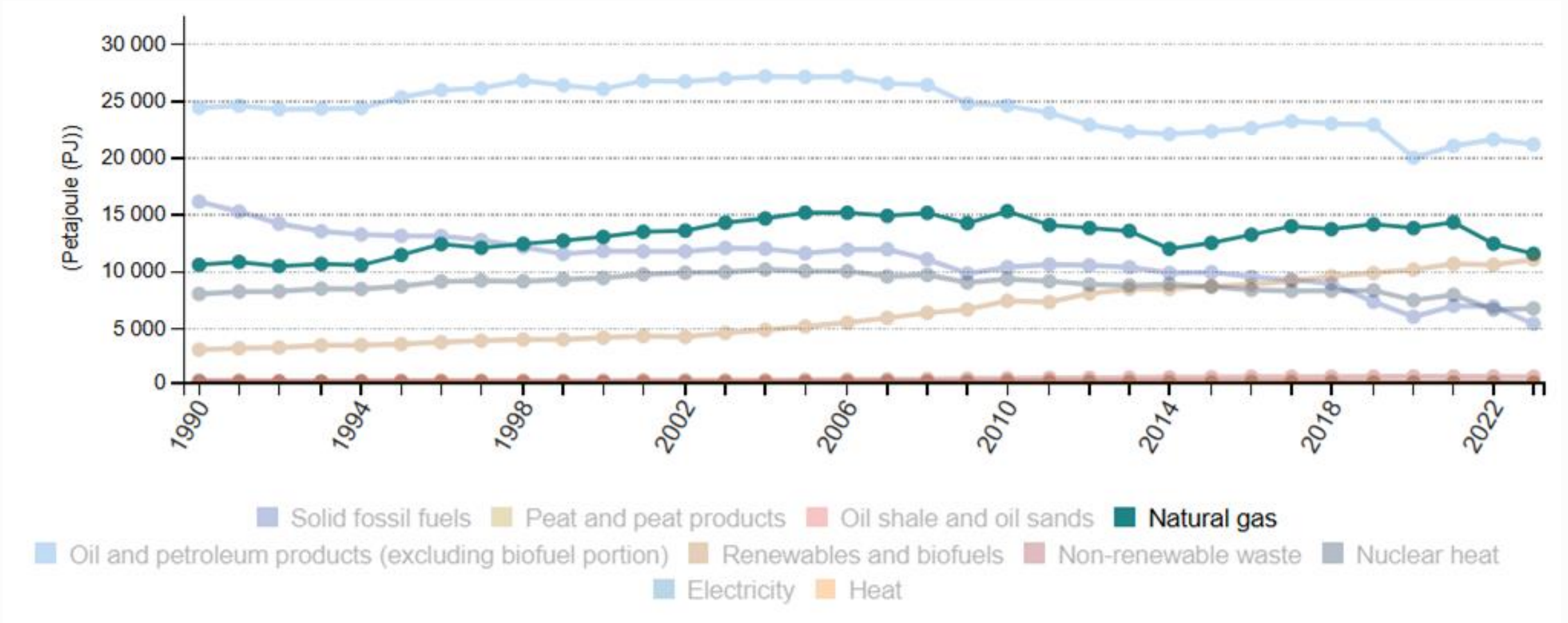
Motivation

EthosEnergy S.P.A developed an injector that allows the introduction of hydrogen – methane mixture to the combustion chamber of a gas-turbine



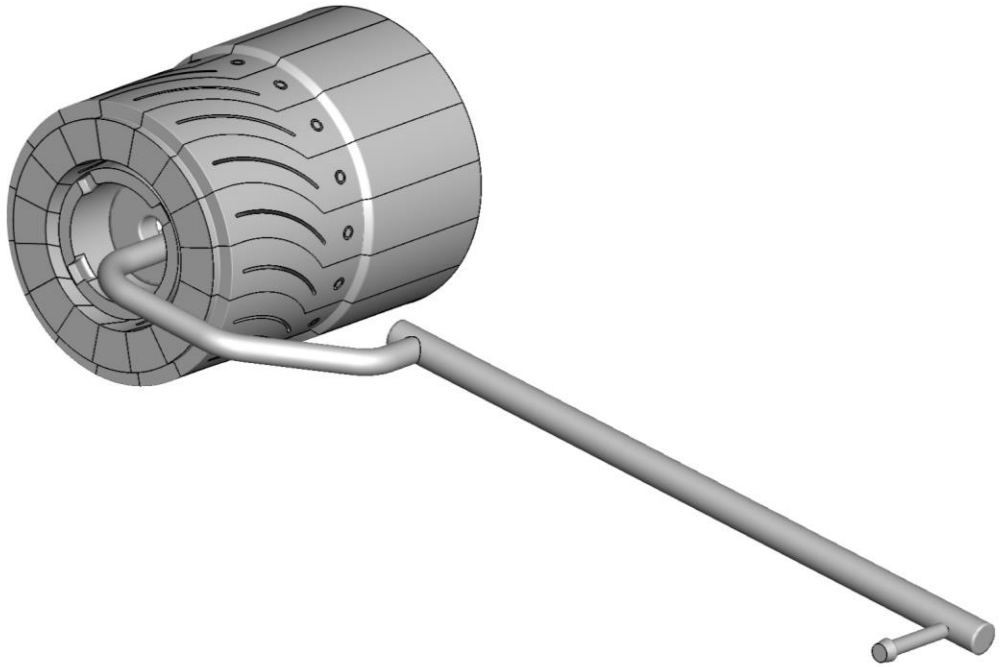


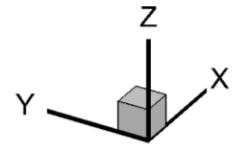
Gross available energy by fuel, EU, 1990-2023



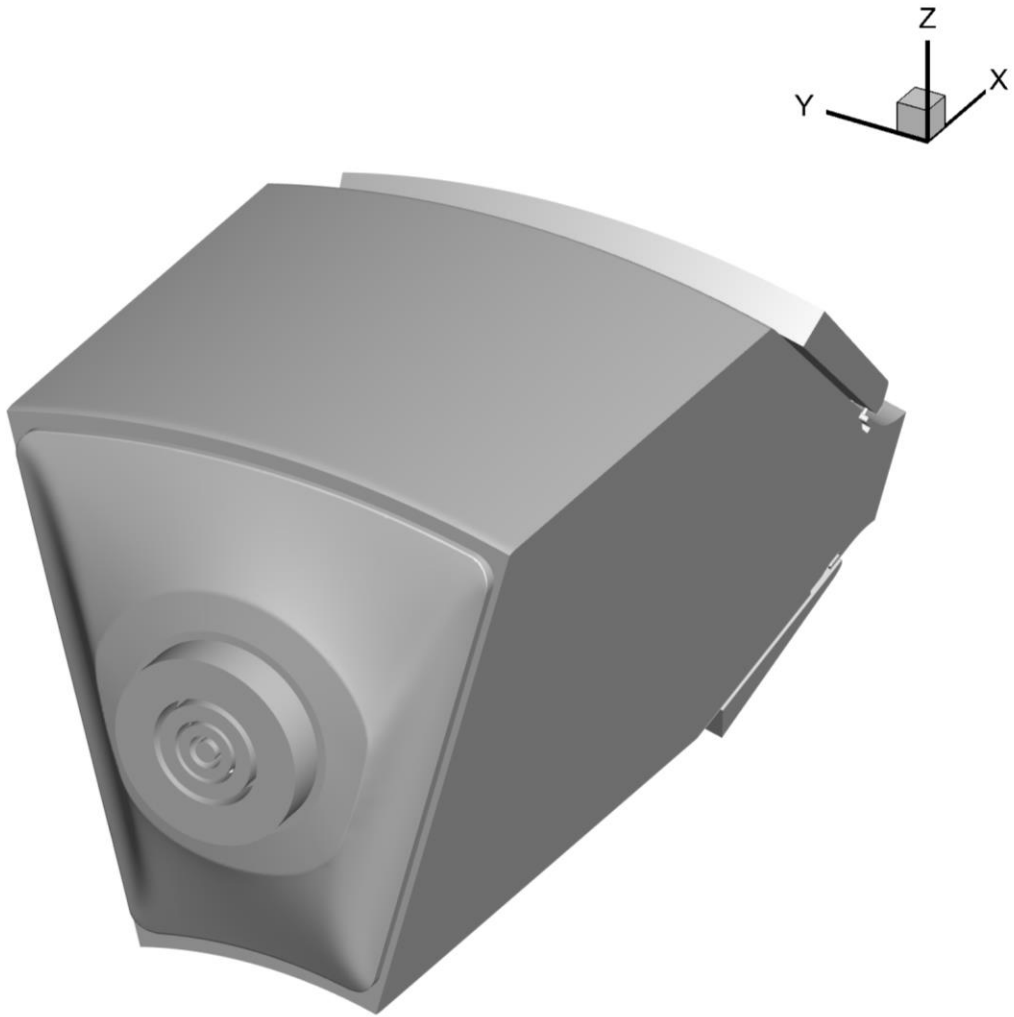
Source: [*Eurostat, "Energy statistics - an overview," 2024*]

