Numerical Investigation and Analysis of RAE2822 Airfoil in Ground Effect

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Summary The aerodynamic characteristics of RAE2822 in ground effect was investigated with finite volume method (VOF) based on the averaged Navier-Stokes equations. The performance of several eddy-viscosity turbulence models on ground effect was assessed by comparison with the available experimental data of NACA4412 including pressure distribution and lift and drag coefficient. Realizable k-epsilon model demonstrates considerably good capability of predicting the flow characteristics. In study of the ground effect on supercritical aerofoil RAE2822, it has been observed that high lift and the ratio of lift and drag only could be achieved in medium angle of attack (AOA). The ground effect would induce the separation of boundary layer on the airfoil.

INTRODUCTION

In the early twentieth century, it was noted that a winged body operating in close proximity to the ground experiences a reduction in induced drag and an increase in lifting force, which results in an increase in the lift-to-drag ratio. This phenomenon, named the wing-in-ground (WIG) effect. It was studied in order to investigate the complicated problems that arise during the landing and take-off of a winged aircraft. For small angles of attack, the lift force is found to increase with decreasing flight altitude. The flow around an airfoil or a wing is considerably modified under the influence of ground effect. The dividing streamline and the stagnation point move down, hence more air flows above the wing; thus there is a decrease in velocity and an increase in pressure below the wing. An air cushion is created by the high pressure that builds up under the wing when it is approaching the ground [1]. There have been some experimental as well as Numerical studies on influence of different wing configurations on the aerodynamic characteristics. Now large aircraft use the supercritical aerofoil to obtained good transonic behaviour. But, few papers have studied the performance of supercritical aerofoil profile in close proximity to the ground, Detailed investigations on the supercritical aerofoil profile of WIG effect are needed.

COMPUTATION METHODOLOGY

Aerodynamic characteristics of a two-dimensional wing in ground effect for airfoil of RAE2822 are numerically investigated by solving compressible two-dimensional Reynolds-averaged Navier-Stokes equations in a realized k-epsilon turbulence model with Finite Volume method. In the present study, aerodynamic characteristics of RAE2822 are simulated at various ground clearances and angles of attack and a Reynolds number of 4.1×10^6 (based on chord length).

COMPUTATIONAL RESULTS AND ANALYSIS

The present work aims at studying aerodynamic characteristics of two-dimensional airfoil of RAE2822 and viscous flow in ground effect， at various angles of attack and ground clearances. Influence of wing in ground effect on aerodynamic characteristics are investigated. Figure 1 shows meshes in computation domain. Ground clearance is defined by distance from the ground to trailing edge of airfoil ***y*** to the chord length ***c*** .

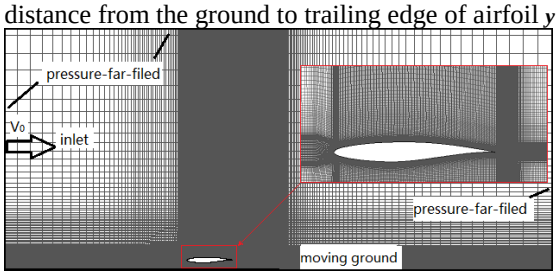

Fig.1 Computational grid and domain

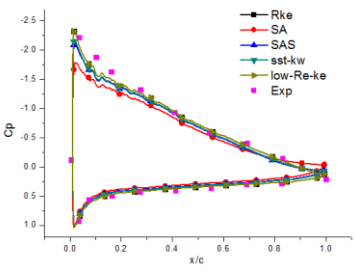

Fig.2 Pressure coefficient distribution of NACA4412(AOA=8°, y/c=0.4)

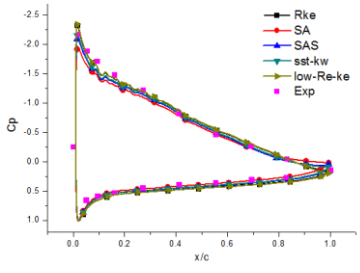

Fig.3 Pressure coefficient distribution of NACA4412(AOA=8°, y/c=1.0)

Validation of computational method

In order to validate the computational methodology's accuracy, aerodynamic characteristics of NACA4412 of in close ground proximity are calculated. Lift, drag and pressure coefficient distributions are compared with experimental data [2]. The result show use the Realized k-e turbulence model can get good lift coefficient and pressure coefficient distributions compared to Experimental data. More viscous effect is introduced may lend to the overestimated drag

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coefficient. So, the methods are used for the research of RAE2822.

