Ground Effect

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Abstract

We want to observe ground effect and study about its principles with a homemade wind tunnel and the simulation software. Therefore, we measure the aerodynamic force when the airfoil is at different heights. To verify the causes of this effect, we add winglets at both ends of the airfoil. We also use Autodesk Flow Design to see the flow and pressure distribution.

Introduction

Ground effect is a phenomenon that the lift-to-drag ratio of a wing is increasing when it moves close to the ground. It exhibits at distances from the ground less than the chord of the wing.

Principle

The pressure difference between the lower and upper surface is larger near the ground than flying in the sky, and thus form air cushion under the airfoil. As long as there is lift, vortices will be created at the wingtips of the finite wings. The lift will reduce, and induced drag will be generated under the influence of vortices. Air cushion enhances the vortices, and the total lift and drag are both increased by it. When airfoil moves toward the ground, vortices will be blocked by the ground. The decrease of vortices region will increase the lift and reduce the drag.

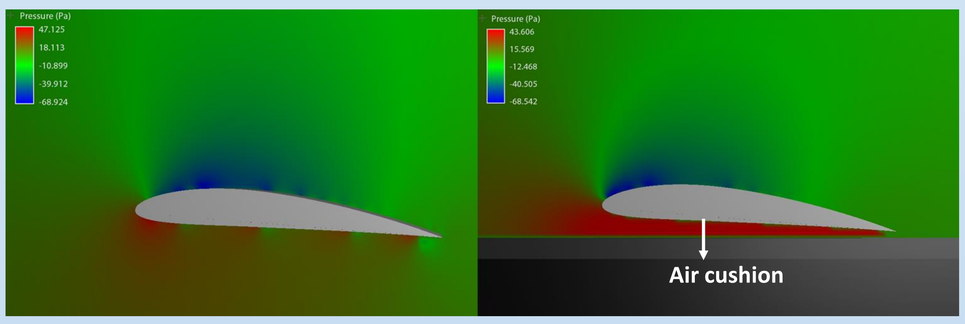


Fig. 1 Air cushion when the airfoil is near the ground.