Starting Geometry

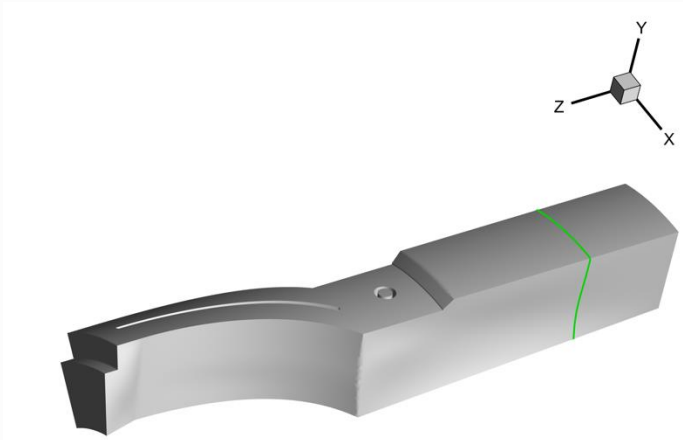




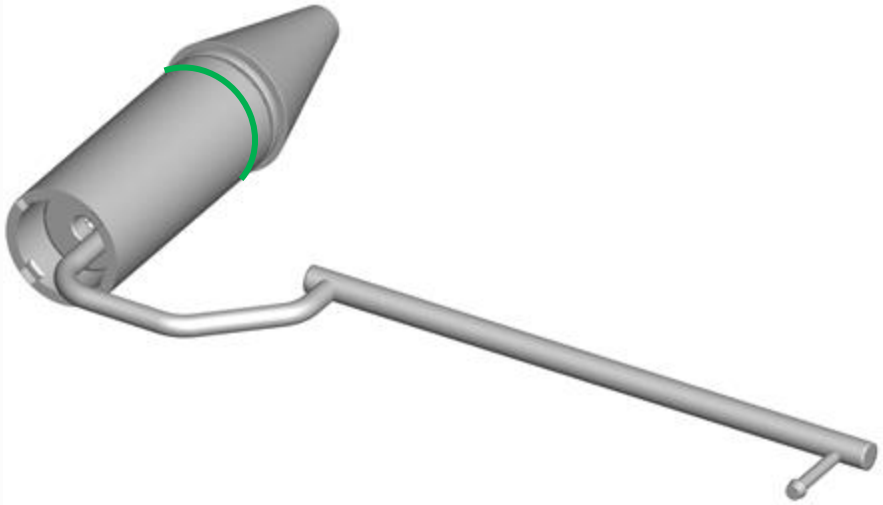
Simulated Geometry



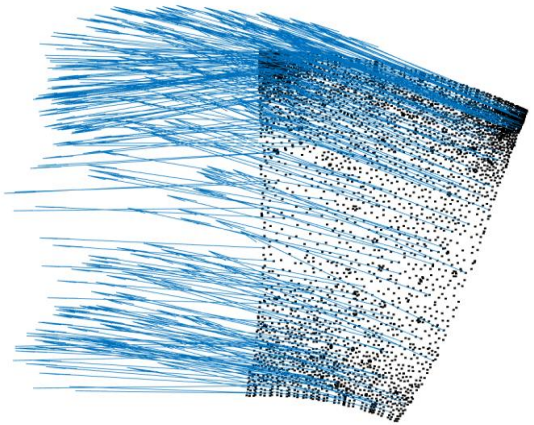
Results Reconstruction

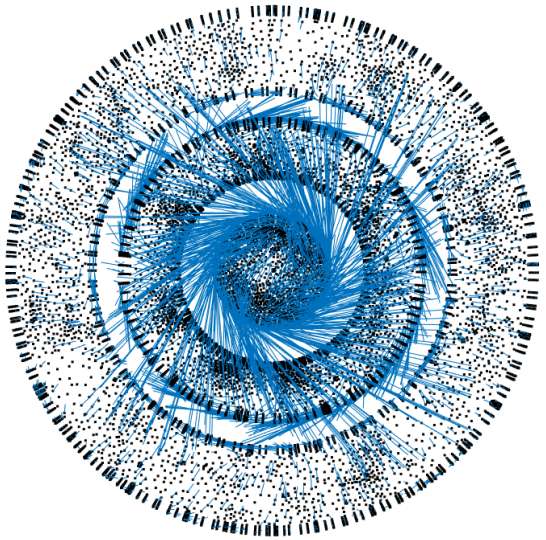


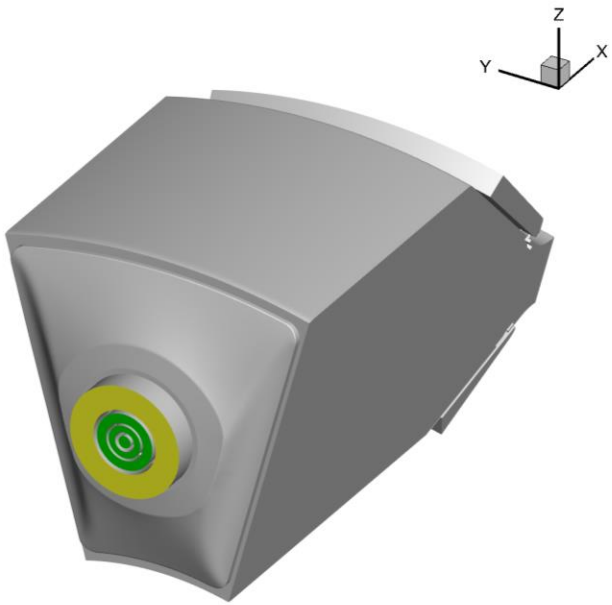
Main



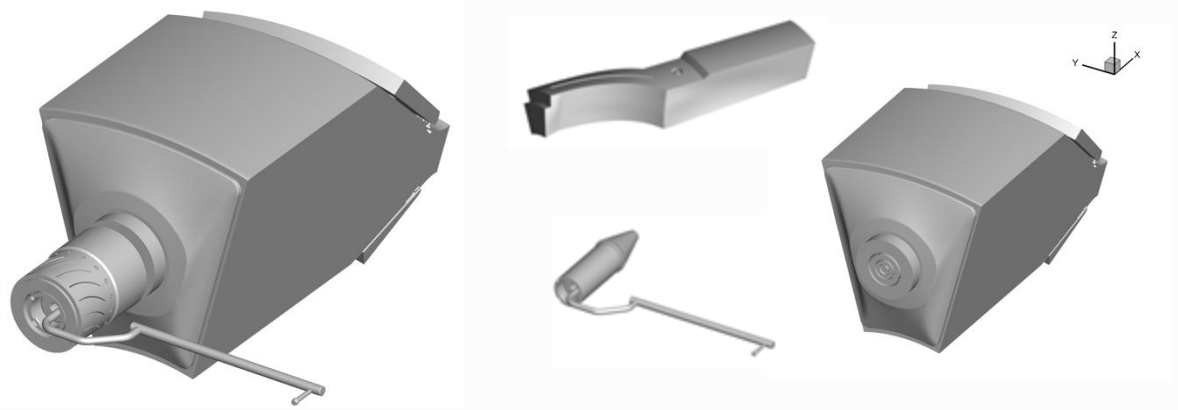
Pilot







Coupling Objective

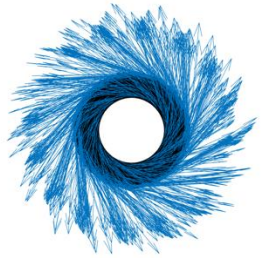


Fluid Volume	Uncoupled	Coupled
Combustion Chamber	26 million	26 million
MAIN	33 million	2 million
PILOT	17 million	17 million
Total	**76 million**	**45 million**

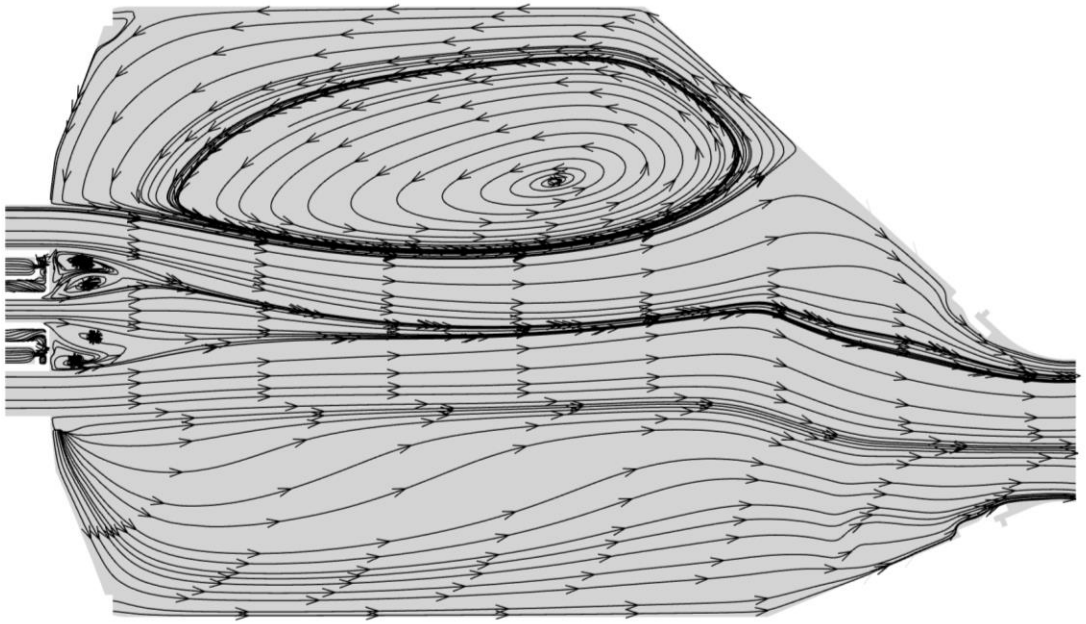
Achieved a 70% reduction in the number of elements

Stream Traces

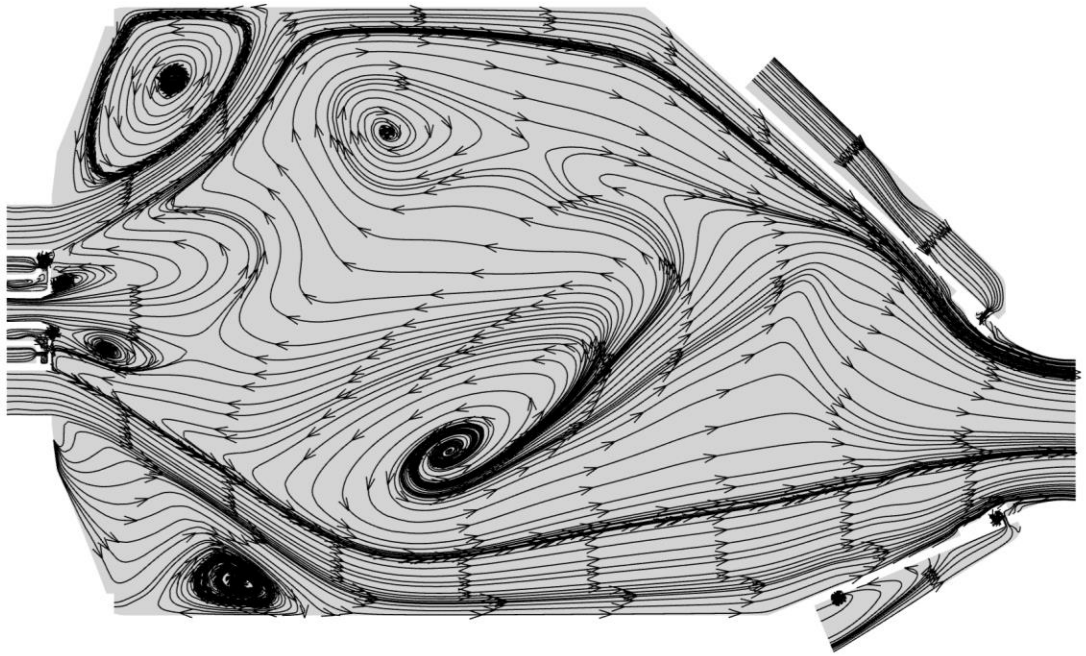
Swirl Number $$S = \frac{\int_{R_i}^{R_o} r\,\rho\,u_{\text{axial}}\,u_\theta\,dA}{R_o\int_{R_i}^{R_o}\rho\,u_{\text{axial}}^2\,dA}$$



