Comment on "Experimental investigation on cellular breakup of a planar liquid sheet from an air-blast nozzle" [Phys. Fluids 16, 625 (2004)]

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The validity of the laser diffraction technique commonly used to measure the longitudinal oscillation of an air-blasted liquid sheet was recently questioned in a paper published in Physics of Fluids.[1] Some experimental results are here presented to demonstrate that it can be safely applied.

In the last years, the large aspect ratio air-blasted liquid sheet has been extensively studied. One of the parameters that has been more often measured is the liquid sheet longitudinal oscillation, induced by the air coflow. Probably the most straightforward method to accomplish this task is applying the light diffraction method first described by Mansour and Chigier.[2] An easy way to implement it consists in propagating a laser beam parallel to the liquid sheet pointing directly to a receiving detector, normally a photodiode.[3,4] When the oscillating sheet crosses the light beam, it is partially blocked, and a difference in light intensity is detected in the photodiode, resulting in a periodic signal with a frequency related to that of the liquid sheet oscillation. Some authors[1] have recently argued that this technique is not applicable for high air-to-liquid relative velocities because the laser beam is spatially integrated through multiple waves in the spanwise direction. In order to refute this assertion we have performed a set of frequency measurements simultaneously applying the laser diffraction method and an alternative technique whose applicability has not been questioned, the detection of the associated acoustic signal, using a Brüel & Kjaer pressure transducer.

The present experiments have been performed in a facility that has been described in detail in previous papers,[3,4] formed by a contoured nozzle head attached to a wind tunnel that ensures the exit of parallel air/water streams with a span of 80 mm. Water injected at the top of the nozzle exits vertically forming a sheet with a width of 0.5 mm. The two air streams that confine the liquid sheet have a width of 3.45 mm at the exit section. Water volumetric flow rate has extended up to 600 l/h, corresponding to a maximum liquid velocity U_w of 4.16 m/s. The maximum air flow velocity has been measured to be $U_a = 80$ m/s.

Frequency measurements for a variety of water and air velocities are presented in Fig. 1. They are in very good agreement with those previously acquired in the same facility.[4] Results obtained with the microphone are denoted by *"mic."* and are represented by hollow black symbols. Frequency values derived from the laser/diode method are denoted by *"diode"* and have been represented by the filled colored symbols. In general, it can be observed that for most air velocities, the frequency values measured with both techniques are nearly identical. In particular, the overlapping for air velocities of 30, 40, 50, and 70 m/s is almost perfect. To analyze these results, it is revealing to examine the Fast Fourier Transform (FFT) of some of the periodic signals recorded both with diode and microphone. Figure 2 shows different examples corresponding to air and water flow rate values that lead to different oscillation regimes. In all cases, the left plots are diode measurements while the right ones have been obtained from microphone registers. For the case presented in Fig. 2(a) water velocity U_w was 2.08 m/s, while air velocity U_a was 60 m/s, corresponding to a momentum flux ratio (MFR), defined as $(\rho_a U_a^2)/(\rho_w U_w^2)$ of 0.83. This is a favorable case, with a clear peak for a single dominant oscillation frequency, which is determined identically with both measurement techniques. In case (b) U_w was 3.47 m/s and U_a was 70 m/s resulting in a MFR of 0.41. Here the dominant peak widens, but still the diode and microphone spectra are

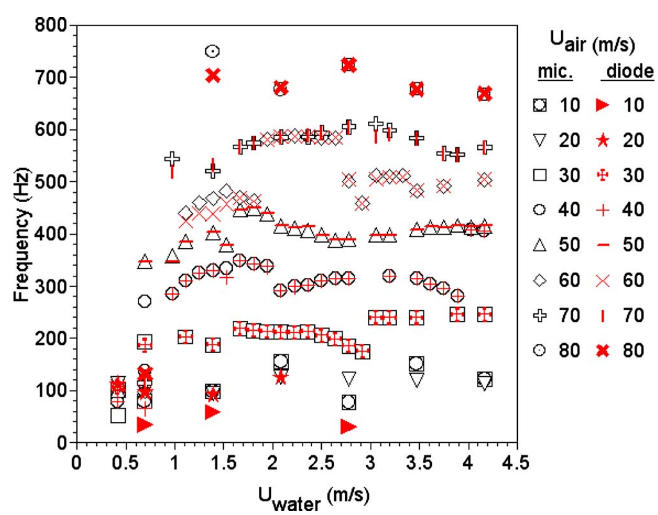

FIG. 1. (Color online) Sheet oscillation frequency measured with a pressure transducer (*mic.*) and detecting with a photodiode (*diode*) the passage of a laser beam.

