INVESTIGATION ON THE POSSIBILITY OF FLOW CONTROL AROUND CAVITY USING TANGENTIAL JET

Yeongbin Lee*
***Agency for Defense Development**

Keywords: *Flow control, Cavity flow, Continuous tangential jet*

Abstract

The cavities in aerodynamic surfaces like as missile and aircraft are significant of aerodynamic weakness such as potential source of the separated shear layer oscillations, vibration and acoustic noise. In this paper, to overcome the aerodynamic weakness of cavities, the possibility of flow control around cavities was investigated by tangential jet. To investigate the possibility of flow control, computational studies were performed as the variations of jet temperature with small velocity jet. First, aerodynamic characteristics around cavities with various ratios of length to depth were analyzed. Then, as the variations of jet temperature such as 400K, 600K, and 800K, flow field were confirmed.

1 Introduction

There are many cavities in nature. Specifically, some kinds of lifting body like as missile and aircraft have the cavity shape in the aerodynamic surface. The cavities are significant causes of aerodynamic weakness such as potential source of the separated shear layer oscillations, vibrations due to vortex, complex wave interactions and acoustic instabilities. In addition, aerodynamic drag increases dramatically. So, many previous researchers have been studied to solve these aerodynamic problems using flow control such as passive and/or active methods. Specifically, active flow control method is a fast growing multi-disciplinary science and technology aimed at altering a national flow state or development path in a more desired state.

In this paper, to overcome the aerodynamic weakness of cavities, the possibility of flow control around cavity was investigated by the numerical simulations. Cavities have the various lengths to depth ratio (L/D) of 2 and 4. Firstly, basic aerodynamic characteristics around cavities were analyzed. Then, flow control of tangential jet as the variations of jet temperature were also analyzed. Finally, tangential jet with hot jet temperature showed reasonable possibility of flow control.

2 Numerical method

In this study, the numerical simulations were performed by, the commercial CFD Solver, STAR-CCM+.

The governing equations are the tree-dimensional compressible Navier-Stokes equations. A third-order monotone upstream centered scheme for conservation laws (MUSCL) and the Implicit Roe's flow difference scheme (FDS) are used to solve the Navier-Stokes equations. To model the turbulence for the flow in the vicinity of the cavity, the k-w shear stress transport (SST) model proposed by Mentor is used. It is known for effectively blending the robust and accurate formulation of the k-w model in the near wall region with the free stream independence of the k-e model in the far field.

Boundary conditions for the numerical simulations are Velocity inlet (U=10m/s), wall condition, symmetry, pressure outlet (P=atm.). Boundary conditions of jet for flow control at front corner were 400K, 600K, and 800K with jet velocity is 1m/s.

3 Numerical results and discussion

The numerical results of cavities with the length to depth ratio of 2 and 4 were as shown in figure 1 and 4.

In the case of cavity with the length to depth is 2, flow is separated by sudden adverse pressure gradients due to the front corner shape. Because of this, flow becomes more unstable and reattach in cavity. Then, recirculation regions appear. Therefore, recirculation regions has major weakness in cavity with the length to depth ratio is 2 as shown in figure 2.

In the case of cavity with the length to depth is 4, flow like as the case of cavity with the length to depth is 2 is also separated by sudden adverse pressure gradient. In addition, the vortices in the shear layer roll up and pair with the adjacent vortices to form larger coherent structure. These vortices entrain fluid from the region below and trigger the recirculation as shown in figure 4.

According to the results of cases of cavities with the ratio of 2 and 4, recirculation region that is coherent structure showed severe aerodynamic weakness as well known in cavity flow. Obviously, flow control around cavity is necessary to overcome aerodynamic weakness of that.

The numerical results of cavities with flow control using tangential jet as variations of jet temperature were as shown in figure 5~16. Tangential jet temperatures for flow control around cavities were varied from 400K to 800K. That is to say, thermal energy can be changed to sufficient momentum energy to control the flow around cavities. In the case of cavity flow with a length to depth ratio of 2, the tangential jet with thermal energy in the front corner can stabilize the overall flow in cavity. More specifically, as the jet temperature of the jet for flow control increases, the heat energy is supplied to the separated flow at the front corner, which can change the flow through increasing the momentum energy. In the case of cavity flow with a length to depth ratio of 5, the tangential jet with thermal energy in the front corner can also stabilize the overall flow in cavity. It is confirmed that the flow control through the generation of heat energy from hot jet is possible even though the size of the cavity increase.

