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# Wind Tunnel Experiment of Taxidermy Black-tailed Gull (*Larus crassirostris*) and Black Kite (*Milvus migrans*)

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## Abstract

Focusing on birds as an example of realizing a morphing wing that can change its flexible wing autonomously, aeronautical engineers and ornithologists jointly conducted wind tunnel experiments on black-tailed gull and black kite. The aerodynamics characteristics were also obtained by recreating the condition of a wing simulated as molting. The idea to simulate a molting was suggested by an ornithologist familiar with ecology, but from an engineering point of view, it was an interesting experiment that could lead to the development of damage-tolerant wings. By using a large wind tunnel, we were able to obtain basic data in a clean, rectified flow without any fluttering of the wings. In the presentation, we will show other results of the experiments not described here, including the results with a wider range of wind speed and pitch angle.

**Keywords:** wind tunnel experiment, morphing wings, taxidermy birds, ornithology

## 1. Introduction

Research on morphing wings that autonomously change their wings has been particularly active in Europe and the U.S. In the U.S., NASA, MIT, FlexSys, and other organizations have conducted test flights of unmanned vehicles[1)] and experimental aircraft, and in Europe, Airbus' small-scale Albatros One aircraft has been tested. In addition, small unmanned vehicles that imitate birds and insects are being developed one after another by Festo (Germany), in particular the Smart Bird, which imitates a seagull; the Bionic Opter, which imitates a dragonfly; the Bionic Flying Fox, which imitates a bat; and the Bionic Swift, which flaps its wings autonomously[2)]. With the development of electronics and new materials, a systematic evaluation[3)] of the entire aircraft, including not only the wings but also the battery and communications, is being conducted.

In Japan, research on morphing blades with shape memory alloy actuators and composite corrugated structures has been conducted mainly by members of the Morphing Technology Research Group of the Japan Society of Mechanical Engineers, which was established in FY2017[4)].

Bird flight, as the most familiar flying system, has a history of more than 100 years of research since Lilienthal[5)] . However, there are still many aspects that have yet to be elucidated. In fact, despite many years of research, there are still many aspects that have yet to be elucidated. In addition to the small Festo airplane mentioned above, there have been detailed studies on the relationship between wing and tail shapes and attitude changes[6)], experiments on model airplanes that mimic the movements of birds and turn by opening and closing their wings[7)], and radio-controlled airplanes implemented with pigeon feathers [8)], a study that investigated the microscopic structure of feathers and the macroscopic performance of deformable wings based on flight experiments with radio-controlled airplanes equipped with pigeon feathers, and other new research results have also been reported. Labor-saving and miniaturization of electronic devices such as actuators, sensors, and wireless communicators, as well as the development of measurement and simulation technologies, have made it possible to quantitatively evaluate flight mechanisms that were previously understood only qualitatively.

In wind tunnel experiments on birds, the differences between stuffed and live birds and models cannot be ignored, and in recent years there has been much research on visualizing airflow by flying live birds in wind tunnels[9]. In wind tunnel experiments with stuffed or model birds, it is possible to measure the forces generated by sensors and other devices, but it is difficult to measure the forces generated by a live bird in free flight.

The authors again focused on birds as an example of a morphing wing system that can change its flexible wings autonomously, and decided to start by obtaining basic characteristics through wind tunnel experiments using stuffed birds as a first step. However, instead of purchasing commercially available stuffed birds, they plan to collaborate with researchers at the Yamashina Institute for Ornithology, Japan's premier avian research center, to create stuffed birds in the most desirable form and to arbitrarily change the shape of their wings. Although the spread of coronary infection delayed the preparation of the taxidermy and postponed the planned wind tunnel experiment, we were able to conduct the taxidermy wind tunnel experiment in last summer and this spring and report the details and results of the experiment.

