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CFD predictions of Swirl burner aerodynamics with variable outlet configurations

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Objective

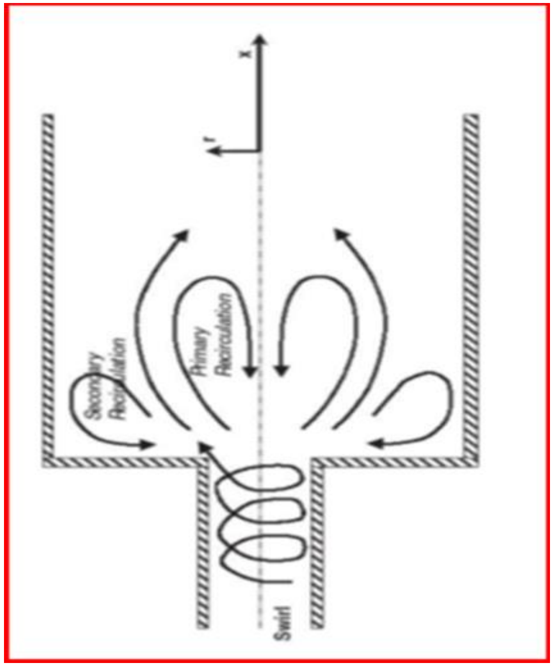
- **Experimental and numerical simulations using software (ansys) to determine the behaviour and impact on blowoff process at various swirl number, nozzle geometries, chamber diameter and syngas compositions at the same power outputs.**

Swirl stabilizer mechanism

Swirl number defining the ratio of the axial flux of tangential momentum to the product of the axial momentum flux and nozzle radius

The pressure tends to decrease where strong swirling motion occurs in the wake of the combustor nozzle.

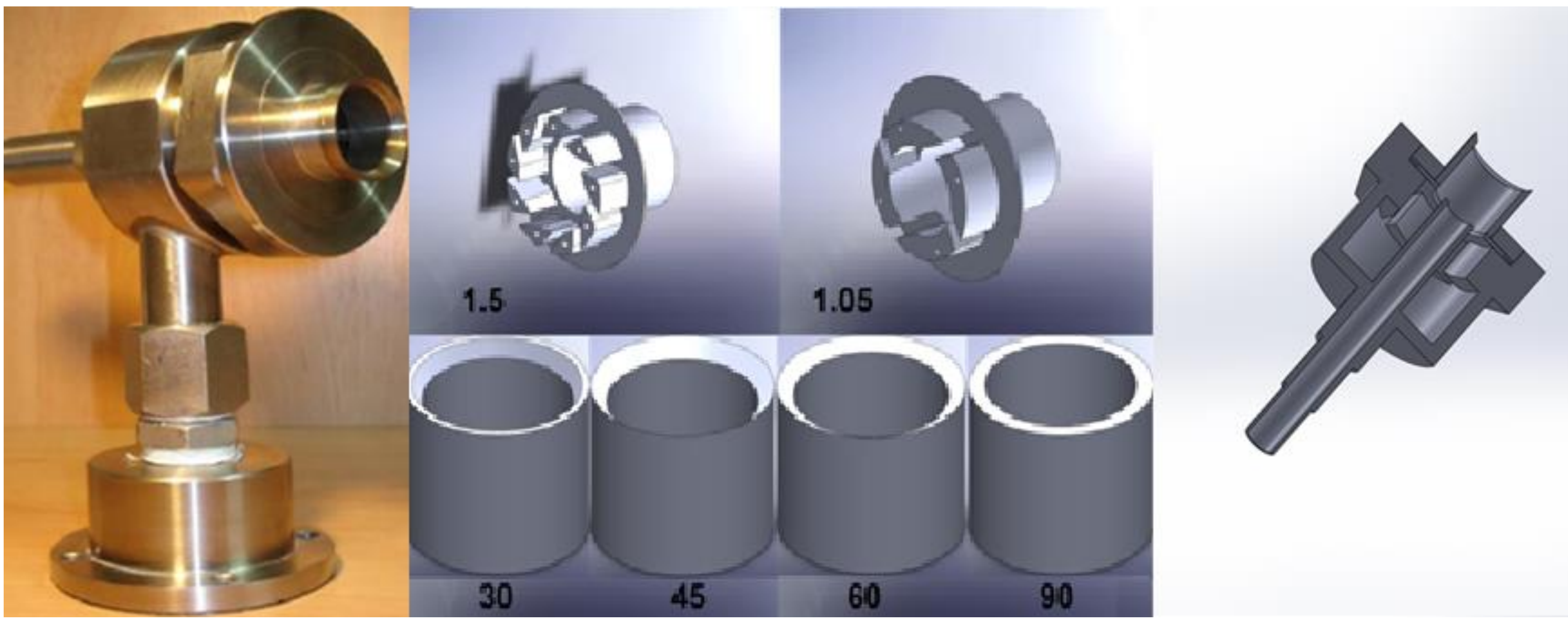
- $\frac{\partial p}{\partial r} = \frac{\rho U_\theta^2}{r}$



