NUMERICAL AND EXPERIMENTAL STUDY OF SECONDARY FLOW FEATURES IN A GAS VORTEX UNIT

Introduction
- Centrifugal field generated by azimuthal injection of gas into a confined disc-shaped static chamber.
- Gas only flow: potential applications such as flame stabilization, clean combustion from secondary flow features.
- Gas-solid flow: dense rotating fluidized bed with high slip velocities suitable for fast reactions such as biomass pyrolysis.

The Gas Vortex Unit
- Swirl ratio= 12
- \( \frac{R}{R_{out}} \) =13,000
- \( A_{in}/A_{out} = 0.042 \)
- \( V_{inj} = 0.4-0.8 \text{ m/s} \)
- \( V_{avg} = 45-120 \text{ m/s} \)

Bulk Flow
- High swirling flow
- Combination of:
  - Free vortex flow: \( r \ U_{\theta} = \text{constant} \)
  - Solid body rotation
  - Swirl induces turbulence due to secondary flow formation

Experimental Techniques
- Stereoscopic PIV
  - Flow inlet
  - Flow outlet
  - Front end-wall
  - Rear end-wall
  - Suction of ambient gas from exhaust.

Secondary Flow Features
- Backflow at the exhaust
  - Near-wall jets
  - Bulk Counterflow

Secondary Flow Feature: Backflow
- Negative gauge pressure near axis (\( r<0.05 \text{m} \)).
- Extended backflow region along the exhaust.
- Suction of ambient gas from exhaust.

Secondary Flow Feature: Countertflow
- Jet entrainment induces a flow reversal.
- Experimental detection of vortex core and stagnation points.
- Tracers needed for PIV are affected by strong centrifugal forces justifying measurement of counterflow.
- Further pushed towards circumferential wall,
- More compact, than in the CFD simulations.

Conclusions
- The bulk flow through the GVV is dominated by the azimuthal velocity exhibiting free-swirl flow in the disc part and solid body-like rotation near the central exhaust.
- Radial jets appear near the two end-walls of the unit due to the imbalance between the centrifugal force and radial pressure gradient.
- Swirl decay due to exhaust wall friction generates an adverse pressure gradient along the exhaust line resulting in an extended backflow.
- Jet entrainment of the bulk gas in the disc part of the unit causes a second flow reversal resulting in the counterflow.

Future Work
- Combination of kinetic models with CFD code to study the effect of the secondary flows in processes such as combustion.
- Particulate flow CFD simulations to study the effect of bed formation on secondary flow features.

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