Abstract

Human beings flying with the help of aircrafts of various kinds have been able to fly for about one century. Although the flapping wings of animals served as an inspiration to pioneers of human flight, we don’t really understand how they work. In this study, we employ the concept of four-bar linkage to design a flapping mechanism which simulates a flapping motion of a bird. Wind tunnel tests were performed to measure the lift and thrust of the mechanical membrane flapping wing under different frequency, speed, and angle of attack. It is observed that the flexibility of the wing structure will affect the thrust and lift force due to its deformation at high flapping frequency. The lift force will increase with the increase of the flapping frequency under the corresponding flying speed. For the same flapping frequency, the flying speed can be increased by decrease of the angle of attack with the trade of loosing some lift force. An angle of attack is necessary in a simple flapping motion in order to derive a lift force. The flapping motion generates the thrust to acquire the flying speed. The flying speed and angle of attack combine to generate the lift force for flying.

Keywords: Ornithopter; Flapping wing; Membrane wing; Flexible wing

1. Introduction

It has been an interesting subject in biology to study the flying mechanism and characteristics of flapping flight of birds [3–8,11]. Flapping flight is more complicated than the fixed-wing flight. For an aircraft with fixed wings, only forward motion is necessary to sustain the body with the induced aerodynamic lift. For the flapping flight, the wing not only has a forward motion but also the up and down flapping. In the down stroke flapping, the wing is fully extended and produces both lift and thrust at the same time. During the up stroke, some part of the wing is folded to reduce the moment of inertia and the drags of the wings. The wings are also twisted during the flapping to vary the angle of attack for various flying motions. During the hovering, fast forward motion, or slow forward motion, different wing strokes and attack angles are employed. The flapping wing flight is also believed to have better maneuverability compared to the fixed wing flight.

In biological flight, the wings not only move forward relative to the air, they also couple the motions of flapping up and down, plunge and sweeping [9,10]. In order to attain efficient lift during the flapping motion, the wing will undergo a twist motion to change the angle of incident in the down and up strokes. In general, the down stroke will produce the most lift and thrust with fully extended wings. At the up stroke, additional lift can also be generated by twisting the wing to change the attack angle, especially during the take-off and hovering flight [2]. For small insect flight, the wings flap at high frequency and the unsteady flow mechanism dominates [12]. During the up stroke, the wing surfaces press together at the end for a period of time. As the wings separate for the next down stroke motion, they rotate around the trailing edges first to form a V shape before they begin to move away. This leads to the large circulation and lift on the wing without the negatives of vortex shedding.

The flapping-wing aircraft configurations (ornithopter) received great attention to the researchers for a long time. One application of the ornithopter, being a micro air vehicle (MAV),