Blow-off Theory

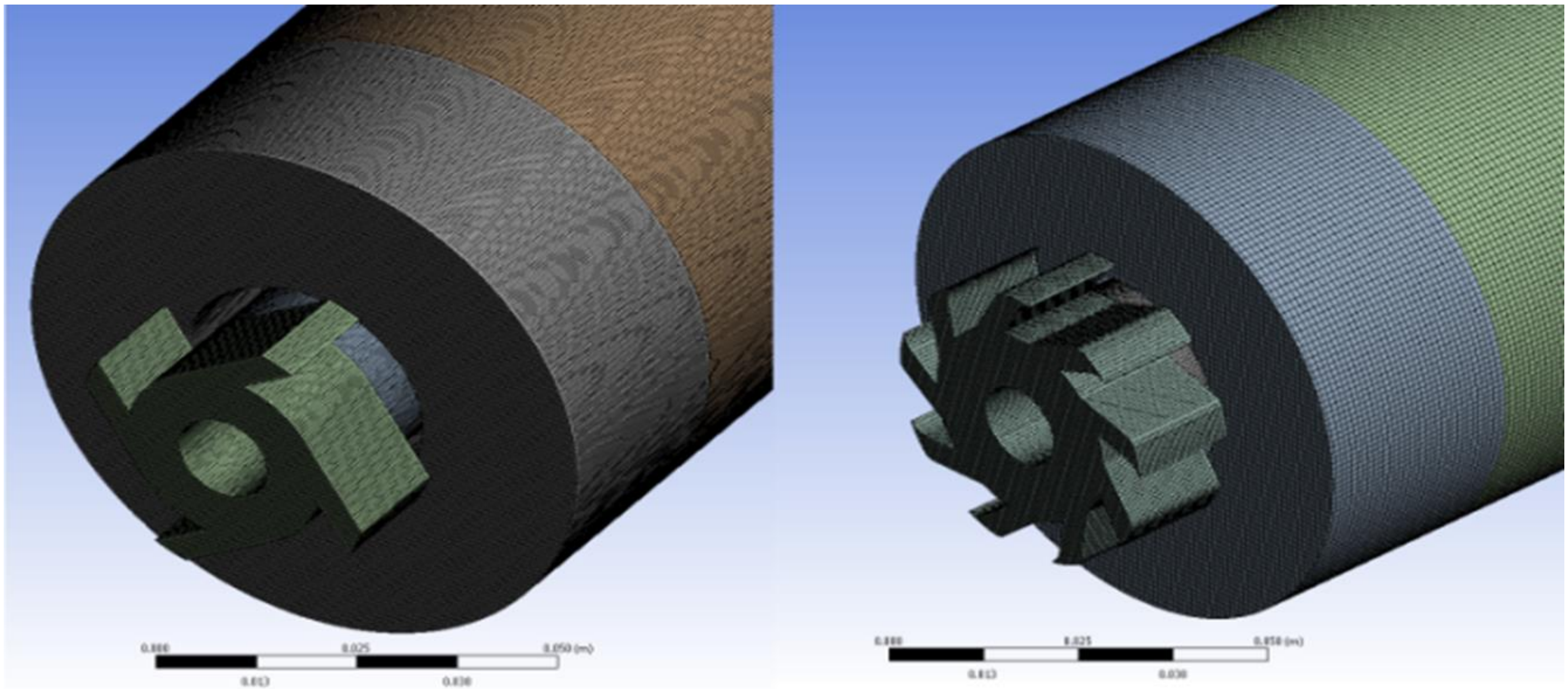
- When local flame speed is lower than the approaching fluid velocity.
- When not possible to balance the rate of entrainment of reactants into the recirculation zone, and the rate of burning of these gases.
- When the heat required by the combustible stream exceeds that received from recirculation zone.
- When the contact time between the combustible mixture and hot gases in the shear layer must exceed a chemical ignition time.
- Blow off occurs by excessive flame stretch.

