Control of High-alpha Stall by Microflap Installed on the Airfoil Surface

Youn-Gyu Jung, Seong-Yoon Hyun, Seong-Wook Choi, Keun-Shik Chang, In-Mo Kang*

Department of Aerospace Engineering
Korea Advanced Institute of Science and Technology
373-1 Gusong-dong, Yusung-gu, Daejeon, 305-701 Republic of Korea
E-mail: kschang@kaist.ac.kr
* Agency for Defense Development
kanginmo@hanafos.com

Key Words: microflap, stall control, Chimera overlapping grid, unsteady turbulent flow

ABSTRACT

Numerical study has been conducted in two dimensions about a NACA 0012 airfoil equipped with an oscillatory microflap on the surface. We show that this microflap is effective in order to control the highly unsteady stall which is introduced on the airfoil when the angle of attack is very high. We solved the compressible Navier-Stokes equations for the free stream Mach numbers 0.1 and 0.15 with a dynamic chimera grid fitted to the oscillatory microflap, which is locally overlapping with the steady grid around the airfoil. Investigated are the effect of three angle of attacks, 15°, 20° and 25°, Reynolds number, and the location where the microflap is installed. It is observed that the oscillatory microflap suppresses the amplitude and frequency of the stall vortex to a significant degree.

The two-dimensional unsteady compressible Navier-Stokes equations are solved on a chimera grid overlapping with the major grid system. The inviscid flux terms are calculated with the Roe's flux difference splitting upwind method. The second-order time accuracy is obtained by the MUSCL approach using the flux limiter of Venkatakrishnan[7]. The viscous flux across each cell is determined by averaging the two cell center values of the adjacent cell. The turbulence model used in this calculations is based on SST $k-\omega$ model[8,9].

The configuration and dimension of the airfoil, NACA0012, with a microflap on its upper surface is given in Fig. 1. The 0.01c microflap is located at 0.2c from the leading egde of the airfoil. The airfoil grid and the microflap grid were generated ingedpendently and then overlaid in a time-dependent by the domain connectivity algorithm. The main airfoil grid and the

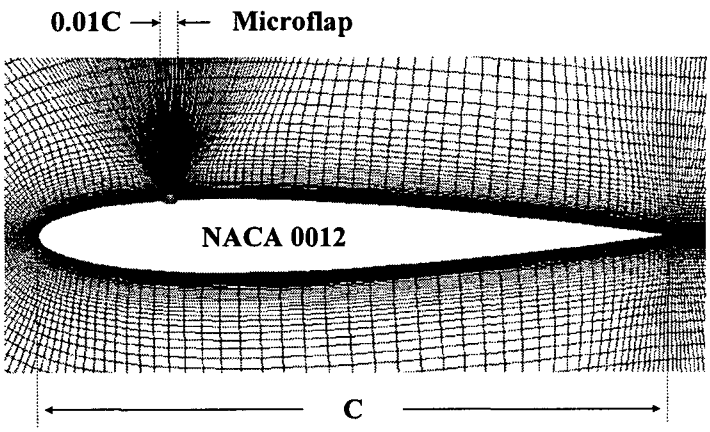
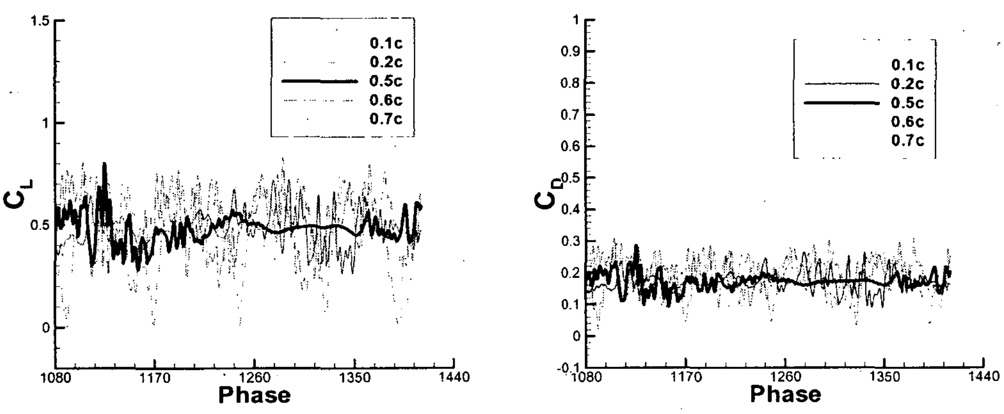


