ICAS 2016
30th Congress of the International Council of the Aeronautical Sciences
DCC, Daejeon, Korea ; September 25-30, 2016

CFD OF BLENDED WING BODY UCAV WITH VORTEX GENERATOR

Sanghyun Park*, Kyoungsik Chang, Dong-Jin Sheen****
***Department of Aeronautical System Engineering, Hanseo University, South Korea**
****Department of AeroMechanical Engineering, Hanseo University, South Korea**

Keywords: *Blended Wing Body(BWB) UCAV, Computational Fluid Dynamics(CFD), Aerodynamic Coefficient, Vortex Generator*

Abstract

The present work performed the numerical simulation for the BWB type UCAV configuration using CFD. In BWB configuration, the stability problem due to the pitch –break or the pitch-up occurs in a region of high angle of attack during take-off or landing. To overcome this instability, the vortex generator was considered and the effect of this stabilizer on the aerodynamic force and moment coefficients was validated using CFD based on the experimental results. Also the delay of the pitch-break was confirmed by the vortex generator through the simulation.

1 Introduction

Unmanned combat air vehicle (UCAV) is an unmanned air vehicle that is armed to accomplish tactical missions. Generally, a long duration of flight capability is necessary for a reconnaissance mission in UAV, whereas low observable capabilities like stealth and high maneuverability are required to increase survival rates of the UCAV. Thus the blended wing body (BWB) type has the advantages of a high ratio of lift to drag and decreased radar cross section through minimizing the discontinuity surface between the body and wings. Also the lambda wing configuration with its cranked wing is used to increase its stealth characteristics, for example, in the planforms of the SACCON in Germany and the UCAV series in USA [1,2].

The aerodynamic characteristics of this type planform reveals that the primary and the secondary leading edge vortex are generated to delay the flow separation and increases the maximum lift force [3]. However, the abrupt collapse of the leading edge vortex causes unexpected pitch-up with nonlinear aerodynamic characteristics [2,4]. Also the swept angle and the curvature of the leading edge have an influence on interaction with the boundary layer. Therefore, the sensitivity to the angle of attack and Reynolds number where the vortex is developed and collapsed should be studied carefully.

In the present work, numerical simulations on the geometry of the BWB UCAV configuration were conducted in both cases with vortex generator and without one to study on the effect of the vortex generator. Also the expected aerodynamic coefficients are compared with the experimental results by Shim et al.[5].

2 Numerical method and simulation setup

2.1 Geometry

The UCAV geometry in the present work is same with the model conducted in the wind tunnel test by Shim et al.[5]. Fig. 1 and table 1 show the geometry with the vortex generator and their detail size. The wing span is 2,000mm and mean aerodynamic chord is 708.3mm from the apex at the leading edge. The swept angle and twist angle are 47˚ and 5˚ respectively. The adopted airfoil is NACA 64A210.

The position of the vortex generator is 0.7 from the center when the center of UAV is zero and the wing tip is one in the spanwise direction.

