

Concentration Measurements inside a Swirl Combustor Chamber Model

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The work presented here provides insight into the features of the swirling flow in the concentric annuli, the vortex breakdown and the concentration distribution inside the flue of an isothermal, incompressible flow in a single annular gas combustor in the Reynolds number range $50.000 < Re_m < 100.000$, volume flow rate ratios $2 < V_c/V_m < 25$, swirl intensities $0.0 < S < 1.2$ and expansion ratio $ER < 2.0$. Special attention was devoted to the mixing of the two flow streams. The selected measurement plane in the inlet section is shown in Fig. 1 (left). The velocity field in the inlet section is measured using the laser Doppler measurement technique characterized by its high spatial and time resolution. All of the Reynolds stresses \overline{uu} , \overline{vv} , \overline{ww} , \overline{uv} , \overline{vw} (not measured) and \overline{uw} are non-zero (not shown here). Selected results of the normalized axial velocity measurements are shown in Fig. 1 (right)

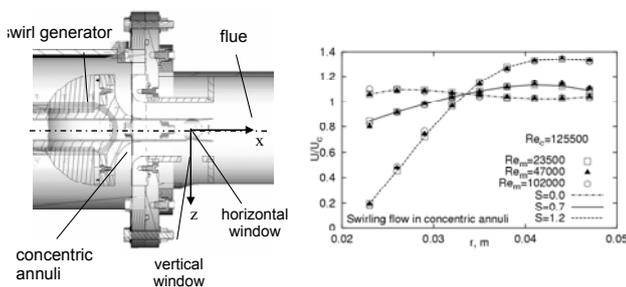


Fig. 1: Measurement planes (left). Normalised axial velocities in the annular flow for $Re=1.2 \times 10^5$ and for various swirl intensities.

The effects of the increasingly swirl in the annular jet and the variable volume rate ratio of the outer (swirling) stream to the inner (non-swirling) one with respect to the position, size and shape of the swirl-induced free recirculation zone in a model combustor model were experimentally investigated. For measuring the velocity field in the flue chamber, a PIV system was used. The increasing swirl intensity contributes significantly to the intensification of the back-flow in the combustor core with a free separation point penetrating towards the combustor inlet; hence promoting the mixing. It is further found, that the volume rate ratio represents an important parameter when controlling the topology of the flow reversal within combustor.

The main topic of this paper is the measurement technique for investigating the mixing of two air flows. The steps of image processing are described, with respect to seeding

intensity fluctuations, the laser beam intensity profile, the laser divergence, angular dependence of the scattering, background light, dark current and noise of the camera.

Fig. 2 (left) shows the principle of the concentration measurement technique. The setup includes a commercial PIV system, the optics for generating a parallel light sheet and a reference cuvette. The concentration measurement technique is based on Mie scattering of laser light from particles uniformly in the main flow [1]. It is assumed that the local intensity of scattered light is proportional to the concentration of the particles in the light sheet and provides information about the mixture fraction of the both flows. A new calculation method of the mean concentration is proposed, which considers the global concentration and shows effectively the mass transport inside the shear layer between the outer flow (swirled) and the inner flow (unswirled), Fig. 2 (right).

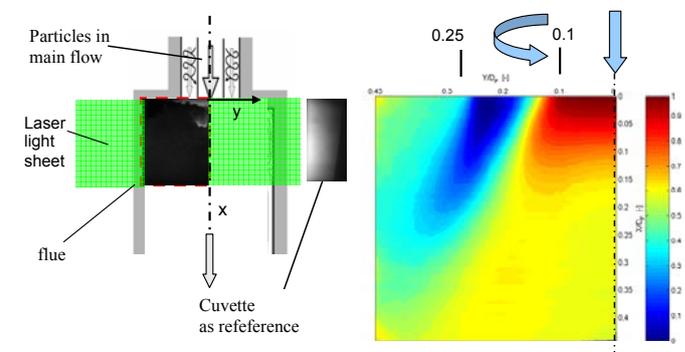


Fig. 2: Principle of the concentration measurement technique (right). Standardised concentration field. U/U_f , $Re_m = 2.35 \times 10^5$, $Re_c = 1.29 \times 10^5$ und $Re_f = 9.437 \times 10^5$, $S = 0.7$, $U_c/U_f = 4.6$, $U_m/U_f = 1.4$, $D_f/D_c = 2.0$, $D_f/D_m = 5.6$

References

- [1] Palm R., Grundmann S., Jakirlić S. und Tropea C., (2005). Experimental investigation and modelling of flow and turbulence in a swirl combustor, *the 4th Int. Symp. on „Turbulence and Shear Flow Phenomena“*, June 27-29, Williamsburg, Virginia, USA