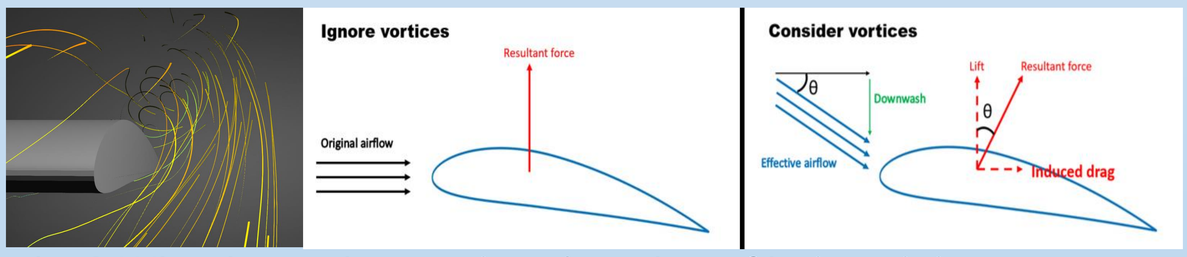
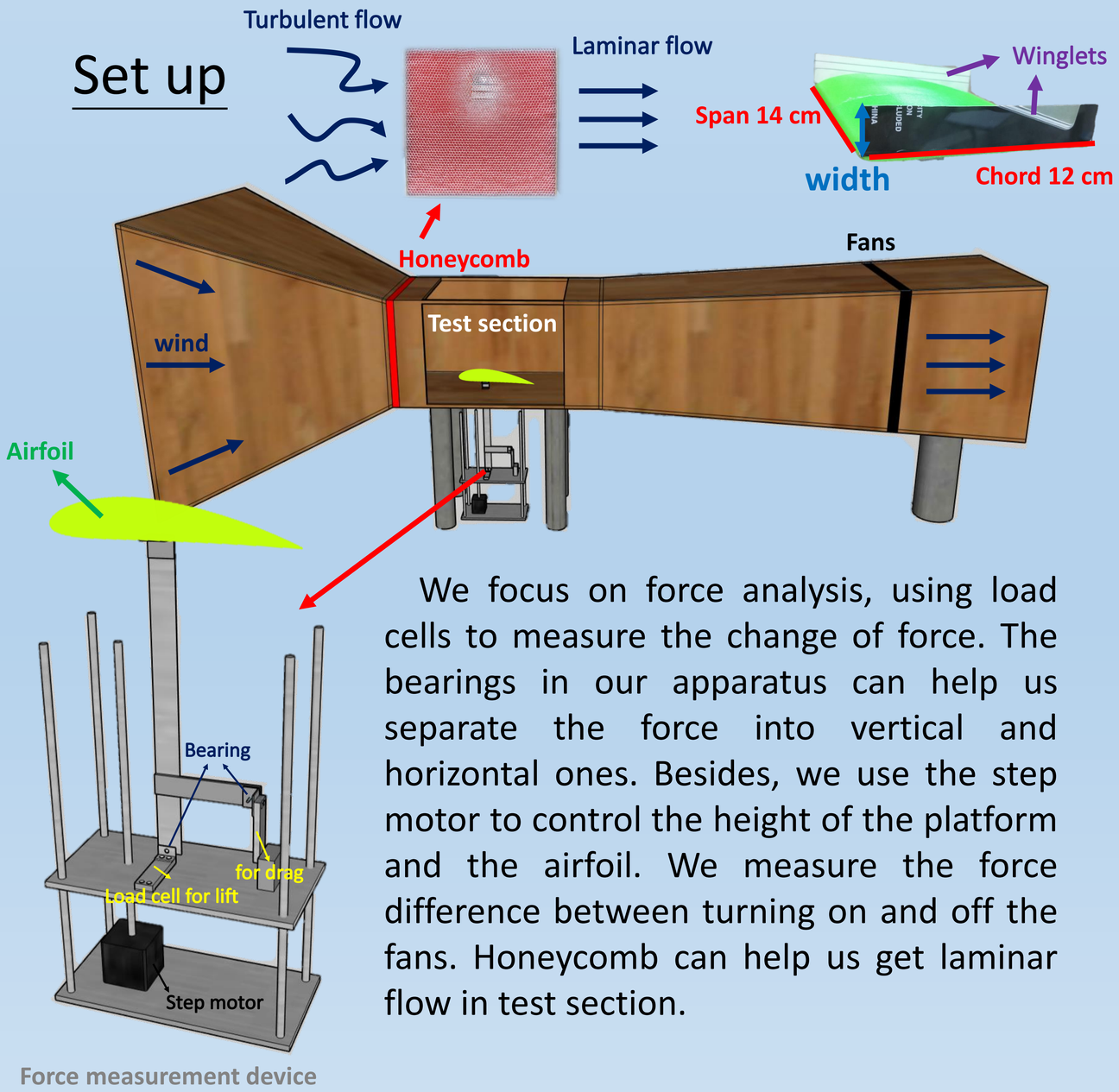


Fig. 2 Wingtip vortices and explanation of induced drag.

Set up



We focus on force analysis, using load cells to measure the change of force. The bearings in our apparatus can help us separate the force into vertical and horizontal ones. Besides, we use the step motor to control the height of the platform and the airfoil. We measure the force difference between turning on and off the fans. Honeycomb can help us get laminar flow in test section.

Result and discussion

The lift is decreasing when the airfoil moves away from the ground. However, for the angle of attack at 6.7 and 10 degrees, and the ground clearances is low, the flow was found to separate from the upper surface well ahead of the trailing edge which leads to a considerable loss of lift. In addition, the drag has no reduction when the airfoil close to the ground. Therefore, we infer the enhanced vortices by air cushion made more contribution to our experiment.