Fig. 1 Chimera overlapping grid systems

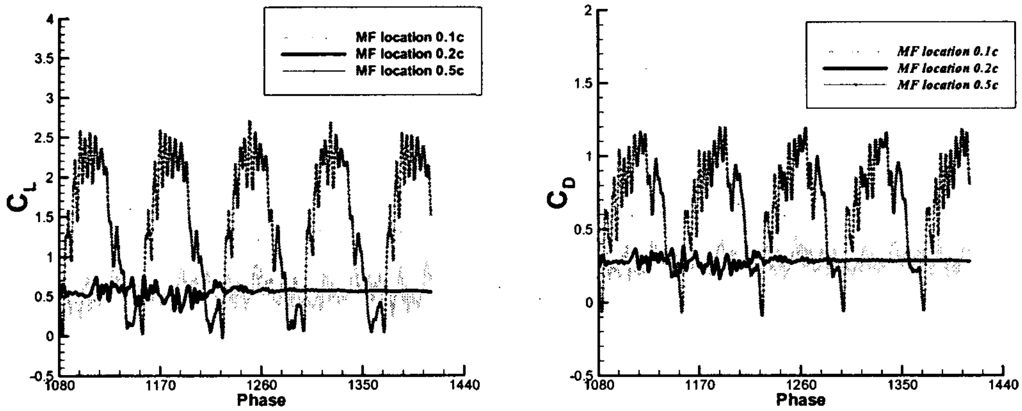
microflap grid had 373×119 and 101×33 C-type grid, respectively. The minimum grid spacing at the wall is set to 0.00001c for the turbulent flow calculation.

We calculated the stalled flow around NACA0012 airfoil equipped with a microflap at high angle of attack. At high angle of attack larger than 20°, fully separated and unstable flow occurs. Computed results show that the oscillatory microflap makes the primary vortex remain attached to the suction side of the airfoil to restrict its movement. Effective location of the microflap differs depending on alpha. For alpha 20°, 0.5c appears to be most effective; see Fig. 2. In the case alpha is 25°, 0.2c seems appropriate; see Fig. 3. It is concluded that after a stall is initiated, the flow can be partially stabilized and cotrolled by the oscillating microflap.



(a) Lift coefficient (b) Drag coefficient

Fig.2 Aerodynamic coefficients (α 20°, Ma 0.15)



(a) Lift coefficient (b) Drag coefficient

Fig. 3 Aerodynamic coefficients (α 25°, Ma 0.15)

REFERENCES

[1] C.M. Ho, Y.C. Tai, "MEMS and Its Application for Flow Control", *J. Fluid Engineering,* Vol. **118**, no. 3, 1996, pp. 437–447.

[2] C.M. Ho, Y.C. Tai, "Micro-Electro-Mechanical-Systems and Fluid Flows", *Annual Review of Fluid Mechanics,* Vol. **30**, 1998, pp. 579-612.

[3] G. Apostolovski, Y. Anreopoulos, "Separation Control by Self-Activated Movable Flaps", *J. Aircraftt,* Vol. 41, no. 6, 2004, pp. 1336-1346.

[4] M. Schatz, T. Knacke, F. Thiele (2004). "Separation Control by Self-Activated Movable Flaps", *42nd AIAA Aerospce Sciences Meeting and Exhibit, Renos,* AIAA2004-1243.

[5] T. H. Pulliam, "Time Accuracy and the use of Implicit Method," *AIAA Paper 93-3360,* July 1993.

[6] H. Ok, "Development of the Incompressible Navier-Stokes Solve and Its Appication to the Calculation of Separated Flow", *Ph.D. Dissertation, Aeronautics and Astronautics Dept., Univ. of Washington, Seattle,* WA, June 1993.

[7] V. Venkatakrishnan, "On the Accuracy of Limiters and Convergence to Steady-State Solutions," *AIAA Paper 93-0880,* Han. 1993.

[8] F. R. Mentor, "Two-equation Eddy-Viscosity Turbulence Models for Engineering Applications," AIAA Journal, Vol. 32, No. 8, 1994, pp. 1598-1605.

[9] S.W. Choi, K.S. Chang, H. Ok, "Parametric Study of Transient Spoiler Aerodynamics with Two-Equation Turbulence Models", *J. Aircraft,* Vol. **38**, no. 5, 2001, pp. 888-894