Experimental study of aerodynamic behavior of NACA0012 airfoil near the surface

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Abstract

When a flying vehicle approaches to a surface of water or land, changes occur in the pattern of the fluid flow field around it. This change in flow field eliminates the direct effect on aerodynamics and control of the vehicle. This is more common when the vehicle is landing and taking off, as well as flying at low altitudes, which is called the "surface effect". In this research, the phenomenon of surface effect and its effect on aerodynamic coefficients and flow pattern around NACA0012 airfoil in static incompressible subsonic regime have been investigated numerically and experimentally. Experimental tests were performed in the incompressible subsonic wind tunnel of the Ghadr National Aerodynamics Research Center of Imam Hossein University with a cross-sectional area of 80 by 100 cm. The simulation of the phenomenon is a fixed ground with the minimum possible thickness of the boundary layer in the wind tunnel. Solve the flow field numerically based on Navier Stokes equations along with the Transition-SST viscous model. Impact of surface effect phenomenon on the change of aerodynamic coefficients has been investigated by considering different distances from the surface in the static state. The pressure distribution on the airfoil surface is measured by an accurate pressure sensor and is due to surface effect phenomenon at close distances to the surface. The results of static analysis show an increase in lift force and a decrease in drag force.

KEYWORDS

Ground effect, Incompressible subsonic, NACA0012, Numerical study, Wind tunnel

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1- Introduction

During the flight, when a flying vehicle approaches the surface (watery or terrestrial), changes occur in the pattern of the flow field around it, and necessary arrangements must be made to keep flight. This change in flow field has a direct effect on the aerodynamics and control of the flying vehicle. This is especially true when the flying vehicle is landing and taking off, as well as flying at low altitudes. The sum of these events leads to a phenomenon known as the "surface effect" [1-3].

Studies show that the main researches in the field of surface effect are related to the study of the effects of airfoil geometric parameters and flow parameters on the aerodynamic behavior of airfoil in static mode. The study of aerodynamic behavior of airfoils with oscillating movements near the surface has not been considered in previous studies.

2- Subject definition

When two-dimensional airfoils are placed near the surface, depending on the shape of the airfoil curve and its angle of attack and the distance to the surface, different positions can occur and different aerodynamic behaviors can be observed, especially in the force factor. For airfoils whose bottom surface is convex and at a low angle of attack, a similar situation is created between their bottom surface and the wall of the venturi nozzle. Another situation is the effect of the current hitting the lower surface of the airfoil and increasing the resulting pressure, which results in an increase in the lifting force. This situation occurs for airfoils that have a flat bottom surface or a high angle of attack.

3- Numerical study

In addition to the experimental study, the existing numerical commercial software has also been used to analyze the problem. The flow field model and its dimensions, as well as the boundary conditions considered for the solution, are in accordance with "Figure 1". Shown distance of the airfoil from the ground (h) measured from the trailing edge of the airfoil to the ground. The airfoil chord (c) is assumed to be 0.15 m.

The suitable boundary grid is created layer network on the surface of the airfoil and the surface of the ground model, and inside the field, a triangular grid has been used.

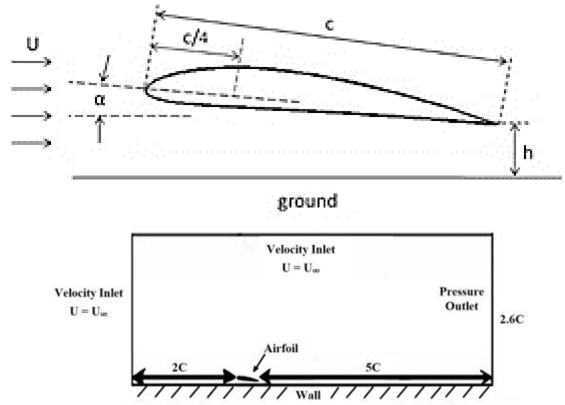

Figure1. Boundary conditions and dimensions of the solution domain

4- Experimental study

Wind tunnel test is used to analyze the flow field around the NACA0012 airfoil under the considered conditions. All testes are carried out in an open circuit, suction type low-speed wind tunnel. The dimensions of the test chamber are 80cm × 100cm. Its operating speed range is 5 to 95 meters per second. Its turbulence intensity is less than 5%.

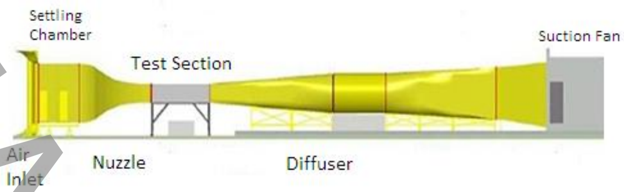

Figure2. Wind tunnel schematic

NACA 0012 airfoil with a length of 0.6 m and a chord of 0.15 m was used for this study. A view of the airfoil model used with the position of the pressure points prepared on its upper and bottom surfaces is shown in "Figures 3".

