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Investigation of small-scale wall near flow structures using NO-tagging

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ABSTRACT

A detailed understanding of transport phenomena (species, heat) in turbulent flows and especially through near-wall laminar boundary layers is essential for a total description of reactive flows. Our research aims at a better understanding of such transport processes by providing experimental data with both, high spatial and temporal resolution to validate the results of mathematical simulations. The main interest of the experimental work focuses on the detection of wall/flow interaction (Doligalski et al., 1994) and the visualization of small-scale turbulent structures and their evolution.

The use of molecular tracers (Hiller and Hanson, 1988; Miles and Lempert, 1997; Grünefeld et al., 1998; Miles et al., 1987; Ribarov et al., 1998, and Krüger and Grünefeld, 1999) circumvents typical problems with particle seeding, where tracking of the gas motion is poor due to the momentum of the particles at high speeds and high turbulence. Furthermore, investigations close to walls become feasible, where particle methods tend to fail due to window fouling caused by electrostatic forces. Experiments monitoring the behavior of molecular tracers can also help to verify CFD-calculations which additionally consider molecular transport. This is essential for the description of reactive flows. Therefore, we developed and applied a flow tagging technique using photodissociation-generated nitric oxide as a molecular tracer (Orlemann et al., 1999, and Doose et al., 1999).

In the study presented here, air flows were homogeneously seeded with NO₂ at low concentrations. By photodissociation of NO₂ using an excimer laser (308 nm), NO was produced along the beam path, forming a spatial line of NO-molecules which was imaged by laser-induced fluorescence (LIF) at various delays after its generation (Orlemann et al., 1999). The detected NO-distribution shows the altered shape of the NO-line, caused by convective and diffusive effects during the time interval between the two lasers shots. Whereas several other tracers disappear rather quickly due to energy transfer processes (from vibrationally excited molecules (Miles et al., 1987)) or high reactivity (in the case of OH (Ribarov et al., 1998)), NO is stable on the time-scale of interest (some milliseconds) due to small reaction cross-sections. Therefore, using NO, the motion of volume elements can be imaged at longer times and larger distances compared to other techniques. Furthermore, with the molecular weight of NO in between those of N₂ and O₂ and diffusion coefficients close to nitrogen, NO turns out to be a good choice to characterize the small-scale behavior of turbulent air flows.