# Chapter 10
# Entomopter Wing Analysis Boon for Mars Mission

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## ABSTRACT

*In this chapter, CFD analysis is performed to understand the aerodynamic characteristics of 3-D Entomopter wing. Entomopter is the MAV which is especially designed for Martian atmosphere exploration. It is a low Reynolds number flyer due to which it can reach to the places where human intervention is not at all possible. The aerodynamic simulations are carried out at different flap angles varying from -20º to 30º in Martian atmosphere. The Entomopter model considered for CFD analysis has a wingspan of 15 cm with varying chord length and Reynolds number ranging from Re=75000 Re=150000 i.e., at a velocity of 2 m/s to 30 m/s. The Entomopter 3-D printed model is designed in CATIA V5 and simulation is carried out using ICEM CFD and ANSYS FLUENT. Entomopters may undertake multimode operations and produce lift by continuously forming and shedding vortices from their flapping wings. So, this research is a viable aspect to understand the future development of MAVs for outer space exploration and can be promising for making impossible things possible.*

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## INTRODUCTION

Many researchers in the field of biology, zoology, aerodynamics, and electronics have long been fascinated by the flapping flight of birds and insects (Michelson, 1998; Han et al., 2009; Jaroszewicz, 2013). This flapping flying mechanism provides excellent manueverability and aerodynamic advantages, particularly at low Reynolds numbers (Han et.al, 2009). Hence, miniature flight platforms are the tiny ones which are unmanned and endeavour to invade the flight regime of birds and insects.

A Micro Air Vehicle (MAV) is a flapping unmanned aerial vehicle (UAV) having a size restriction of as small as 15 cm i.e., (approximately 6 inches). It is an insect-sized aircraft that is generally expected to be launched by hand. It uses flapping wings to generate the aerodynamic forces and moments needed for flight, and it maintains stability through a complex wing motion that includes flapping, pitching and plunging, twisting, and lagging motion (Djojodihardjo et al.,2016). Small size and slow flight add to the advantages of a MAVs. Also, a micro air vehicle can enter enclosures and effectively navigate the interiors. Though it is an unmanned aircraft, it can be operated in a similar way to that of a conventional aircraft.

MAVs are generally designed for hobby purposes and remote observation of hazardous environmental conditions (Khan, Khan, & Padhy, 2021).These activities are accomplished by Nano Air Vehicles (NAVs), Ornithopter and Entomopters, of micro air vehicles (MAVs) kind (Gerdes et al.,2012).

An example of a MAVs (micro air vehicles) that demonstrates high degrees of innovation and biological inspiration is the Entomopter, bio-mimicked from Manduca Sexta shown in Figure 1 (a). It is a bioinspired flight that flies using the wing-flapping aerodynamics of an insect. The word is derived from entomo (meaning insect: as in entomology) + pteron (meaning wing) (Michelson, 2004, 2011).

The entomopter is an electromechanical multimode insect capable of flying, crawling, and even swimming, proving it to be an all-time favourite unmanned aerial vehicle. Michelson (2011) and his Georgia Tech Research Institute design team are working on it. This electromechanical device is based on a recent breakthrough known as a Reciprocating Chemical Muscle (RCM), which can generate modest quantities of power for on-board devices using a chemical energy source. In other words, we can say that RCM provides autonomic wing beating for entomopter during its flight.

The entomopter has the extra benefits of indoor operations, high manoeuvrability, slow flying, obstacle avoidance, and multimode locomotion (Michelson, 2004). Furthermore, an entomopter wing can be stationary, rotating, flapping, or lighter-than-air (LTA). Low Reynolds number aerodynamic phenomena, extreme downsizing, high degrees of system integration, and efficient use and re-use of energy are all challenges that the mechanical robot must overcome(Austin, 2011; Michelson, 2004)).The entomopter began as a bio-mimetic design, but rather than attempting

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