Turbulence Flow for NACA 4412 in Unbounded Flow and Ground Effect with Different Turbulence Models and Two Ground Conditions:

Fixed and Moving Ground Conditions

Abdolhamid Firooz, Mojgan Gadami
Mechanical Engineering Department
University of Sistan & Baloochestan
Postal Code: 98164-161, Daneshgah Avenue, Zahean, Iran. Tel: +98(541)2446251-2767,
Fax: +98(541)2447092,
E-mail: (ahfirooz@hamoon.usb.ac.ir)

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ABSTRACT

In this paper, the turbulence fluid flow around a two dimensional wings, NACA4412, on different angles of attack near and far from the ground with the RANS (Reynolds averaged Navier-stokes) equations is calculated. Realizable $K\!-\!\varepsilon$ turbulence model with Enhanced wall treatment and Spalart-Allmaras model are used (Re=2 ? 10^6). Equations are approximated by finite volumes method, and they are solved by segregated method. The second order upwind method, "Barth, Jespersen et al. [1]", is used for the convection term, also for pressure interpolation the PRESTO, "Patankar et al. [2]", method is used, and the relation between pressure and velocity with SIMPLEC"Vandoormaal, Raithby et al. [3]" algorithm is calculated.

The computational domain extended 3C upstream of the leading edge of the airfoil, 5C downstream from the trailing edge, and 4C above the pressure surface. Distance from below the airfoil was defined with H/C where C is chord, and H is ground distance to the trailing edge.

Velocity inlet boundary condition was applied upstream with speed of (U_∞=29.215) and outflow boundary condition was applied downstream. The pressure and suction side of the airfoil and above and below's boundaries of domain were defined independently with no slip wall boundary condition. Moving wall with speed of (U_∞=29.215) for above, and fixed or moving wall for below the airfoil were used.

An unstructured mesh arrangement with quadrilateral elements was adopted to map the flow domain in ground effect and unbounded flow. A considerably fine C-type mesh was applied to achieve sufficient resolution of the airfoil surface and boundary layer region. Particular attention was directed to an offset 'inner region' encompassing the airfoil, and also C-type mesh was applied on near the airfoil at above and bottom, which it's domain depends on the H/C in ground effects condition. Continuing downstream from leading edge and continuing far from above the airfoil H-type mesh was applied.

Distance from the wall-adjacent cells must be determined by considering the range over which the log-law is valid. The distance is usually measured in the wall unit, y^+

($=\rho u_\tau \; y/\mu$). By increasing the grid numbers and changing the type of arranging mesh, refining , around the airfoil a proper y^+ value, is obtained, and with this value solution results have good agreement with experimental data. Fig (1), Fig (2).

The aerodynamic characteristic of an airfoil in ground proximity is known to be much different from that of unbounded flow. The condition of the wind tunnel bottom, I. e., moving or fixed relative to the airfoil would influence the performance of the airfoil in ground effect. The presence of boundary layer when air is flowing over bottom of the wind tunnel would be different from the real situation for a flying WIG, "Carr & Atkin et al. [4]".

Proper velocity in the moving ground boundary condition is considered, and boundary layer is considered with the fixed ground, and in the moving ground the boundary layer's effect is omitted, and so is the proper velocity in the fixed ground," Chung et al. [5]".

A grid independence analysis was conducted using seven meshes of varying cell number. Each mesh was processed using the Realisable $K-\varepsilon$ turbulence model with Enhanced wall treatment and Spalart-Allmaras model. If the resolution extends to viscous sublayer, the numerical data have good agreement with experimental data, "Abbott, &, Doenhoff et al. [6]". In this suggestion, grid independence has been achieved. If the resolution extends to buffer layer the numerical data have not good agreement with experimental data, "Abbott, Doenhoff et al. [6]".

In order to validate the present numerical data the computational results for NACA 4412 in unbounded flow is compared with experimental data, "Abbott, Doenhoff et al. [3]". Fig (3).

Fig (4) shows Cp variation on surface of the airfoil at seven relative ground height. (α $=6^{\circ}$, Re $= 2 * 10^{6}$). By comparing the pressure fields in unbounded flow and ground effect, it can be noticed that a dramatic pressure increases in the region between the lower surface of the airfoil and the ground occurs, resulting in the lift increase. As the airfoil approaches the ground, the pressure on the pressure side of wing gradually increases due to slow- down of flow (Figure 6), although the pressure on the suction side of airfoil gradually increases, but the increase rate of the pressure on the pressure side is much larger than the increase rate of pressure on suction side of the airfoil resulting in lift increase that is regarded as the advantage of the WIG vehicle.

The velocity fields around this section in ground effect with H/C=0.08 for two different ground conditions at $\alpha=6$ are shown in Fig (5) and (6). The difference in the velocity field near the airfoil surface due to the bottom condition differences in Fig (5) and (6), and a boundary layer developed on the fixed ground can be clearly seen. On the other hand, for the moving ground with oncoming undisturbed velocity, the velocity decreases with increasing high.

Meanwhile the lift coefficient simulated by the moving bottom condition near the ground is greater than the fixed bottom condition, and far from the ground is vice versa, Fig (7), but the drag coefficient simulated by the moving bottom far from the ground is to some extent larger than that of the fixed one and near the ground is vice versa, Fig (8). Also it is concluded that on different angles of attack lift coefficient of the airfoil increases as it approaches the ground, Fig (7). In the moving ground the drag coefficient decreases as the approaches the ground, and in the fixed ground the drag coefficient decreases far from the ground and increases near the ground, as it approaches the ground, Fig (8).