Simultaneous Measurements of Mixing Fraction and Velocities of a Coaxial Jet in a Turbulent Channel Flow

J. Klinner[1,*], V. Mayer[2], J. Heinze[1], C. Willert[1]

1: DLR Institute of Propulsion Technology, German Aerospace Center, 51170 Köln, Germany
2: Daimler AG, D-70546 Stuttgart, Germany
* Correspondent author: joachim.klinner@dlr.de

Keywords: acetone PLIF, PIV, confined jet, turbulent mass flux, RANS

This contribution describes a generic mixing experiment aimed at providing experimental data of turbulence induced mass transfer to validate Reynolds averaged Navier-Stokes (RANS) and mass transport simulations.

The experiment provides simultaneous velocity and concentration measurements of the isothermal mixing of a confined coaxial jet in air. Measurements are performed in a small scale wind tunnel (see **Fig. 1**). The wind tunnel is operated in suction mode and has a 830 mm long test section with a square cross-section of internal width of 76 mm. Quartz windows with 45° edge bevels provide optical access to the entire cross-section. The mixing port is placed at a third of the test section length and consists of a 90° bend. The inner tube diameter is 25 mm with the bend exit aligned coaxial to the channel's center line.

The Reynolds number of the incoming main flow of the tunnel is 16000 and the Reynolds number of the injected air is 32000 (both based on bulk velocities and hydraulic diameter). The Reynolds number is 26000 based on the velocity difference of streams and on the hydraulic diameter of the injection port.

Instantaneous concentration measurements are implemented using planar laser induced fluorescence (PLIF) of the acetone seeded injected flow [1,2]. Simultaneous velocity measurements are performed using particle image velocimetry (PIV). A second double frame camera provides the out-of-plane velocity component via stereoscopic imaging. The contribution provides details of the PIV-PLIF measurement setup and of the methodology to obtain instantaneous measurements of the local mixing fraction and velocity as shown in **Fig. 2**.

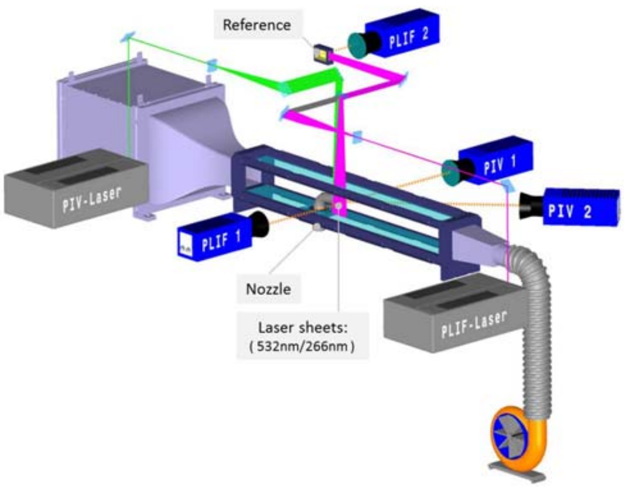

Figure 1 Schematic of the combined PLIF-PIV setup for the simultaneous measurement of velocity and concentration fields of a turbulent jet in co-flow

Ensemble-averages of velocity, mixing fraction, Reynolds stresses and turbulent mass flux are determined at four positions downstream of the nozzle using sets of up to 3600 PIV recordings. The convergence of the root-mean-square of velocity and concentration measurements over N is assessed in exemplary regions within the shear layers of the mixing zone.

The recovered profiles of ensemble-averaged velocity, concentration, Reynolds stresses and turbulent mass fluxes are compared to corresponding RANS simulations using a variety of turbulence models in an effort to assess their performance in predicting the mixing processes. Here it is found that the statistics of the RANS prediction show a strong underestimation of the degree of mixing and diffusion which in part may be attributed to the anisotropic behavior of the turbulent flow.

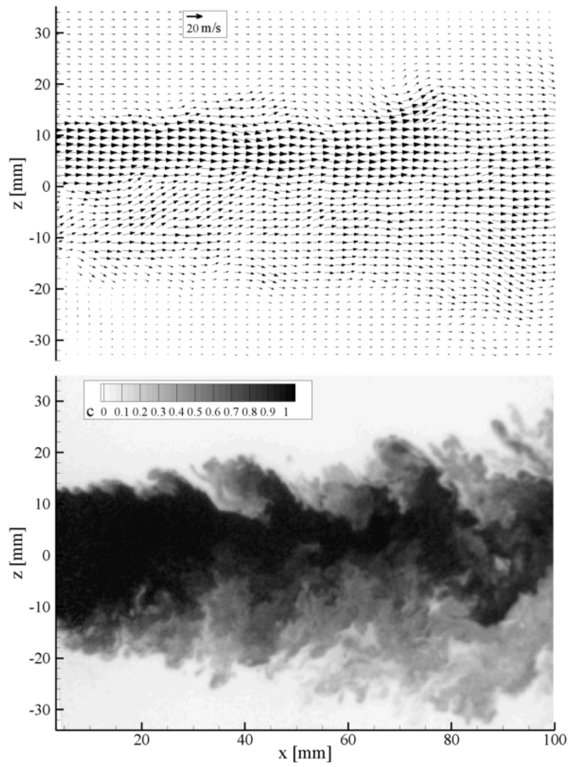

Figure 2 Snapshot of simultaneous velocity (2x2 vector skip) and concentration fields

[1] Bryant RA, Donbar JM, Driscoll JF (2000) Acetone laser induced fluorescence for low pressure/low temperature flow visualization. Exp Fluids 28(5):471–476

[2] Lozano A, Yip B, Hanson R (1992) Acetone: a tracer for concentration measurements in gaseous flows by planar laser induced fluorescence. Exp Fluids 13(6):369–376