Effects of the mixing chamber length and of the nozzle-to-plate distance on the external flow field of impinging sweeping jets

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ABSTRACT The external flow field of impinging sweeping jets has been experimentally investigated through the application of the Particle Image Velocimetry (PIV) technique. Three sweeping jet devices, characterized by different mixing chamber lengths (L_f /w = 2.5 , 3.5, 4.5, being w the width of the throat section of the fluidic oscillator), have been investigated and their impinging flow fields have been evaluated for non-dimensional nozzle-to-plate distances H/w ranging between 2 and 10. In order to highlight the influence of the nozzle-to-plate distance and of the mixing chamber length on the impinging flow field of the investigated sweeping jets devices, time-averaged and phase-averaged analyses have been carried out.

1 INTRODUCTION

Due to intrinsic flow instability mechanisms, sweeping jet fluidic oscillators are devices which are able to convert a steady jet into an oscillating jet. Over the last years, the interest in fluidic oscillators has remarkably grown, because of their simplicity, reliability, and low maintenance costs; indeed, the oscillations are entirely self-induced and self-sustained (Bobusch et al.). In the literature several actuator designs have been proposed to generate a sweeping jet. Three main categories are suggested by Woszidlo et al.: feedback-free oscillators, oscillators with one feedback channel and oscillators with two feedback channels (as the one investigated in the current work, illustrated in Figure 1, left).

2 EXPERIMENTAL SETUP

The impinging flow field of the issued sweeping jets has been investigated through the application of the PIV technique. All the experiments have been performed at the same value of the Reynolds number (2.16×10^4). In the employed experimental apparatus (depicted in Figure 1, right) a centrifugal blower is used to collect the air from the ambient; in order to keep the air temperature equal to the ambient one, the air then passes through a heat exchanger. The flow is then directed to the nozzle and comes out in the flow domain, where it impinges on the plate. In order to allow the variation of the nozzle-to-plate spacing H/w, the impinging plate has been mounted on a translation stage. The flow is seeded with olive oil particles generated by a Laskin nozzle. A laser sheet 1 mm thick, provided by a Quantel Evergreen laser, illuminates the region between the nozzle and the impinged plate. The laser sheet passes through the transparent impinging wall and illuminates the entire domain, following the streamwise direction of the flow.

3 RESULTS AND CONCLUSIONS

The effects of the nozzle-to-plate distance and of the mixing chamber length over the flow field of an impinging sweeping jet have been experimentally investigated with the planar PIV technique; the results are presented in terms of the time-averaged and phase-averaged velocity fields and of the distribution of the TKE and of the PKE in the flow domain. Indeed, the phase evolution of the impinging sweeping jet has been effectively reconstructed through the evaluation of the instantaneous signal of the pressure drop across the feedback channel. For each device, values of the non-dimensional nozzle-to-plate distance H/w equal to 2, 4, 6, 8 and 10 have been analyzed. As regards the effect of the nozzle-to-plate distance, for L_f /w = 4.5 the jet sweeps in a rigid way between the two most deflected positions at small impinging distances, while at higher distances there is a phase delay between the motion of the jet in proximity of the exit nozzle and the motion of the jet in proximity of the wall. As regards the influence of the mixing chamber length, in agreement with the numerical work of Seo et al., it has been found that for the devices having L_f /w < 4.5 no sweeping oscillation of the jet can be detected; indeed, a single jet structure has been found in these, while for the device having L_f /w = 4.5 it has been possible to observe that the jet exhibits a typical twin-jet pattern (see Figure 2 (a)). Therefore, the main effect of reducing the length of the mixing chamber is that the twin-jet structure turns into a classical single-jet structure, as can be seen from Figure 2. Moreover, from the analysis of the axial velocity profiles along the direction of the oscillation for the three investigated devices it has been possible to observe that the values of the axial velocity are greater for the devices having L_f /w = 2.5 and L_f /w = 3.5 than the ones obtained for the device having L_f /w = 4.5.