## 2. Wind Tunnel Experiment and Taxidermy Specimen

### 2.1 Wind Tunnel Experiment and Set Up

The wind tunnel used in this study is the JAXA 6.5m x 5.5m Low Speed Wind Tunnel (LWT1). The experimental apparatus is shown in Fig.1. The taxidermy specimen was fixed to a stainless steel support on a six-axis force gauge manufactured by Toyo Sokki ( Capacity: Fx=Fy=20kN, Fz=40kN, Mx=My=2Nm, Mz=1Nm). The force gauge is assembled to the mount via a jig that allows the pitch angle to be varied. In this study, we measured lift and drag force at a wind speed of 5 m/s, 7.5m/s and 10m/s and a pitch angle of plus or minus 30 degrees at 0.1 degree per second. Only in case of taxidermy black kite, the minus side is limited to -20degrees for safety reasons.

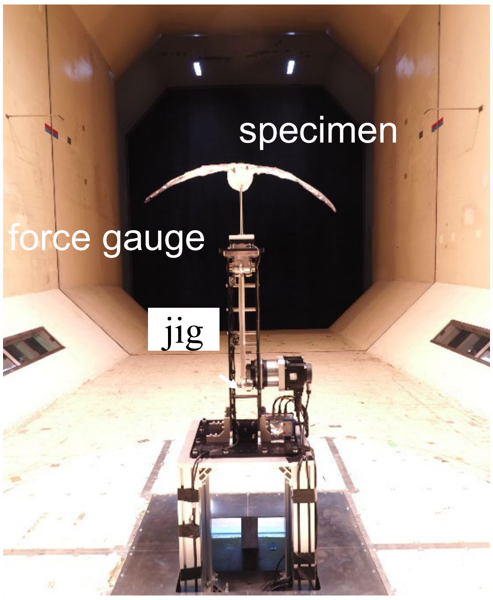



Figure 1 – Experimental set up.

The pitch angle refers to the pitch angle of the top surface of the jig, not the angle of the taxidermy wing or body axis, because the taxidermy installation posture was not strictly set in the experiments.

## 2.2 Taxidermy Specimen

The taxidermy birds used in the experiment were the black-tailed gull (*Larus crassirostris*) which were obtained by one of the authors, Dr.Tomita, from adult birds killed in an accident at Kabushima Island in Hachinohe, Aomori Prefecture, one of the best breeding grounds in Japan for close-up observation of black-tailed gulls. Dr. Tomita, who has been observing black-tailed gulls, supervised the design of the wings, and produced two types of wing shapes; one with the wings spread (black-tailed gull A, span length: approximately 1200mm) and one with the wings slightly closed (black-tailed gull B, span length: approximately 900mm). In addition, we prepared a taxidermy black kite, which was exterminated at Haneda Airport. All taxidermy birds shown in Figure 2 were stuffed by Dr. Iwami, one of the authors.

As with commercially available stuffed specimens, the interior of the stuffed specimen consists of a rigid urethane foam body to which the sings, head, and tail are attached using wire. However, preliminary studies showed that the humerus, where the wings are attached to the body, is weak with wire alone, so it was reinforced with rigid urethane foam, the same material used for the body.

