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Investigation of film flow by means of μ-PIV

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Shear-driven liquid wall films play a major role in the fuel preparation process in state of the art prefilming gas turbine combustor nozzles. Advanced two-phase flow CFD-codes have been identified as a valuable tool in the design and the optimisation process of these components. To simulate the interaction of the liquid film and the air flow within complex geometries, e.g. airblast atomisers, a detailed understanding of the dynamics inside the shear driven liquid film is needed. Mean film heights of less than 100 microns and a rough wavy film surface hamper the application of measurement techniques. Previous investigations have led to the assumption, that most of the film liquid is transported in waves rolling on a viscous sub-layer. Experiments with a modified μ-LDV system ([1], [2]) enabled for the first time the validation of this model. A direct numerical simulation of Burkhard [3] additionally supports the experimental results. To finally proof the model assumption, a planar measurement technique would be advantageous, which overcomes the inherent uncertainty in the assigning of punctual LDV data points to a location inside a defined standard wave, as shown in Fig. 1.

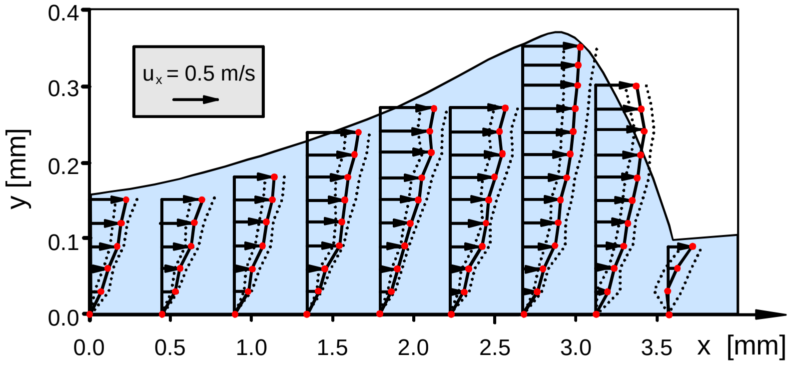

Fig.1: Velocity profiles inside a shear driven liquid film, combined by matching simultaneous film thickness and velocity measurements.

Particle Image Velocimetry (PIV) is a versatile tool to investigate fluid flow. Its main advantage is the planar character and thus the ability to capture a two-dimensional field inside the flow at one instance in time, thus gaining spatial coherent information. The present study is focused on the adaptation of a PIV measurement system to investigate the flow inside a shear driven wall film. This means especially a very small area of interest of approx. 0.2 x 1 mm². The particles inside the film are illuminated by a highly focused laser light sheet and the scattered light is recorded by a CCD-camera equipped with a long distance microscope. Due to the constrains studying a vertical plane inside a thin liquid film horizontally, a optical setup under Scheimpflug condition assures focused particle images (Fig. 2).

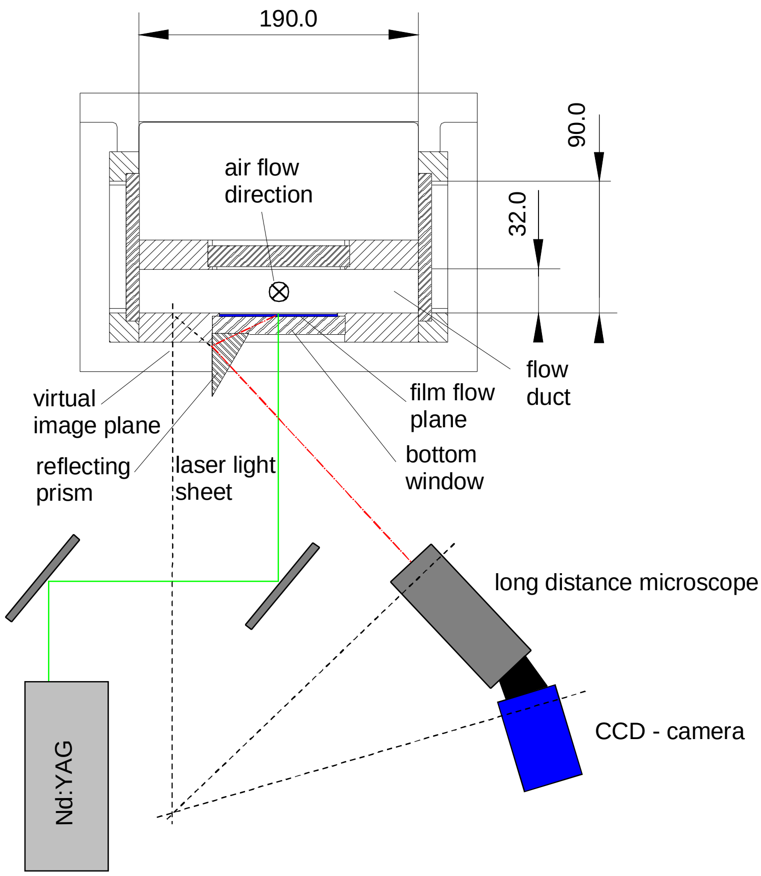

Fig. 2: Experimental setup of the PIV system for film flow investigations

The biggest problem of applying laser optical measurement techniques to shear-driven liquid wall films arises from reflections at the wavy liquid-air interface. To assure a steady laser-light sheet plane for the PIV measurements, the film has to be illuminated from the bottom through a transparent wall. To avoid reflections from the light sheet saturating large parts of the CCD chip, a special arrangement of the receiving optics is chosen. In the case of a direct reflection of the laser light sheet at the surface towards the camera, the angle between the laser light sheet and the perpendicular of the surface is equal to the Brewster's angle. At the Brewster's angle the p-polarized component in the reflected light is completely absent. Choosing a p-polarized light sheet and additionally applying a polarizing filter, disturbing light reflections at the surface can be avoided.

The results of the ongoing PIV measurements finally allow a detailed view on the internal film flow dynamics of shear-driven liquid wall films. Varying the driving air flow, the film load and the viscosity of the film liquid permits the investigation of the interaction between the viscous sublayer, the rolling waves and the driving air flow.

Literature:

[1] Wittig, S. and Elsäßer, A. and Samenfink, W. and Ebner, J. and Dullenkopf, K., Velocity Profiles in Shear-driven Liquid Films: LDV-Measurements, Proceedings of the Eighth International Symposium on Applications of Laser Techniques to Fluid Mechanics, Lisbon, Portugal, July 8 – 11, 1996.

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[3] Burkhardt, A. (2000). Dynamik Gasgetriebener Filme. Dissertation, Fachbereich Strömungsmaschinen, Universität Karlsruhe (T.H.).