χ_{H_2}	0	0.25	0.35	0.5
S	30.01	29.54	29.46	29.24

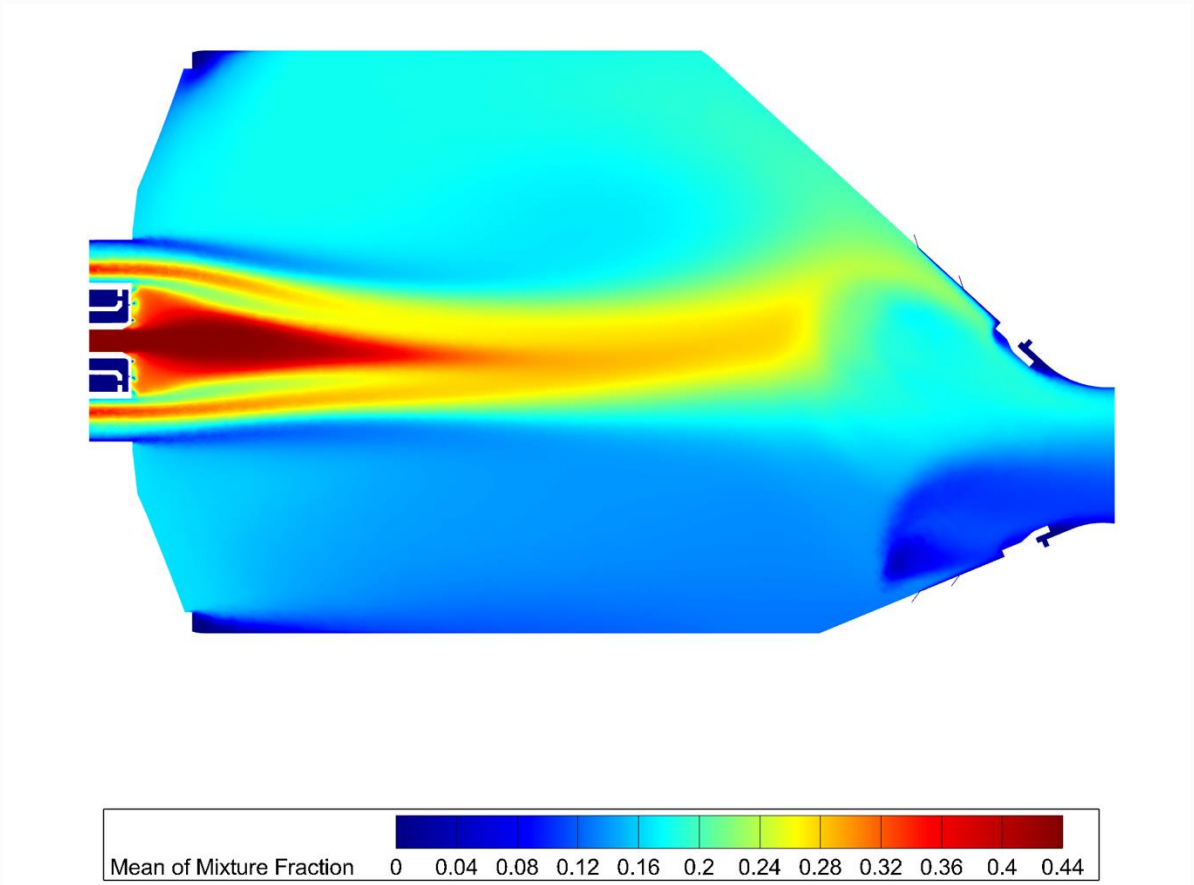


Without Swirl

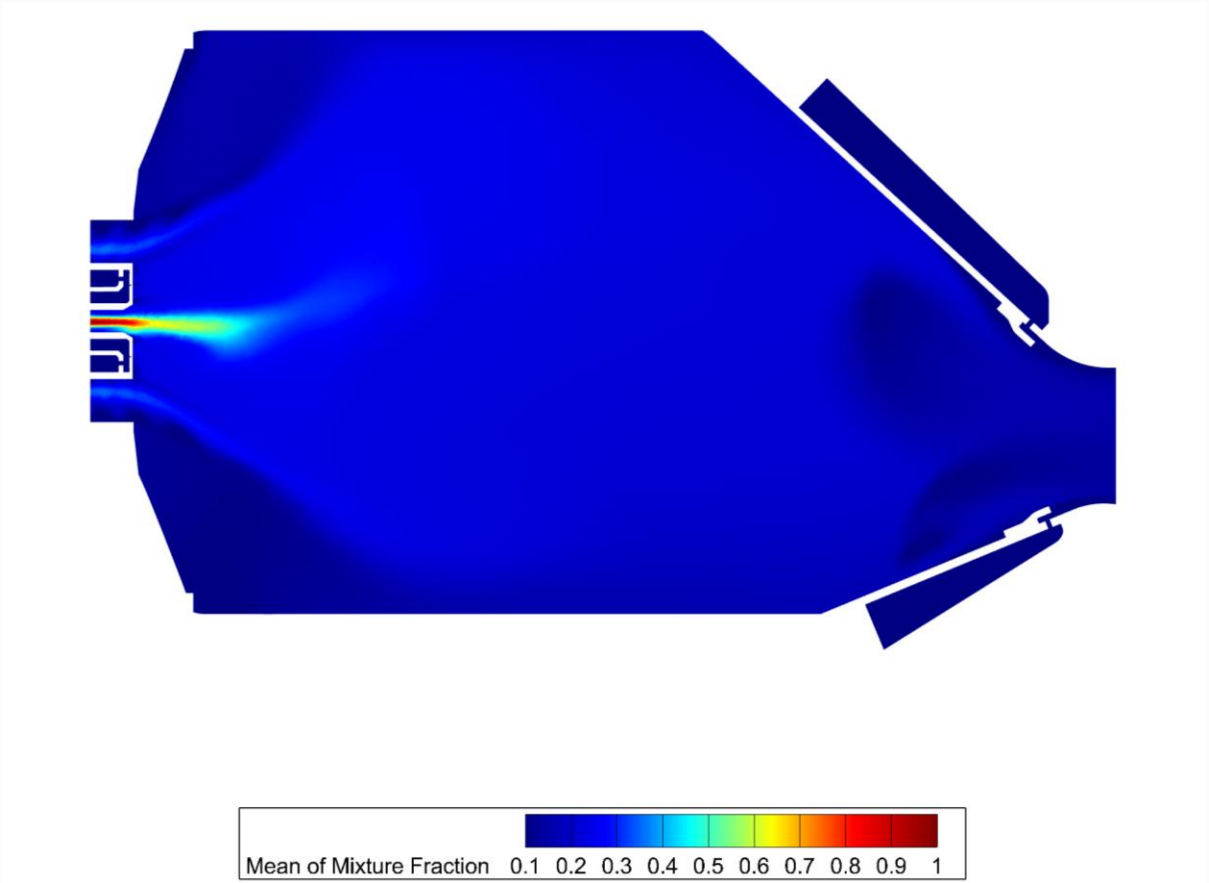


With Swirl

Fuel Distribution

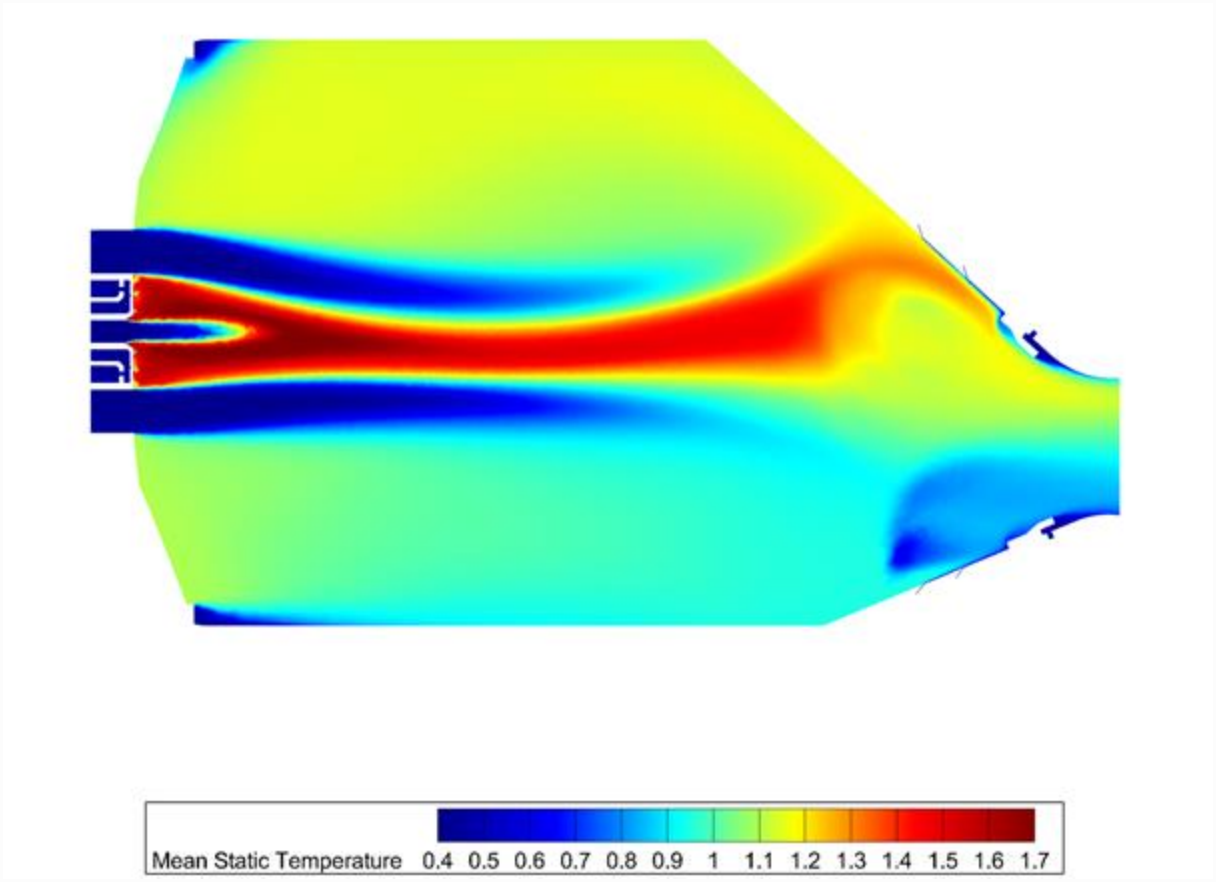


Without Swirl

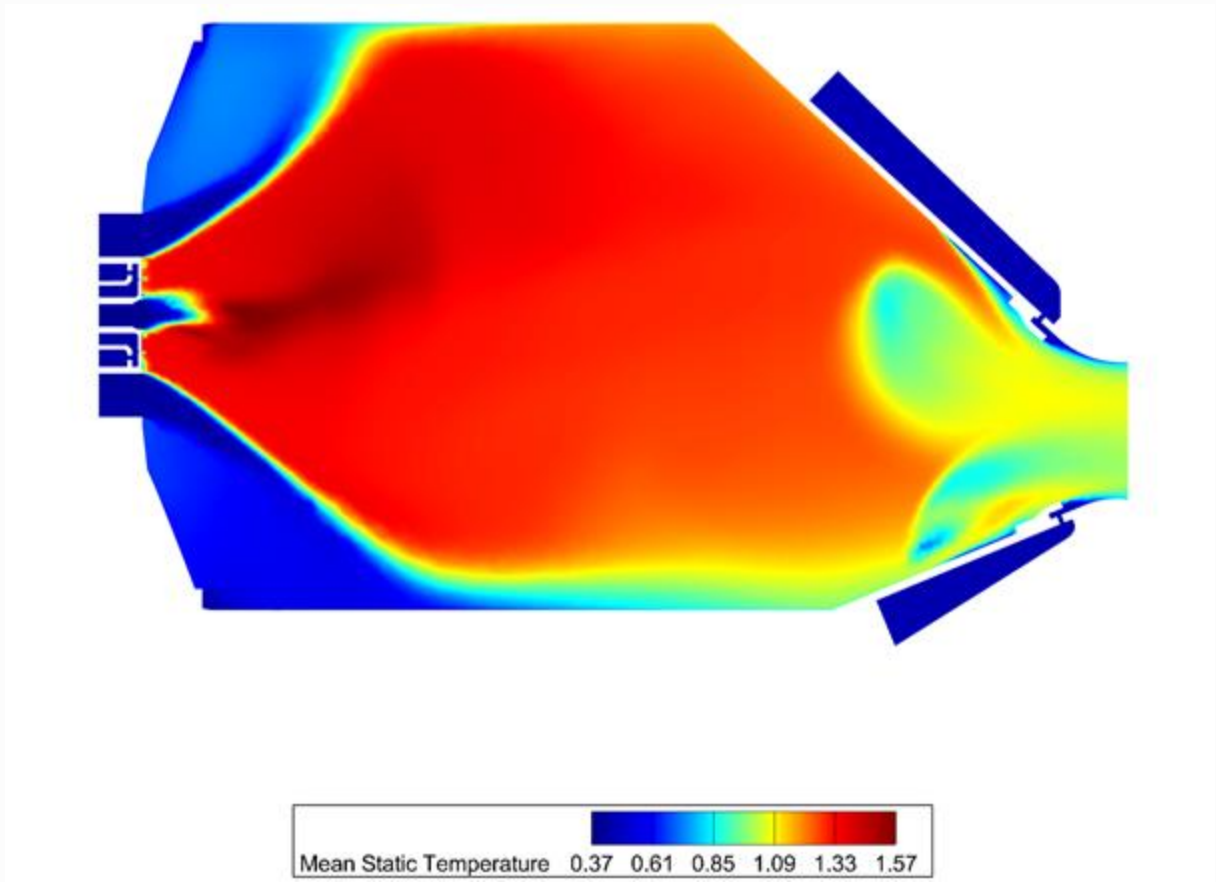


