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Comparison of Four Methane Injection Configurations in a Turbine Engine Combustion Chamber

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1. Introduction

A combustion chamber in an aircraft turbine engine is a crucial component where the fuel-air mixture is ignited and burned. This process generates high-pressure, high-temperature gases that drive the turbine blades and producing thrust. The chamber must withstand extreme temperatures and pressures while ensuring efficient and stable combustion. It typically consists of a diffuser, a burner, and a liner with cooling holes to protect against heat damage. Efficient combustion chambers maximize energy conversion and minimize emissions, contributing to the engine's overall performance and environmental compliance.

2. Theoretical background

Model used in this project is generalized eddy-dissipation model, because the reaction in mainly controlled by oxidiser/fuel mixing. We assumed complete conversion of fuel to CO_2 and H_2O, in that case a global one-step reaction mechanism is adequate. The reaction equation:

$$CH_4 + 2O_2 + \rightarrow CO_2 + 2H_2O$$

That gives Air/Fuel ratio of about 17.

3. Boundary conditions:

- Inlet air temperature: 500K;
- Inlet fuel temperature: 300K;
- Air mass flow rate: 0.5 kg/s;
- Fuel mass flow rate: 0.12 kg/s, assuming that 40% of air is involved in the reaction process

4. Mesh

Our chamber mesh model was based on drawing found in [1], maintaining all the proportions and detail.

