# NUMERICAL SIMULATION OF NON-PREMIXED LEAN METHANE-AIR TURBULENT COMBUSTION IN A HIGH SWIRL BURNER

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*Abstract* Obtaining high efficiency while keeping low levels of NOx emissions is a problem in burner technology that has attracted a lot of attention recently. A swirling flow in combustion ensures a fixed position of a compact flame. In this paper we present simulations of the reacting flow of a non-premixed lean methane/air mixture confined in a high swirl burner. RANS equations are solved with a finite volume method and a SIMPLE algorithm for pressure-velocity coupling. The mesh is composed of more than one million cells. Turbulence was modeled using a RNG K-epsilon using the swirl-dominated version. A PDF was used to model the combustion.

Local properties of the mixture were calculated based on the temperature and local composition. These calculations were developed with the commercial software ANSYS Fluent. The results obtained from this study show that the Inner Recirculation Zone (IRZ) plays a major role in stabilizing the location of the flame in the shear layer between the IRZ and Outer Recirculation Zone (ORZ). In conclusion, the swirling motion allows a more stable combustion of lean mixtures, reducing the fuel consumption and NOx emissions.

## NUMERICAL MODEL

The benchmark is that of Roback and Johnson [1], see scheme on figure 1. The strong swirl on the annular jet is responsible of an Inner Recirculation Zone (IRZ) on the test chamber [2-3]. The sudden expansion from the annular nozzle to the test chamber is a precursor of the Outer Recirculation Zone (ORZ). The swirler is composed of 8 fixed blades located on the annular nozzle [4]. The modification of the angle of the trailing edges modifies the swirling flow. Two different swirl numbers are tested: one mild without IRZ and another strong with IRZ.

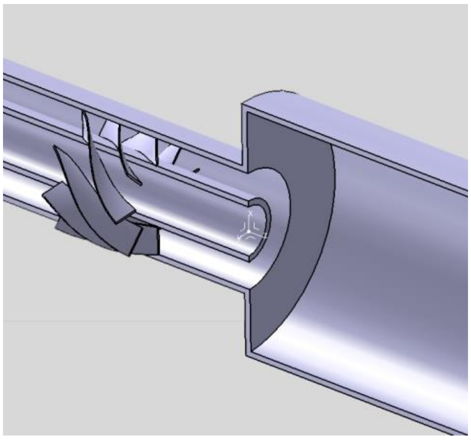

**Figure 1.** Scheme of the burner of Roback and Johnson.

**Table 1.** Summary of geometrical details and the inlet conditions for the nozzles.

| Magnitude | Central jet | Annular inlet | Test Chamber |
|---|---|---|---|
| Diameter (m) | 0-0.025 | 0.0306-0.059 | 0.122 |
| Velocity (m/s) | 0.66 | 1.52 | |
| Intensity of turbulence (%) | 12 | 7.5 | |
| Composition | CH4 | 22% O2 78% N2 | |
| Specific Heat(J/kg/K) | Polynomial function of temperature | | |

Navier-Stokes equations for turbulent and reactive flows were solved in a mesh around 1 million grid points, [5]. Pressure-Velocity coupling was SIMPLE. The code solves the transport equations for mixture fraction and its variance with the PDF model proposed by Jones [6]. Table 1 shows the boundary conditions and properties of the mixture.

## RESULTS

Contours of Mean Mixture Fractions, depicted in figure 2, are convex for mild swirling flows and concave for strong swirling case. Shadow surfaces correspond with the iso-value of null axial velocity. In the case of swirl number 0.14, the lack of IRZ produces a thick reaction zone associate to weak temperature gradient. The ORZ in mild swirl numbers is larger than that of the strong swirl configuration.
Numerical results predict that no fuel reaches the IRZ even if other references assert it may be possible. Bearing in mind the criterion to locate the flame front as the maximum mixture fraction gradient, it is clear the thin reaction zone for swirl numbers of 0.74 that is located ahead of the lead stagnation point of the IRZ.

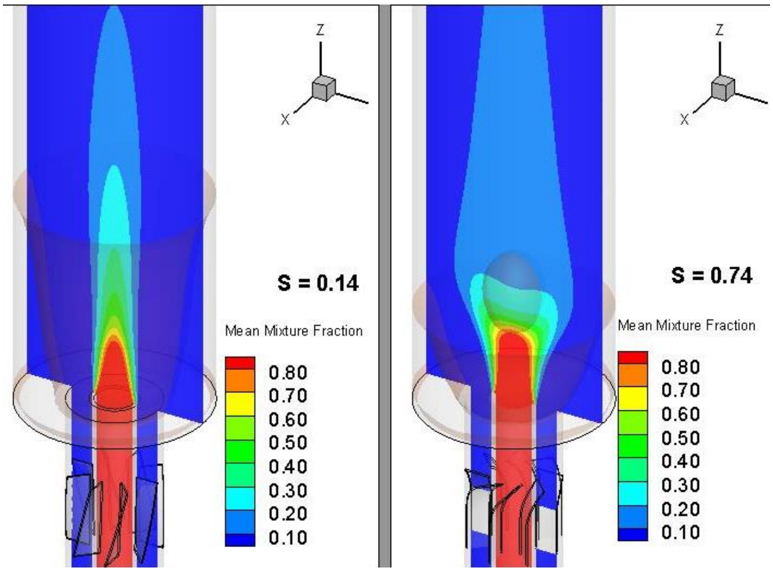


**Figure 2.** Longitudinal contours of Mean Mixture Fraction for different swirl numbers. Grey shadows are the iso-volume of null axial velocity.

## CONCLUSIONS

Low swirling injectors do not promote the fluid to turn over near the centre of the chamber, resulting in larger mixing and reaction zones with weak gradients of temperature and species' mass fractions, whereas high swirl burners promote the formation of an inner recirculation zone with hot products of reaction. The lead stagnation point of the IRZ plays an important role in fixing the location of the flame front in swirling burners.

**Acknowledgment**

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