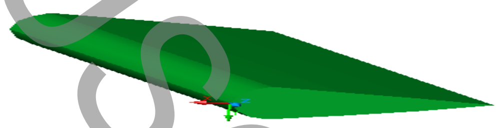

Figure3. Three-dimensional and two-dimensional view of NACA0012 airfoil model

In order to prepare the surface effect phenomenon simulator in the wind tunnel by the stationary surface method, the surface effect phenomenon simulation plate was installed in the wind tunnel test section. To have the lowest boundary layer effect and provide a suitable and uniform flow, some modification are made to the plate, including angling the plate against the flow by 2º and adding a wedge piece in front of the plate.

The following are the test results of the NACA0012 model in static and pitching oscillating motion.

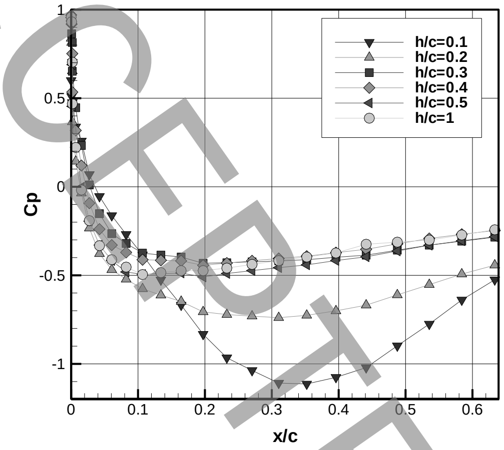

Figure4. Variation of pressure coefficient on the lower surface of NACA0012 airfoil at v=30 m/s, α=0 and different h/c

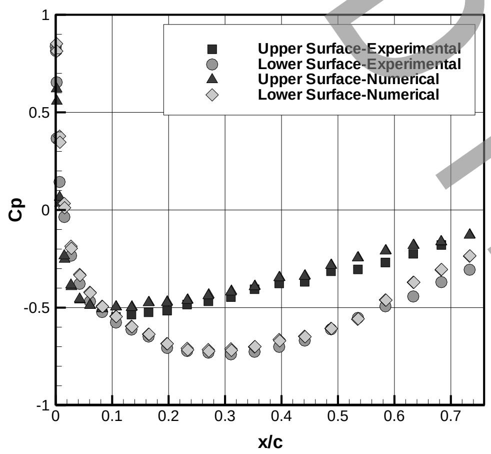

Figure5. Comparison the experimental and numerical pressure coefficient results for NACA0012 airfoil at h/c=0.2, α=0 and V=30 m/s

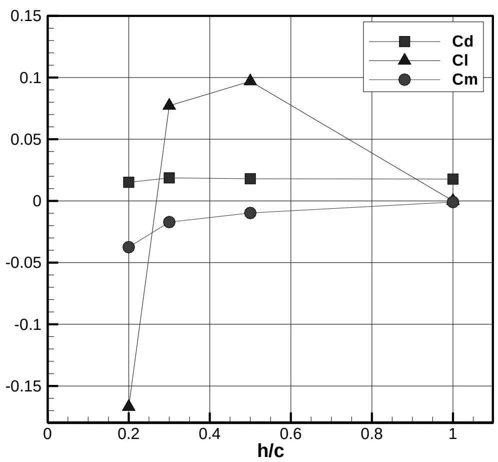

Figure6. Aerodynamic coefficients of NACA0012 airfoil at V=30 m/s, α=0 and different h/c

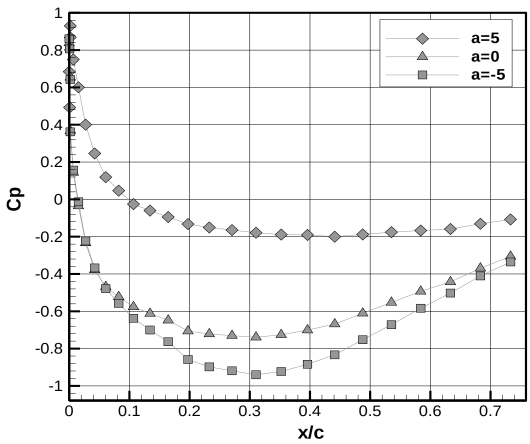

Figure7. Comparison of pressure coefficient distribution on the lower surface of NACA0012 airfoil at h/c=0.2, V=30 m/s and different attack angles

5- Conclusion

In this study, unlike conventional airfoils used in flying vehicles facing the surface effect phenomenon (airfoil with flat bottom surface), the aerodynamic behavior of NACA 0012 symmetrical airfoil adjacent to the surface has been statically investigated. The results show that the drag coefficient decreases and the lift coefficient increases. For airfoils with a convex underside, height reduction can have different effects on the lift force coefficient. Also, the type of airfoil surface curve leads to different distribution of pressure coefficient in the lower surface of the airfoil in the face of the surface effect phenomenon, which is due to the formation of a venturi nozzle between the convex lower surface of the airfoil and the plate below it. The pressure coefficient of the airfoil adjacent to the surface changes with the angle of the airfoil, so that it decreases with decreasing angle of attack.

6- References

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