Aerodynamic Characteristics of Bird-like Assembled Wing

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Abstract

The aerodynamics of bird wing has not been researched so much. Therefore, there are a lot of unsolved problems about it. One of the problems is the function of gap between primary feathers. In this study, the wind tunnel experiments were conducted to clarify the function of gap by using the hand-made bird-like assembled wing with various gap sizes between primary feathers, and the relationship between the lift or the drag coefficients and the angle of attack was investigated. Some benefits of bird-like assembled wing were clarified such as the stall characteristics and the lift-to-drag ratio, indicating the advantage of assembled wing over the conventional wing for the operation in air turbulence.

1 Introduction

In recent years, unmanned air vehicles are researched widely for the purpose of information gathering in the disaster area or in the battlefield, etc. Especially, the earthquake which occurred last year in Japan strongly proposed the necessity of speedy information gathering system which can sense the damage for the urgent rescue. The small size airplane called MAV (Micro Air Vehicle) is beneficial for this purpose because it is light-weight and low-cost, and thus can be easily equipped at many places, and also it can fly at low speed which prevents the danger of secondary disaster by crash. However, there is a problem that it cannot fly under the strong air disturbance. The flight of birds is effective in this respect because they can fly under the terrible condition with lots of air turbulences. If we can clarify the key parameters for this ability, it is really beneficial for realizing useful information gathering system usable anywhere and anytime. Fig. 1 is one of the examples of MAV based on the configuration of bird.

In this study, we focus on the flight of birds which specialize in the gliding flight, such as hawks or eagles, and analyzed the characteristics of their wing especially focusing on the gaps between the primary feathers. We analyzed the function of those gaps by conducing wind tunnel experiment with a hand-made bird-like assembled wing with various gap sizes between primary feathers.

Fig. 1. Bird-like MAV [1]

2 Method

2.1 Fabrication of assembled-wing [2] [3]

We used an aluminium plate and a stainless rod as the material of artificial primary feather. The dimension of single feather is 210×30mm (AR=7) and the thickness is 0.1mm, and the diameter of stainless rod for the support of wing is 8mm. This size is determined referring to the real primary feather of crow as shown in Fig. 2. Next, we aligned four primary feathers in a line with various sizes of gap between feathers to make a assembled wing as shown in Figs. 3-6. The size of gap is 10mm, 20mm, 30mm as shown in Figs. 3, 4, 5, respectively. For a no gap case, single aluminum plate is used, the size of which corresponds to the four primary feathers without gap, i.e. 240×120mm (AR=2), as shown in Fig. 3.