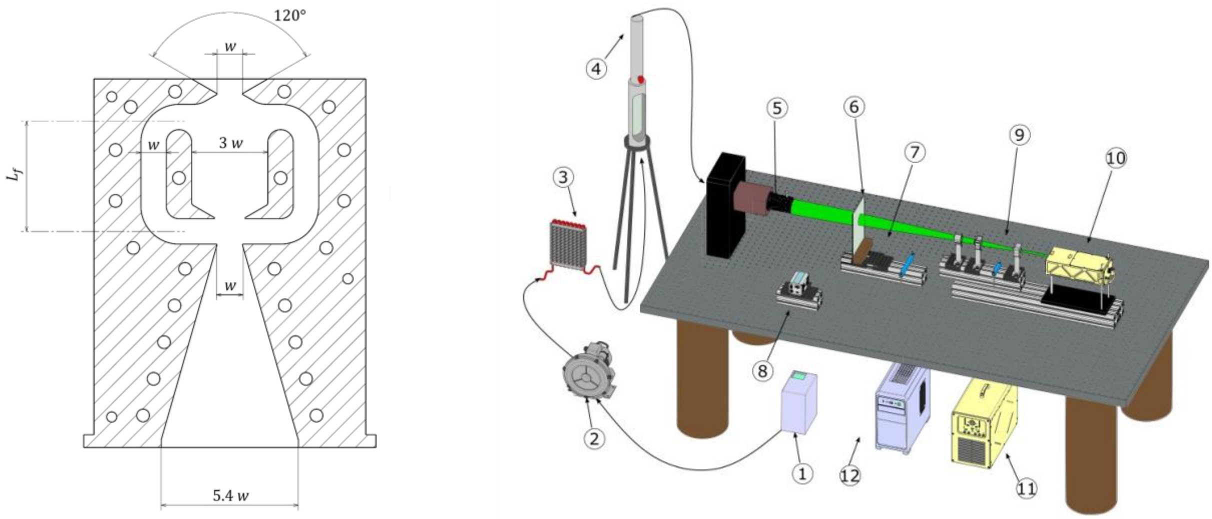

Figure 1. Draft of the employed fluidic oscillator (left) and schematic representation of the experimental setup (right): inverter (1), centrifugal blower (2), heat exchanger (3), flow meter (4), nozzle (5), impinging plate (6), traversing system (7), camera (8), optical lens (9), laser (10), laser power supply (11), computer (12).

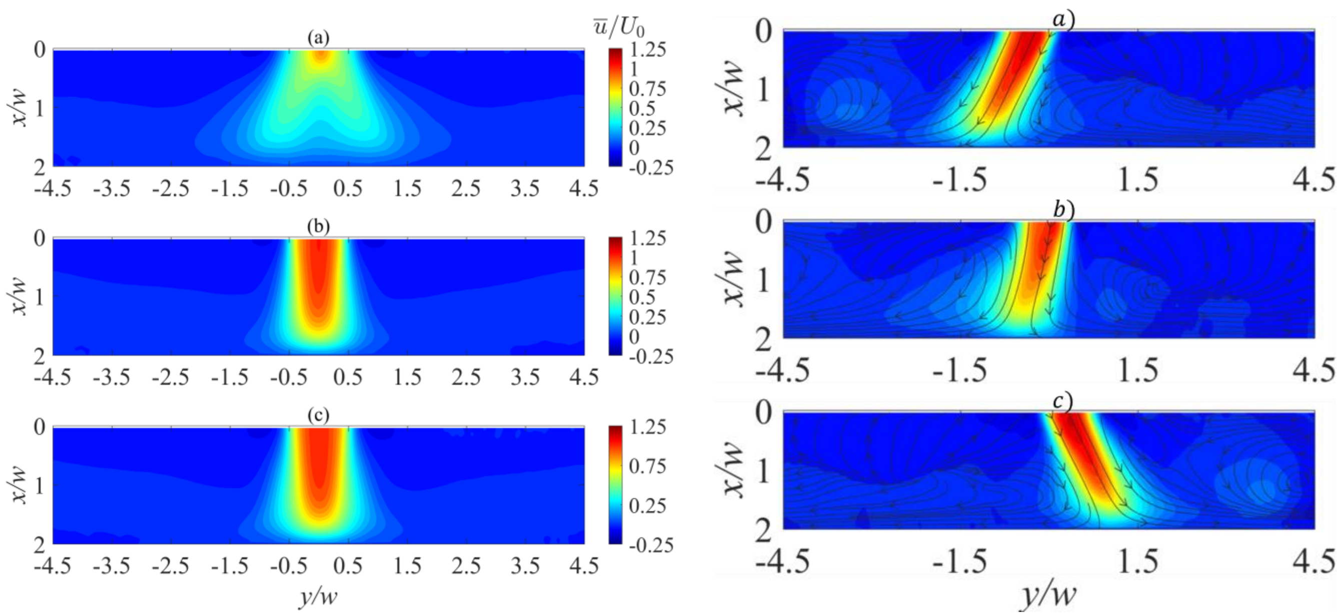

Figure 2. Contours of the time averaged axial velocity field (left) for $L_f/w = 4.5$ (a), $L_f/w = 3.5$ (b), $L_f/w = 2.5$ (c). $H/w = 2$, $Re = 2.6 \times 10^4$ and phase-averaged velocity field (right) for (a) $\varphi = 0°$, (b) $\varphi = 90°$ and (c) $\varphi = 180°$ the for $L_f/w = 4.5$ $H/w = 2$, $Re = 2.6 \times 10^4$.

Furthermore, it has been possible to observe that the values assumed by the PKE for the device having $L_f/w = 4.5$ are significantly greater than the ones obtained for the devices having $L_f/w = 2.5$ and $L_f/w = 3.5$, due to the absence of the jet oscillation. The turbulent kinetic energy assumes higher values in proximity of the jet axis for the decive having $L_f/w = 4.5$; instead, for the devices having $L_f/w = 2.5$ and $L_f/w = 3.5$ the highest values of the turbulent kinetic energy are reached in the jet shear layers, which are aligned to the streamwise direction.

4 REFERENCES

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