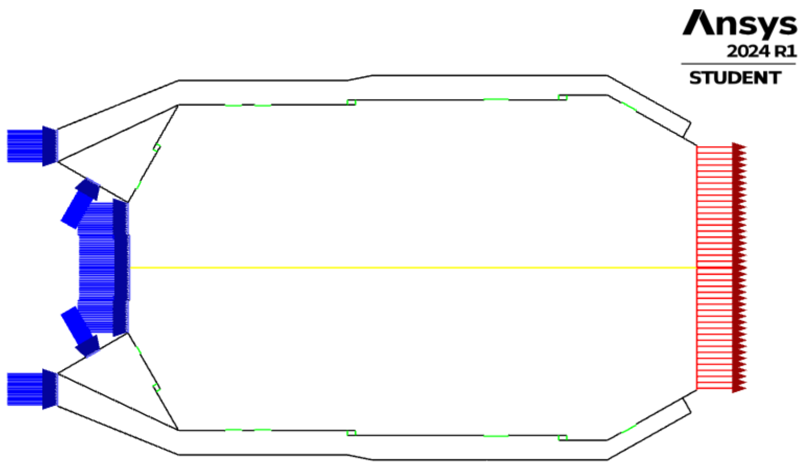

Figure 1 Model of the combustion chamber

5. Results and visualization

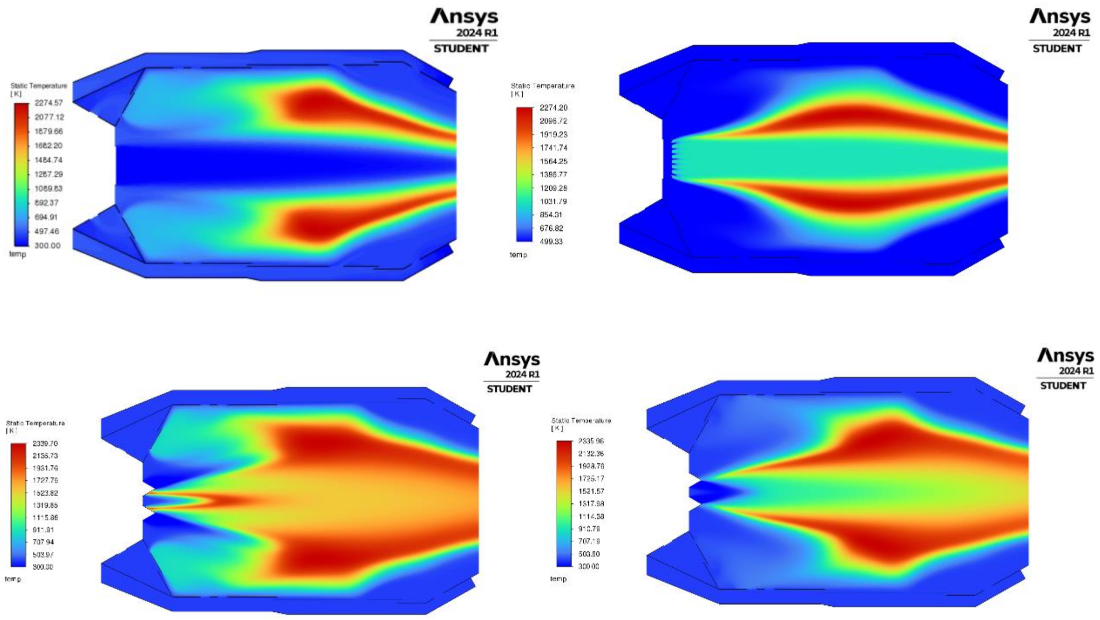

Figure 2 Visualizations of static temperature in the chamber

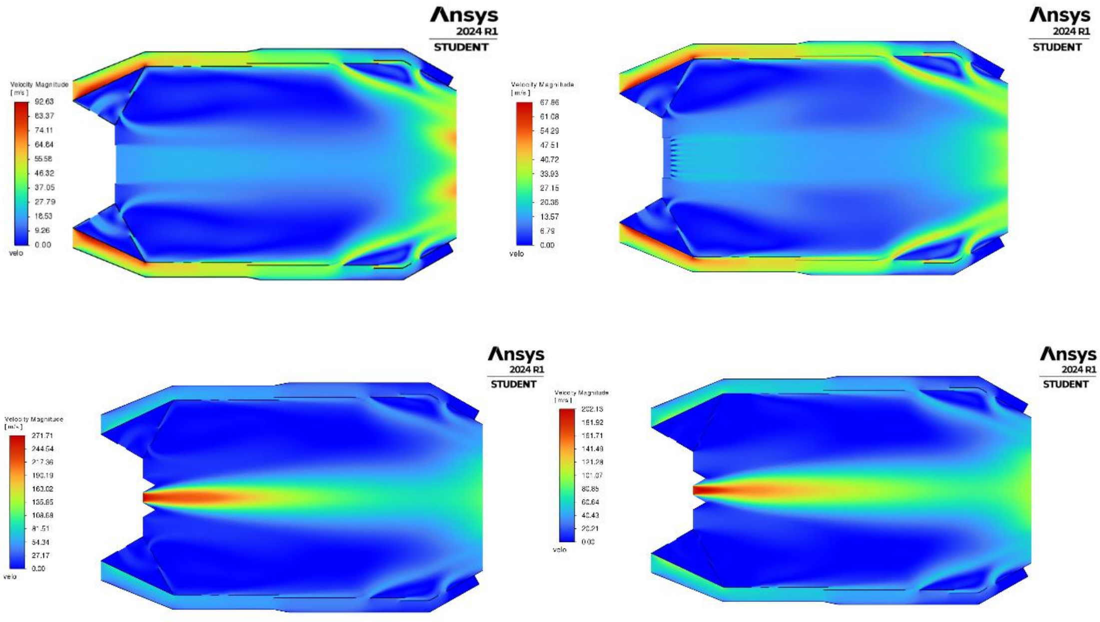

Figure 3 Visualizations of velocity magnitude

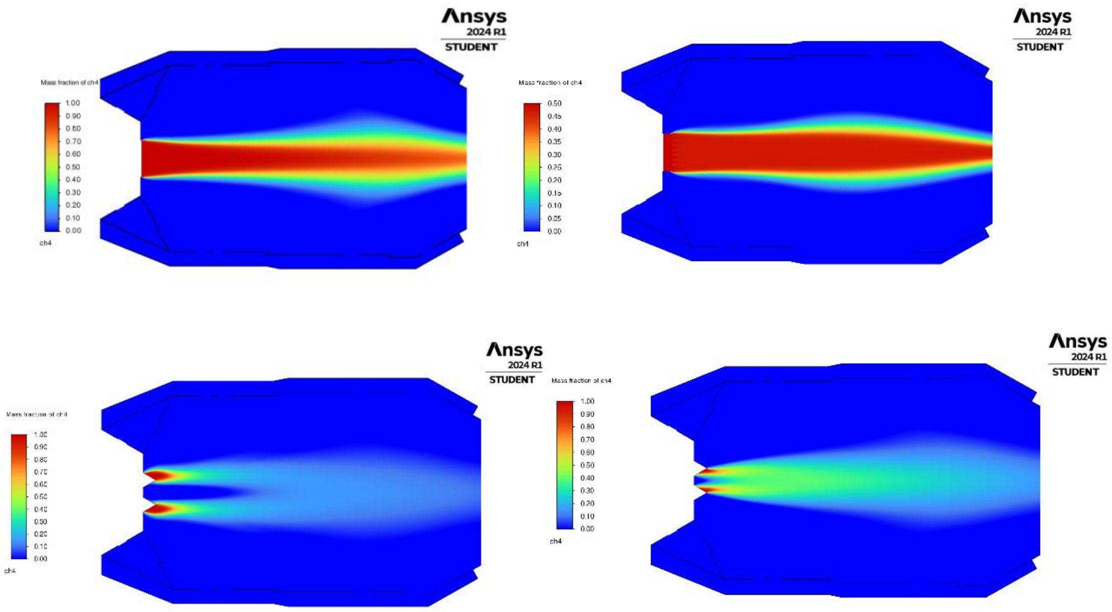

Figure 4 Visualizations of fuel mass fraction