With Swirl

Temperature Distribution

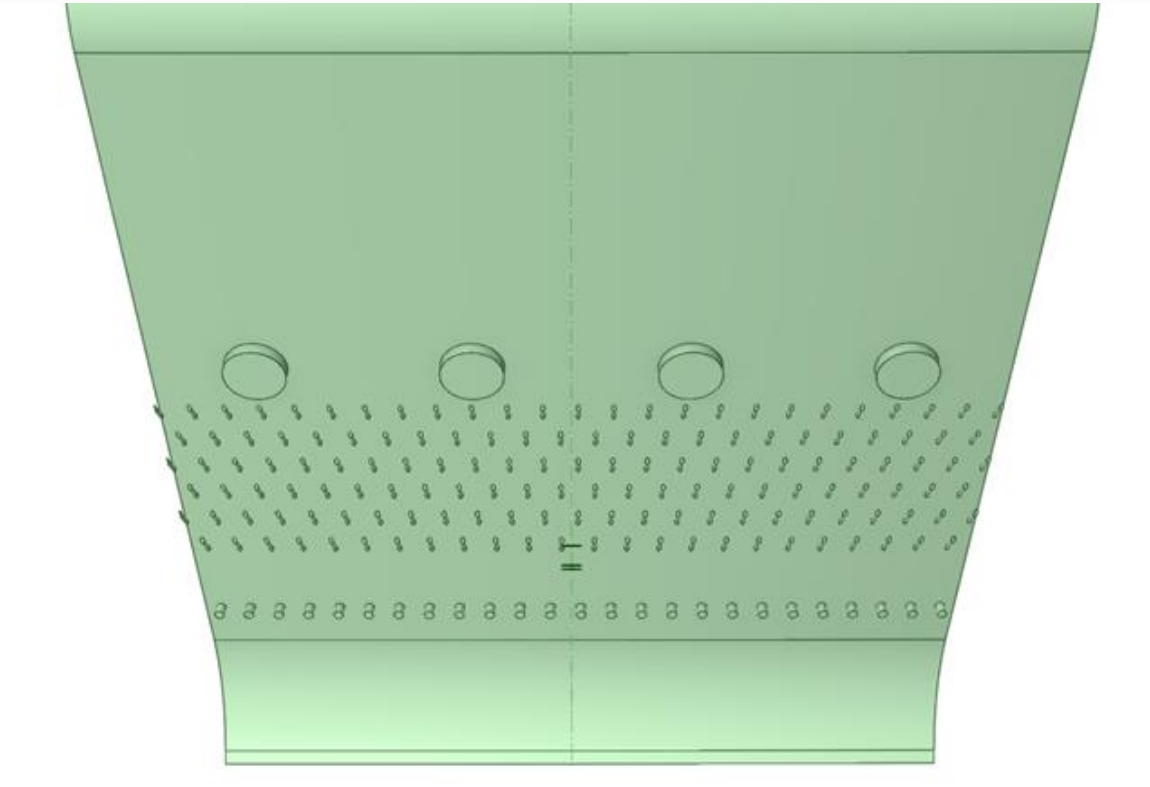


Without Swirl

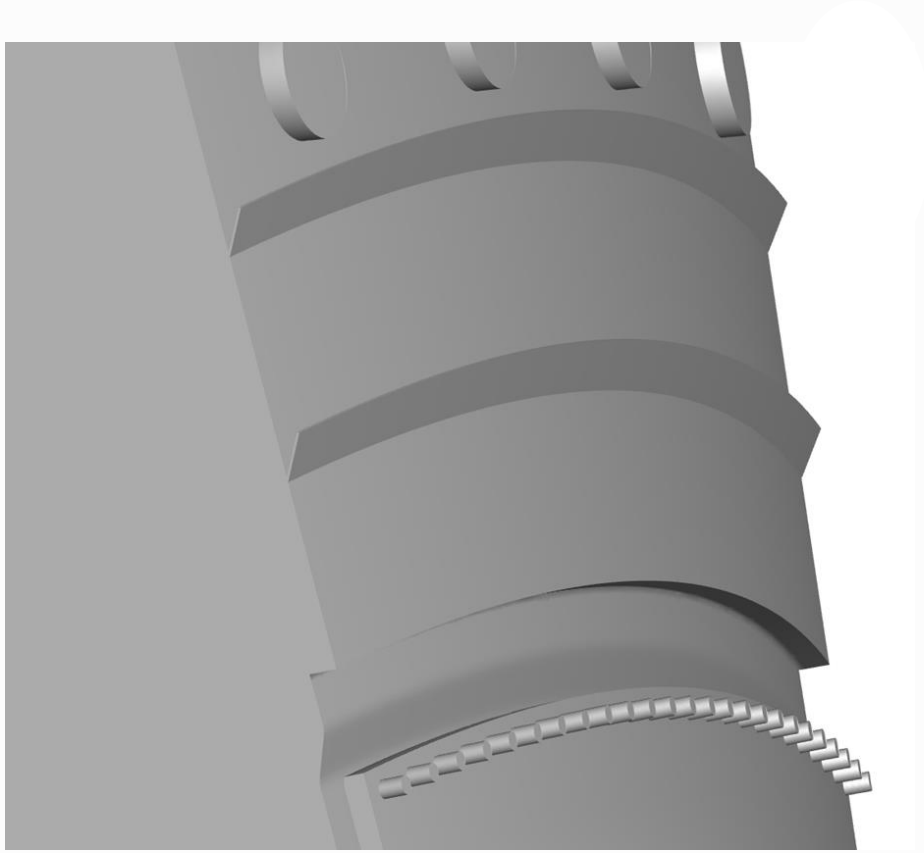


With Swirl

Effusion Holes

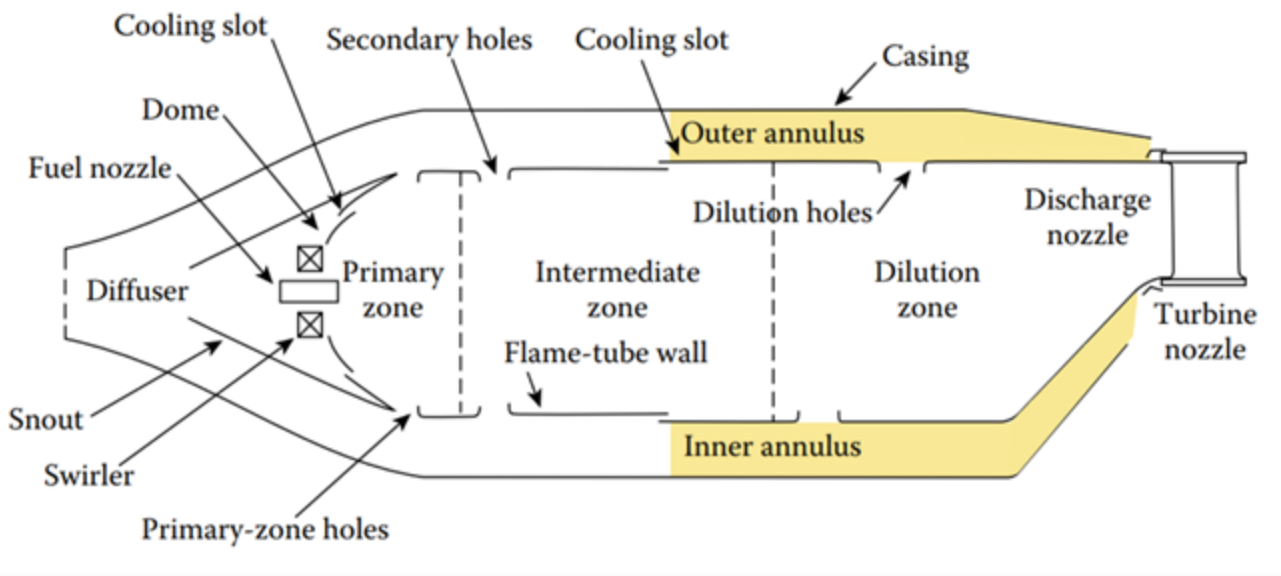


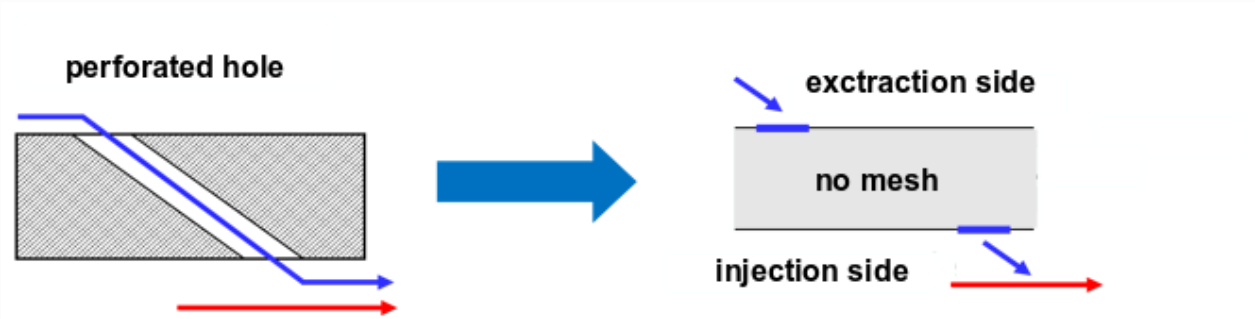
Real Geometry

