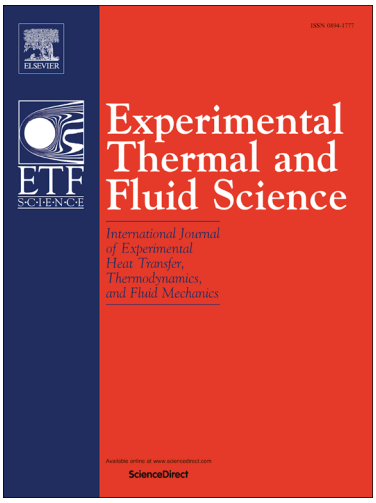

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Digital particle image velocimetry study on parameter influence on the behavior of impinging synthetic jets

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Abstract

This study conducts an experimental investigation of the effects of the stroke length and the Reynolds number on synthetic jet vortex rings impinging onto a solid wall. A two-dimensional time-resolved particle image velocimetry system is employed to measure the planar velocity field across the jet centerline. All the experiments have been performed at a constant orifice-to-wall distance (H_0/D_0 = 8.0), whereas three different stroke lengths (L_0/D_0 = 1.8, 3.6, and 7.2) and two Reynolds numbers (Re_{sj} = 111 and 333) are selected for comparison. Time-mean characteristics are first presented to reveal the basic flow feature of an impinging synthetic jet, and phase-averaged vorticity fields provide the information of the vortex evolutions during the interaction between synthetic jet vortex rings and the wall, i.e., the unsteady behavior of the impinging synthetic jet. With the help of the quantitative particle image velocimetry data, instantaneous wall pressure and wall shear stress distributions are evaluated simultaneously to link the dynamic vortical events in the vicinity of the wall with the wall fields. Finally, a proper orthogonal decomposition analysis is applied to extract dominant coherent structures in the flow field of the impinging synthetic jet and to highlight the combined effects of the stroke length and the Reynolds number. It is found that the stroke length effect on an impinging synthetic jet is mainly reflected in the vortex ring coherence before impacting the wall, whereas the effect of the Reynolds number on the flow behavior for a small stroke length is more significant than that for a large one. In particular, the previously impinged vortex ring is beneficial in suppressing the flow separation as well as the development of the secondary vortex ring. This validates the substantial difference between the impingement of consecutive vortex rings of a synthetic jet and that of a single vortex ring.

Keywords: impinging synthetic jets, vortex dynamics, wall pressure and wall shear stress, proper orthogonal decomposition

1. Introduction

Synthetic jets are produced by an oscillating membrane or piston to periodically force and suck fluid through an existing exit, resulting in consecutive vortex rings caused by an orifice or vortex pairs through a slot in the downstream flow field. During an oscillation cycle, the amount of fluid ejected from the exit is equal to that of the fluid drawn in, i.e., the fluid net mass flux through the exit is zero. Accordingly, the synthetic jet is also named zero-net-mass-flux jet [1,2]. With this unique feature, the synthetic jet requires neither an external fluid supply nor complex piping, which enables synthetic jets to be used as a popular device in the field of active flow control [3–8]. The flow characteristics of a synthetic jet are mainly determined by