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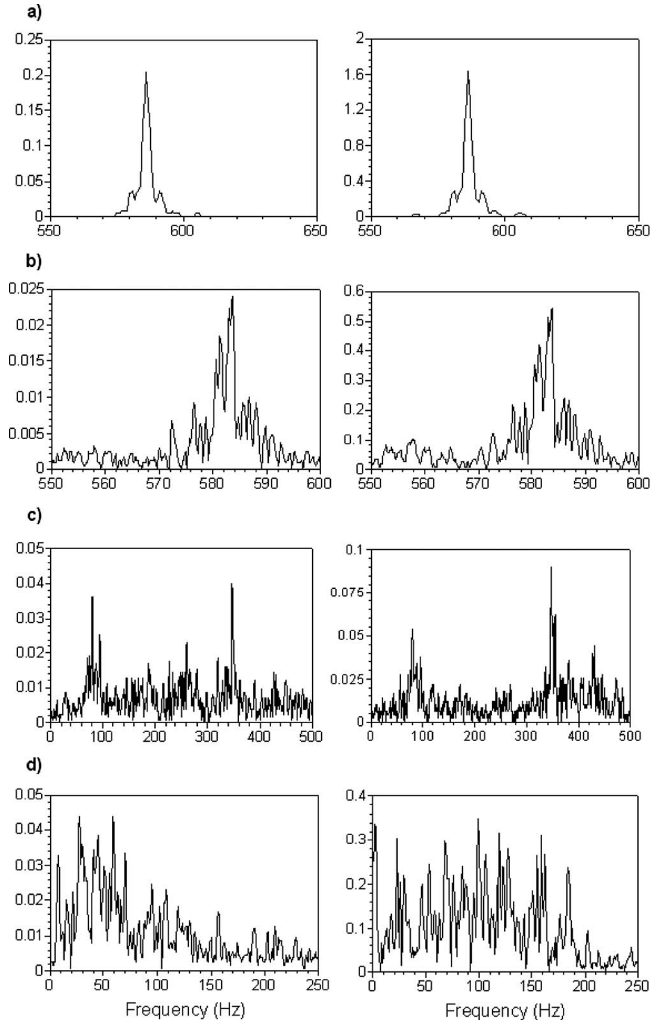

FIG. 2. Fourier spectra of diode (left) and microphone (right) signals for different air and water flow conditions: (a) U_w=2.08 m/s, U_a=60 m/s, and MFR=0.83, (b) U_w=3.47 m/s, U_a=70 m/s, and MFR=0.41, (c) U_w=0.69 m/s, U_a=50 m/s, and MFR=5.25, and (d) U_w=1.39 m/s, U_a=10 m/s and MFR=0.05.

totally similar. In Fig. 2(c) MFR has been increased to 5.25, with a water velocity U_w of 0.69 m/s and an air velocity U_a of 50 m/s. Although the two graphics show a mixture of frequencies, the same dominant values can be extracted from both of them. Finally, Fig. 2(d) corresponds to U_w =1.39 m/s, U_a=10 m/s, and MFR=0.05. Here not only both spectra are noncoincident, but it is not possible to discern a dominant oscillation frequency. It has to be noted, though, that under these conditions, the sheet oscillates with very low amplitudes, so poor diode measurements could be expected. In some limiting cases, for example air velocities lower than 20 m/s and liquid velocities higher that 2.75 m/s, no reliable values have been obtained with the laser/diode technique (note that these points have not been included in Fig. 1). The problem, however, is not only of inaccurate measurements but of an oscillating regime (denoted by Mansour and Chigier as zone C) that might not be properly characterized by a single oscillation frequency.

In summary, both measurement methods appear to be equally valid for a very ample range of air and water velocities and MFR values, including those corresponding to high air-to-liquid relative velocities. Integration along the spanwise waves does not seem to be an impediment to the application of the laser/diode measuring technique.

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