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NUMERICAL STUDY OF THE AERODYNAMICS OF A RECTANGULAR MULTI-ELEMENT WING IN GROUND EFFECT

RAMESH K. AGARWAL AND NING DENG

Department of Mechanical Engineering and Materials Science
Washington University in St. Louis, St. Louis, MO 63131, USA
E-mail: rka@wustl.edu, web page: http://www.mems.wustl.edu

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Summary. The focus of this paper is on simulation of flow past a rectangular multi-element wing with 30P30N three-element airfoil cross-section in ground effect. For validation of the simulation approach, computations are performed for the two-dimensional 30P30N airfoil in unbounded flow and are compared with the experimental data. The commercial CFD solver ANSYS FLUENT is employed in computations. Compressible Reynolds-Averaged Navier-Stokes (RANS) equations in conjunction with Spalart-Allmaras (SA) turbulence model are solved using a finite-volume method. The validated code is employed to simulate the flow field of a rectangular wing with 30P30N three-element airfoil in ground effect. The effects of flight heights above the ground on the aerodynamic properties and flow field are analyzed.

1 INTRODUCTION

High-lift devices are widely used in modern aircrafts during take-off and landing. The aerodynamics and flow physics of high-lift devices are very complex. During take-off and landing, the ground effect (GE) further accentuates the complexity of the flow around the high-lift devices. The research effort devoted to the study of GE of high-lift devices has been very limited. Most of the previous research on the ground effect has focused on 2D high-lift devices [1]. This paper focuses on the study of aerodynamics and flow physics of a finite rectangular multi-element wing in ground effect. 30P30N, a typical three-element airfoil [2], is used as the cross section of the wing. In order to study the flow past the wing in ground effect, the flow past a 2D 30P30N airfoil in unbounded flow is first investigated followed by the 3D high-lift configuration. The 2D flow fields are first validated against the experimental data. The validated code is then used to study the rectangular finite wing in unbounded flow field and in ground effect. Computations are performed by solving the Reynolds-Averaged Navier-Stokes (RANS) equations with the Spalart-Allmaras (SA) turbulence model. The flow physics resulting from the wing and the ground effect is analyzed and discussed. The effect of ground on 3D high lift devices at different flight heights at a fixed angle of attack is simulated and its effects on the aerodynamic characteristics are investigated.

2 RESULTS and DISCUSSION

Erreur ! Source du renvoi introuvable. shows the geometry of rectangular wing with 30P30N airfoil. Its chord length is $c = 1\,m$; semi span is $b = 5\,m$; hence the aspect ratio is $AR = 10$. The flow field around the rectangular wing is computed at $\alpha = 10^{\circ}$. The freestream Mach number is $M = 0.2$ and Reynolds number is $Re_c = 9 \times 10^6$ based on the chord length. The three flight heights considered in the simulation over the flat ground are $h/c = 0.1, 0.5,$ and 1. For the unbounded flow, the flight height h is regarded much larger than c, that is $h/c \gg 1$. The flight direction is along the negative direction of the x axis. Figure 2 shows the surface grid on the wing and nearby boundaries including the ground.

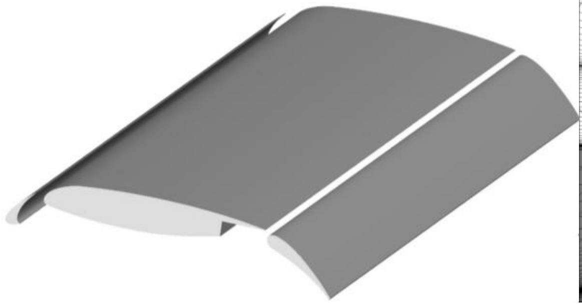

Fig. 1: 30P30N Three-element wing

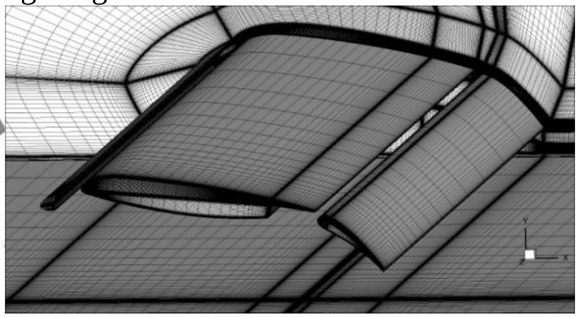

Fig. 2: Surface grid on the wing and ground

Figure 3 shows the comparison of computations and experimental data for 2D 30P30N airfoil. Figure 4 shows the pressure distribution on various cross-sections of the three-element wing from root to tip at h/c = 0.5, α = 19 deg. and M = 0.2. These are sample results; extensive results illustrating the effect of ground for various h/c will be presented in the complete paper.

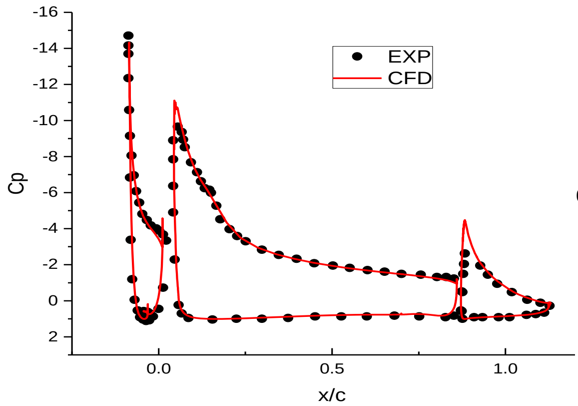

Fig. 3: Comparison of CFD & exp. on 30P30N

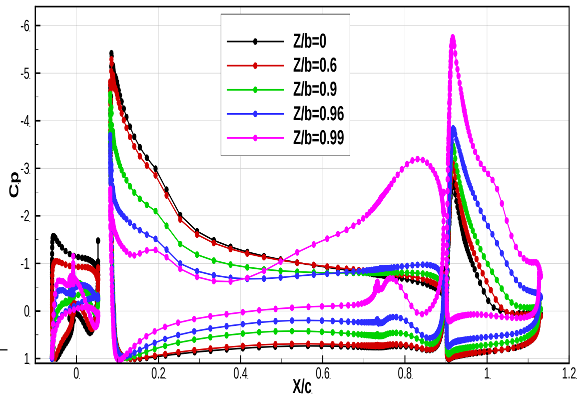

Fig. **4:** C_p on wing from root to tip, h/c = 0.5

3 CONCLUSIONS

The ground effect leads to larger pressure gain on the upper surfaces and smaller increment on the lower surfaces of all three elements. The variation in aerodynamic forces becomes larger with decreasing ride height, especially near the wingtip. The ground effect near the wingtip pushes flow both outward and upward. Thus, the wingtip vortex is stronger in proximity to the ground and the wingtip vortex has significant influence only in the span-wise range $Z/b = 0.95{\sim}1$. The wingtip vortex trajectory moves outwards, which is similar to the case of the clean single wing in ground effect.

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