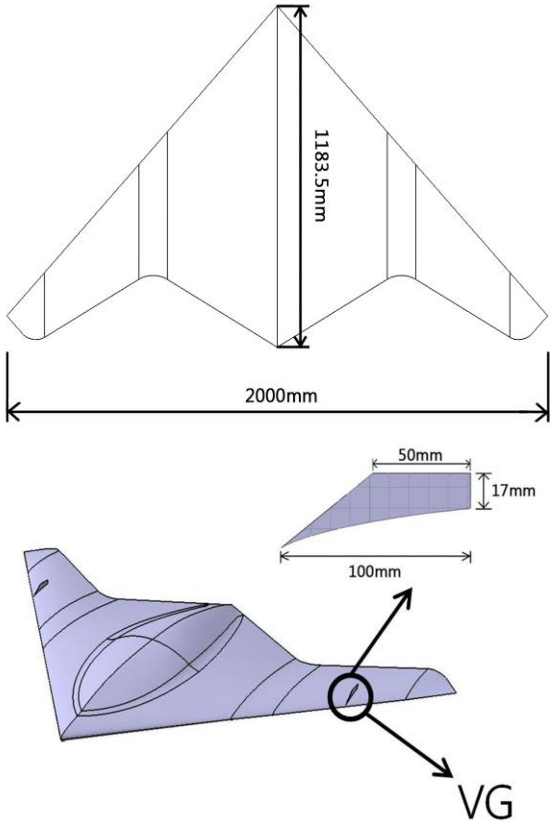

Fig. 1 Geometry of UCAV with vortex generator

Table 1 UCAV data

Wing span	2,000 mm
Center chord length	1,183.5 mm
Wing area	1.0354 m^2
M.A.C.	708.3 mm
Sweep angle	47 °
Twist angle	5°

The detail dimension of the vortex generator is shown in Fig. 1.

2.2 Computational domain and grid

The length of the computational domain was 15C in forward direction and 18C backward. The height and width in the computational domain were set to 15C. Because the angle of the side slip is not considered in the present study, a symmetric boundary condition was applied to the surface of half geometry.

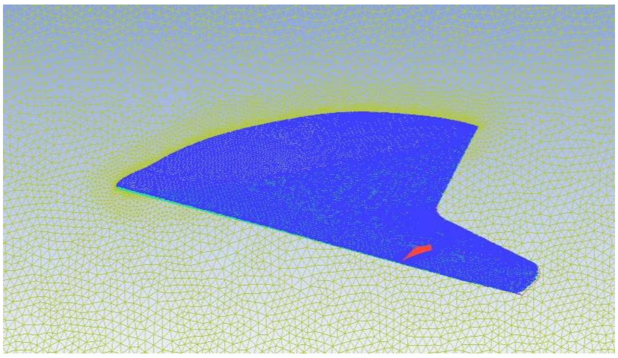

Fig. 2 Mesh of UCAV with vortex generator

The grid and computational domain were generated with commercial software, ICEM-CFD of ANSYS[6]. A tetrahedral unstructured cell and prism type cell were adopted in whole domain to generate complex geometry with vortex generator. Total number of mesh is 5×10^6 and yplus was measured as 6 approximately at the angle of attack, 0˚.

2.3 Simulation

The commercial CFD code, ANSYS Fluent 15.01[7] has been used to solve the compressible Navier-Stokes equations. The second-order discretization scheme in space and time was adopted and the correction of the pressure-velocity was done using a SIMPLEC algorithm. The time step was set to 0.0012 s which was corresponding to 10% of M.A.C. time scale($=C_{M.A.C.}/U_{\infty}$).

The freestream velocity is 50 m/s and the Reynolds number, based on the mean chord and the freestream velocity, is 2.74×10^6. To meet the experimental condition of Shim et al.[5], the atmospheric conditions at sea level were used. The boundary condition of the pressure outlet was applied to the far boundary and the wall of the UCAV was treated as a no-slip wall. Menter's shear stress transport (SST) k-ω model was adopted to simulate turbulent flows.

For efficient simulation and fast convergence, a steady simulation with a 1st-order accuracy scheme was done and then an unsteady simulation with a 2nd-order scheme was performed. The criterion of convergence is that the residual of the continuity was less than 10^{-6}.

