펄스형태로 분출하는 플라즈마-제트의 명확한 이해를 위한 다양한 가시화 방법의 적용

Application of Various Imaging Methods for Detailed Understanding of a Pulsed Plasma-Jet

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There are many methods to visualize fluid flows such as, the schlieren (or shadow) imaging, visible emission imaging, and the laser-induced fluorescence imaging, depending on their applications. Each method has its inherent strengths and shortcomings, where the latter can sometimes mislead the truth of the observed flow phenomena.

For example, the visible emission (Fig. 1) of a pulsed plasma-jet is seen as many things are in the shock-bounded region (i.e., inside barrel shock) but, it turns out to be false when laser induced fluorescence measurement (Fig. 3) is performed;(1) the copper laser-induced fluorescence (LIF) shows rather empty inside the barrel shock instead much bright outside. Moreover, through the Schlieren imaging (Fig. 2) of the plasma-jet, it was observed that the underexpanded plasma-jet (i.e., visible emission) is surrounded by a strong spherical shock wave. Therefore, for a complete and unambiguous investigation of a compressible flow, it is desirable to apply more than just one visualization method.

An example of this combined visualization imaging is shown below; visible emission (Fig. 1), Schlieren imaging (Fig. 2), and copper planer laser induced fluorescence (Fig. 3). The electrothermal-chemical (ETC) capillary plasma source (not shown here)(2) is driven by a pulse-forming network (PFN), consisting of a 251 μF capacitor charged to a maximum of 5.0 kV (3.1 kJ) and a 26 μH inductor. The capillary is made of polycarbonate (Lexan, $C_{16}H_{14}O_3$). It is 3 mm in diameter and 30 mm long and is open at one end only. Aluminum fuse wire (64 μm diameter) was used between two electrodes to initiate the discharge. In order to resist the erosion, the electrodes were constructed with inserts made of a copper-tungsten alloy (30% Cu, 70% W). The peak current through the plasma jet is approximately 4.6 kA for an initial capacitor voltage of 5 kV (discharge energy, 3.1 kJ), and the duration of discharge is approximately 250 μs.

Figure 1.

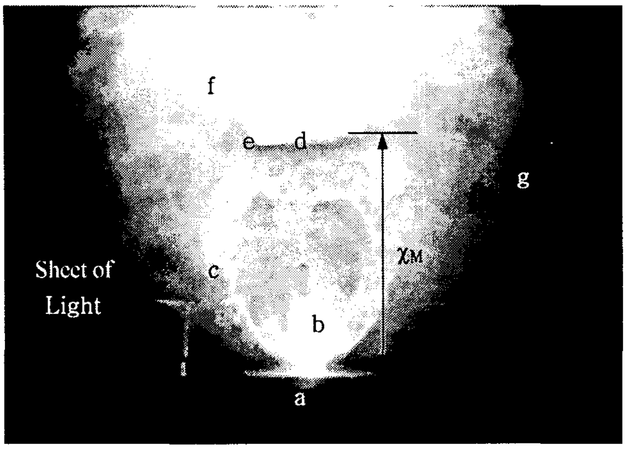

Figure 2.

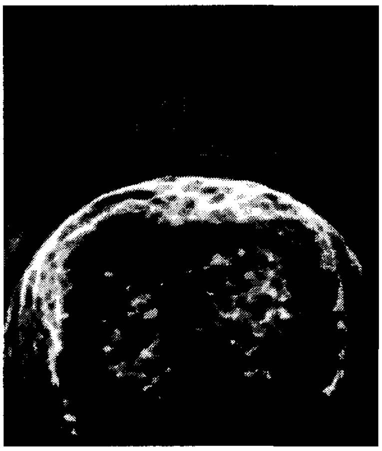

Figure 3.

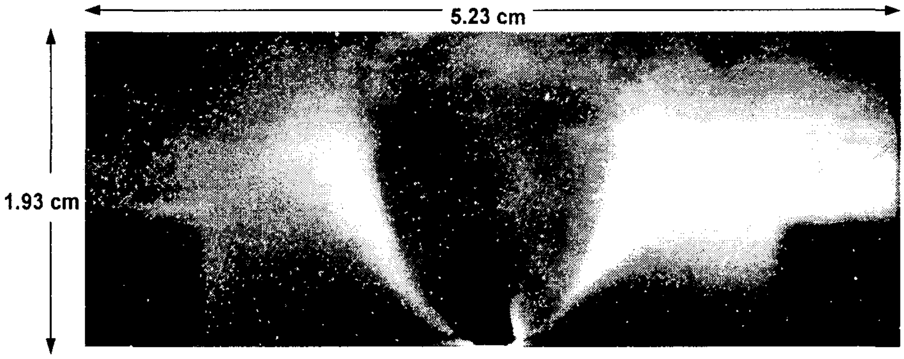

Fig. 1. Visible emission image taken at 105 μs after the plasma discharge at 3.0 kV (**a**: capillary exit, **b**: Mach cone, **c**: barrel shock, **d**: Mach disk, **e**: triple point, **f**: reflected shock, **g**: contact surface). Where χ_M is the vertical distance from the exit of the capillary to Mach disk location.

Fig. 2. Typical Schlieren image of the freely expanding pulsed plasma jet taken at 105 μs for initial charging voltages of 3.0 *kV*.

Fig. 3. Typical Copper Planer Laser-Induced Fluorescence (Cu-PLIF) image taken at 105 μs after the plasma discharge at 3.0 kV (i.e., ground state copper was excited by $^2S_{1/2} \rightarrow {}^2P^0_{1/2}$ (327.396 nm), and the fluorescence signal was observed in the transition $^2P^0_{1/2} \rightarrow {}^2D^0_{3/2}$ (578.213 nm)).

[References]

[1]. Kim, J. U., and Suk, H., *Appl. Phys. Lett.* in press Jan. 21, 2002.
[2]. Kim, J. U., and Kim, Y. J., *KSME Int. J.* 15, pp. 1691-1698, 2001.