Geometries



- **Pure methane and methane blends with carbon dioxide were used to compare experiments based on previous works .The gas composition and the operating conditions of the burner are given in Table**

Test	Inlet T	Inlet P	CH4 [g/s]	AIR [g/s]	CO2 [g/s]	Total [g/s]	Power output
T1	300K	1 bar	0.27	5.5	None	5.85	14.985 KW
T2	300K	1 bar	0.27	4.94	0.27	5.48	14.985 KW


0.025
0.025

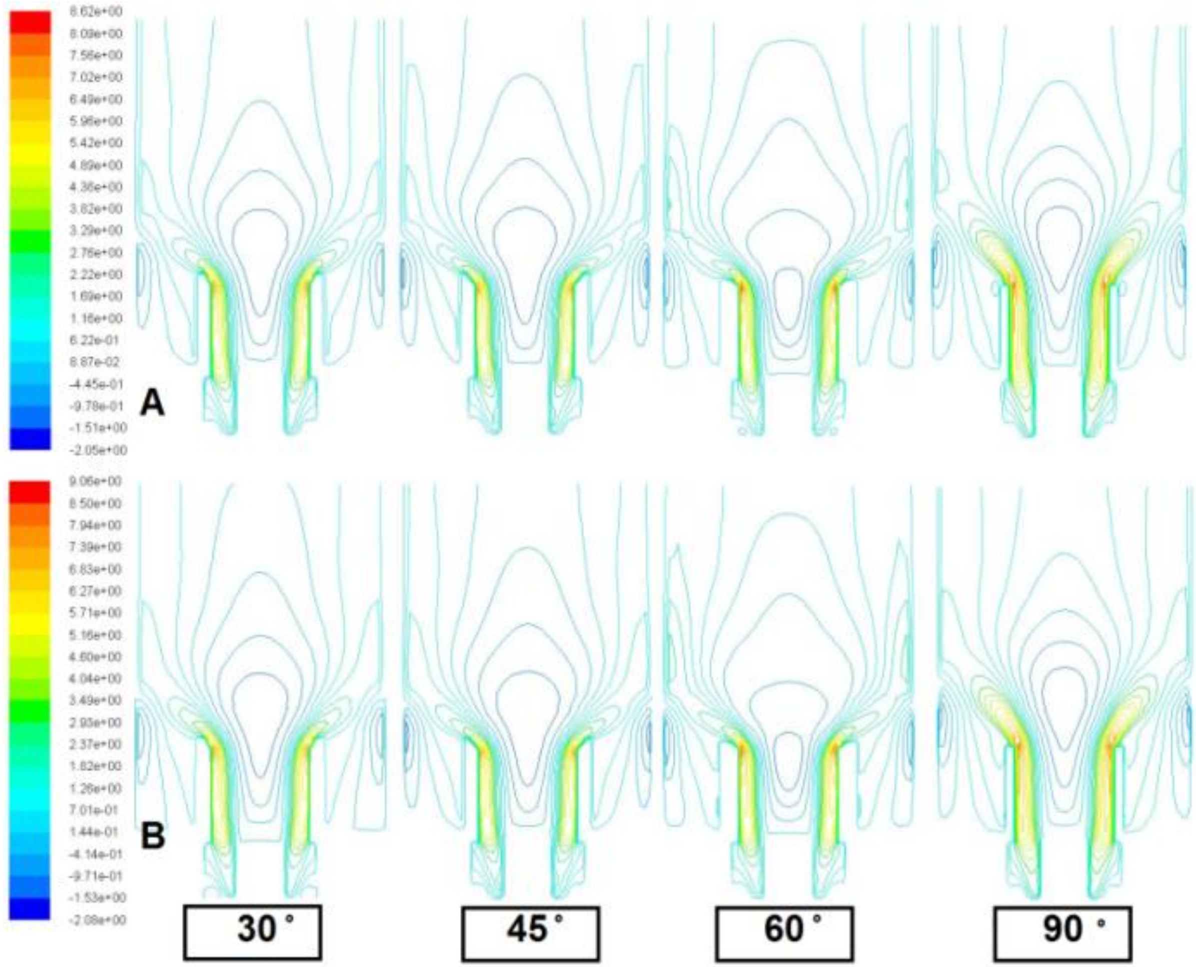
- **Turbulence modelling**