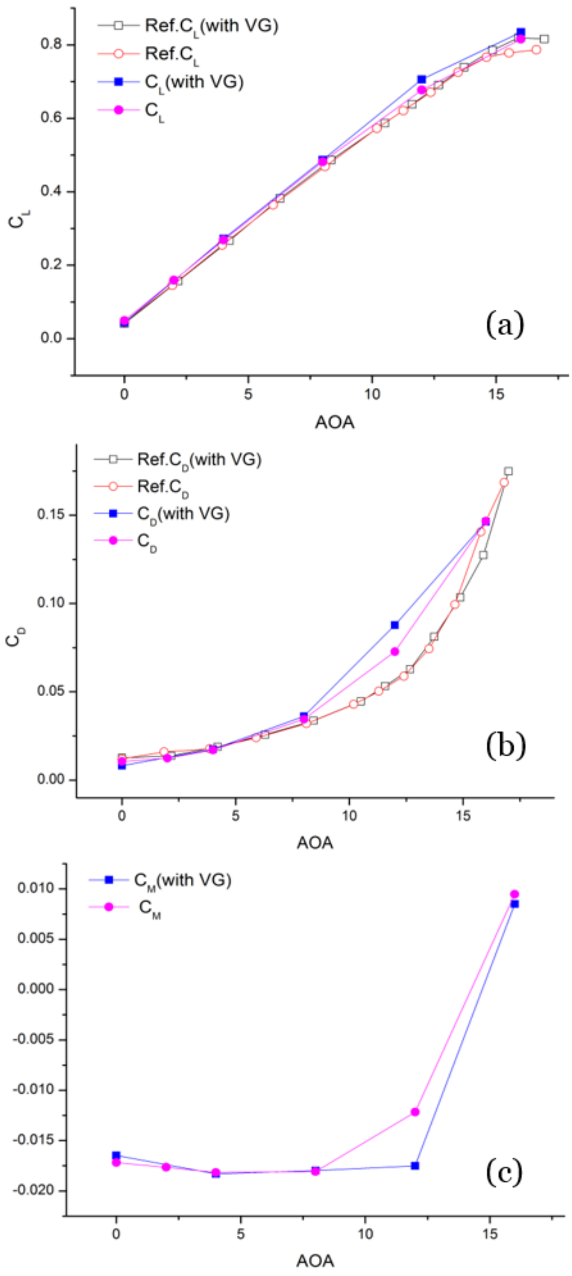

Fig. 3 Force and moment coefficients : (a) lift coeff. (b) drag coeff. (c) Pitching moment coeff.

3 Results

Fig. 3 shows the comparison of aerodynamic coefficients between simulation results and experimental data by Shim et al.[5]. Two cases with and without vortex generator are considered. The lift coefficient in Fig. 3(a) doesn't show difference between both cases in the experiment and simulation results show same trend. In the comparison with drag coefficient, overall simulation results are consistent with experimental one except an angle of attack, 8°. At this angle of attack, there are difference between simulation and experiment. Also the drag coefficient with vortex generator have higher value than that without vortex generator, which is reasonable phenomenon that the obstacle upon the surface increase the drag. When the pitching moment coefficients are compared in Fig. 3(c), the pitch break have already occurred at the angle of attack, 12°. However, in the case with vortex generator, the pitching moment coefficient is still constant at 12° and therefore the pitch break is delayed in the case with the vortex generator than the case without one.

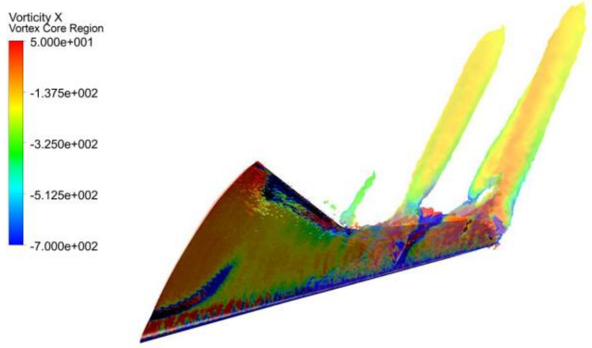

Fig. 4 Isosurface of vortex core (A.O.A. 12° with vortex generator)

