ACCURACY OF BACKGROUND ORIENTED SCHLIEREN FOR DIFFERENT BACKGROUND PATTERNS AND MEANS OF REFRACTION INDEX RECONSTRUCTION

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ABSTRACT: Different sources of error in Background Oriented Schlieren (BOS) technique for measuring the refraction index field are analyzed. They can be divided into three groups: cross-correlation errors similar to Particle Image Velocimetry (PIV), optical defects of the original images, limiting the capabilities of post-processing, and computational errors associated with procedure of refraction index field reconstruction from its gradient.

The errors of the first group are closely related to the problem of choosing the optimal background pattern. In contrast to PIV, seeding density, size and shape of the pattern elements can be fully controlled to minimize peak-locking and in-plane loss-of-pairs due to limited interrogation window size. In present investigation these errors are estimated for popular multi-pass cross-correlation interrogation with discrete window offset [1] and several types of black-and-white background pattern by generating synthetic images with known displacement field and post-processing them. Constant displacement fields are used to estimate the accuracy and sinusoidal ones — to assess spatial resolution. Best results are shown to be obtained with randomly positioned square dots 2×2 or 3×3 pixels. Also, tests for the displacement gradient error are performed using displacement fields, simulating thermal boundary layers or shock waves.

The errors of the second group include defocusing and distortion of the image elements due to out-of-plane and in-plane nonlinear variations of refraction index (lens and false mirror effects). The latter is shown to influence less than cross-correlation failure for the same value of displacement gradient. The former is simulated by Gaussian blur filter applied to the second image of the pair. Black-and-white square dot patterns are shown to be more robust with respect to blur than grayscale wavelet-noise ones.

The third group of errors is specific for BOS. If solving Poisson equation is used, it includes right-hand side error related to displacement evaluation, approximation error of solution due to finite grid step and the error of boundary conditions, estimated from the displacement field. Approximation error can be decreased by interpolating the displacement field to a finer mesh. Boundary conditions can contribute about half of the total error. However, least-squares fit can be used instead of Poisson equation to determine refraction index directly from the displacement field.

The results of numerical experiments are proven with the real images of thin thermal layer below the surface of evaporating liquid.

References

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