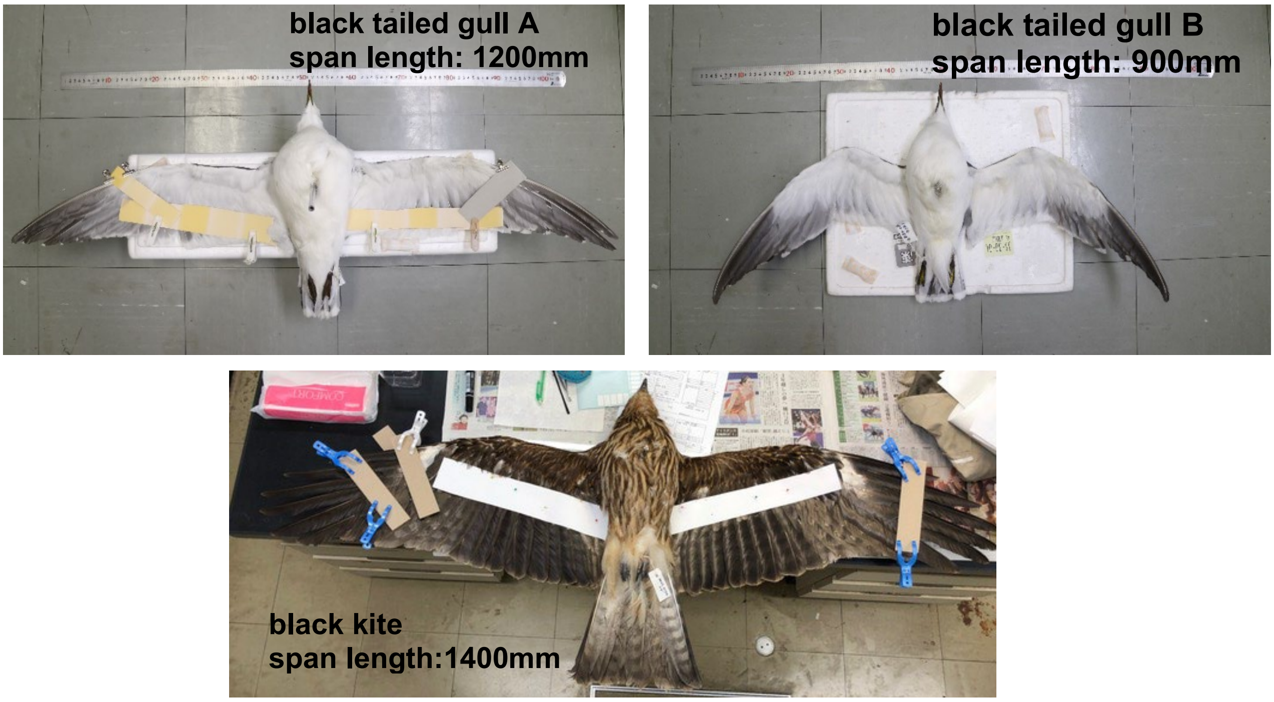
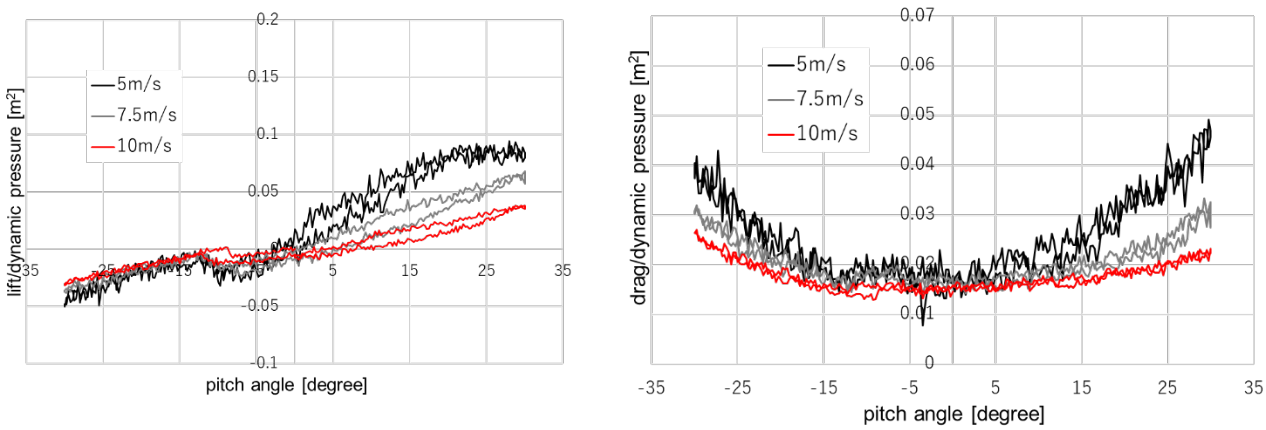



Figure 2 – Taxidermy black-tailed gulls and black kite.