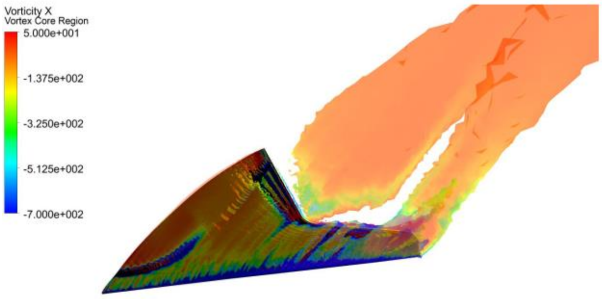

Fig. 5 Isosurface of vortex core (A.O.A. 12° without vortex generator)

Fig. 4 and Fig. 5 show the isosurface of vortex core at both cases to elucidate the flow mechanism. Fig. 4 is the case with the vortex generator and Fig. 5 is one without the vortex

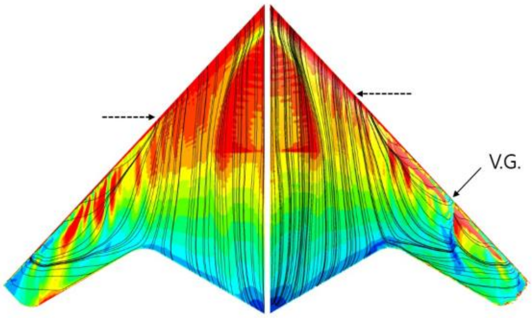

Fig. 6 Skin friction lines

generator. In the case with vortex generator, strong vortex is generated around the vortex generator and near the wing tip. However the strong vortex core is shown near the center of wing in the case the vortex is not attached. It seems that this vortex is the main reason of the pitch break and the decreased vortex by the vortex generator suppress this negative phenomenon.

The contours of shear stress and skin friction lines at the angle of attack, 12 ° are shown in Fig. 6. Left figure is corresponding to the case without vortex generator and right one the case with vortex generator. Two arrows indicate the position where the leading edge vortex collapse and the flow separation starts on the upper surface. The planform with the vortex generator shows earlier separation which causes smaller lift in the forward region from the mean aerodynamic chord and decreases the pitching moment. Finally the pitch break is delayed. The flow around the vortex generator increases shear stress to larger drag than the case without vortex generator.

3 Conclusions

In the present work, BWB type UCAV with and without the vortex generator is simulated using SST k-ω model and the CFD results are compared with experimental results by Shim et al.[5]. The considered Reynolds number is $2.74\text{x}10^6$. The lift and drag coefficients are predicted similarly with ones by experiment except the angle of attack, 8°. In the case with the vortex generator, the pitching moment coefficient is still constant at the angle of attack, 12°. Whereas the pitch break has occurred at this in the case without vortex generator. Based on the present study, the effect of the position of the vortex generator will be investigated using numerical simulation methodology.

References

[1] Khalid, M., Yua, W., and Zhang, F. A CFD study of UCAV 1303 baseline model at cruise mach numbers. *26th international congress of the aeronautical sciences*, 2008.

[2] Gursul, I., Gordnier, R., and Visbal, M. Unsteady aerodynamics of nonslender delta wings. *Progress in aerospace sciences*, Vol. 41, pp. 515-557, 2005.

[3] McParlin, S.C. and Bruce, R.J., Hepworth A.G., and Rae. A.J. Low speed wind tunnel on the 1303 UCAV concept. *24th applied aerodynamic congress*, AIAA 2006-2985, 2006.

[4] Luckring J.M. and Boelens, O.J. A unit-problem investigation of blunt leading edge separation motivated by AVT-161 SACCON research. NF1676-12101, 2011.

[5] Shim, H. and Park, S. Passive control of pitch-break of a BWB UCAV model using vortex generator. *Journal of Mechanical Science and Technology*, Vol. 29, No. 3, pp. 1103-1109, 2015.

[6] ANSYS ICEN-CFD User’s Guide

[7] ANSUS Fluent User’s Guide

Corresponding author
kschang76@hotmail.com

Copyright Statement