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EXPERIMENTAL STUDY OF THE MECHANICS OF MOTION OF FLAPPING INSECT FLIGHT UNDER WEIGHT LOADING

Timothy Reissman

Robert B. MacCurdy

Ephraim Garcia

Sibley School of Mechanical and Aerospace Engineering, Cornell University, Ithaca NY, USA

ABSTRACT

The results of this study are an evaluation of the mechanics of motion of a weight loaded *Manduca sexta* Hawkmoth during flight using accelerations recorded with an onboard sensory system. Findings indicate that these ‘normal’ flapping insects maintain relatively fixed body frequencies in both free and weight loaded flight, which correspond with the driving frequency, or wing beat frequency. Within the analysis, a presence of a harmonic body frequency at twice the wing beat frequency was also discovered. The conclusions from this study indicate an average excess muscle power of over 40mW available in free, unloaded flight. Stability robustness of these flapping insects in flight using the results of a large payload disturbance, 856mg or nearly half to one-third the mass of insect, is demonstrated, and their usefulness as platform for cyborg MAV (CMAV) development is presented.

INTRODUCTION

A significant amount of engineering and biological research has focused on developing an understanding of the mechanics of flapping flight [1-16], but little has been cited on the effects of this motion given the presence of disturbances, specifically weight loading [17-21]. This paper aims to provide further insights and reveal its impact on how a biological specimen adapts to such a disruption of its fundamental vehicle dynamics.

The study of flapping flight has many useful applications, from realizing the transition of forward to hovering flight, to understanding unsteady aerodynamic forces, to creation of biomimetic small-scale aircraft, such as flapping micro-air vehicles (MAVs). In examining the vast literature available on the subject of flapping flight [1-16], it is important to note the size and type of flapping motion that is under investigation. In this work, an experimental study is performed on the *Manduca sexta* Hawkmoth, where the physical properties of the male and

female specimens tested are listed in Table 1, along with an overhead photograph of the insect in Figure 1.

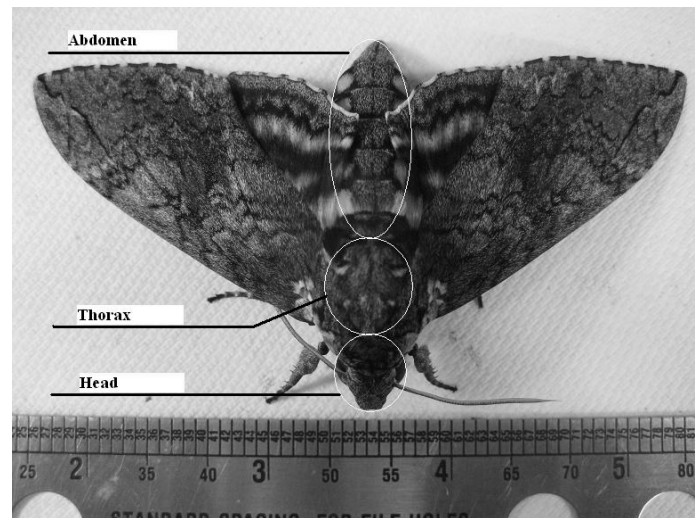


Figure 1. *Manduca sexta* Hawkmoth insect.

Table 1. Physical parameters of insects tested.

	Head mass	Thorax mass	Abdomen mass	Wing mass	Wing area
Female	127mg	833mg	1519mg	104mg	591.4mm ²
Male	123mg	678mg	650mg	76mg	449.6mm ²

These insects utilize ‘kinematics of normal insect flight,’ [17-18] as opposed to a ‘clap-and-fling’ method which insects such as Damselflies and butterflies implement. While it has been cited [17] that ‘normal’ flight produces 25% less lift than ‘clap-and-fling’ flight, the reasoning for selection of this species as a model in which to study the effects of weight loading in flapping flight are easily summarized; they are relatively large insects with a well studied literature on their