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A TWO-COLOUR TECHNIQUE FOR VELOCITY MAPPING IN SPRAY COMBUSTION

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Introduction

Improved combustion performance of spray-fuelled combustors, through increased efficiency and reduced emissions, is a high priority research requirement. A determining factor in this performance is fuel spray behaviour, which affects fuel/air mixing, flame stability, soot formation, flame radiation, and unburned hydrocarbons. Thus it is important to characterize individual droplet velocities in fuel sprays, in both combusting and noncombusting flows. To study the complex flow-fields found in combustion, with large scale structures such as recirculation zones, it is frequently important to acquire an instantaneous view of the overall flow structure.

In order to achieve this, a laser-based optical diagnostic has been developed for simultaneous full-field (two dimensional) velocity mapping. This paper describes a two colour double pulse technique in which spectral separation is employed to resolve the 180° directional ambiguity common to conventional monochromatic methods for acquiring particle image velocimetry (PIV) images. This technique was first developed to study spray plume propagation in diesel fuel injection [1]. It has also been applied to look at the flow through a turbine cascade [2]. Other methods for resolving directional ambiguity are the velocity bias technique [3,4] and illumination pulse coding [5].

In this technique a droplet/particle-laden flow-field is doubly exposed with spatially coincident, temporally sequential laser sheets of two different colours. The Mie scattering from the droplets/particles is recorded on colour photographic film, and a film scanner is used to digitise and spectrally separate the two images. These images are then digitally processed to determine the velocity map.

The objectives are to apply this technique to a wide range of combusting and non-combusting flows that involve droplet sprays or are seeded and have velocities as high as a 100 m/s.

Experimental

To achieve the high degree of flexibility required for the wide range of experimental conditions anticipated in various combustor configurations, the illumination source used was two Candela SLL-250 flashlamp pumped pulsed broadband dye lasers, one lasing at 454 nm (blue) and the other at 545 nm (green). These wavelengths were selected to minimize interference from combustion radiation and to permit colour separation. The laser pulse duration is 300 ns FWHM, which can be reduced to as little as 40 ns (by selecting a portion of the output with a Pockels cell) when image blurring due to high velocities occurs.

The lasers are triggered sequentially with the delay between pulses variable from 500 ns to 3 ms. Each laser has an output energy of up to 1 J/pulse, and a beam diameter of 10 mm. The beam has a top-hat profile, which results in more uniform illumination in the sheet than lasers with Gaussian profiles would provide. A sheet 50 mm wide and 0.9 mm thick was formed with a -60 mm cylindrical lens followed by a 300 mm spherical lens. This optical arrangement is shown in Figure 1.

A Nikon F-801 35mm camera with a 105mm f/2.8 Micro Nikkor lens recorded the images on Kodak Ektar 125 ASA film. This camera has a 1/250 sec flash sync. speed, which provides better discrimination against non-laser radiation than the typical 1/60 sec, the lens has excellent flat-field and close-up imaging characteristics for uniform image quality and high magnification, and the film has a high resolution of up to 160 lines/mm. The photographs were digitised with an Imapro QCS-35 Film Scanner, which scanned at resolutions up to 6144 x 4096 pixels, and stored the images in spectrally separated form.

Analysis

The approaches most often used for PIV analysis are the Young's fringe method [6] and the spatial auto-correlation method [6]. However, these methods do not recognize the advantages of the two-colour method. Thus the histogram approach has been taken. The images are processed to eliminate background noise and to enhance and sharpen the droplet/particle images, and then the centroid of each image is located. A histogram of relative locations of green images to each blue image is computed, with the peak at the location of the mean flow velocity. From this, an attempt is made to find a matching green image for each blue image. The separation distance for each pair is calculated and a velocity computed. These velocities then make up the vector map for the flowfield.

Results

The two colour method was used to examine the flow-field in an unconfined axisymmetric liquid fuelled bluff-body stabilized diffusion flame burner, shown in Figure 3. The particles were heptane droplets of ~40 microns SMD, produced by a piezoelectric atomizer. Manual analysis at the periphery of images of non-combusting flow produced velocities consistent with known exit velocities. typical example is shown in Figure 4. This image was taken with a delay of 202 microseconds between the blue pulse and the green pulse. The ratio of test object size to film image size was 2.44:1 and the film was scanned at 166 pixels/mm. This resulted in each pixel between the corresponding blue and green droplet images representing a velocity of 0.0714 m/s. The vectors shown in Figure 4 are in the range of 2 to 5 m/s. The Ektar 125 film does not provide good spectral separation, so that the green layer will respond to 454 nm and the red layer will respond to 545 nm. This accounts for the yellow colour appearing in the highest intensity regions of the green images. Films such as Kodacolor Gold 100 provide better spectral separation at a cost of lower resolution (100 lines/mm), which may be the best compromise for this application.