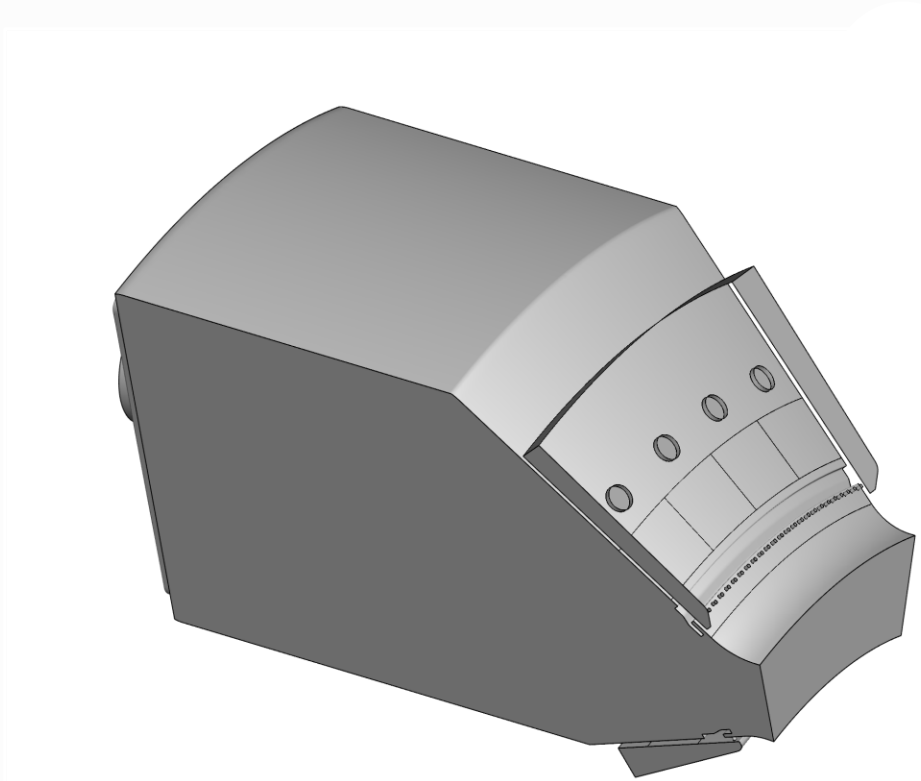


Two Cooling Stripes

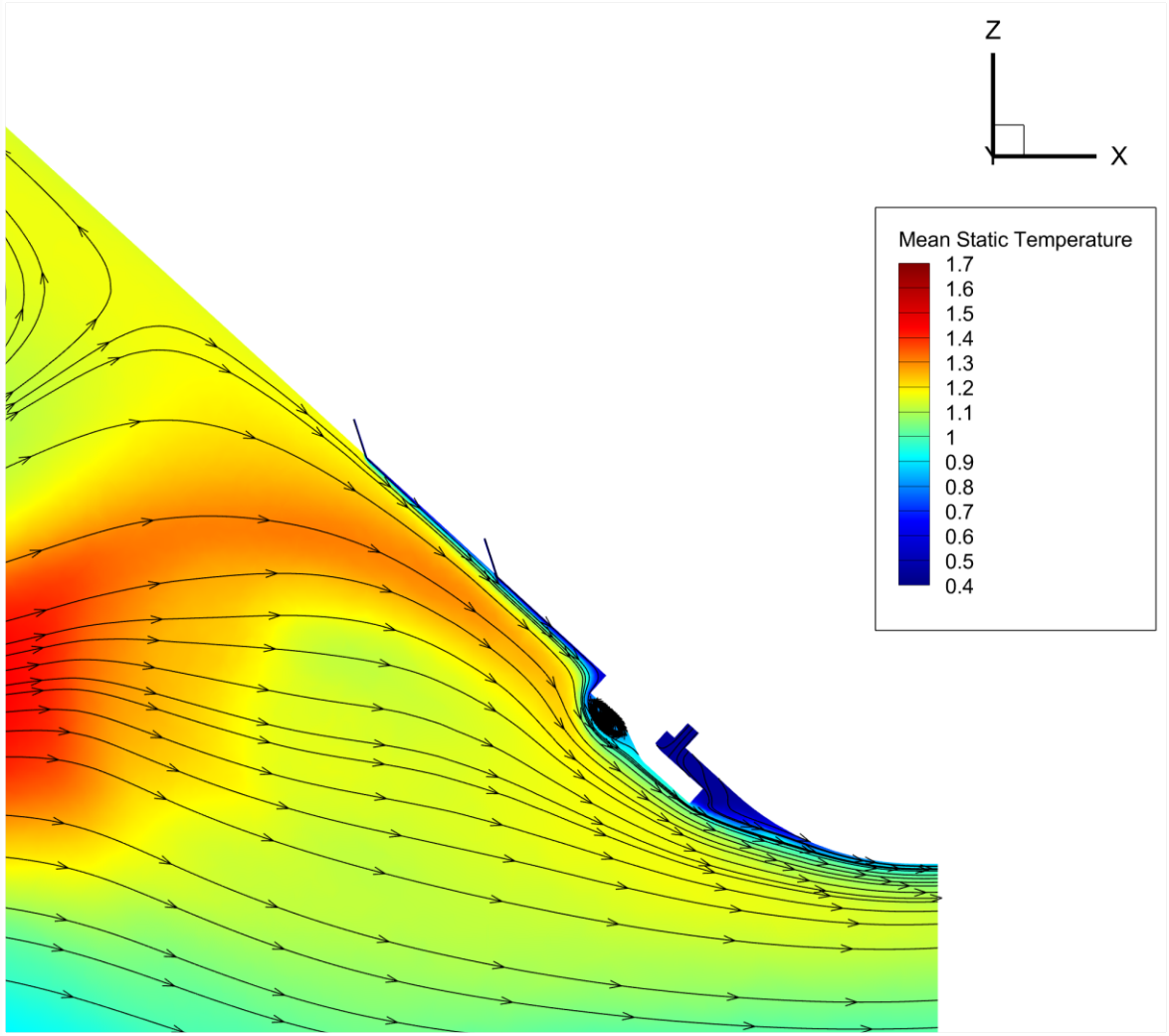
Perforated Wall Model



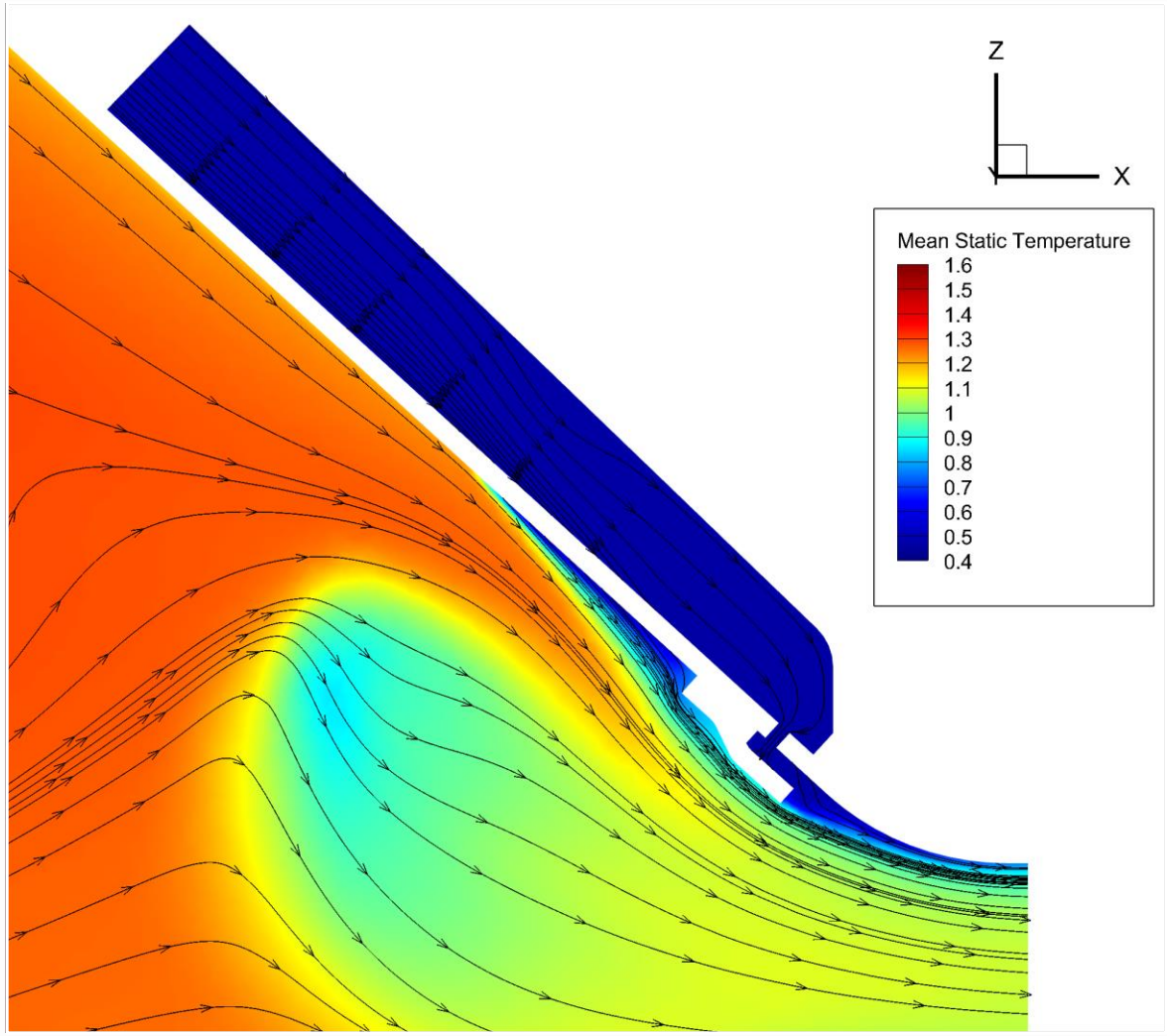




Wall Cooling – Film Cooling

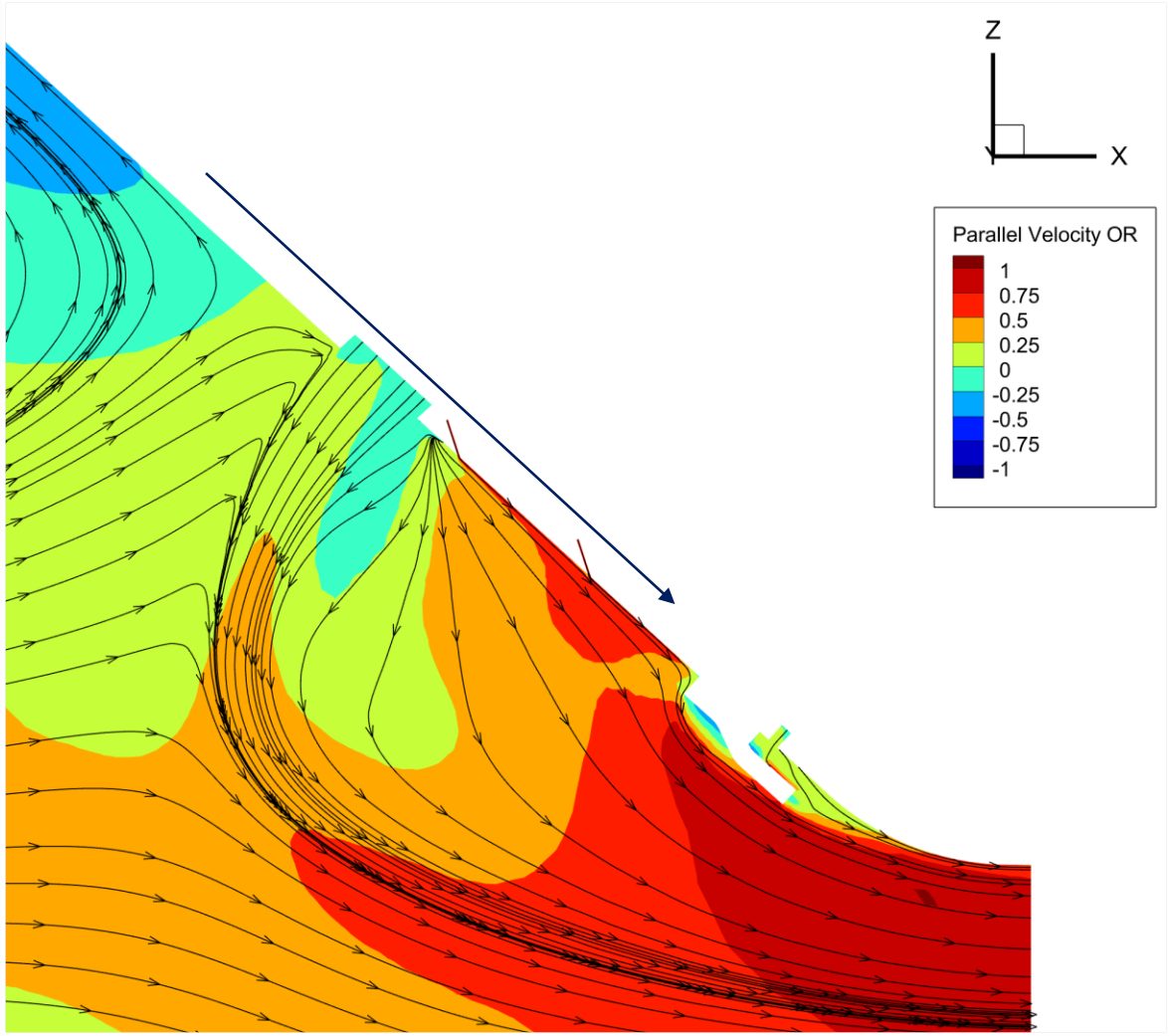


Two Cooling Stripes

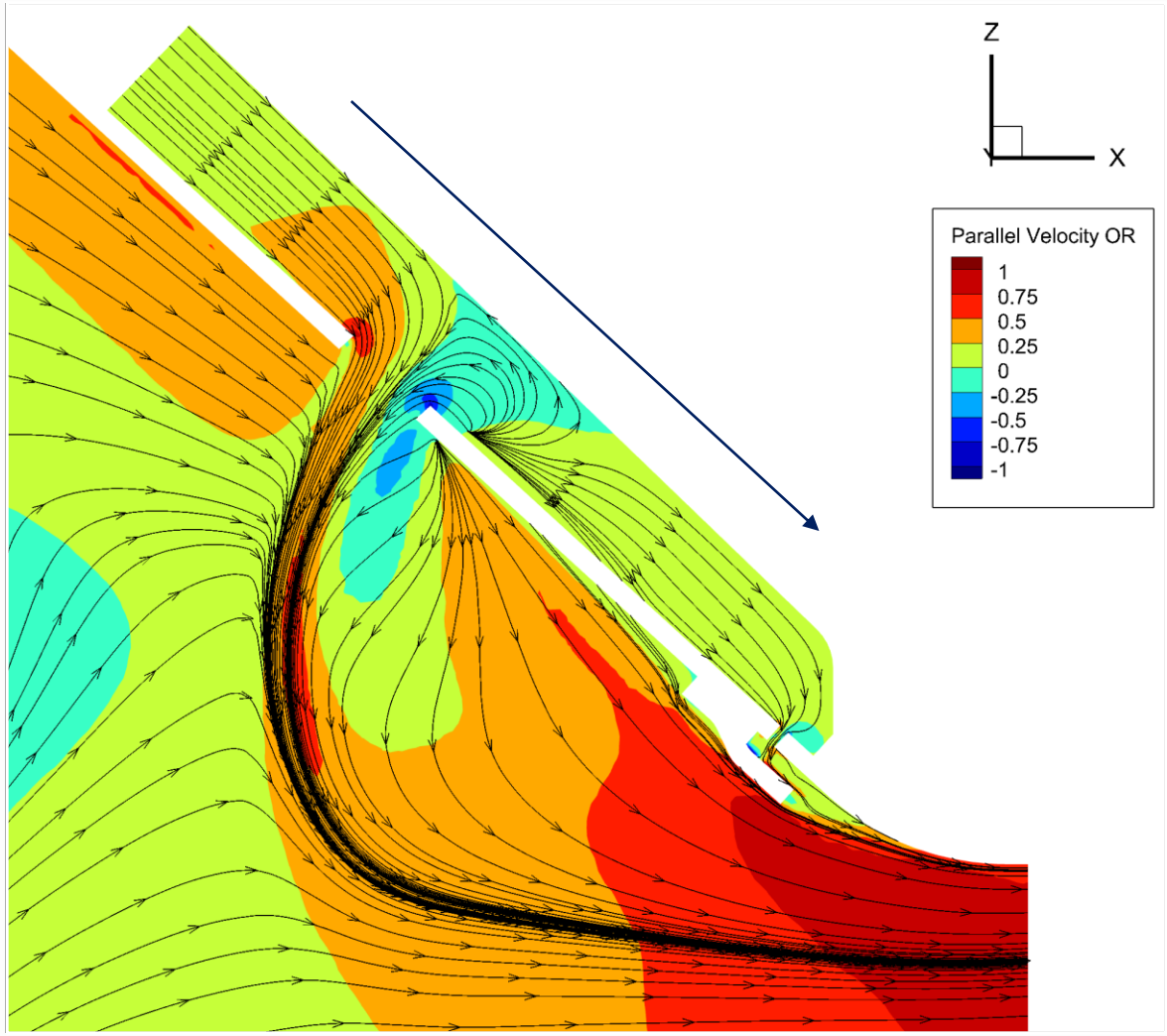