The turbulence model that is used is the shear-stress transport (SST) k-ω model, so named because the definition of the turbulent viscosity is modified to account for transport of the principal turbulent shear stress.

Numerical methodology

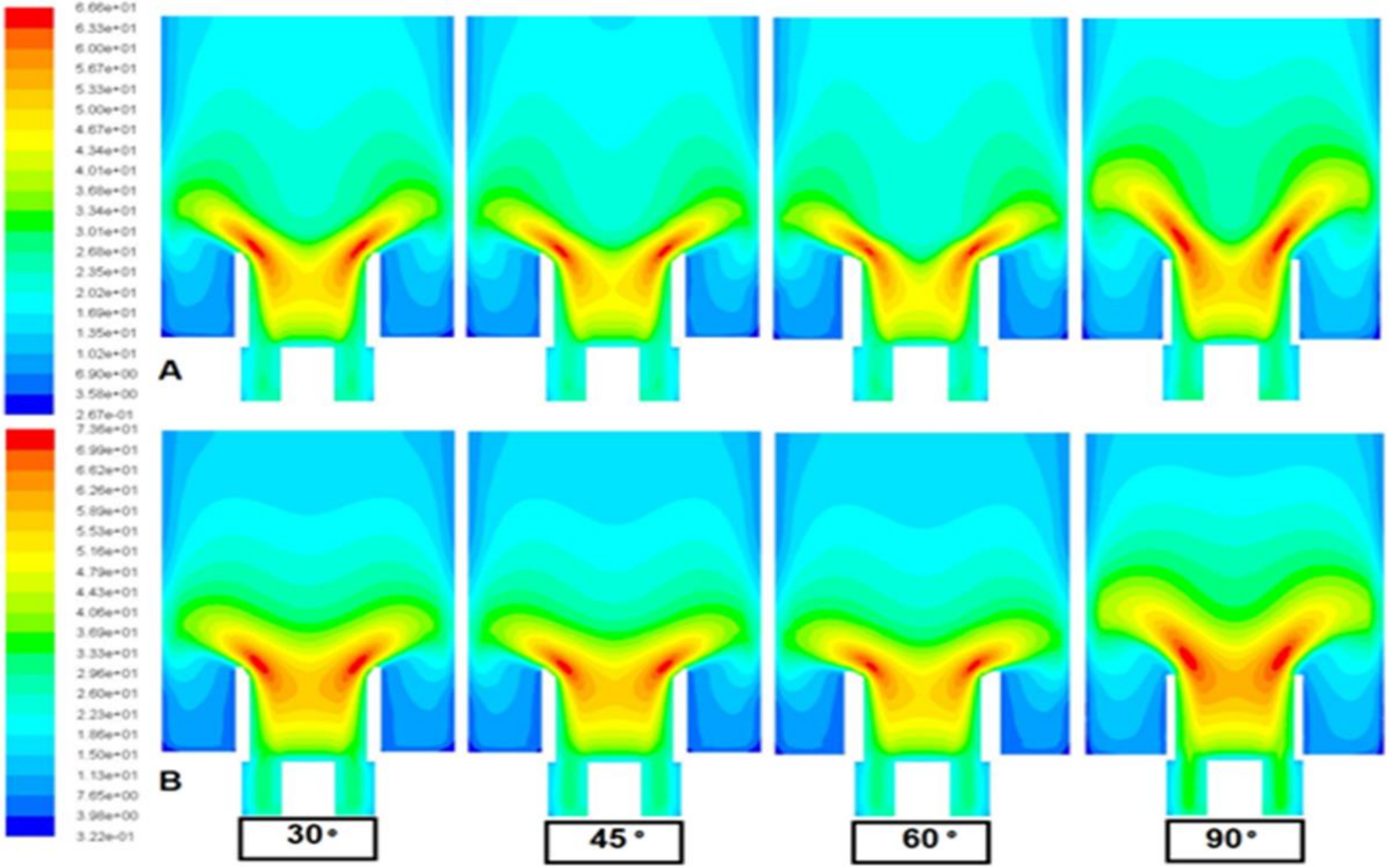
- **The pre-processor used to construct the model grid was ICEM 14.5.7**
- **Boundary conditions were defined using a pressure of 1 bar and inlet temperature of 300 K**

