Swirl Number for Non-Reacting and Reacting conditions of Cambridge Stratified Swirl Burner

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Abstract

The swirl numbers of Non-Reacting and Reacting conditions of Cambridge Stratified Swirl Burner are of interest to the community studying the burner. The operating conditions are listed in Table 1. This report presents the data processing routines and results for the swirl numbers. Global and local swirl numbers are also presented for comparison.

Data processing

Swirl number

The degree of swirl for a swirling flow is usually characterized by the swirl number. It was originally proposed by Chigier and Beer [1] and simplified by Sheen et al. [2] as follows:

$$S_{CB} = \frac{G_{tg}}{RG_{ax}} = \frac{\int_0^R wu\, r^2\, dr}{R\int_0^R u^2\, r\, dr} \tag{1}$$

Where G_{tg} stands for the axial flux of the tangential momentum, G_{ax} is the axial flux of the axial momentum, R is the outer radius of the annulus, w and u are the tangential and axial velocity at corresponding radial position r.

The swirl number can also be defined as:

$$S_m = \frac{J_{tg}}{J_{ax}} = \frac{\int_0^R wu\, r\, dr}{\int_0^R uu\, r\, dr} \tag{2}$$

Where J_{tg} stands for the momentum of tangential velocity component and J_{ax} is momentum of axial velocity component.

The present report provides results based on both definitions.

Global or local

Considering that the swirl is generated only in the outer annulus of the burner, a local swirl number is introduced with the integration limit from R_2 to R_3, where R_2 and R_3 are the radii of inner and outer annulus, respectively. It would be interesting to see the difference between the local swirl number and global swirl number which is integrated from 0 to R_3.

Thus, the following parameters are calculated:

$$S_{CB\_global} = \frac{\int_0^{R_3} wu\, r^2\, dr}{R \int_0^{R_3} u^2\, r\, dr} \tag{3}$$

$$S_{CB\_local} = \frac{\int_{R_2}^{R_3} wu\, r^2\, dr}{R \int_{R_2}^{R_3} u^2\, r\, dr} \tag{4}$$

$$S_{m\_global} = \frac{\int_0^{R_3} wu\, r\, dr}{\int_0^{R_3} uu\, r\, dr} \tag{5}$$

$$S_{m\_local} = \frac{\int_{R_2}^{R_3} wu\, r\, dr}{\int_{R_2}^{R_3} uu\, r\, dr} \tag{6}$$

Results

The results below are based on axial location near the burner exit: z=2 mm.

Swirl level	Case	S_{CB_global}	S_{m_global}	S_{CB_local}	S_{m_local}
Non swirl	*Sw*B1	0.0323	0.0407	0.0938	0.0418
	*Sw*B5	0.0357	0.0446	0.1044	0.0464
	*Sw*B9	0.0337	0.0429	0.0980	0.0441
	*cSw*B1	0.0345	0.0408	0.1008	0.0454
Medium swirl	*Sw*B2	0.3376	0.4006	1.0622	0.4619
	*Sw*B6	0.3379	0.4018	1.0649	0.4644
	*Sw*B10	0.3295	0.3957	1.0503	0.4625
	*cSw*B2	0.3353	0.4091	1.0684	0.4779
Highly Swirl	*Sw*B3	0.5383	0.6334	1.6761	0.7240
	*Sw*B7	0.5293	0.6254	1.6700	0.7242
	*Sw*B11	0.5349	0.6292	1.6737	0.7227
	*cSw*B3	0.5467	0.6639	1.7526	0.7818

Reference

[1] N. A. Chigier, and J. M. Bedr. *J. Basic Eng.* 788-796, 1964.
[2] H.J. Sheen, W.J. Chen, S.Y. Jeng, T.L. Huang. *Experimental Thermal and Fluid Science* (12) 444-451, 1996.

Table 1: Operating conditions for reacting and non-reacting cases. The gas flows in all experiments were metered using mass flow controllers. All the controllers used for the velocity characterization were Alicat mass flow controllers and unit for the flow rate is SLPM. Φ_g: global equivalence ratio; Φ_i: equivalence ratio in the inner annulus; Φ_o: equivalence ratio in the outer annulus; SR: stratification ratio; SFR: swirl flow ratio.

						Outer Main		Outer Swirl		Inner		Coflow
Case	Φ_g	SR	Φ_i	Φ_o	SFR	Air	CH4	Air	CH4	Air	CH4	Air
*Sw*B1	0.75	1.00	0.75	0.75	0.00	441.70	34.80	0.00	0.00	144.00	11.35	765.60
*Sw*B2	0.75	1.00	0.75	0.75	0.25	331.28	26.10	110.43	8.70	144.00	11.35	765.60
*Sw*B3	0.75	1.00	0.75	0.75	0.33	295.94	23.32	145.76	11.48	144.00	11.35	765.60
*Sw*B4	0.75	1.00	0.75	0.75	0.40	265.02	20.88	176.68	13.92	144.00	11.35	765.60
*Sw*B5	0.75	2.00	1.00	0.50	0.00	452.70	23.80	0.00	0.00	140.60	14.77	765.60
*Sw*B6	0.75	2.00	1.00	0.50	0.25	339.53	17.85	113.18	5.95	140.60	14.77	765.60
*Sw*B7	0.75	2.00	1.00	0.50	0.33	303.31	15.95	149.39	7.85	140.60	14.77	765.60
*Sw*B8	0.75	2.00	1.00	0.50	0.40	271.62	14.28	181.08	9.52	140.60	14.77	765.60
*Sw*B9	0.75	3.00	1.13	0.38	0.00	458.40	18.10	0.00	0.00	139.00	16.42	765.60
*Sw*B10	0.75	3.00	1.13	0.38	0.25	343.80	13.58	114.60	4.53	139.00	16.42	765.60
*Sw*B11	0.75	3.00	1.13	0.38	0.33	307.13	12.13	151.27	5.97	139.00	16.42	765.60
*Sw*B12	0.75	3.00	1.13	0.38	0.40	275.04	10.86	183.36	7.24	139.00	16.42	765.60
*cSw*B1	-	-	-	-	0.00	476.5	0.00	0.00	0.00	155.35	0.00	765.60
*cSw*B2	-	-	-	-	0.25	357.38	0.00	119.13	0.00	155.35	0.00	765.60
*cSw*B3	-	-	-	-	0.33	319.26	0.00	157.25	0.00	155.35	0.00	765.60