Uniform Perforated Wall Model

Dilution Holes

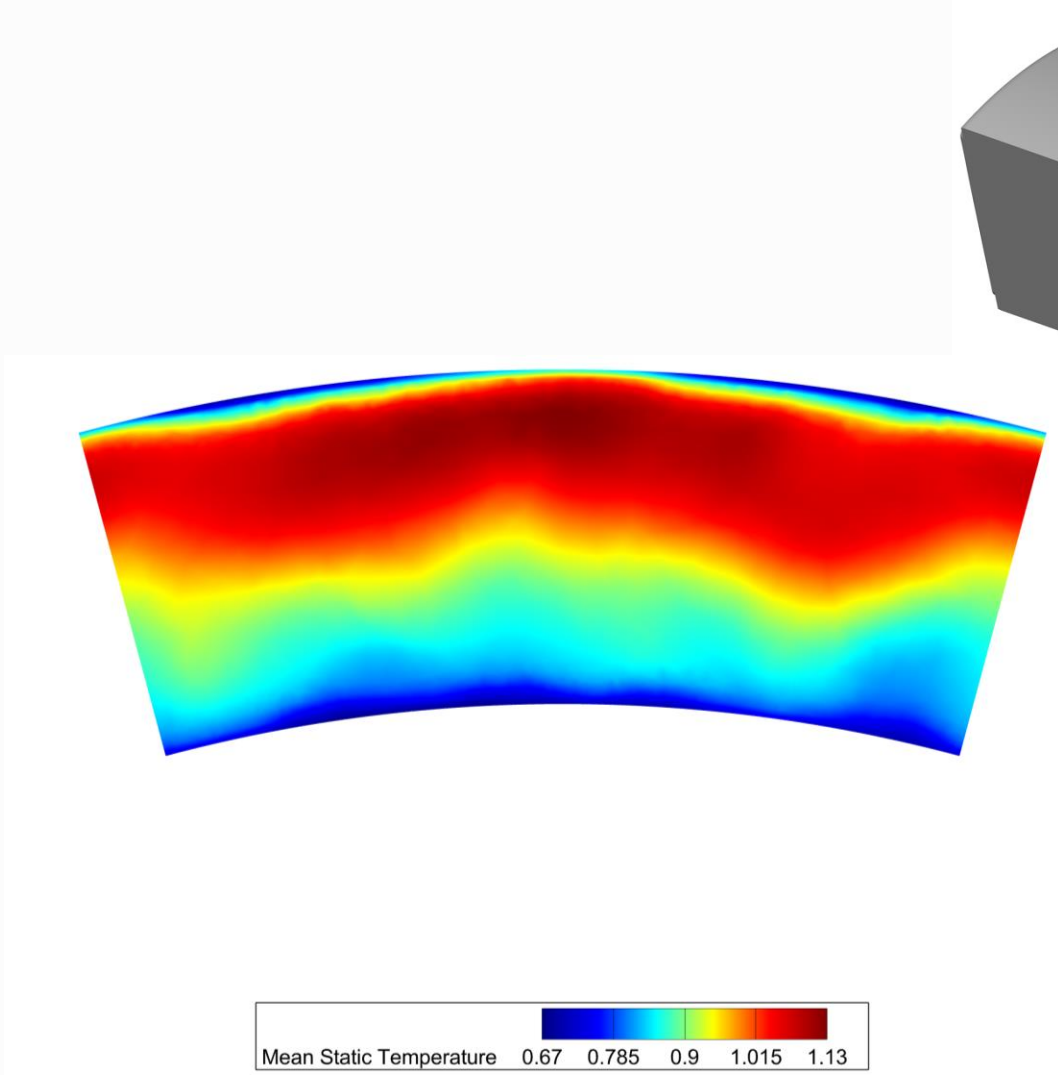


Two Cooling Stripes

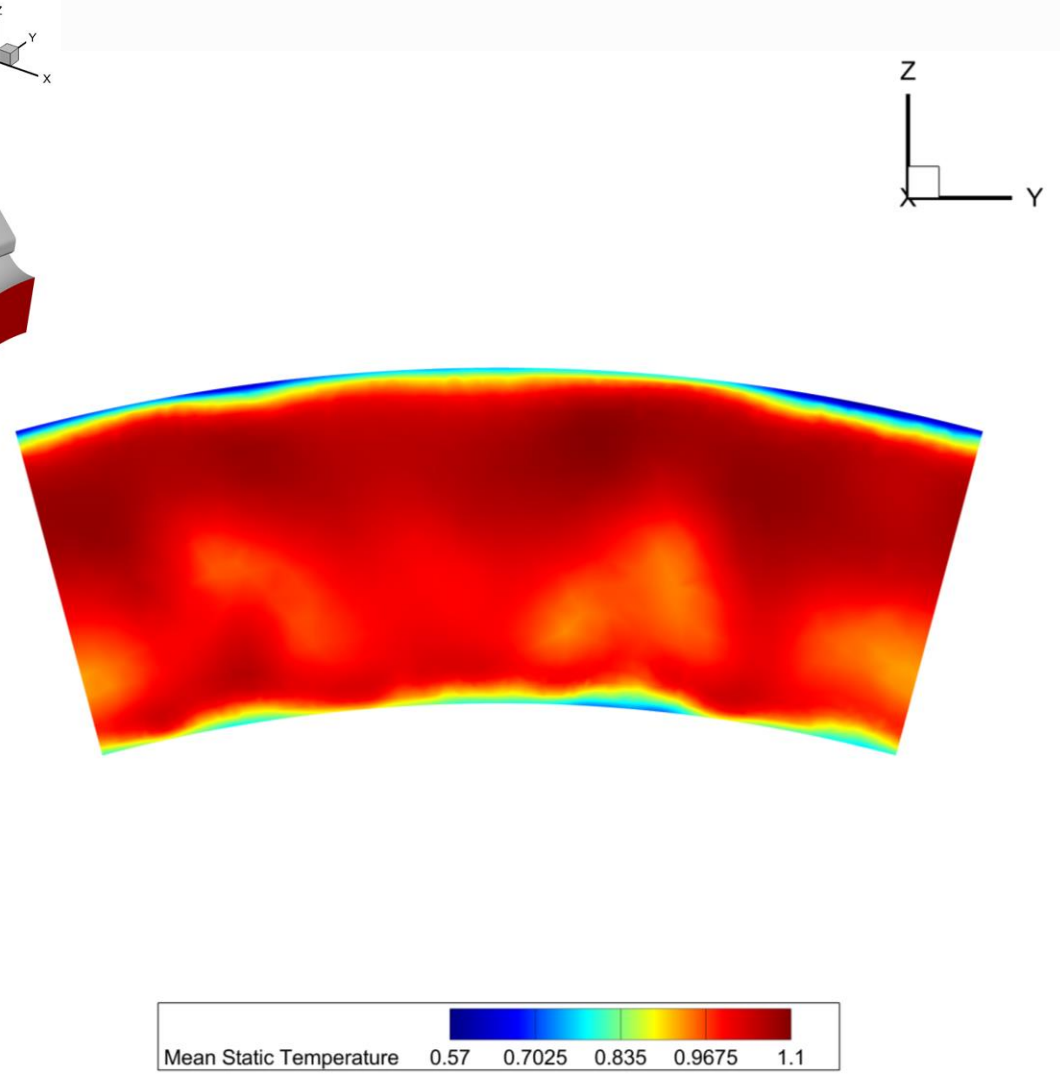


Uniform Perforated Wall Model

Outlet Temperature Distribution



Without Swirl and with Cooling Stripes