# 3. Experimental Results of Lift and Drag Forces

## 3.1 Results of two types of taxidermy black tailed gulls (*Larus crassirostris*)

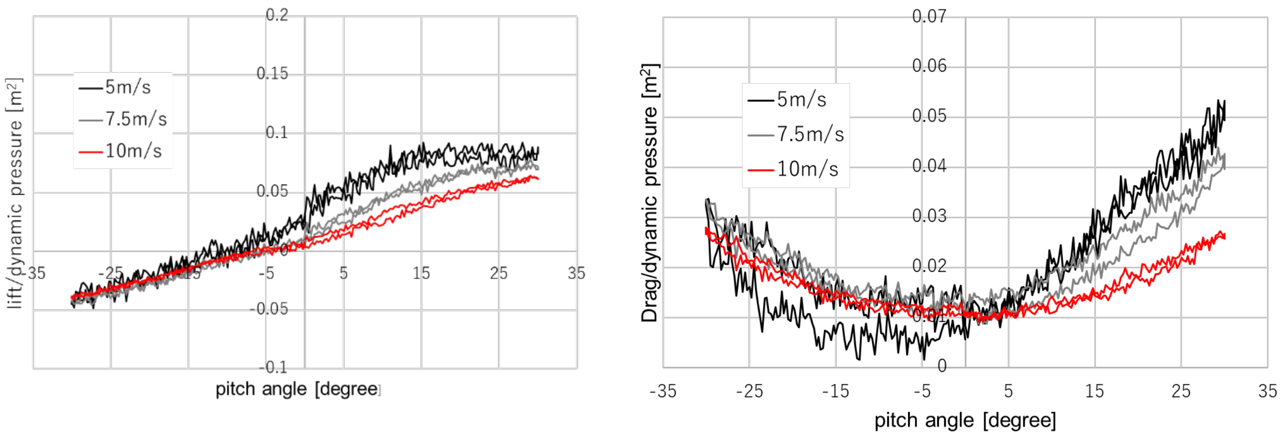
Figure 3 shows the relationship between pitch angle and lift and drag forces for the black-tailed gull A. The vertical axis is the lift or drag force divided by the dynamic pressure, not by the wing area. This is because the wing area varies with the flexibility of the wing, as will be explained later. This figure shows that both lift and drag forces are found to be wing speed dependent especially in the positive pitch angle region. A characteristic change in lift appears for all wind speeds.




(a) Lift force (b) Drag force

Figure 3 – Lift and drag forces of black tailed gull A.

Figure 4 shows the relationship between pitch angle and lift and drag forces for the black-tailed gull B. This figure shows that both lift and drag forces are found to be wing speed dependent especially in the positive pitch angle region. No characteristic change in lift is observed.

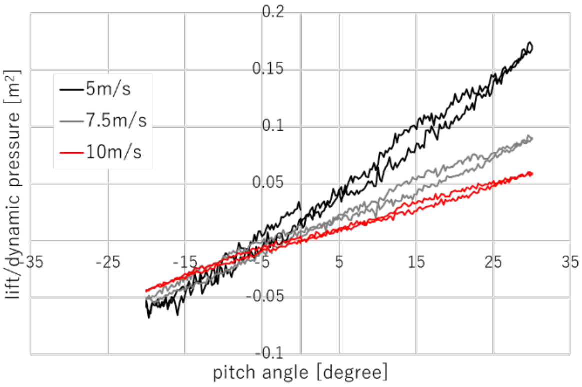



(a) Lift force (b) Drag force

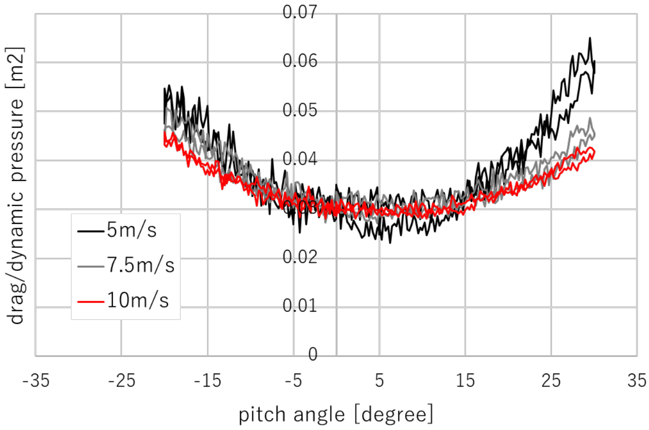
Figure 4 – Lift and drag forces of black tailed gull B.