Fig. 2. Artificial primary feather

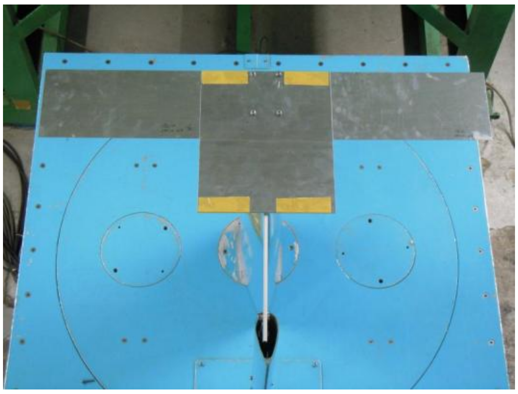

Fig. 3. Flat plate

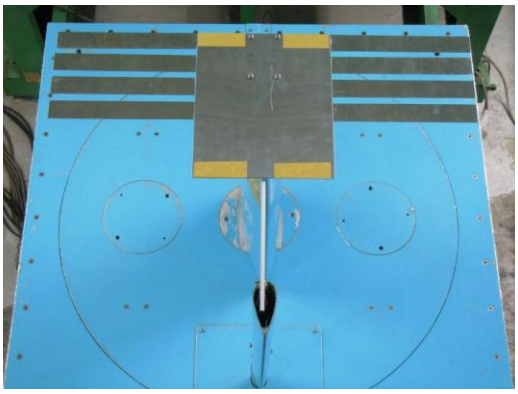

Fig. 4. Wing with 10mm gap

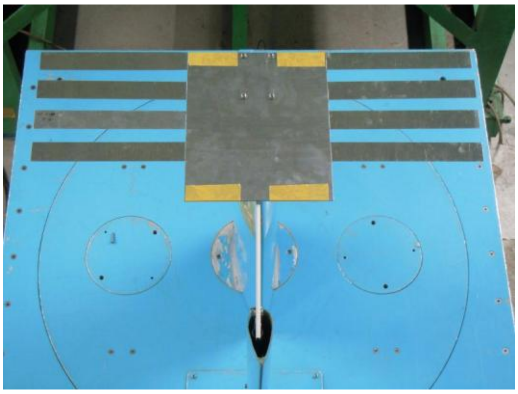

Fig. 5. Wing with 20mm gap

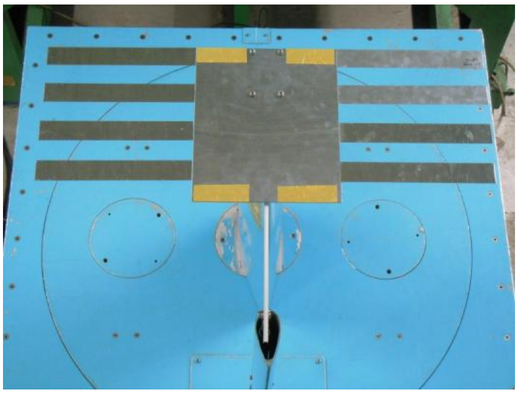

Fig. 6. Wing with 30mm gap

2.2 Wind tunnel experiment

Wind tunnel experiments were conducted using a low-speed Göttingen type wind tunnel at Tokai University as shown in Fig. 7. The experimental condition for all cases is as follows:

Wind speed, V: 10 and 15m/s

Angle of attack, α: from -10° to 28°.

Fig. 7. Low-speed Göttingen type wind tunnel

3 Experimental results and discussion

3.1 Relationship between the angle of attack α and drag D

As shown in Figs. 8 and 9, the drag increased as the angle of attack α increased until about α=20° and it became almost constant after α=20°. It also increased as α decreased below α=0°. The wing with small gap (gap=10mm) showed the smallest drag and it increased as the gap increased although the drag of large gap wing (20mm and 30mm gap) was almost equal. The drag of flat plate was almost equal to that of the large gap wings when α is lower than 20°.

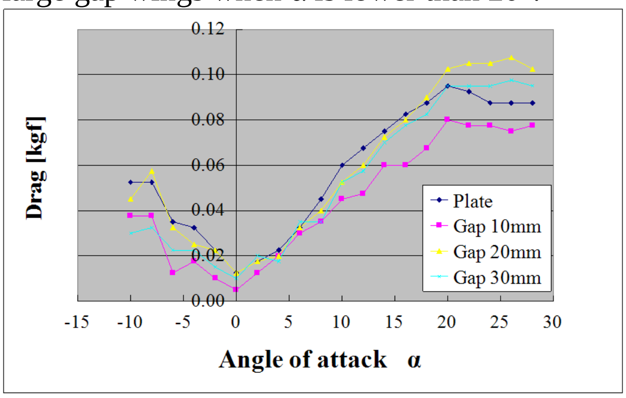

Fig. 8. Drag vs. α (V=10m/s)

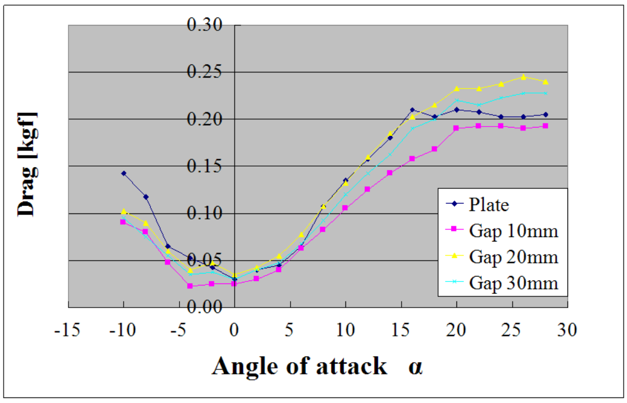

Fig. 9. Drag vs. α (V=15m/s)

3.2 Relationship between the angle of attack α and the lift L

As shown in Figs. 10 and 11, the change of lift with angle of attack α was almost qualitatively equal for both V=10m/s and 15m/s cases. The flat plate had the largest lift slope, but it started to reduce at small α (α=10°), indicating the stall began at the small angle of attack. The wing with gap showed lower lift slope than the flat plate, where the wing with 10mm gap showed the smallest lift slope and other two wings with 20mm and 30mm gap showed a similar lift slope which was more than that of wing with 10mm. The conspicuous difference of lift characteristics between the wings with gap and the flat plate is the aspect of stall. The lift slope of wing with gap started to decrease at about α=12° or more, indicating the stall occurred at larger angle of attack than in the flat plate (about α=10°). This delay of stall is more conspicuous for the wing with large gap (20mm or 30mm gap), indicating the anti-stall characteristics of the wing with gap like the assembled wing in this study.

