ICCES, 2026, vol.36, no.1

Tech Science Press

DOI: 10.32604/icces.2026.013523

PROCEEDINGS

Wing Kinematics and Aerodynamics of Mosquitoes in Forward Flight

Zengshuang Chen[1], Xueguang Meng[1,*], Pengyuan Yang[1], and Gang Chen[1,2,*]

[1]State Key Laboratory for Strength and Vibration of Mechanical Structures, School of Aerospace Engineering, Xi'an Jiaotong University, Xi'an, 710049, China

[2]Shaanxi Key Laboratory of Environment and Control for Flight Vehicle, School of Aerospace Engineering, Xi'an Jiaotong University, Xi'an, 710049, China

[*]Corresponding Author: Xueguang Meng; Gang Chen. Email: mengxg@xjtu.edu.cn; aachengang@xjtu.edu.cn

ABSTRACT

Mosquitoes exhibit unique motion patterns that have attracted researchers to explore the underlying aerodynamic mechanisms. However, previous studies have primarily focused on hovering flight. In the present study, we measured for the first time the kinematic and morphological data of mosquitoes *Aedes togoi* in forward flight using three orthogonally aligned and synchronized high-speed cameras, and numerically computed the forces acting on the wing and the surrounding flow. The results show that mosquito wing kinematics in forward flight exhibit two distinctive features that differ from those observed in most other insects. One feature is that the mosquito's stroke plane remains nearly horizontal; the other is that its wing pitching motion is remarkably asymmetric between the downstroke and upstroke. More specifically, the pitch-down acceleration at the beginning of the stroke and the pitch-up amplitude in the middle of the stroke are highly asymmetric. Through establishing the kinematic-fluid aerodynamic link, three key features of aerodynamic force generation are revealed: fast acceleration, leading-edge vortex, and rapid pitching-up rotation. The leading-edge vortex and rapid pitching-up rotation are responsible for producing the large vertical force and thrust, respectively. Additionally, the power consumption of mosquitoes is mainly contributed by the aerodynamic power, with the mass-specific power being about 27% lower than that of small-sized mosquitoes *Aedes aegypti*, which may facilitate seeking and feeding on hosts. These findings not only provide a better understanding of mosquito flight but also help in the design of micro-flapping wing vehicles.

KEYWORDS

Insect flight; forward flight; kinematics; aerodynamics

Funding Statement: This research was supported by the National Natural Science Foundation of China (Grant Nos. 12172276 and 125B2053) and the Fundamental Research Funds for the Central Universities, China (No. xzy022025070).

Conflicts of Interest: The authors declare no conflicts of interest to report regarding the present study.

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