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Heat transfer of impinging sweeping jets

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Abstract

The convective heat transfer performances of sweeping jets impinging on a heated thin foil are experimentally investigated. The investigations are performed by employing Infrared Thermography technique coupled with the Heated Thin Foil heat flux sensor. In particular, two sweeping jet devices, characterized by different mixing region lengths, are employed and their heat transfer performances are evaluated for nozzle-to-plate distances ranging between 0.5 and 10. Time-averaged and phase-averaged analyses have been performed in order to characterize the heat transfer behaviour of these sweeping jets and the influence of the mixing region length.

1. Introduction

Sweeping jets are particular jets characterized by an oscillating motion. Such an oscillation is caused by the fluidic oscillator device, shown in figure 1, whose geometrical internal characteristics influence and govern this sweeping phenomenon. The most interesting characteristic of these devices is the absence of moving parts and piezo-electrical elements, making them a candidate for application in flow control and heat transfer fields.

The fluidic oscillator is characterized by a pressure supply that makes the jet move through it. The fluid arrives in a mixing region through a power nozzle and it separates alternately from each sidewall. Separation bubbles develop in the mixing region and grow in strength until a perturbation causes one to dominate. The most powerful separation bubble forces the flux core to the opposite sidewall and, due to the Coanda effect, the flow attach to the wall [1]. As the flow develops through the fluidic oscillator, some fluid passes through the throat section and attaches in the diverging nozzle surface opposite of the sidewall where the Coanda effect occurs. The remaining fluid enters the corresponding feedback channel and moves upstream to the exit section of the feedback channel, near the power nozzle (in the upper part of the mixing region). This flow pushes the core of the jet making it sweep to the opposite sidewall and the process repeats cyclically [1]. This process occurs in time with a certain frequency generating a sweeping jet exiting from the exit nozzle of the fluidic oscillator.

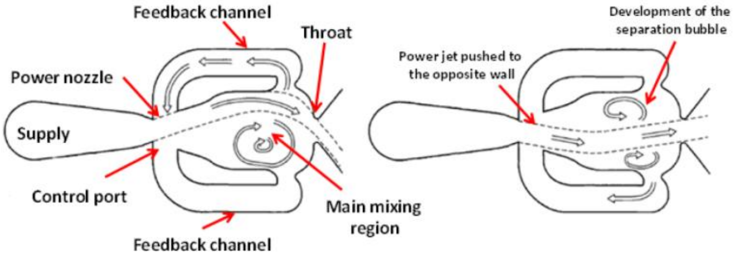

Fig. 1. *Scheme of a conventional sweeping jet device geometry and its flow field [1]*

Experimental studies and numerical simulations have focused on the influence of geometrical parameters on the flow field characteristics of a sweeping jet. Differently, lower attention has been paid to their impinging flow field and to the influence of such geometrical parameters on the heat transfer performances. Hence, the scope of the present work is to assess the influence of the mixing region length and the nozzle-to-plate distance on the heat transfer performances of impinging sweeping jets through time-average and phase-averaged analyses.

2. Experimental setup

The experimental setup is sketched in figure 2 (left). The air flow supplied by the blower, moves through a heat exchanger. Then the flow passes to the flow meter and to a plenum chamber. The plenum chamber is a chamber with two honeycomb grids that break the vortical structures generated upstream of the chamber. The fluidic oscillator, depicted in red in the figure, is connected to the plenum chamber and finally the flow impinges the foil on its bottom face. The infrared camera looks at the face of the foil opposite to the jet impingement.

The convective heat transfer coefficient is computed by applying the heated thin foil heat flux sensor [2]. Nozzle-to-plate distances ranging between 0.5 w and 10 w, with w being the nozzle slot-exit width, have been investigated.

The sweeping jet device is depicted in figure 2 (right). Two devices with similar internal geometry have been tested. They are characterized by a mixing region length L equal to 2.5w and 4.5w, with L being the distance between the centre of the feedback channel exit and enter sections, as shown in figure 2 (right).