Table 1 Lift and drag coefficient of NACA4412 （AOA=8°）

	Cl(*y*/*c*=0.4)	Cd(*y*/*c*=0.4)	CL(*y*/*c*=1.0)	Cd(*y*/*c*=1.0)
EXP[2]	1.262	0.0157	1.268	0.0185
CFD	1.215	0.021	1.201	0.022

Aerodynamic characteristics of RAE2822 in ground effect

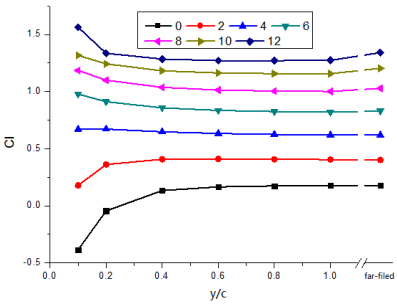

Fig.4 Lift coefficient of RAE2822

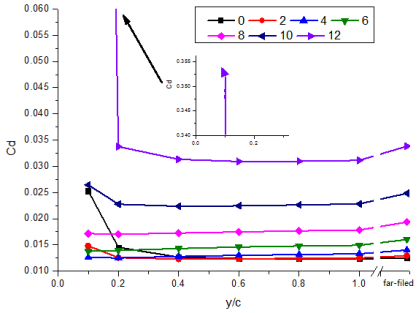

Fig.5 Drag coefficient of RAE2822

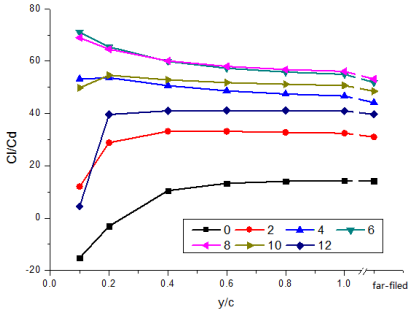

Fig.6 Lift /Drag ratio of RAE2822

Figure 4-6 present lift, drag coefficient and lift/drag ratio of RAE2822 at different ground clearance ratio from 0.1 to 1.0 and far filed, angles of attack from 0° to 12° . It found in medium angle of attack, like 6° and 8° , increased lift and decreases drag are obtained when airfoil running in close to the ground. The lift coefficient becomes negative at a small angle of attack， and the drag coefficient decreases sharply with increase AOA. When AOA=12° , the average drag coefficient increase dramatically to 0.338 in ground clearance ratio y/c=0.1, and the lift and drag coefficient oscillating periodically, but, with the increase of ground clearance ratio, it become constant gradually, as show in Figure 7. So, it is concluded that the ground effect induced the separation of boundary layer on the airfoil.

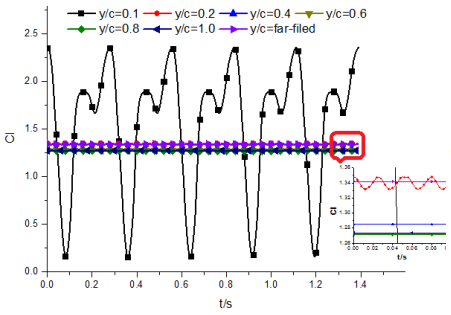

Fig.7 Lift coefficient distribution of RAE2822 (AOA=12°)

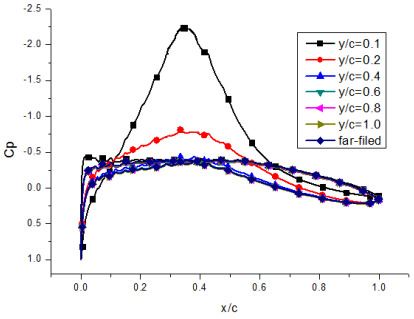

Fig.8 Pressure coefficient distribution of RAE2822 (AOA=0°)

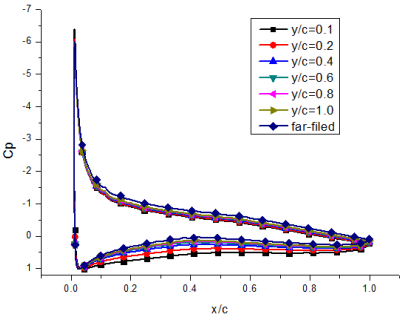

Fig.9 Pressure coefficient distribution of RAE2822(AOA=8°)

Figure 8 and 9 show the pressure coefficient distribution on the airfoil at AOA=0° and 8° . When AOA=0° , in lower ground clearances， the area between ground and airfoil forms a convergent-divergent passage[1]. Due to ramming action， pressure is high on the lower surface near the leading edge. Pressure reduces with acceleration of flow in convergent region. The RAE2822 section has maximum thickness at 37.9% of the chord, where the gap between airfoil and ground is minimum, the velocity of air is high, and so, the low pressure induced the suction effect. But, pressure in the divergent region increases sharply to meet pressure of the upper surface near the trailing edge. Pressure distribution on the upper surface does not change significantly with ground clearance. Suction effect on the lower surface contribute to the negative lift coefficient. When AOA=8° , the pressure coefficient of upper surface did not change significantly, but, the lower surface pressure coefficient increase when the airfoil coming close to the ground. So, the increase of pressure coefficient on lower surface contributed to the increase of lift.

CONCLUSIONS

In the present work, a detailed investigation of the aerodynamic characteristics of supercritical aerofoil RAE2822 at different ground clearances was carried out. It was found: Realizable k-epsilon model demonstrates considerably good capability of predicting the flow characteristics. In study of the ground effect on RAE2822, high lift and the ratio of lift and drag only could be achieved in medium angle of attack, because of pressure on the lower surface increase when approaching ground. The ground effect would induce the separation of boundary layer on the airfoil.

References

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