DIGITAL IMAGING OF TWO-PHASE SHEAR FLOWS

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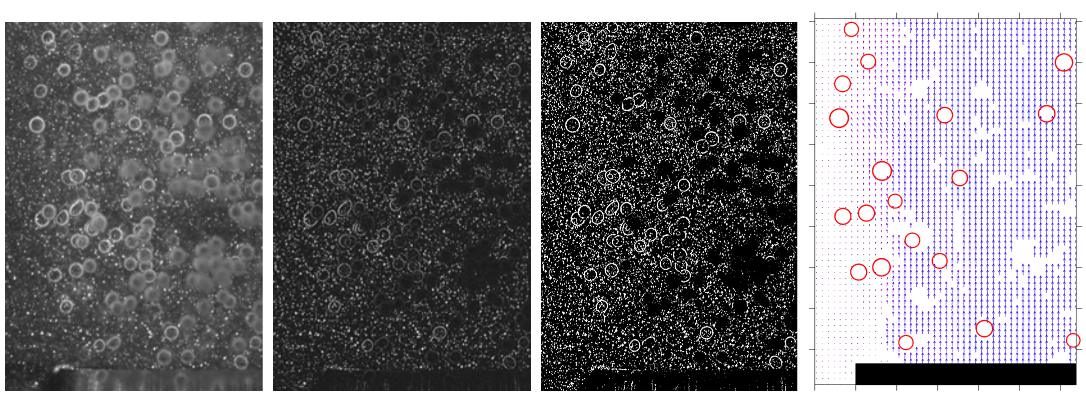
The lecture presents an overview of results on the application of modern non-intrusive experimental techniques – Particle Image Velocimetry (PIV), Laser Induced Fluorescence (LIF) – to the study of several types of two-phase shear flows such as turbulent jets of different configurations and also wavy films disturbed by turbulent gas flow or by local impact of the micro-drop.

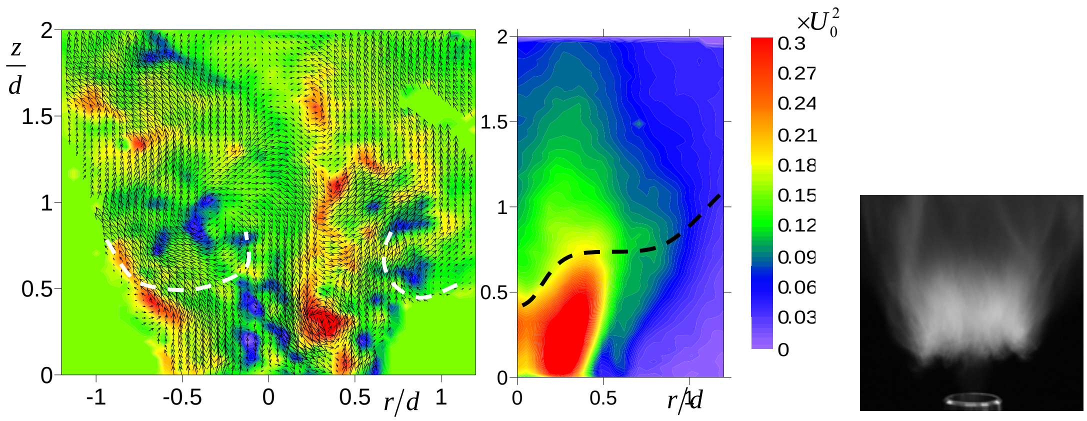
Besides the basic principles of PIV and LIF techniques, we present new approaches developed in the Institute of Thermophysics (Siberian Branch of RAS) which were applied to the investigation of rather wide spectrum of flows.