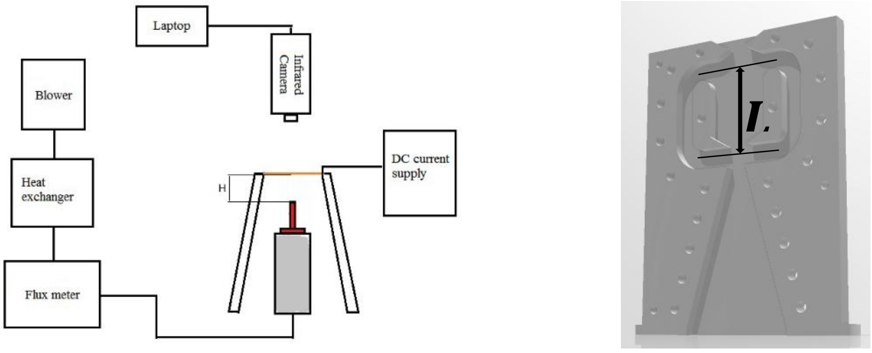

Fig. 2. *Experimental apparatus (left) and sweeping jet device (right)*

3. Results

In figure 3, the time averaged Nusselt number distribution for H/w equal to 0.5, 3 and 6 are presented for the sweeping jet device characterized by $L/w = 4.5$.

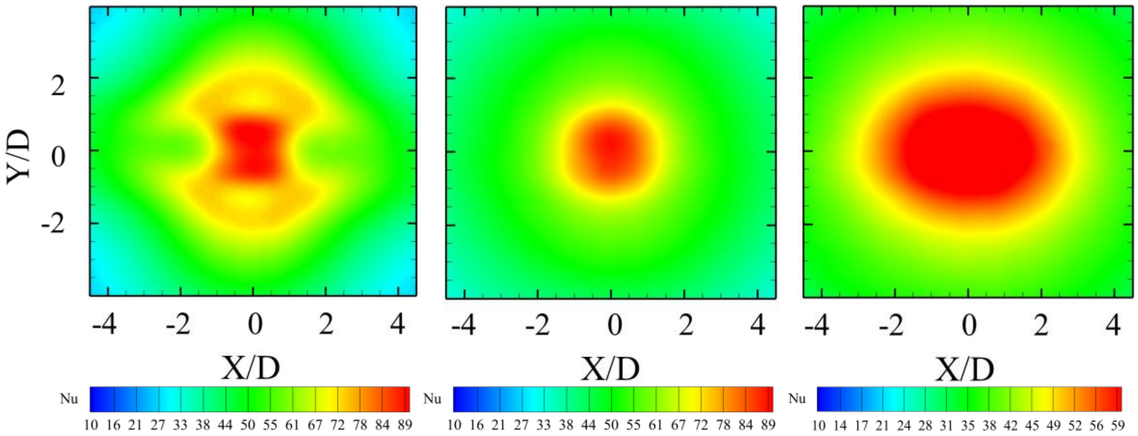

Fig. 3. *Time averaged Nusselt number distribution for the sweeping jet device with L equal to 4.5w*

At the lowest H/w, it is possible to observe a central zone with higher Nu which is slightly elongated and formed by two lobes along the Y direction, normal to the direction of oscillation of the sweeping jet. As the nozzle-to plate distance increases, the Nusselt number values decrease, and the heat transfer distribution drastically changes assuming an oval shape with a major axis in the direction of the jet oscillation.

Differently from the configuration characterized by high mixing region length, at lower mixing region length L, no oscillation can be detected in the phase-averaged Nusselt number distribution, not presented for the sake of brevity.

4. Conclusions

The influence of the mixing region length and the nozzle-to-plate distance on the heat transfer performances of impinging sweeping jets has been investigated. The increase of the nozzle-to-plate distance causes a decrease of the Nusselt number and a significant modification of its distribution. As regards the mixing region length influence, a too small value of this geometric parameter causes the suppression of the jet oscillation and a consequent drastically change in the Nusselt number distribution.

REFERENCES

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[2] Carlomagno G.M., Cardone G., Infrared thermography for convective heat transfer measurements, Experiments in fluids, Vol. 49, no.6, pp. 1187-1218, 2010.