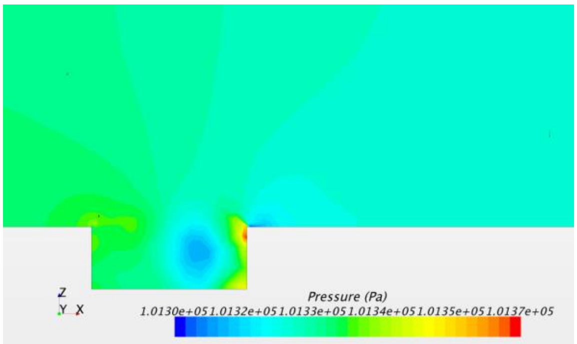

Figure 1 Pressure contour of L/D=2 at U=10m/s without flow control

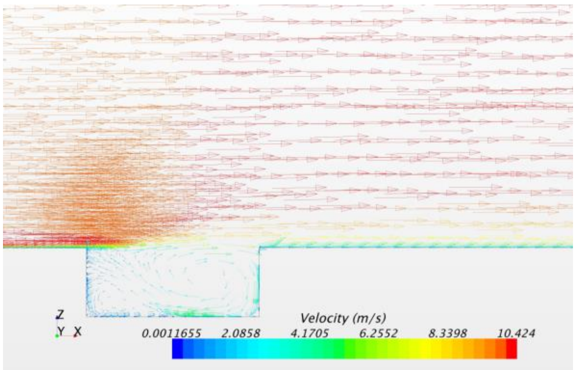

Figure 2 Velocity vector of L/D=2 at U=10m/s without flow control

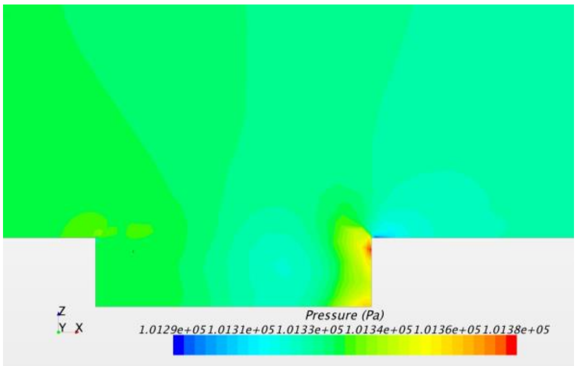

Figure 3 Pressure contour of L/D=4 at U=10m/s without flow control

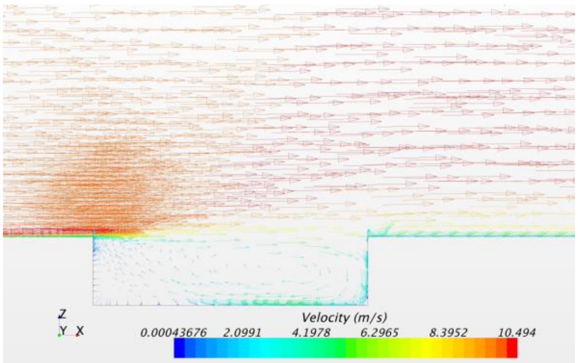

Figure 4 Velocity vector of L/D=4 at U=10m/s without flow control

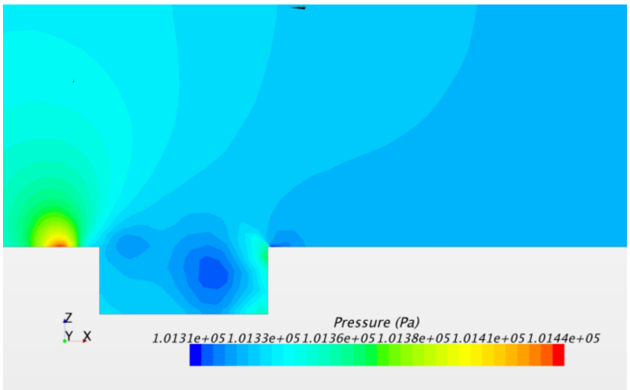

Figure 5 Pressure contour of L/D=2 at U=10m/s & Tjet=400K

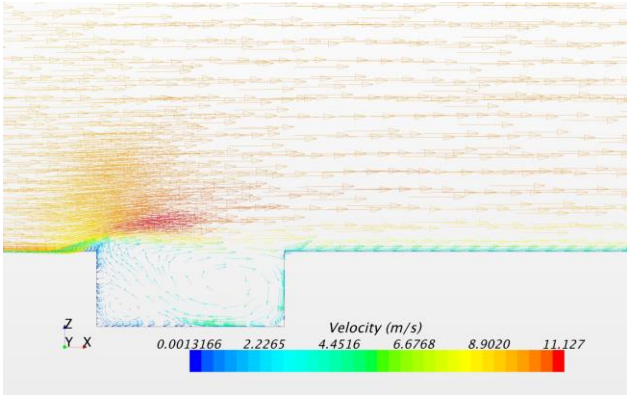

Figure 6 Velocity vector of L/D=2 at U=10m/s & Tjet=400K

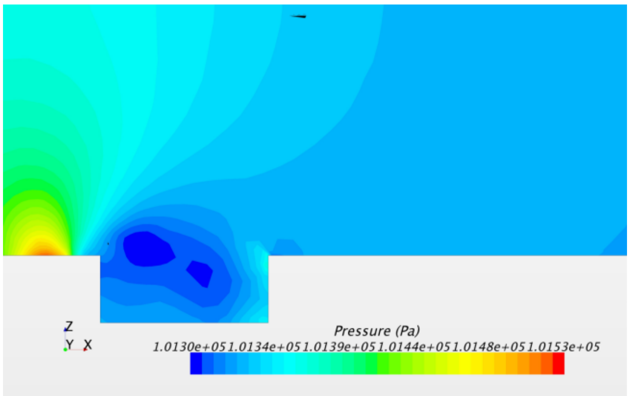

Figure 7 Pressure contour of L/D=2 at U=10m/s & Tjet=600K

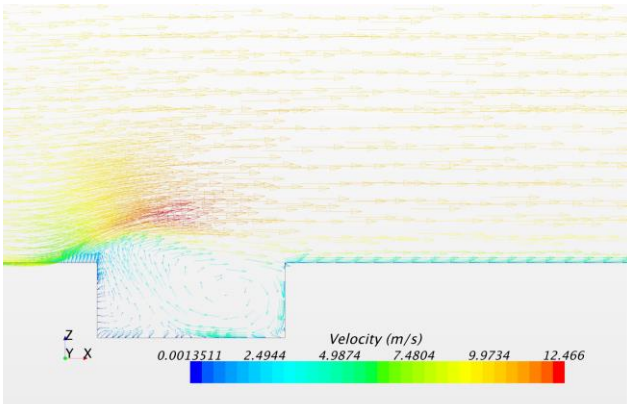