1. For the diagnostics of bubble flows a novel PLIF based technique was developed and calibrated. Method is based on the simultaneous addition of a fluorescent dye and particles into the carrier fluid. The optical separation and appropriate application of bubble identification algorithms, combined with PIV and PTV approaches allowed to obtain a wide set of characteristics of gas-saturated free and impinging jets at the range of volumetric gas content $\beta = 0 - 5$ %. Spatial distributions of the mean velocity and void fraction were obtained as well as the complete set of statistical moments including void fraction-liquid



(a) (б) (в) (г)

Fig.1. PLIF method for bubble jet diagnostics. Initial region of an axisymmetric bubble jet. (a) – initial image, (b) – characteristic function, (c) – bubble flow pattern after binarization, (d) – velocity field and bubbles distribution..



(a) (b) (c)

Fig.2. The instantaneous velocity and vorticity fields (a), axial component of turbulent kinetic energy (b) and photograph of turbulent reacting swirling jet (c) at $S = 1$; Re = 4,100; $\Phi = 2.4$.

velocity correlations. Strong effect of bubbles on the turbulent structure of the free and impinging jets was demonstrated. The illustration of technique principles and examples of results are presented in Fig. 1.

2. The advanced PIV algorithms are developed for turbulent flame diagnostics. The experimental study of reacting jet flow in a model open flame burner was performed (see example in Fig. 2). The work was inspired by the problem of extension of the range for stable and effective combustion which is basically determined by the turbulent flow structure in reaction zone. To approach this target spatial distributions of the mean velocity, turbulent kinetic energy were measured and the role of organized vortical structures have been studied. The main technique used is a laser based stereo PIV system. The measurements were performed in a central section of the jet flame. Regular swirl parameter of the flow was varied from 0 to 1.0. Reynolds number was changed between 1000 and 8000. Equivalence ratio Φ variation band was between 0.5 and 4. Effect of the nozzle geometry was studied using nozzles with different exit diameters.

3. The new method of 3D LIF quantitative visualization with high spatial and temporal resolution is developed. The experimental study of evolution of solitary waves on the falling liquid film was performed for the range of small and moderate Reynolds numbers. The main scenarios of solitary waves evolution were registered. For the first time the existence of stationary solitary wave on the liquid film surface was confirmed (Fig. 3).

4. High-speed fluorescent visualization complex has been developed for quantitative investigation of the process of interaction of waves on liquid film in annular two-phase flow. Evolution of ripples on disturbance waves surface and disturbance waves coalescence are investigated. It is shown that all the ripples in presence of disturbance waves appear at the base of the back front of disturbance waves and then either decelerate travel on substrate and are overtaken by the following disturbance wave or

accelerate, grow and then disappear at the front of disturbance wave. The disappearance happens due to entrainment of liquid into the core of gas stream. Several scenarios of coalescence of disturbance waves were identified. For disturbance waves with close velocities, different types of remote interaction were observed.

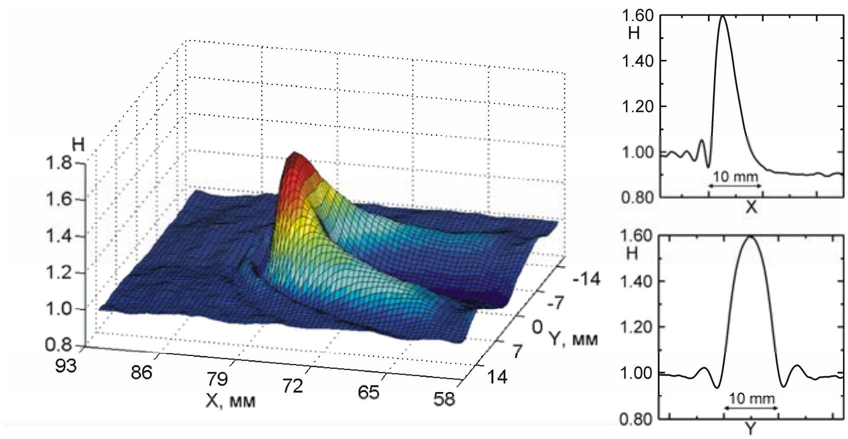


Fig.3. Stationary solitary wave on falling liquid film. Re = 3.9.