Comparison of isothermal and combustion different nozzles S =1.05 case (a) isothermal and (b) combustion

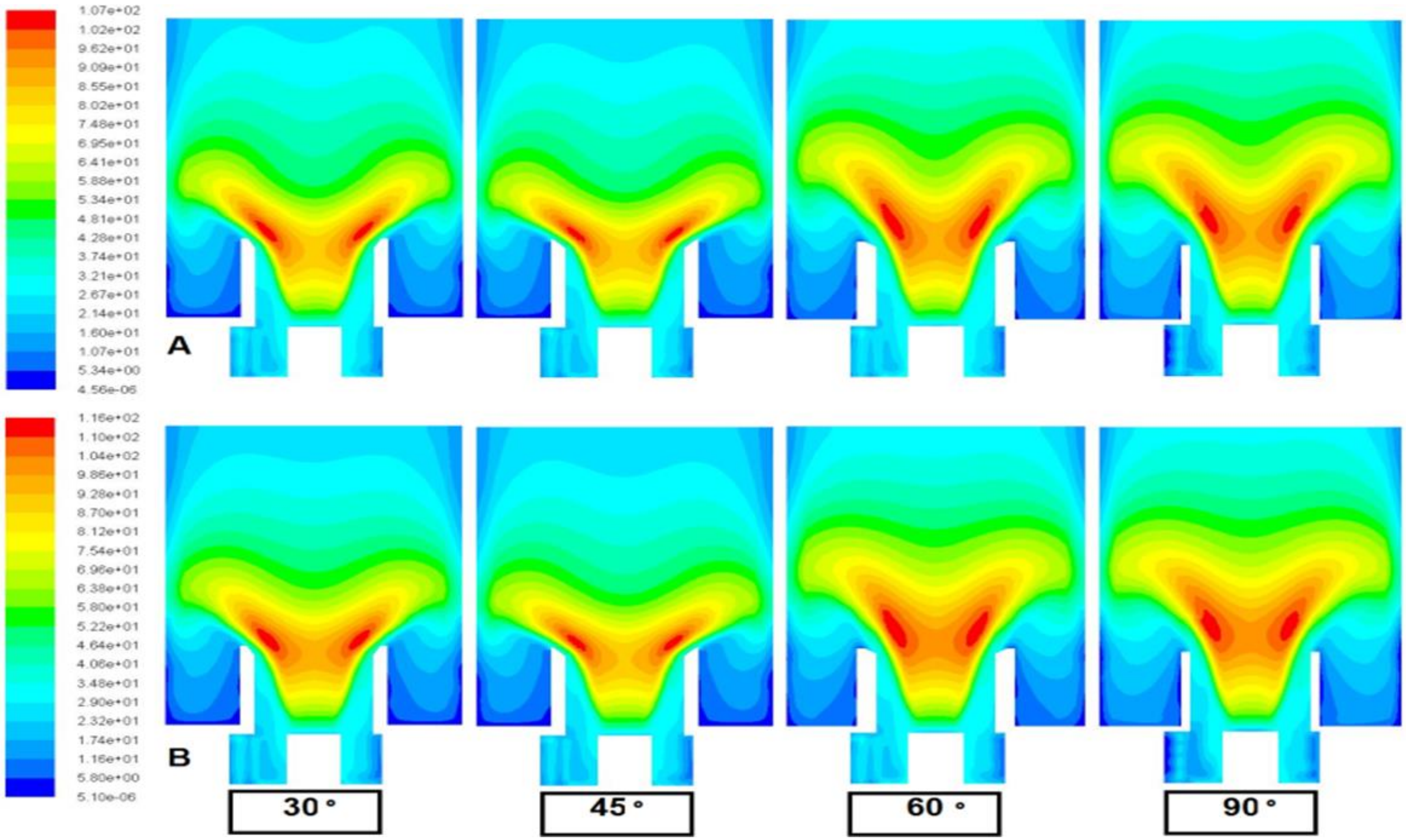


- **Comparison of isothermal and combustion patters of the CRZ using different nozzle angles**

	30^0	45^0	60^0	90^0	Conditions
Width	1.23D	1.34D	1.66D	1.19D	ISOTH
Higher	2.65D	2.97D	3.41D	2.93D	ISOTH
Width	1.19D	1.34D	1.58 D	1.15D	COMBUS
Higher	2.53D	2.85D	3.29D	2.89D	COMBUS



Comparison of turbulence intensity of (a) methane and(b) methane blend with CO_2 S.N 1.05.



Comparison of turbulence intensity of (a) methane and (b) methane blend with CO2 S.N 1.5

Comparison of turbulent intensity of all cases pure methane and blend with CO2

Gas mixture	30º	45º	60º	90º	S.N
CH4	66.6%	67.4%	65.3%	63.5%	1.05
CH4+CO2	73.6%	76.2%	74.5%	69.4%	1.05
CH4	107%	109%	103.4%	95.4%	1.5
CH4+CO2	116%	117%	106.8%	100.2%	1.5