Figure 8 Velocity vector of L/D=2 at U=10m/s & Tjet=600K

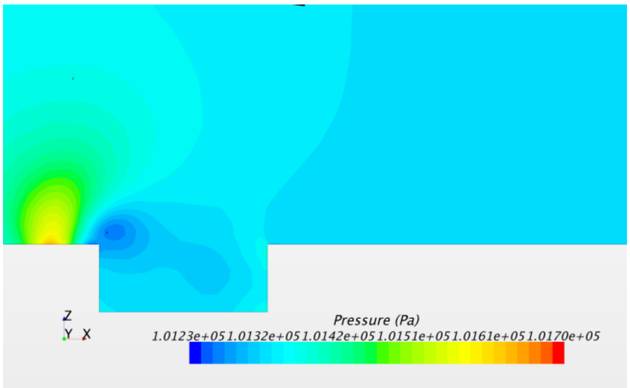

Figure Pressure contour of L/D=2 at U=10m/s & Tjet=800K

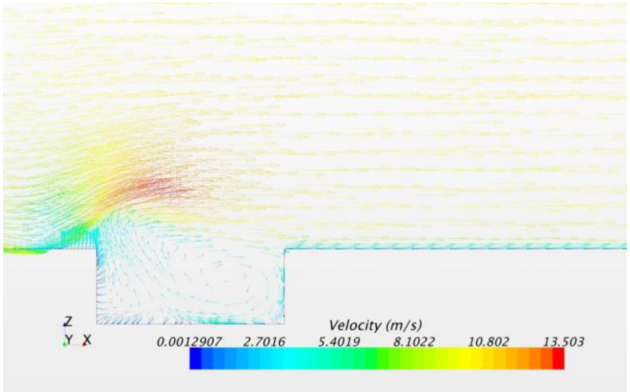

Figure 9 Velocity vector of L/D=2 at U=10m/s & Tjet= 800K

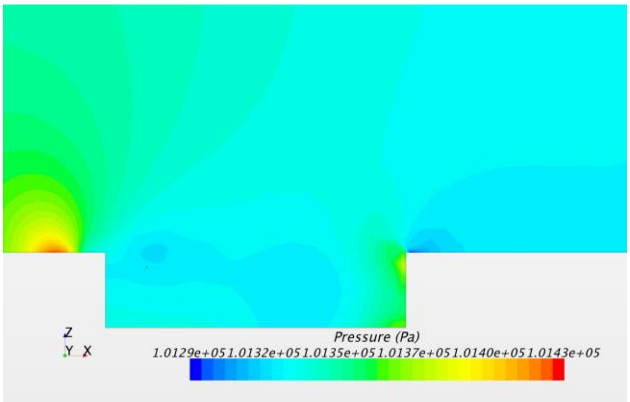

Figure 10 Pressure contour of L/D=4 at U=10m/s & Tjet=400K

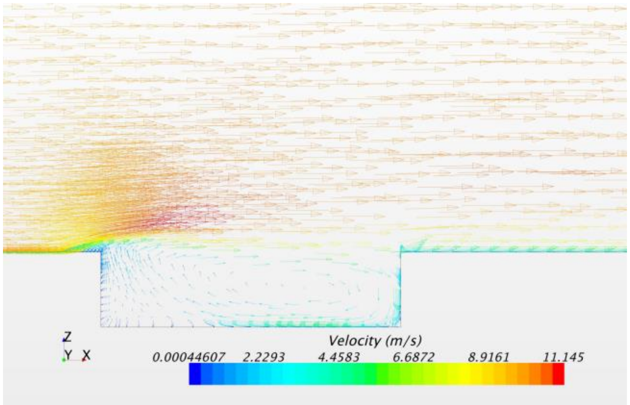

Figure 11 Velocity vector of L/D=4 at U=10m/s & Tjet= 400K

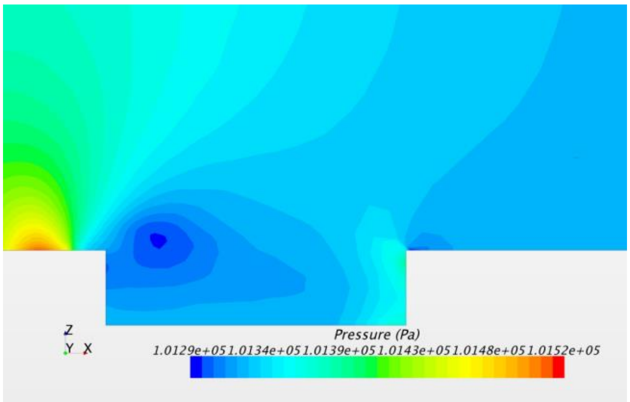

Figure 12 Pressure contour of L/D=4 at U=10m/s & Tjet=600K

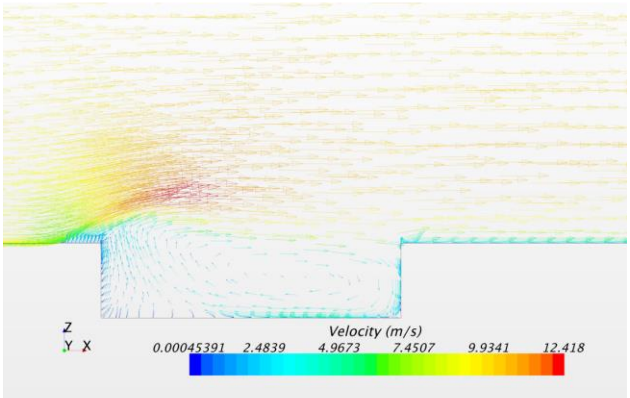

Figure 13 Velocity vector of L/D=4 at U=10m/s & Tjet= 600K

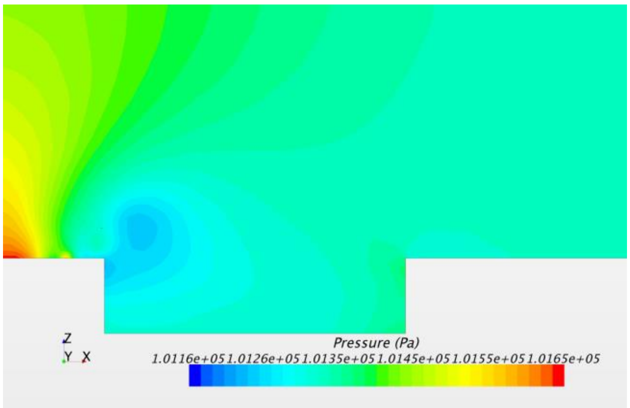

Figure 14 Pressure contour of L/D=2 at U=10m/s & Tjet=800K

