An application of speckle-based background oriented schlieren for optical microcalorimetry

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Keywords: Background Oriented Schlieren, Calorimetry, Spark, Ignition

HIGHLIGHTS

• A speckle-based background oriented schlieren setup was designed and operated in small dimension fields.
• Setup validation, uncertainty and precision estimations is made on a laminar steady CO jet in ambient air.
• Enthalpy deposit at the end of an electrical inductive discharge is measured.

ABSTRACT

The aim of the present study is to validate an experimental method of in-fluid enthalpy variation measurement by means of Speckle-based Background Oriented Schlieren. The method applies on resolving the millijoule thermal-energy transfer to fluid induced by an electric discharge in air. Our BOS implementation uses recent developments of speckle-background oriented schlieren [1]. A coherent continuous 3W DPSS laser delivers a 532nm beam, is expanded and impact a ground glass creating a speckle which is used as a reference pattern as it allows an easier access to high density pattern for subcentimetrics imaging. Our optical collection is composed of a tailored objective working at a magnification of M=1 based on two lenses of respective focal length 500mm and 300mm and a diaphragm. An intensified camera is used with a 1μs exposure time to match the electric discharge exposure time constraint. Geometrics optics principles are used to extract the line of sight integrated index of refraction. Local density field is then computed through filtered back projection of Gladstone-Dale equation. The method is first validated in close experimental conditions provided by the density measurement on a millimeters-dimensions CO gaseous laminar jet. An analysis on the jet gives useful insights on noises sources and uncertainties of the method which is then transposed to the discharge. On a 100 averaged acquisitions on the jet, the mean density at core over one diameter (in laminar conditions) is supposed to be the CO density (0.8% mean precision and a 3.5% spatial dispersion within the 6.5% estimated uncertainty). The ignitor is an automobile inductive coil. The discharge configuration consists in facing 2mm diameter spike electrodes with a gap distance between tip of 2mm. Over 9 acquisitions, taken at 2.5ms after the breakdown, the enthalpy variation (Fig.1b) H yields H=10.2±0.5mJ (4.6%). Electrical measurements yields E = 38.4 ± 1.5mJ which leads to a global thermal efficiency of η=26.7±1.6% which is consistent with values found in literature.

Fig.1 Time averaged density field on CO. jet (a) (iso-0.05kg/m³) – Local enthalpy deposit from a discharge (b) (iso-0.05mJ/mm³)