## 3.2 Results of taxidermy black kite (*Milvus migrans*)

Figure 5 shows the relationship between pitch angle and lift and drag forces for the kite. Note that the negative pitch angle is limited to -20 degrees for safety reasons. As with the results of the black-tailed gulls, this figure shows that both lift and drag forces are found to be wing speed dependent especially in the positive pitch angle region. In this case, the lift at a wind speed of 5m is linear over a wide range than that of black-tailed gulls. As well as the black-tailed gull B, no characteristic change in lift is observed.




(a) Lift force



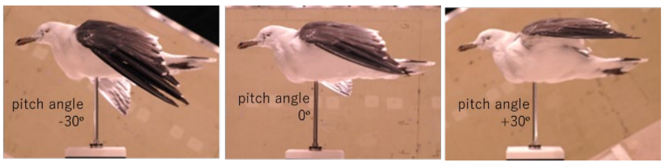

(b) Drag force

Figure 5 – Lift and drag forces of black kite.

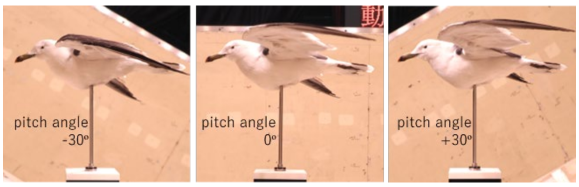
## 4. Comparison and Discussion

Comparing Figures 3 and 4, the values of lift and drag were not much different for the black-tailed gull A and B. As described before, in the case of the black-tailed gull A, a characteristic change in both lift and drag was observed around a pitch angle of minus 10 degrees. In the case of lift, the difference with wind speed was smaller in the case of the black-tailed gull B. We inferred that wing deformation was the cause of these features, and the shapes of the wing at wind speed 5m/s and 10m/s are shown in the figure 6. In these figures, the photographs are rotated so that the orientation of the body is aligned so that the deformation of the wings relative to the body can be easily seen.

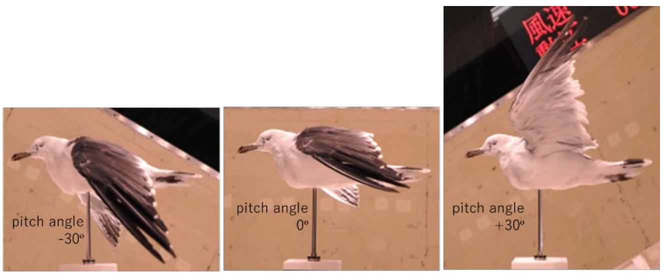
Of course, the higher the wind speed, the greater the deformation of the wing. The deformation is larger in the black-tailed gull A, especially the downward warp angle at a negative pitch angle.



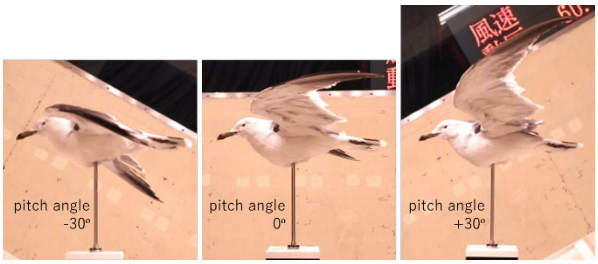

(a) Black tailed gull A ( Wind speed: 5m/s)




(b) Black tailed gull B ( Wind speed: 5m/s)



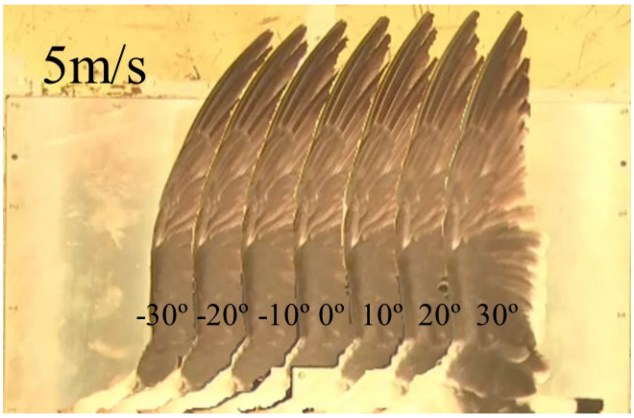

(c) Black tailed gull A ( Wind speed:10m/s)



