Vortex Flow Developed in the Wing Chord Direction of a Flapping Butterfly Wing

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In recent years, small flap flying objects and Micro Air Vehicle (MAV) are developed actively at home and abroad. These technologies are expected to be applied to various fields such as maintenance inspections of structures, lifesaving supports in a disaster area where there is a danger of a secondary disaster, monitoring of dangerous persons and counter-terrorism. Until now, a number of researchers have attempted to develop small flap flying objects and MAV with various actuators and devices however they have not reached practical use at the present time. One of the reasons is that flying mechanism of birds and insects has not been clarified sufficiently.

It is well known that a butterfly combines flapping motion of its wing with gliding to fly and the figure of flying is very beautiful. Moreover, it does not perform linear flying motions such as a dragonfly however it flies like dancing by flapping with low frequency.

The authors have conducted a flight observation experiment of Cynthia cardui and clarified behaviors of its wing in its flight. By spacial evaluation of the wing in a flapping flight, the authors have clarified that flapping angles of the butterfly have periodic triangular waveforms and the ratio of the time needed for flap-up and flap-down is approximately 1:1.25. Moreover, we have clarified that the wing deforms elastically not only in the wing chord direction but also in the wing span direction. Furthermore, we evaluate dynamic behaviors of a wing observed from the butterfly's viewpoint in its flight. The butterfly realizes its flapping motions by changing not only flapping angles but also lead-lag angles in free and fixed flights. In particular, in a free flight, a butterfly performs flapping by greatly changing feathering angles in the wing span direction and furthermore, it has been found that its vein at the wing tip twists in opposite phase around the body and wing tip.

In this study, we evaluate in detail the vortex flow structure on a flapping butterfly wing. In particular, the authors conduct a PIV measurement around a flow field of the flapping butterfly wing of Cynthia cardui performing a fixed flight. We clarify the vortex flow stru cture developed in the wing chord direction on a flapping butterfly wing and aim at clarifying the relation between the vortex flow structure on the wing and the dynamic beh

aviors of wing. Furthermore, we perform the comparison with the vortex flow structure of the butterfly wing and that of a robofly wing developed in our laboratory, and also consi der the stability of robofly flight.

Keywords: Vortex, Butterfly, Wing, PIV