ANALYSIS OF VARIOUS FLOW CHARACTERISTICS OF FLAPPING WING MICRO ARIEL VEHICLE AERODYNAMICS

Akij Ahmad1, Saurav Das2, Saikat Das3, Kuheli Mondal4

1 Department of Mechatronics Engineering, International Islamic University of Malaysia, Gombak Campus, Kuala Lumpur
2 Associate Professor and H.O.D, Department of Mechanical Engineering, T John Institute of Technology, Gottigere, Bengaluru, India
3 Department of Mechanical Engineering, Jadavpur University, Kolkata, India
4 Department of Mechanical Precision Engineering, Malaysia Japan International Institute of Technology, Universiti Teknologi Malaysia, Kuala Lumpur,

Abstract: Flapping wing dynamics in micro air vehicle has been the focus of present research for its innate complexity of physical knowhow. The physics behind the flow and their flow phenomenon is yet to be deciphered in detail. There remains some mathematical paradox, that are yet to be interlinked to the physics of the problem. The present study is a novel attempt in that direction to unravel the physical knowhow that will form the bridge in knowing the details of flapping wing system. The present study is the preliminary research work done in explaining the physical knowhow of the motion of flapping wing aerodynamics.

IndexTerms - Flapping wing dynamics, micro air vehicle, aerodynamics

I. INTRODUCTION

Flapping wing system has been the focus of research since last thirty years. The flapping wing system were first highlighted by Dickenson and Götz [1], after which the path breaking paper of Sanjay P Sane [2] led to the advancement of mathematical models. There are a few works done by Sane and Dickenson [3-4], where the flight dynamics of flapping wings were reviewed. Computational Fluid Dynamics of flapping wings [5-12] have been the focus of research to unravel the intricacies of aerodynamic forces and visualizations. The Fig.1 [2] shown below depicts the basic terminology of wing aerodynamics. In the figure, part A denotes the sketch of an insect, part B is the sectional view of the insect wing, part C denotes the phases of insect wing kinematics and part D denotes linear translation and part E depicts flapping translation.

Figure 1 Basic terminology of wing aerodynamics [2]

The present study is aimed unravelling the flow physics behind rolling motion of flapping wing system, an area which lacks proper understanding. The flapping wing dynamics is replicated in the present model which is aimed at understanding flow physics that plays a key role in its motion.
II. Methodology

The present study is an attempt to study the physics behind the flapping motion aerodynamics. The Fig. 2 below shows the flow direction that takes place in flapping wing aerodynamics. The flow enters from the top of the model as is the case with flapping wings. Normal flying condition is used for the numerical simulation [9].

![Figure 2 Flow domain](image)

III. Results and Discussions

In this simulation the model is set in motion with a preliminary roll amplitude of 30°, pitch amplitude of 5° and yaw amplitude of 0°, where the results are obtained for a flow time of 0.05s. In order to get to know the flow features of flapping wing aerodynamics, velocity vectors, velocity magnitude, contour of total pressure and contours of turbulent intensity that are key components of flapping wing aerodynamics are analyzed for the said flow time. This preliminary study is aimed at understanding the flapping motion aerodynamics that is now the focus of current research perspectives. For the preliminary study, the flow features are observed over the wing domain of the model. The mesh resolution study shown below in Fig.3 that finer mesh of 2017897 elements is adopted for this complex flow study.

![Figure 3 Mesh resolution study](image)

The velocity vectors gives an estimate of the flow behaviour of that takes place in flow domain. As the flapping wing dynamics is time variant, so velocity vectors gives an instantaneous information of the flow behaviour at that particular instant. The velocity vectors, shown below in Fig.4, observes that the flow is developed from the uppermost part of the wing to the lowermost part. There are occasional sudden changes in between that points to uncertain flow features that are predominant in flapping wings.
The velocity magnitude gives first-hand knowledge of the flow variation that is occurring in the flow domain. It can give an estimate of the speed of the flow that can be an important deciding factor for this research for better understanding of its flow physics. The velocity magnitude shown below in Fig. 5 shows the variation of velocity across the flow domain. The flow as usual develops from the uppermost part of the wing as travels to the lowermost part with occasional abrupt changes in between. There are some increment abrupt changes in the flow domain that points to typical flow behaviours of flapping wing aerodynamics.
The main component that can give an important insight to the flow features that affects the flow domain is the total pressure contour. It not only delivers information about the variation of flow parameters, but on which area of the flow domain there is greater incidence of total pressure is objectified. The total pressure contour shown in Fig. 6 paints a more stable phenomenon with less abrupt changes, the changes happening more to the edges than the interior of the wings. Overall there is less change in the total pressure contour across the flow domain, which is another key observation noticed from the simulation results.

The turbulent intensity is a major deciding factor for time varying problem of computational fluid dynamics. In this flapping wing aerodynamics, it gives an estimate of the turbulent structures that are developed in the flow that are observed in the contour plot. The contours of turbulent intensity shown in Fig. 7 predict an overall sudden abrupt increased change in the interior of the wings, while the edges remain stable to much extent. The flow domain paints the interesting flow features that are important aspects of flapping wing aerodynamics.

![Contour of Total Pressure](image.png)
IV. Conclusions

In this research, the flow physics of flapping wing aerodynamics of 3D model replicating the insect flight dynamic is studied by numerical simulation. The preliminary simulation results gives us some insight into interesting flow features which points to some intriguing results in key flow physics parameters that are an important aspect in insect flight dynamics. The sudden and abrupt changes in flow features open up an interesting feature of flow physics of flapping wing aerodynamics that need to be studied in greater detail to understand the various key motion parameters. There is a need of detailed computational analysis that will help in studying the flow features of this challenging research problem in great depth by using more computational power.

References