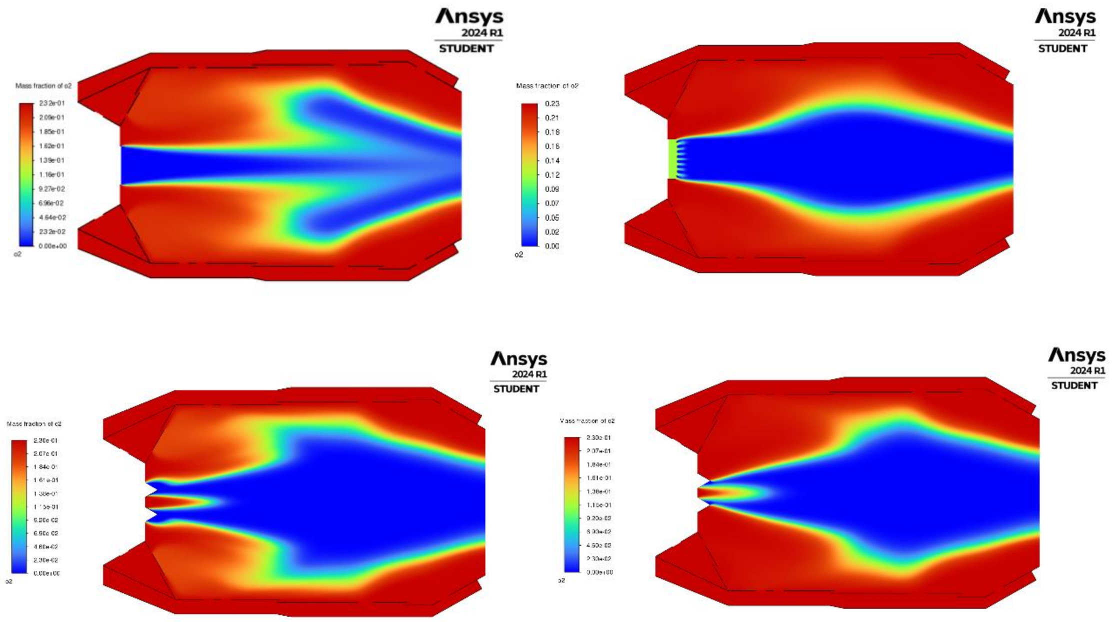

Figure 5 Visualizations of O2 mass fraction

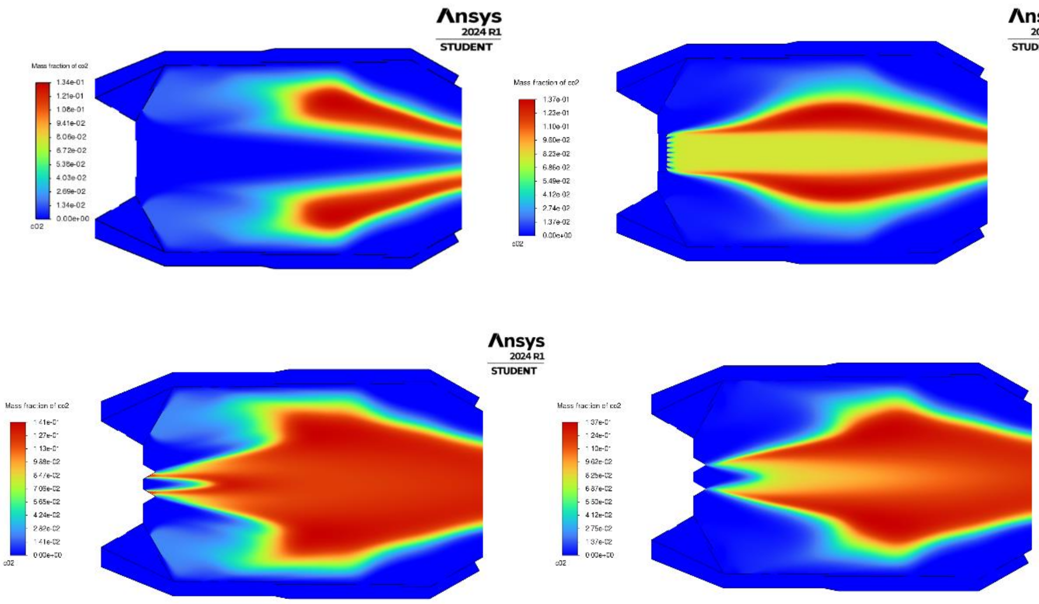

Figure 6 Visualizations of CO2 mass fraction

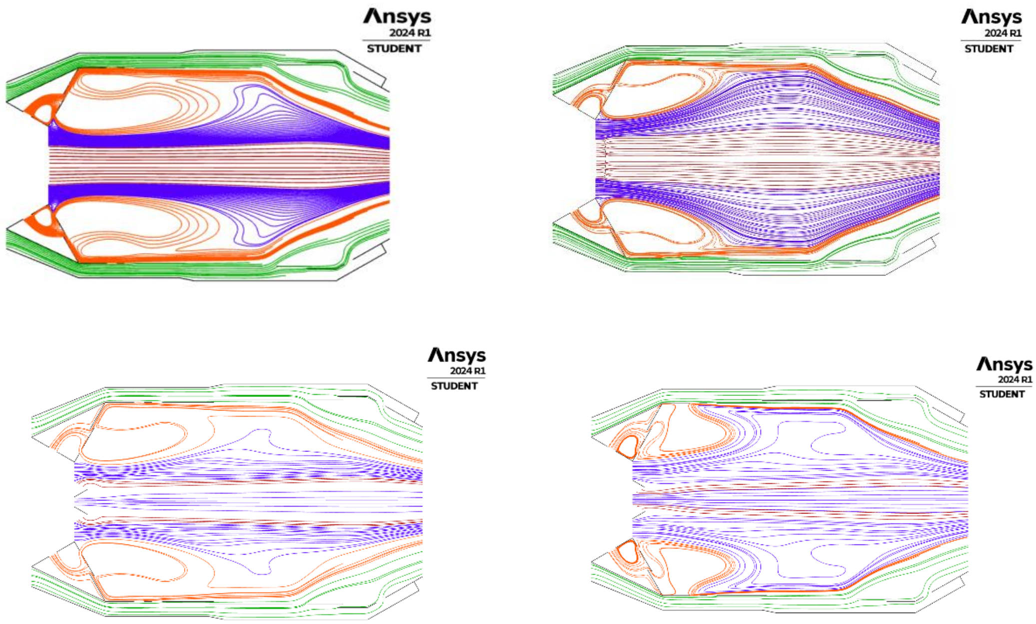

Figure 7 Flow visualizations of fuel, O2 and CO2

6. Conclusions

Our calculations show that the most efficient of the four shown injections is the third one, as most of the fuel is burned, and the temperature is most evenly distributed across the combustion chamber. This way of injection causes high turbulence and good air/fuel mixing. Also the internal air nozzle enables fuel to mix from two different sides, which maximises the volume of mixing. Next step to improve the efficiency of the combustion chamber is to implement flame holders, which will greatly increase turbulence and in effect improve the temperature distribution.