Summary

A two-colour technique for obtaining PIV images has been developed. This technique has been demonstrated in a complex recirculating flowfield under isothermal conditions. The use of two colours overcomes the 180° directional ambiguity limitation of conventional double-pulse PIV, and reduces data analysis requirements. High resolution digitization and initial processing of PIV images has been achieved, but the histogram analysis code requires further development.

Acknowledgements

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References

1. G.J. Smallwood, W.S. Neill, and D.R. Snelling, "Diesel Engine Combustion Program at the Defence Research Establishment Ottawa",

DREO Report No. 926 (1985).
2. L.P. Goss, M.E. Post, D.D. Trump, B. Sarka, C.D. MacArthur and G.E. Dunning, "A Novel Technique for Blade-to-Blade Velocity Measurements in a Turbine Cascade", AIAA-89-2691 (1989).
3. R.J. Adrian, "An Image Shifting Technique to Resolve Directional Ambiguity in Double-Pulsed Laser Velocimetry", Appl. Opt. **25**, 3855 (1986).
4. L. Lourenco, "Application of Laser Speckle and Particle Image Velocimetry in Flows with Velocity Reversal", Bull. Amer. Phy. Soc. **31**, 1723 (1986).
5. B. Khalighi and Y.H. Lee, "Particle Tracking Velocimetry: An Automatic Image Processing Algorithm", Appl. Opt. **28**, 4328 (1989).
6. R.J. Adrian and C.S. Yao, "Development of Pulsed Laser Velocimetry for Measurement of Fluid Flow", in *Proceedings, Eighth Biennial Symposium on Turbulence*, X.B. Reed, G.K. Patterson and J.L. Zakin, Eds. (University of Missouri, Rolla, 1983).

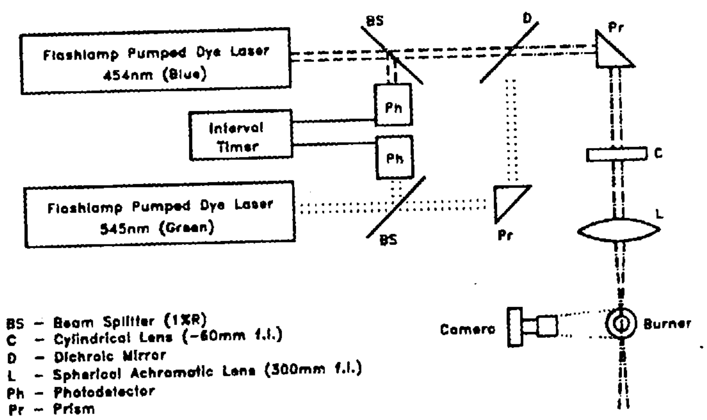

Fig. 1. Optical arrangement of the two colour double-pulse particle image velocimetry apparatus.

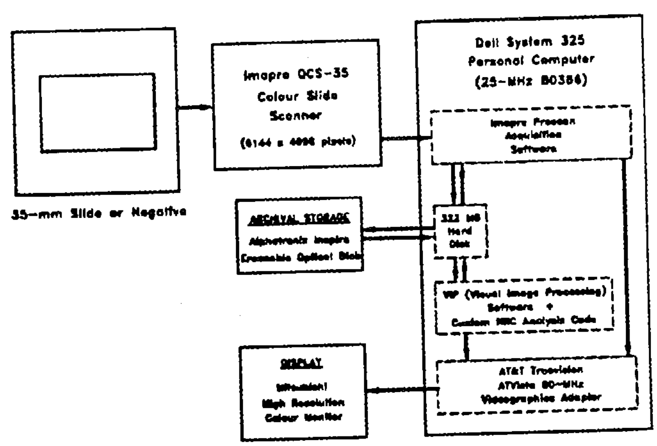

Fig. 2. Schematic diagram of the digital image processing workstation.