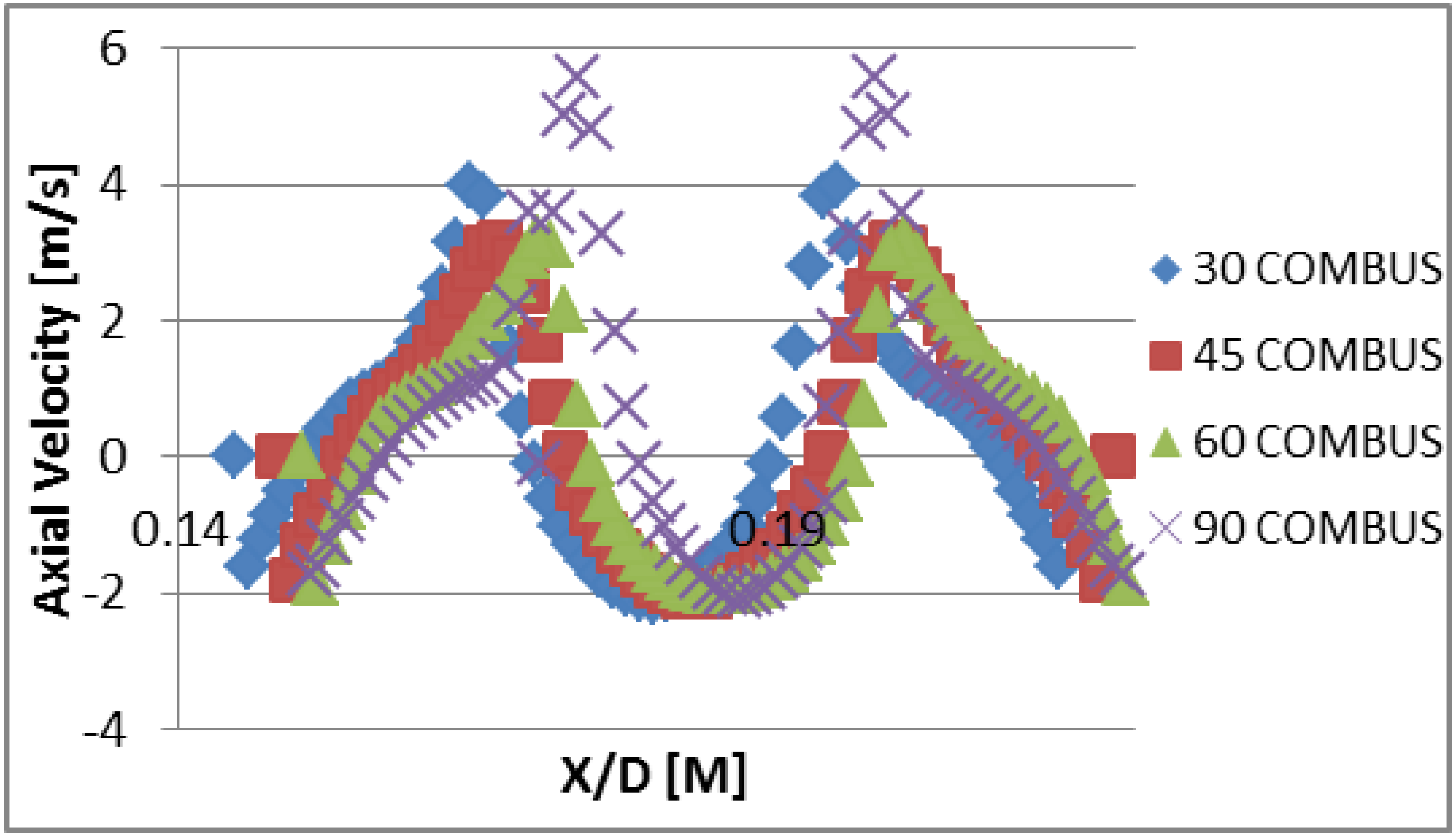
- **Comparison of CRZ size using all nozzles with swirl numbers of 1.05 and 1.50.**