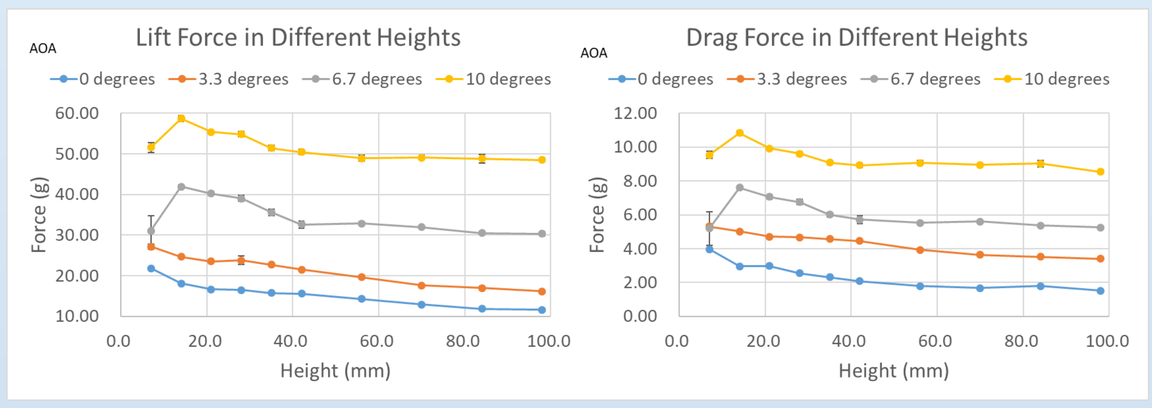


Fig. 3 Ground effect in different angle of attack, and wind speed is 7.0 m/s .

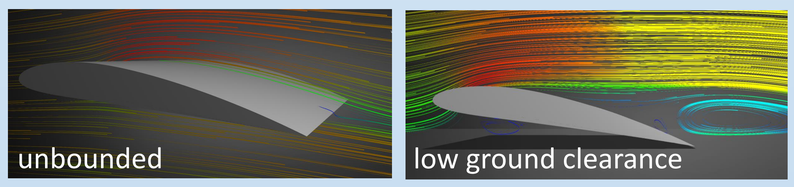


Fig. 4 The flow over the airfoil at the unbounded condition and low ground clearance for 10 degrees AOA.

The lift force increases obviously when we add winglets to block the vortices. We also changed the width of the winglets so that we can make sure the change of the vortices region can change the lift force. The airfoil gets larger lift when the winglets are wider.

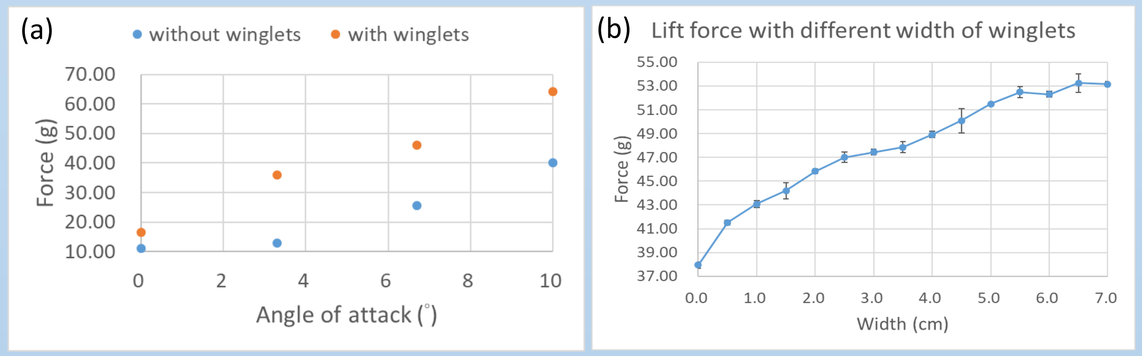


Fig. 5 (a)The influence of winglets on the lift force. (b)The lift force with different width of winglets. The height of airfoil is at 150.0 mm.

Conclusion

We have observed the ground effect in our experiment, and the enhanced vortices by air cushion make more influence on it. Additional winglets can reduce the influence from downwash to enhance lift force. The longer winglets can block more vortices and cause the lift to increase. When the airfoil is close to the ground, the vortices can be blocked by ground.

Reference

- M. R. Ahmed, T. Takasaki and Y. Kohama, “Aerodynamics of a NACA4412 Airfoil in Ground Effect”, AIAA Journal, Vol. 45, No. 1, January 2007.