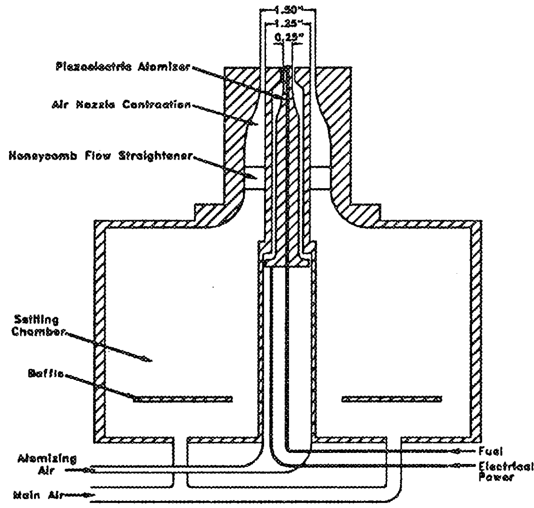

Fig. 3. Sectional view of unconfined bluff-body stabilised liquid fuelled diffusion flame burner.

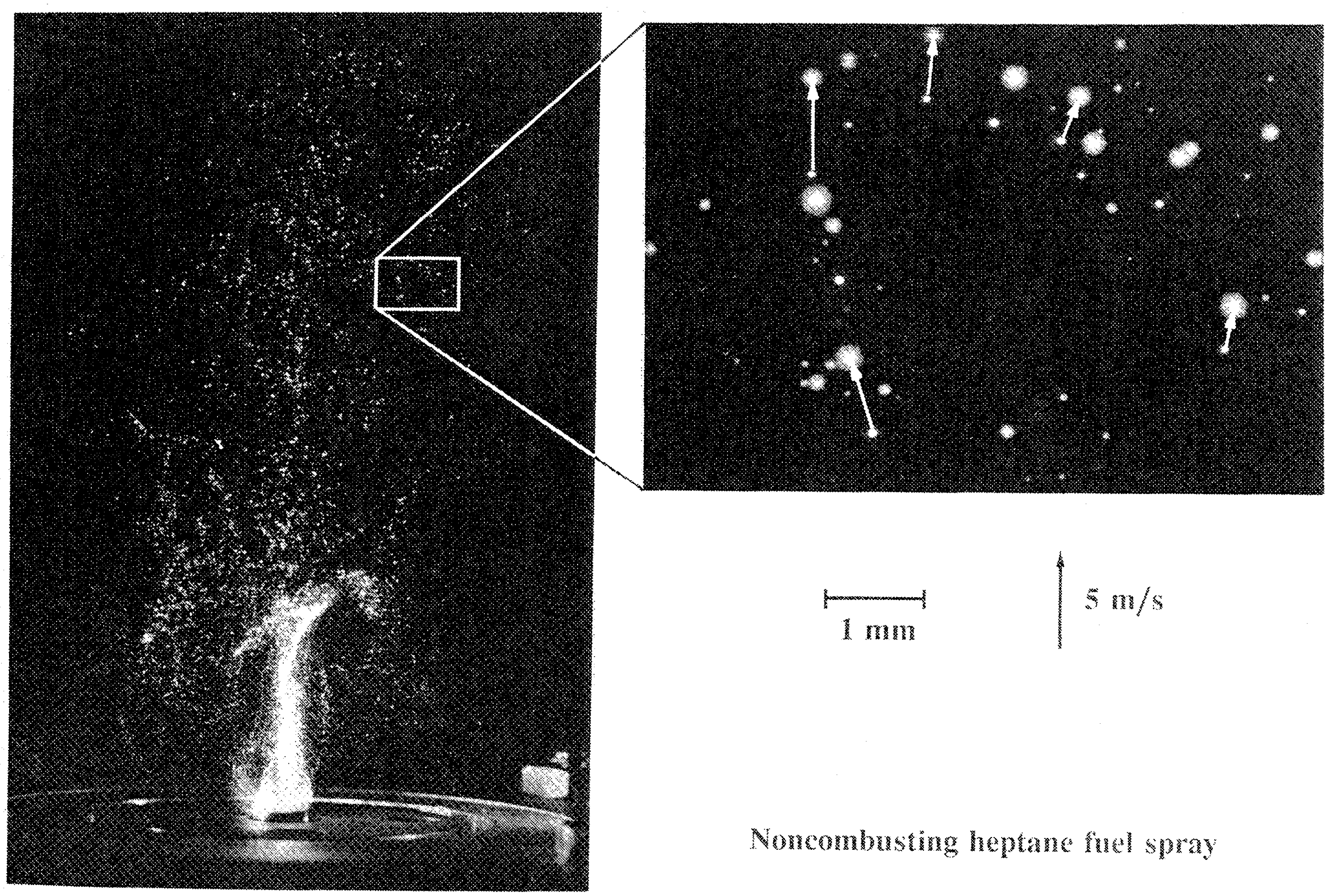

Fig. 4. Example of two colour double exposure technique.