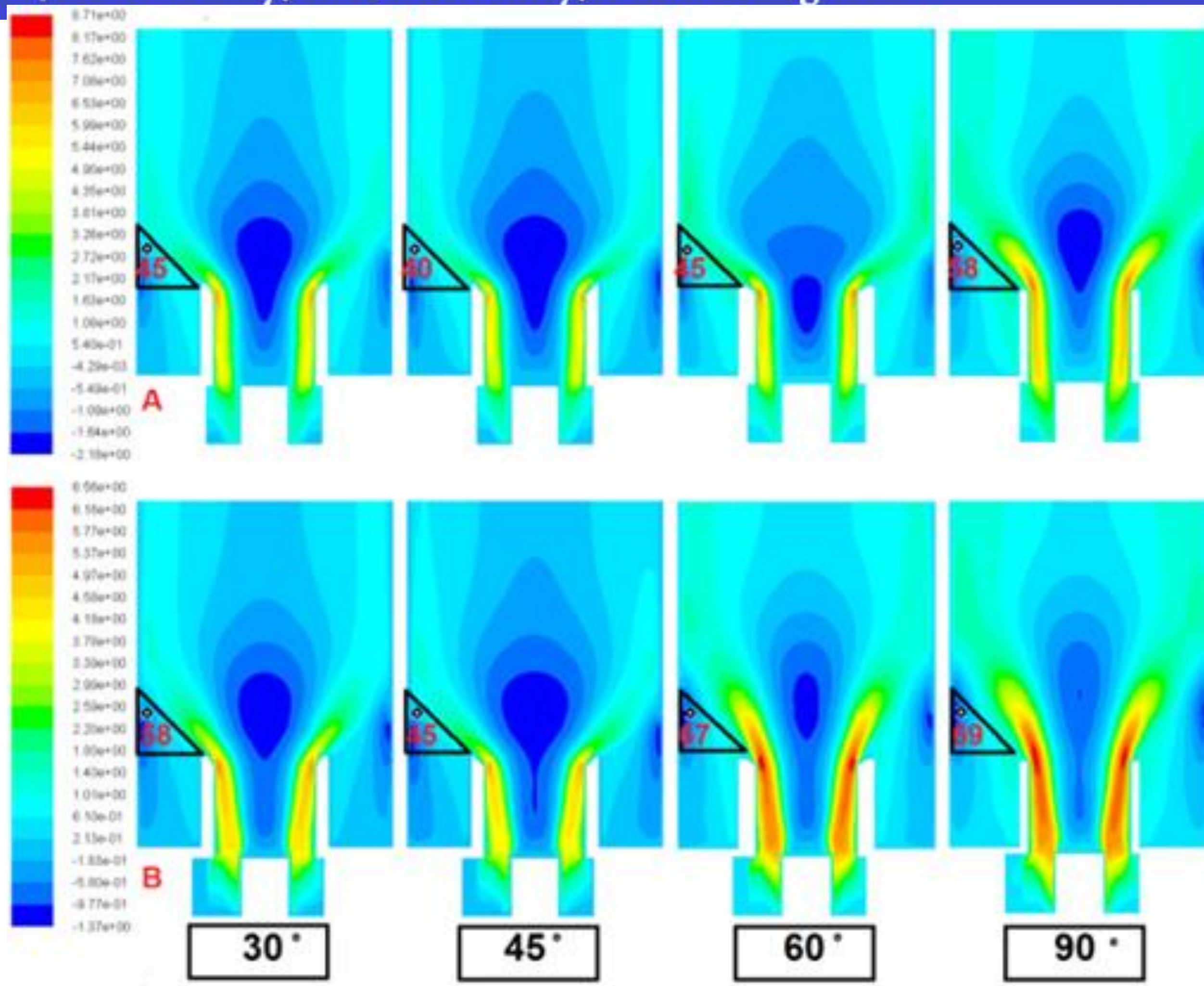
N	30º	45º	60º	90º	Gas mixture	S
W	1.19D	1.34D	1.58D	1.15D	CH4	1.05
H	2.53D	2.85D	3.29D	2.89D	CH4	1.05
W	1.07D	1.27D	1.03D	0.95D	CH4	1.50
H	2.25D	3.01D	2.85D	2.77D	CH4	1.50
W	1.30D	1.34D	1.60D	1.23D	CH4+CO2	1.05
H	3.53D	2.89D	3.51D	2.79D	CH4+CO2	1.05
W	1.07D	1.27D	1.03D	0.95D	CH4+CO2	1.50
H	2.53D	3.01D	2.89D	2.77D	CH4+CO2	1.50

30°	30°	45°	45°	60°	60°	90°	90°
CH_4	CH_4 + CO_2	CH_4	CH_4 + CO_2	CH_4	CH_4 + CO_2	CH_4	CH_4 + CO_2

Comparison of CRZ size of all nozzles combustion of methane and methane blend with CO_2 .

- **Comparison of the axial velocity of different angles**





Combustion of methane (a) S=1.05 (b) S=1.50. and shear layer flow direction angle

Conclusion

- The CFD predictions of swirl burner aerodynamics show how variable outlet configurations and inert gas compositions change the CRZ patterns.
- The addition of CO2 in the blend with methane can be of great importance to the change of the CRZ. It is clear that the CRZ is increased with the usage of CO2 whilst changing outlet nozzles angles. The addition of the CO2 produces longer recirculation zones
- Changing the angle of the nozzle will control the direction of shear layer.
- This in return could be beneficial for new blends and the increase of the residence time of the products/reactants of these and other fuel/diluent compositions.