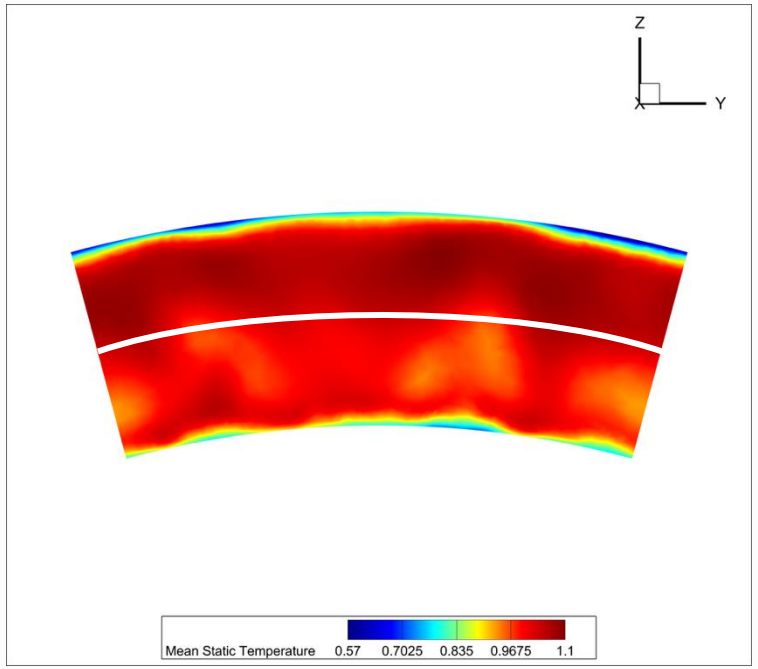


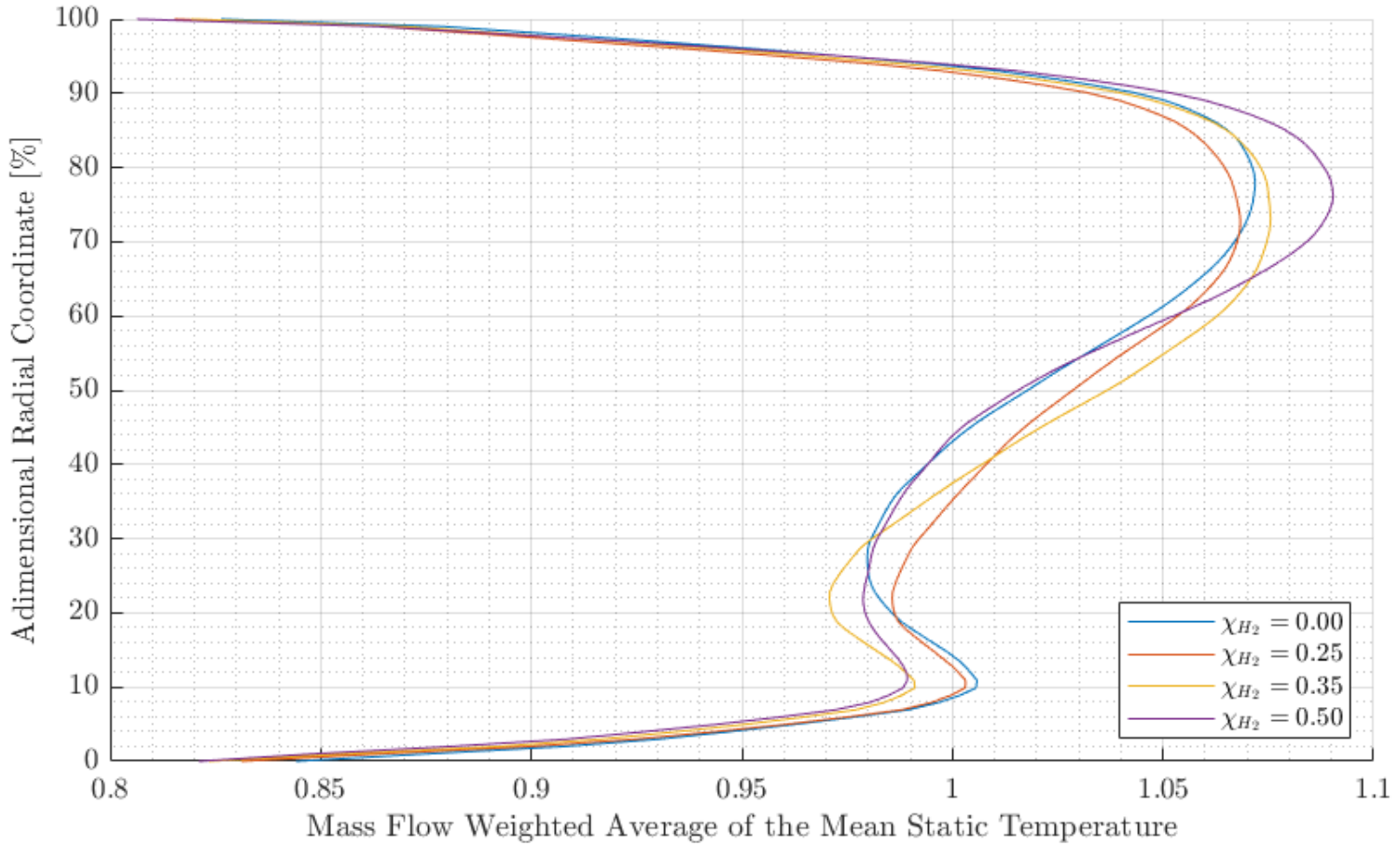
With Swirl and with Perforated Wall Model

Outlet Temperature Distribution

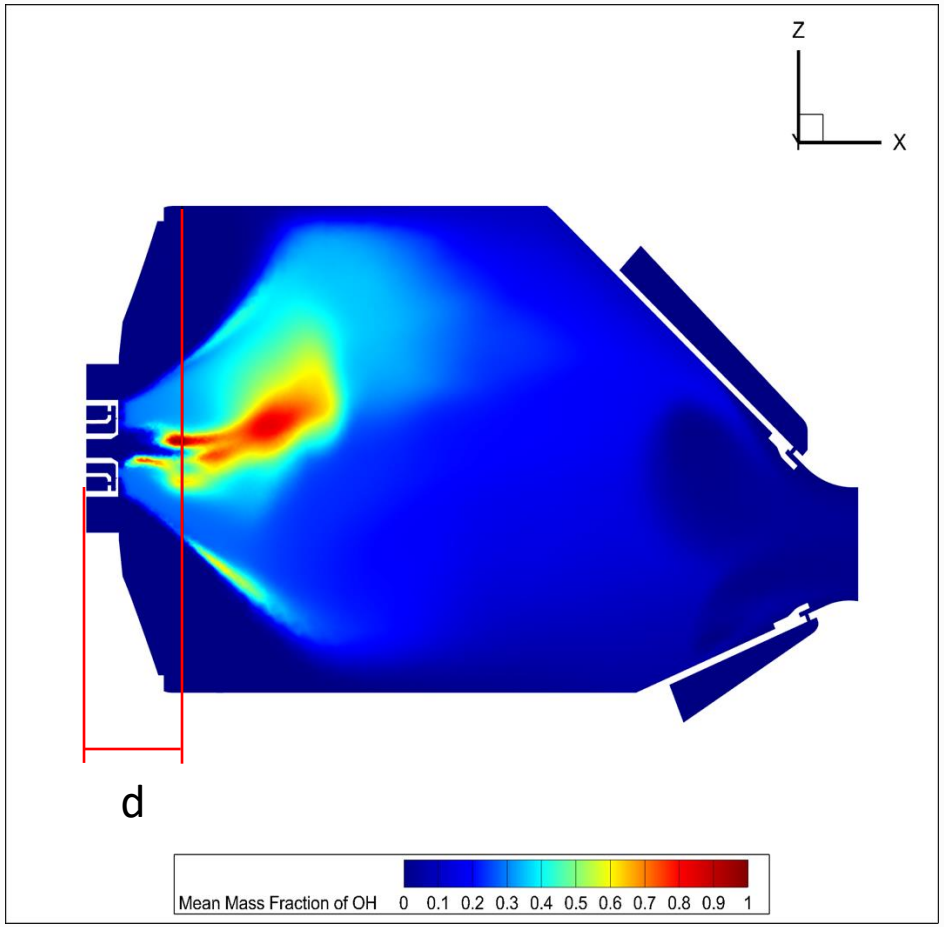
$$PF = \frac{T_{max} - T_{\text{out}_{\text{mean}}}}{T_{\text{out}_{\text{mean}}} - T_{\text{in}}}$$