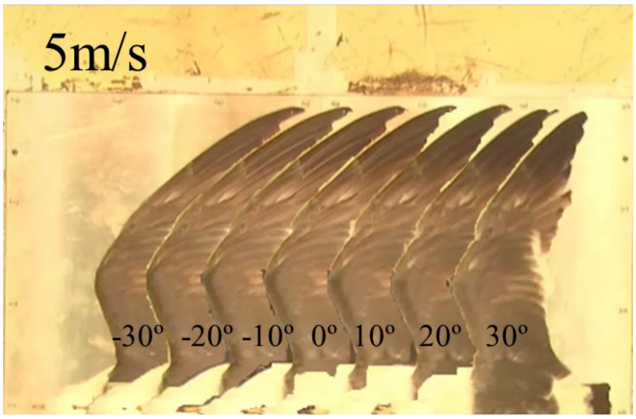

(d) Black tailed gull B (Wind speed: 10m/s)

Figure 6 – Side view of the black tiled gulls during the experiments .

To better observe the wing shape, Figure 7 shows the wing shape variation viewed from directly above. The wind speed and pitch angle are shown in the figure. This figure also shows that the wing deformation is greater and the projected length in the span direction is shorter for black-tailed gull A, especially at negative pitch angles.




(a) Black tailed gull A ( Wind speed: 5m/s)




(b) Black tailed gull B ( Wind speed: 5m/s)


(c) Black tailed gull A ( Wind speed:10m/s)


(d) Black tailed gull B (Wind speed: 10m/s)

Figure 7 – Top view of the black tiled gulls during the experiments .

Similarly, Figure 8 shows the shape of the wing from the side and Figure 9 shows the shape of the wing from directly above in the case of the black kite.


(a) Wind Speed: 5m/s


(b) Wind Speed: 10m/s

Figure 8 – Side view of the black kite during the experiments .

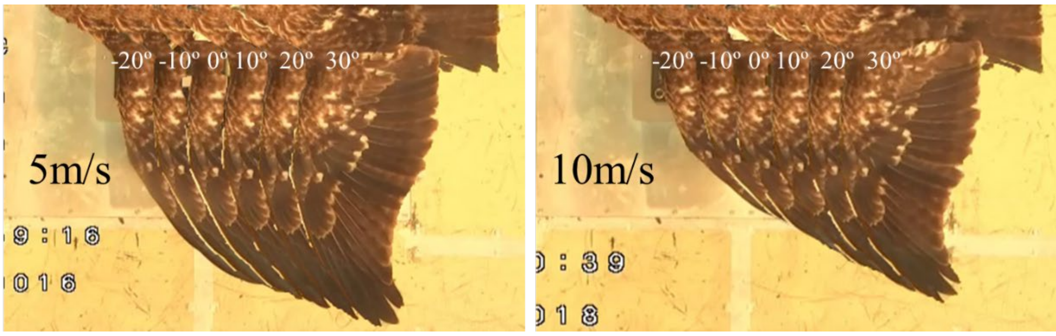



Figure 9 – Top view of the black kite during the experiments .

The shape of the wing changes significantly as the pitch angle changes. Although there does not appear to be much difference in the side view, the top view shows that the shape of the wing changes significantly even at different wind speeds.

## 5. Conclusion

Focusing on birds as an example of a morphing wing that can autonomously deform its flexible wings, we fabricated a stuffed black-tailed gulls and black kite for a wind tunnel in collaboration with ornithologists. And we measured basic aerodynamic characteristics including lift and drag while changing pitch angle in JAXA's 6.5m x 5.5m low-speed wind tunnel. Basic data was obtained in a clean, rectified flow with no large disturbance in the wings.

(a) During strong winds

(b) During weak winds

Figure 10 – Live black-tailed gulls in flight.

On the other hand, the wing shape produced in the wind tunnel experiments differs from the wing shape of a bird in flight in nature shown in Figure 10. Especially, the curvature in the span direction is different. In the future, we plan to conduct wind tunnel tests that reproduce actual wing geometry and wing flexibility as much as possible.

## Acknowledgement

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