# The Velocity Distribution Around Aerofoil for Wing in Ground Effect

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**ABSTRACT**

Flow characteristics around aerofoil for wing in ground effect are studied experimentally in a wind tunnel. Lift and drug forces were measured directly by 3-component force transducer and velocity distributions around the aerofoil were obtained by PIV. Experimental results show that lift and drag forces were consistent with the data obtained earlier qualitatively. With decreasing a ground clearance, the stagnation point moves backward and the effective angle of attack increases. For this reason, the flow rate between the aerofoil and the ground decreases, and the flow between the aerofoil and the ground is decelerated, and the pressure on the undersurface of the aerofoil increases. This is one of the causes of the wing in ground effect.

Key Words: Wing in ground effect, Effective angle of attack, Stagnation point

## 1. Introduction

When a wing approaches the ground or a water surface, its lift-drag ratio increases greatly. This phenomenon is called "wing in ground effect (WIG)"[1]. The transportation system using WIG was proposed by Kohama et al.[2] This WIG vehicle is referred to as "Aero-Train," and it is developed by them.

The wing in ground effect is the effect of pressure rise under the wing and weakening of the wing tip vortices. Sometimes, it is said that this pressure rise is caused by ram pressure (compression of the air by dynamic pressure). However, at low speed, the ground effect can be found without ram pressure. Therefore, the pressure rise seemed not to be attributed to ram pressure. In this paper, to confirm why pressure increases under the wing, the flow around the aerofoil was investigated experimentally.

## 2. Experimental Procedure

Figure 1 shows the experimental setup. The airfoil profile was NACA6412 modified (Fig.2) that was the same profile of the Aero-Train model of Kohama et al.. The size of the wing was 152mm chord, 295mm span. A lift and drag of the wing was measured directly by a 3-component force transducer (Nissho Electric Works Co., Ltd., LMC-3501-50N). The velocity distribution around the wing was measured by PIV system. (This system belongs to Division of Instrumental Analysis, Life Science Research Center, Gifu Univ.) To make PIV measurement under the wing possible, the ground plate was made by a Plexiglas flat plate. Figure 3 shows the coordinate system used here and the definition of height of the aerofoil $h$, which is the ground clearance. The free-stream velocity $U$ was set at 20m/s, and the Reynolds number was $2.0\times10^5$ .

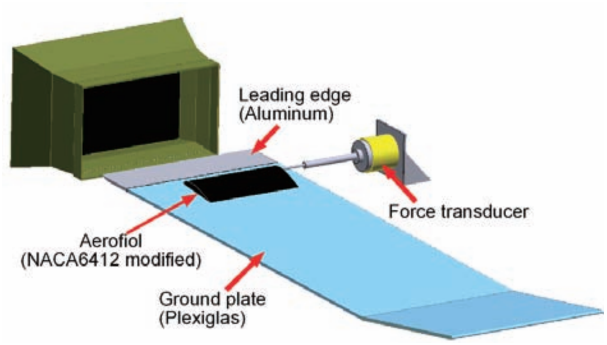


Fig.1 Experimental apparatus

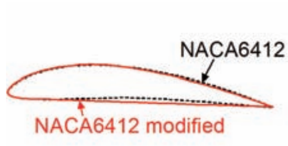


Fig.2 Aerofoil profile

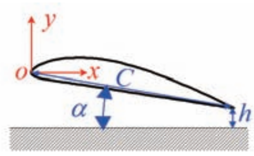


Fig.3 Coordinate system

## 3. Results and Discussion

Figure 4 shows lift, drag, and lift-drag ratio against the ground clearance. The lift increases and the drag decreases as the wing approaches the ground. As a result, the lift-drag ratio increases markedly. These results are consistent with previous data qualitatively, and it was confirmed that the ground effect occurred with this equipment.

Figure 5 shows the velocity distribution around the wing. The data was measured by dividing into four areas, then combined numerically. The data shown in Fig.5 is the time mean velocity averaged over 50 data. As the wing approaches the ground, the velocity under the wing decreases, and the velocity above the wing rises. Paying attention to the velocity near the leading edge, it seems that the stagnation point moves downward. In order to investigate in more detail, the velocity distribution near the leading edge was measured. The result is shown in Fig.6. The direction of velocity vectors near the leading edge becomes upward with decreasing the ground clearance, which means the effective angle of attack increases. The dividing streamline, which is a line that separates the flow above the wing and the flow under the wing, was calculated from these data. These lines are shown in Fig.7 as a stream line that passes a point whose vorticity is zero near the leading edge. When the wing approaches the ground, the stagnation point moves downward and the effective angle of attack increase. The shift of the stagnation point and the increase of effective angle of attack lead to the reduction of the flow rate between the wing and the ground. This reduction in flow rate means the reduction of velocity and pressure rise under the wing. Therefore, it is found that the pressure rise is caused by the velocity reduction and it is not the ram pressure.

