Rayleigh imaging of mixing in partially premixed jets

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Jets in cross-flow configurations or transverse flows are widely used in several fields, e.g. in the NASA hydrogen burner (Schefer et al, 2003) and the injection jets in gas turbines (Lefebvre, 1999). In the scope of this work non-intrusive Rayleigh measurements have been performed to determine the local mixing fraction of hydrogen and air, at the exit plane of miniature jet where hydrogen is injected upstream in a cross-flow configuration with low momentum flux ratios in the range of 1/25 to 1/160. The momentum flux ratio, the Reynolds number and the mixing length are the variables of the experimental study in order to investigate their influence on the mixing process. The flow rates correspond to a range of operational conditions of a selected premixed hydrogen-air burner for a fuel cell system in automotive applications presented by Voss et al. (2011). The measurements were obtained 2.5 mm downstream of the mixing jets exit plane and contain examinations of three different mixing lengths \( l_{mix} = 15, 30 \) and \( 100 \) mm for non-reactive mixtures at ambient conditions, see cross-jet configuration in Figure 1. Therefore, the second harmonic (532 nm) of a Nd:YAG solid state laser has been utilized and reflections from solid surfaces were considered. Additionally, a coflow continuously provides filtered particle and dust free air to minimized Mie scattering, see experimental setup in Figure 2. By using the Rayleigh scattering cross-sections of hydrogen and air, the signal allows the prediction of local mixing fractions. For different Reynolds numbers and different momentum flux ratios and for a mixing length of \( l_{mix} = 15 \) mm, an elliptic form combined with a strong central core has been detected on the penetration side of the jet in cross-flow configuration, see Figure 3. An enhancement of mixing due to turbulence effects was observed only within the elliptic structure but the inhomogeneity in the hydrogen profiles remained despite the high diffusion velocity of hydrogen in air. The investigations for different mixing lengths have shown that an adequately homogenous mixture can be achieved with a mixing length of at least 100 mm. It can be concluded that the mixing process is mainly controlled by the complex three-dimensional flow structure within jet in cross-flow configurations, and for the given conditions and mixing length of 15 mm, the diffusion transport is not the dominating feature.

![Figure 1](image1.png)

**Fig. 1** Jet in cross-flow configuration with mixing length \( l_{mix} \) (15 ... 100 mm)

![Figure 2](image2.png)

**Fig. 2** Experimental Setup

![Figure 3](image3.png)

**Fig. 3** Relative concentration images of the non-reactive hydrogen-air gas mixture at ambient iso-thermal conditions for a constant mixing length \( l_{mix} = 15 \) mm and a constant momentum flux ratio of \( J = 1/159 \) and different Reynolds numbers with a constant equivalence ratio of \( \phi = 0.4 \); hydrogen penetration point is from the left side

References