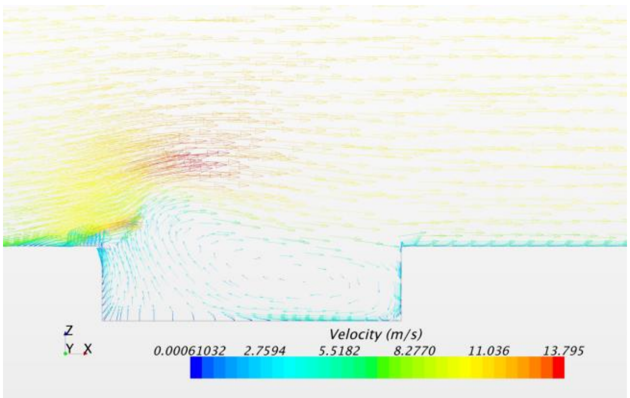

Figure 15 Velocity vector of L/D=4 at U=10m/s & Tjet= 800K

4 Concluding remarks

In this paper, the possibility of flow control around cavities using tangential jet was investigated by numerical simulation. According to the numerical results of cavities with flow control using tangential jet as variations of jet temperature, it is confirmed that tangential jet with hot temperatures has the possibility of flow control around cavities. Moreover, it is verified that the flow control through the generation of heat energy from hot jet is possible even though the size of the cavity increase.

References

[1] Clarence W. Rowley and David R. Williams. Dynamics and control of high Reynolds number flow over open cavities. *Annu. Rev. Fluid Mech.*, Vol. 38, pp 251-276, 2006.

[2] Louis N. Cattafesta III and Mark Sheplak, Actuators for active flow control. *Annu. Rev. Fluid Mech.*, Vol. 43, pp 247-272, 2011.

[3] Abe T, Takizawa Y, Sato S, Kimura N. 2008. Experimental study for momentum transfer in a dielectric barrier discharge plasma actuator. AIAA J. 46:2248–56

[4] Cattafesta, L., Williams, D. R., Rowley, C. W., and Alvi, F., “Review of active control of flow-induced cavity resonance,” AIAA Paper 2003-3567, June 2003

[5] Stanek, M. J., Raman, G., Kibens, V., Ross, J. A., Odedra, J., and Peto, J. W., “Control of Cavity Resonance Through Very High Frequency Forcing,” AIAA Paper 2000-1905, June 2000.

mailto: yblee@add.re.kr

Copyright Statement