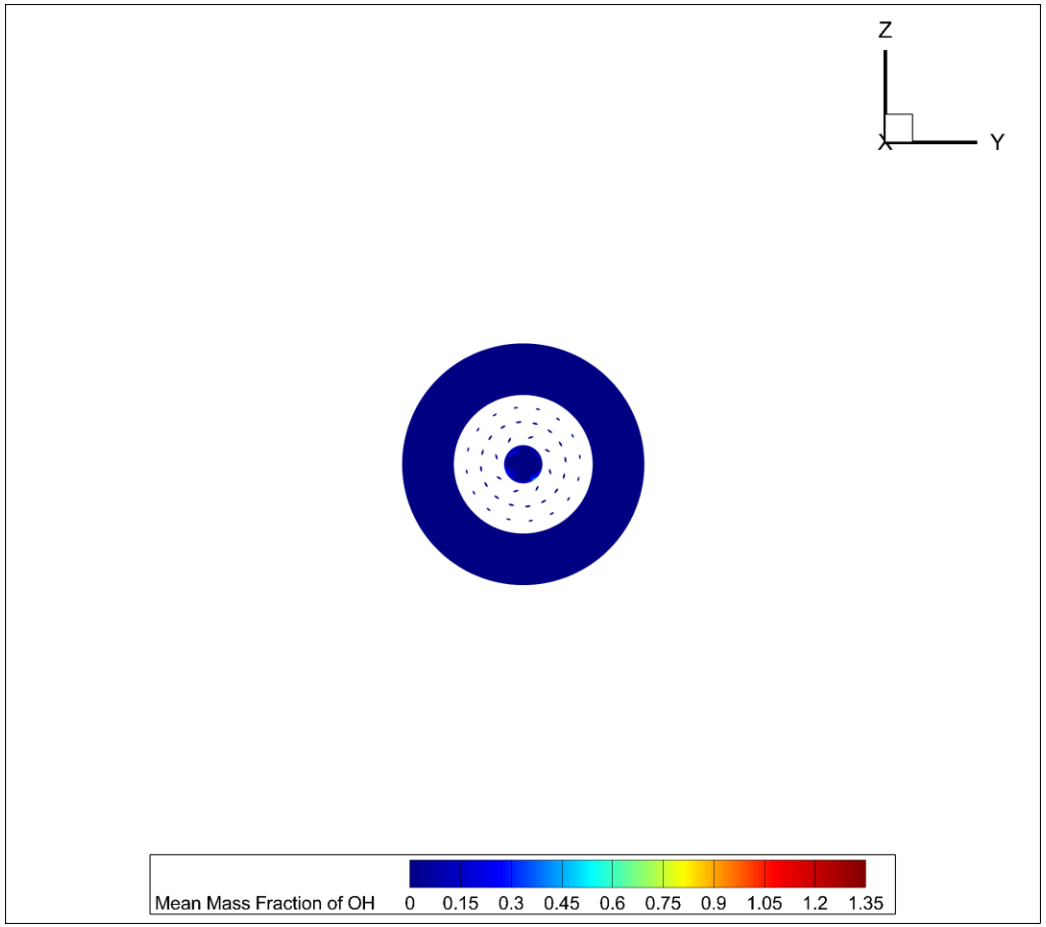
χ_{H_2}	0 %	25 %	35 %	50 %
Pattern Factor	0.1639	0.1961	0.2060	0.2339



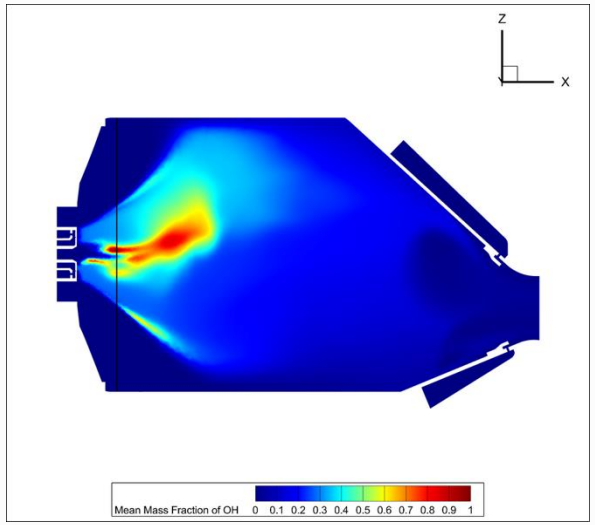


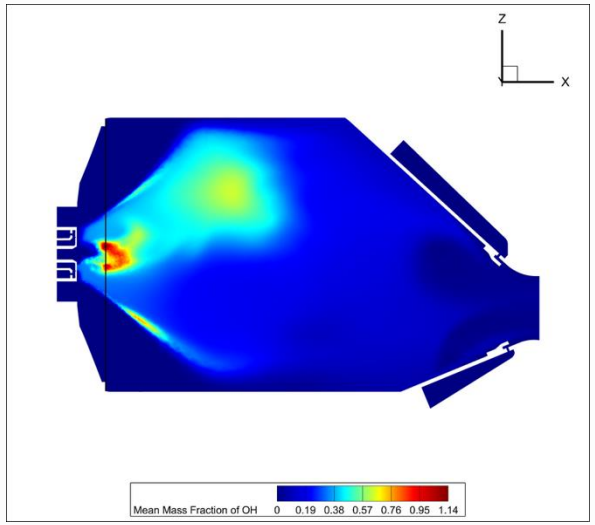
Flame

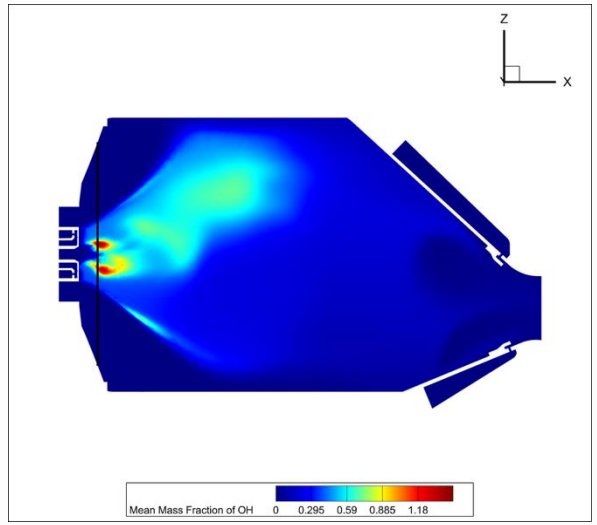

Z
X
d
Mean Mass Fraction of OH 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

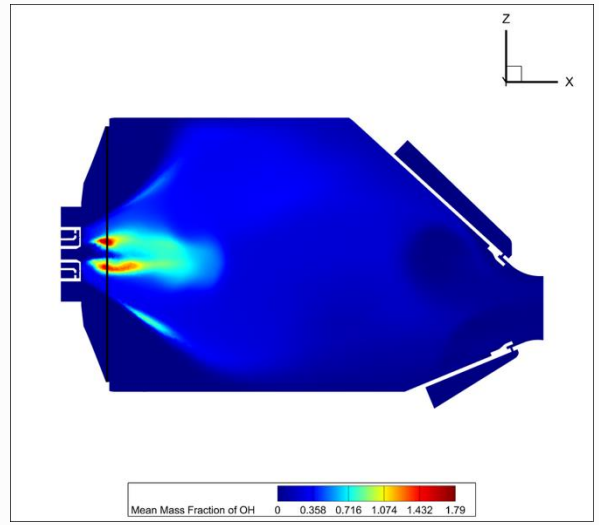

Z
Y
Mean Mass Fraction of OH 0 0.15 0.3 0.45 0.6 0.75 0.9 1.05 1.2 1.35

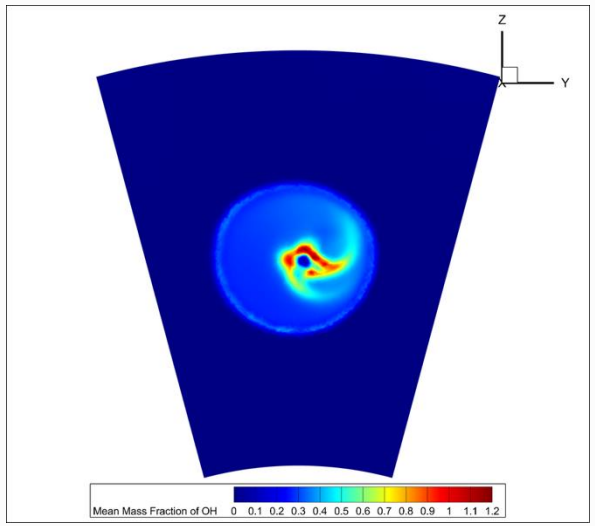
Flame Behavior

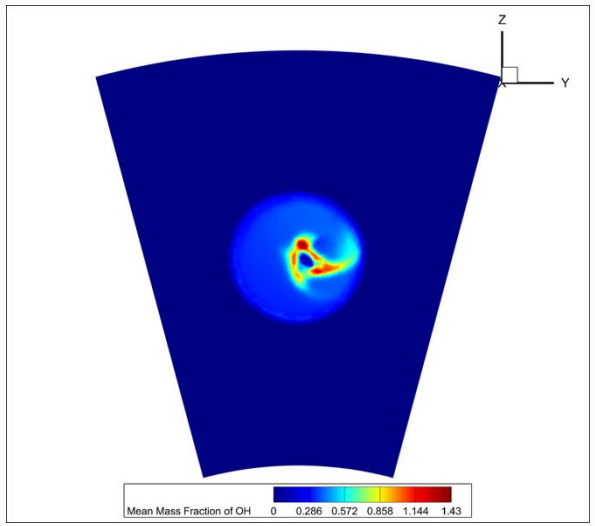


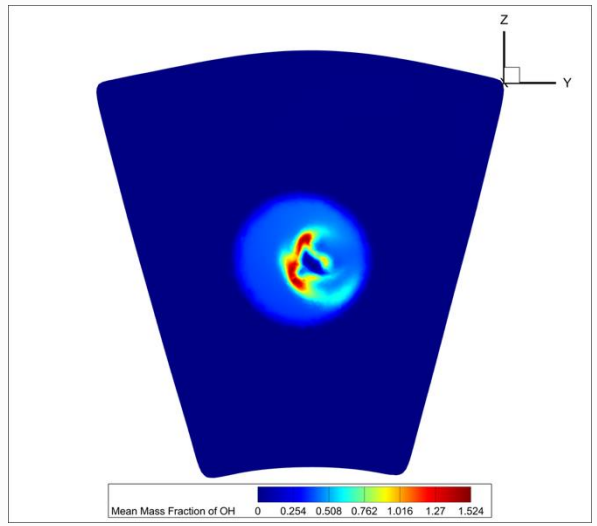


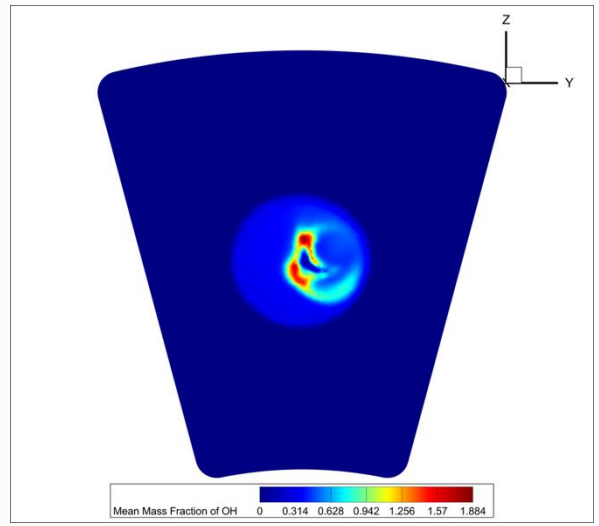












0% H2 | 25% H2 | 35% H2 | 50% H2

Achievements

70% reduction in the number of elements

Achieved an accurate, functioning combustion model

Obtained results with four different fuel blends

CFD Analysis of a Lean Premixed Gas Turbine Combustor for H2 Applications