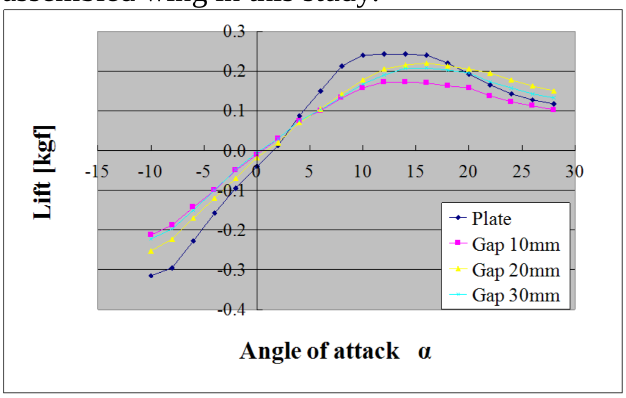

Fig. 10. Lift vs. α (V=10m/s)

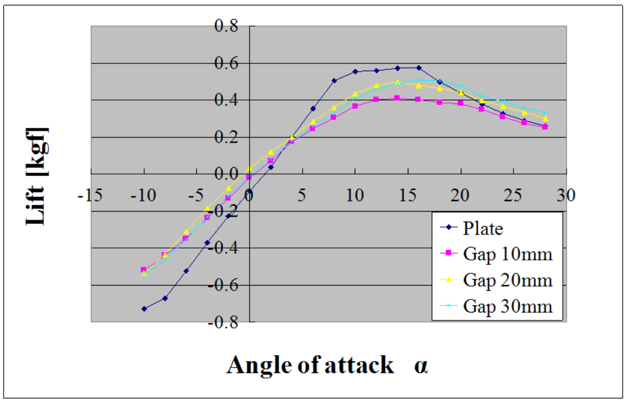

Fig. 11. Lift vs. α (V=15m/s)

3.3 Relationship between the lift L and drag D

Figs. 12 and 13 show the polar curves for V=10m/s and 15m/s, respectively. The maximum lift to drag ratio is indicated by the slope of tangential line drawn from the origin of axis to each line. The flat plate showed the maximum lift-to-drag ratio for both wind speeds, i.e. about 3.75 (V=10m/s) and about 4.0 (V=15m/s). Therefore, the wing with gap is not beneficial with respect to the lift-to-drag ratio.

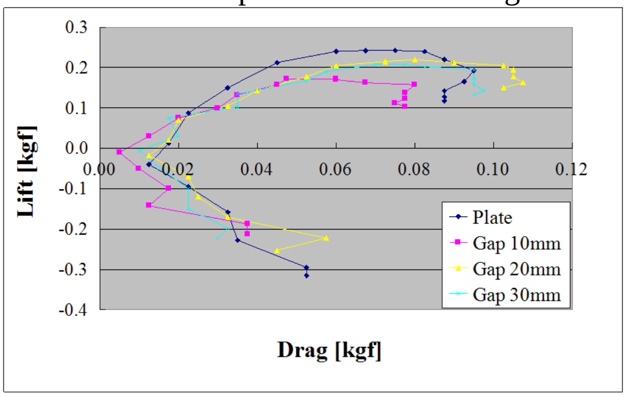

Fig. 12. Lift vs. drag (V=10m/s)

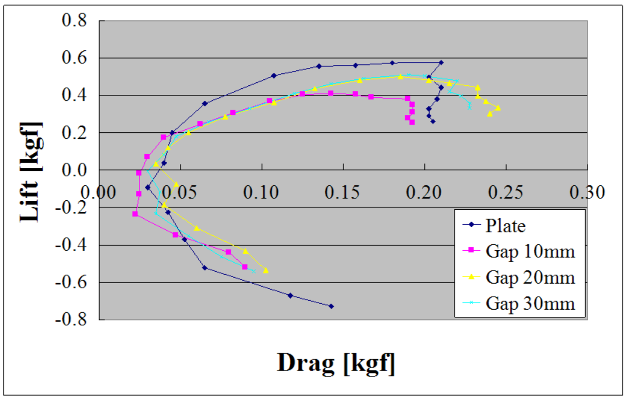

Fig. 13. Lift vs. drag (V=15m/s)

4 Conclusion [4]

The wind tunnel experiment was conducted by using a hand-made bird-like assembled wing to investigate the function of gap between primary feathers. As a result, the wing with gap generated less drag than the flat plate without gap. This drag reduction was more conspicuous in the small gap wing (gap=10mm) than in the large gap wing (gap=20 and 30mm) which had similar drag to the flat plate. The lift slope and the maximum lift-to-drag ratio of the wing with gap are less than that of flat plate without gap. The aspect of stall showed conspicuous difference between the wing with gap and the flat plate. The stall of the wing with gap began at larger angle of attack than that of the flat plate, indicating the better tolerance to the air turbulence of the wing with gap, and thus indicating the possibility of better performance of bird-like assembled wing than the conventional planar wing when it is used in the turbulent condition.

5 Reference

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