## References

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2) S.Kikuchi, F.Ohta, T.Kato, T.Ishikawa, Y. Kohama: *J. Fluid Sci. and Tech.*, 2(1), (2007), pp.226-237.

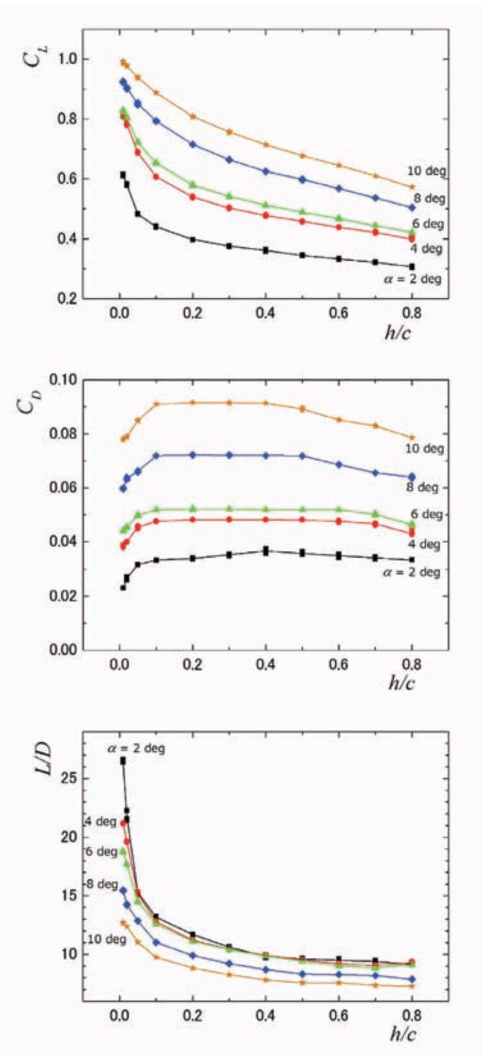


Fig. 4 Aerodynamic force

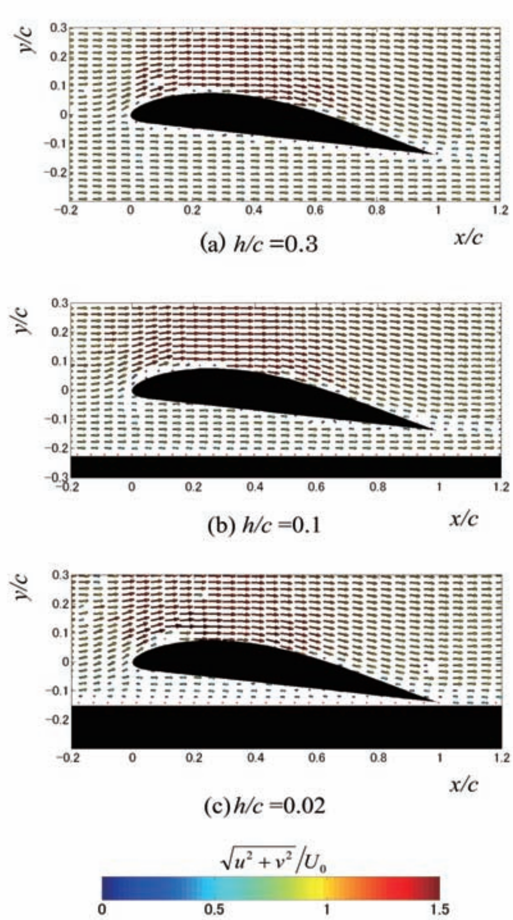


Fig.5 Velocity distribution around the wing ($\alpha$= 8deg)

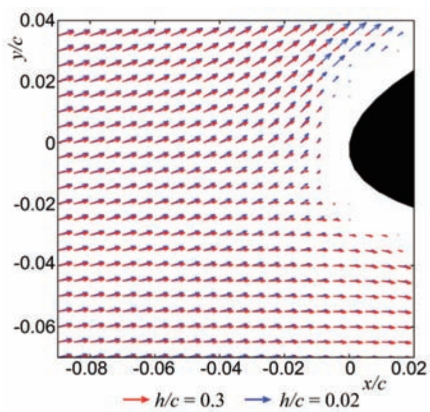


Fig.6 Velocity near the leading edge ($\alpha$= 8deg)

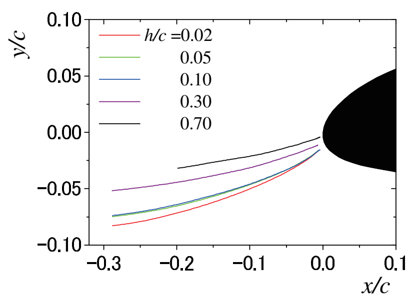


Fig.7 Dividing streamline ($\alpha$= 8deg)