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Direct numerical simulation of flows over a cavity with flow control using a moving bottom wall

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Control of cavity flow oscillations is one of the challenging topics in flow control problems. We developed a new control method for self-sustained oscillating flows over a cavity using a moving bottom wall of cavity by two-dimensional numerical simulations [1] [2]. We focused on relationship between the shear layer oscillations and recirculating flowfield inside the cavity. In our control method, the bottom wall of the cavity was moved horizontally toward upstream direction. There are usually two or three oscillating vortices in the cavity with no control. The recirculating flowfield became one clockwise vortex due to shear stress on bottom wall. Then, the shear layer oscillations were suppressed completely in two-dimensional simulations. In this paper, we apply our control method using a moving bottom wall to three-dimensional flow over a cavity and demonstrate the effects of the control method by direct numerical simulations.

The aspect ratio of cavity is 2.0. The Reynolds number based on the cavity depth and the free-stream velocity is 6,000. The incompressible Navier-Stokes equations are discretized by the fully conservative second order finite difference scheme of Morinishi et al [3]. The time integration is carried out using fractional-step method of Armfield and Street [4]. Velocity of moving bottom wall u_w is varied from 0.0, that is a no-controlled case, to -1.0. The negavite value means that the bottome wall moves in the upstream direction. The initial condition of controlled case is the self-sustained oscillating flow filed of no-controlled case at $t = 660$.

The effect of moving bottom wall on the reduction in the amplitude of shear layer oscillations is shown in Fig. 1. The rms values of the vertical velocity component, v_{rms}, and the pressure, p_{rms}, near the downstream corner of cavity dramatically decrease between $u_w = -0.30$ and $u_w = -0.40$. At $u_w = -0.34$, the v_{rms} is reduced by 68.8% of the no-controlled value. Time traces of v at the near downstream corner of cavity for $u_w = 0.0$ and -0.34 are shown in Fig. 2. The amplitude of v for $u_w = -0.34$ is substantially suppressed after the control is started. Instantaneous vortical structures in cavity at $t = 1060$ for $u_w = 0.0$ and -0.34 are shown in Fig. 3. In Fig. 3(a) with no control, the vortex sheet of separated shear layer rolls up by Kelvin-Helmholtz instability and the large vortical structure is observed in upstream of cavity trailing edge. On the other hand, in Fig. 3(b) with $u_w = -0.34$, recirculating flowfiled in the cavity become one clockwise circular flow and the shear layer oscillations are suppressed.

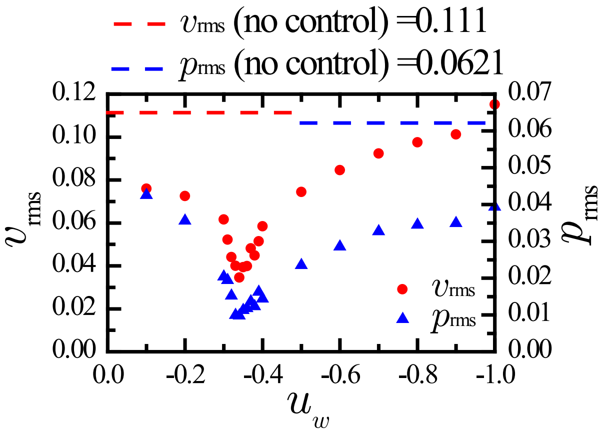


Fig. 1 Variation of rms velocity and pressure fluctuations for moving bottom wall velocity

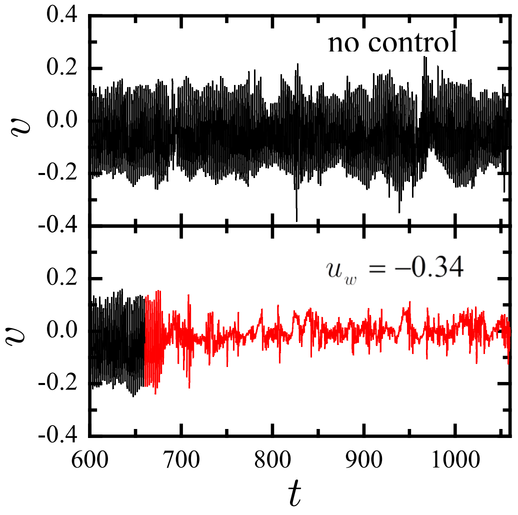
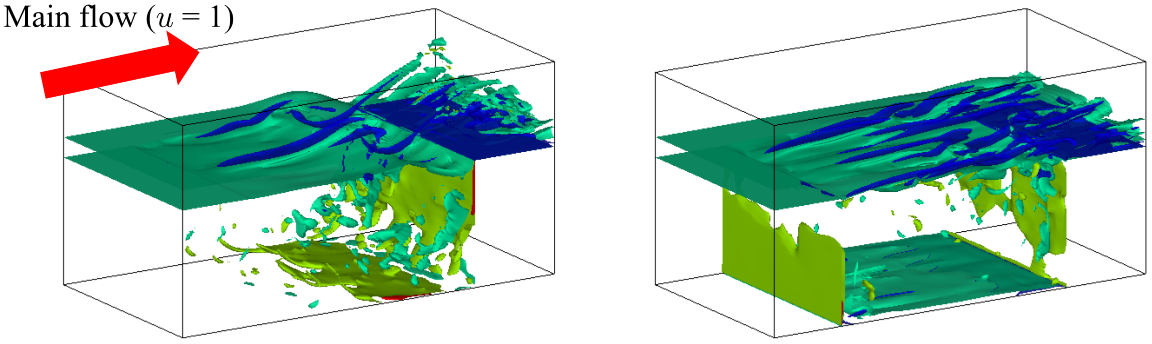


Fig. 2 Time trace of fluctuating velocity v



(a) no-controlled case

(b) controlled case with $u_w = -0.34$

Fig. 3 Visualization of cavity shear layer structure by isosurfaces of z-vorticity .

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