Flow characteristics passing past an open cavity containing two mass injection slots. Application to the Trapped Vortex Combustor concept.

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Reducing pollutant emissions, especially NOx, in aeroengines has received considerable attention in recent years. Conventional aeroengines continue to be optimized but should not yield viable solutions with more stringent regulations, e.g. -90% in NOx by 2050 in Europe. Therefore, studies should be focused on new burner geometries to meet the pollutant levels and investigations on new combustion modes such as Lean Premixed (LP) combustion. However, it is clear that these engine modifications need more developments to avoid hazardous issues: flashback, blow-off, high altitude relight, mechanical vibrations due to combustion instabilities.

In this work, we investigate a fully annular Trapped Vortex Combustor. The stabilization mechanism is based on hot gases recirculation via an open cavity which contains a pilot flame. The latter is used to anchor a main premixed flame passing past the cavity (fig.1) [1]. This burner is designed to fully operate in LP mode.

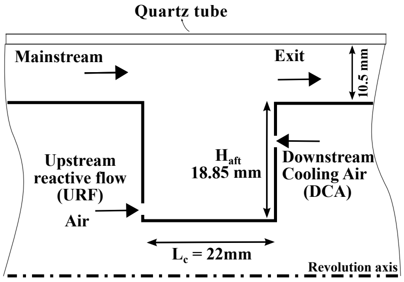


Figure 1: Scheme of the TVC geometry.

Flows past passive cavities -no injections within the cavity- have been studied for many years by the aerodynamic community [2] and is found in many applications such as landing systems of aircraft or bomb bays. However, our geometry is quite different from existing ones:

- Mass is injected -via two slots- in the cavity such that the latter becomes "active".
- When the burner is fuelled, heat release changes the flow behaviour.

In view of the above considerations, it is of great importance to drive a full descriptive experimental study, in cold conditions to clearly identify the key physical mechanisms that control this type of flow. This work will also serve as a preliminary work for analyzing the reactive flow. A particular attention is paid to understand how the cavity flow is coupled to the mainstream.

The cavity length and height are kept constant (aspect ratio $L_c/H_{aft} = 1.19$). Two air injection slots are used in the cavity at their nominal point of operation [3]. Note that three cases have been performed as follows (Fig.1):

- Case 1: Main flow only (passive cavity).
- Case 2: Main flow and Downstream Cooling Air ($\dot{m}_{DCA} = 1.0 g.s^{-1}$).
- Case 3: Main flow, Downstream Cooling Air and Upstream Reactive Flow ($\dot{m}_{URF} = 0.8 g.s^{-1}$).

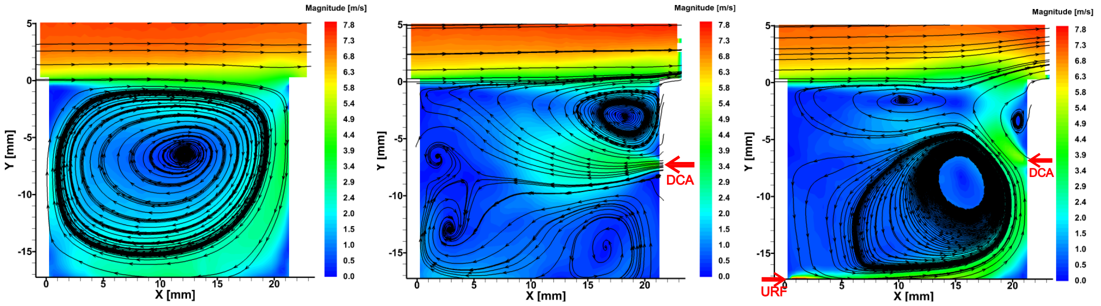
High-speed Particle Image Velocimetry $-2.5KHz$ repetition rate– was used to obtain two component data. This allowed us to get access to both instantaneous, mean velocity vector fields as well as cyclic variations. A particular attention was paid to determine an accurate spatial resolution for this technique.

The mean flow topology for each case is analyzed to put in evidence the different recirculation zones and the effect of the mainstream velocity.

Passive cavities -no mass injection in the cavity- are sensitive to "flow-induced cavity oscillations". A shear layer develops at the upstream edge of the cavity and impinges the downstream cavity edge. Then, a feedback loop occurs in the cavity and modify in turn the shear layer characteristics. As a consequence, cavity tones are produced. An investigation is done in our cases to determine if this mechanism is present when injecting mass in the cavity.

An effort is also done to understand and characterize the shear layer at the interface region, between the cavity and the mainstream. Flow fluctuations regions are identified as well as turbulence intensity. This information is crucial - essentially in combustion- since it is representative of a good mixing.

A more detailed analysis is done to evaluate the interactions between the mainstream and the cavity. Local mass exchanges are calculated along the interface region to see how mass transfers occur. A kinetic energy balance is also done, to evaluate the production, transport and dissipation terms.



(a) *Main*

(b) *Main + DCA*

(c) *Main + DCA + URF*

Figure 2: Streamlines of vector field colored by velocity magnitude. Mainstream air flow rate $\dot{m}_{main} = 20 g.s^{-1}$.

As shown on Fig.2, the mean flow topology -for the three cases listed above- is quite different. A particular attention will be paid to characterize the interface region (not shown here).

References

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