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WING ANALYSIS OF A FLAPPING WING UNMANNED AERIAL VEHICLE USING CFD

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***Abstract**:Traditional micro air vehicles (MAVs) are miniature version of full scale air craft from which their design principles closely follow. Non-traditional (UAVs) resemble to the design of birds or insects. A flapping wing model having interaction of aerodynamics and inertial loading which can cause deformation of the wings is designed. This work emphasis on analysis of the using of a flapping wing type of UAV. Wings with different shapes will be analysed and its behaviour will be studied in different air borne conditions. ANSYS CFX solver is used for the analysis purpose.*

***Keywords:** UAVs, Flapping wing, CFD analysis*

I. INTRODUCTION

Drones, also called unmanned aerial vehicles (UAVs), are aircraft without a human pilot on board that can be either remotely piloted or completely autonomous. UAVs are slowly becoming part of our daily lives. While 20 years ago they were almost exclusively used by the military, the recent technological advancements made them accesible even to the general public. Nowadays, UAVs are being used in many fields ranging from aerial photography to remote inspection and small drones can be found in hobby stores for less than e150, including a live video link.
Micro air vehicles (MAVs) are a class of UAVs restricted in size. DARPA originally defined an MAV as a micro-drone of no more than 15 cm. The term, however, started to be used more broadly and refers to smaller UAVs. Thus, palm sized UAVs are sometimes called nano air vehicles. Most MAVs can perform hovering flight and operate indoors, although this is not a requirement. Their popularity over larger UAVs increases as they are easily portable, more discreet and less dangerous in case of a crash.

Fig.1Unmanned Aerial vehicle

II.UAV Applications

UAVs are being used in various fields and their number is growing (Figure 1). Traditionally, UAVs are equipped with an on-board camera and provide a live video feed to the operator or to the ground station. They can be, however, also equipped with other sensor types (chemical, biological, radiation).The obvious application of camera equipped UAVs is video surveillance and reconnaissance. Apart from military use, the UAVs are starting to be employed by police and fire brigades. No men aboard and much lower costs compared to traditional aircraft allows their use even in risky conditions. The UAVs can be deployed during natural catastrophes or after terrorism acts to quickly map the situation, find access routes, identify potential dangers, look for victims, their small size allows them even to enter into buildings through windows and fly through confined spaces.Another field of application is aerial photography. Images from a bird's-eye view are used for cartography, but also in archaeology, biology or in urbanism. UAVs were also quickly adopted in sports-photography and cinematography to shoot action scenes from unusual perspectives. UAVs are further used for remote inspection of pipelines or power lines, as well as by farmers for inspecting their fields and choosing the optimal moment for fertilization or harvest. Security applications like patrolling around private properties or along the borderlines are also emerging. Last but not least, the use of UAVs for goods deliveries is being explored.

III. LITERATURE SURVEY

Martin Alexander Jones [1] "CFD Analysis and Design Optimization of Flapping Wing Flows", North Carolina A&T State University,2013

The main objectives of this research work are to perform the CFD analysis of the 3-D flow around a flapping wing in a gusty environment and to optimize its kinematics and shape to maximize the performance. The effects of frontal, side, and downward wind gusts on the aerodynamic characteristics of a rigid wing undergoing insect-based flapping motion are analyzed numerically. (Fig 1)The turbulent, low-Reynolds-number flow near a flapping wing is governed by the 3-D unsteady Reynolds-Averaged Navier-Stokes (URANS) equations.

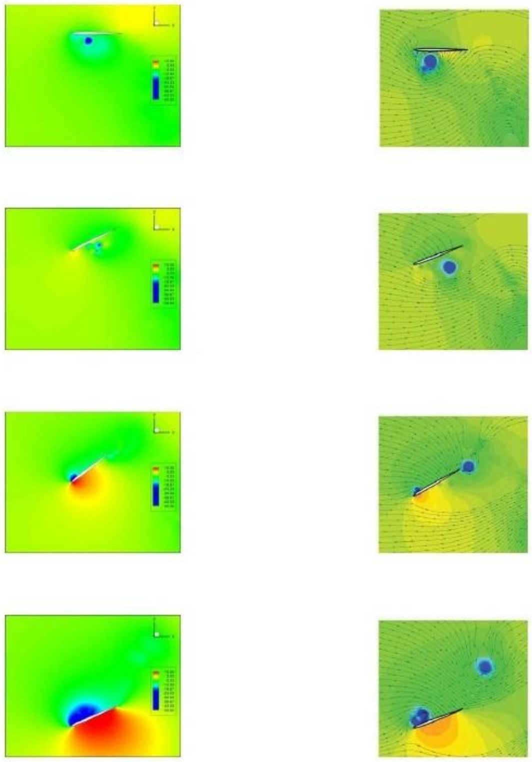

Figure 1 Comparison of pressure coefficient contours computed using the FUN3D code

Satish K. Chimakurthi, Bret K. Stanford, Carlos E. S. Cesnik, and Wei Shyy [2] "Flapping Wing Cfd/Csd Aero Elastic Formulation Based On A Co Rotational Shell Finite Element" AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference 17th 4 - 7 May 2009, Palm Springs, California

Flexible flapping wings have garnered a large amount of attention within the micro aerial vehicle (MAV) community: a critical component of MAV flight is the coupling of aerodynamics and structural dynamics. This paper presents a computational framework for simulating shell-like wing structures flapping in incompressible flow at low Reynolds numbers in both hover and forward flight. The framework is developed by coupling an in-house co-rotational finite element structural dynamics solver suitable for small. strain and large rotations, to an in-house pressure-based Navier-Stokes solver. The development of the computational structural dynamics (CSD) solver and its coupling with the computational fluid dynamics (CFD) solver is discussed in detail. Validation studies are presented for both the CSD and the aeroelastic solvers using different wing configurations. Structural dynamics solutions are presented for rectangular wings with either a prescribed plunge or a single degree-of-freedom flapping motion. The aeroelastic response is computed for two different wing configurations: 1) a thin-plate rectangular aluminum wing (aspect ratio 6) undergoing a single-axis large amplitude flapping motion and 2) a rectangular wing of NACA0012 cross-section (aspect ratio 6) under a pure plunge motion. Results are validated against available experimental data and those obtained from a different aeroelasticity framework previously developed by the authors.

A. Roshanbin, C. Collette, A. Preumont [3] "Mathematical Modelling Of Insect–Like Flapping Wings For Application To Mavs" University of Brussels av. F.D.Roosevelt 50,1050 Brussels – Belgium

The flight of birds or insects has fascinated physicists and biologists for many centuries. Flapping motion, as shown by many nature flyers, is the most efficient way of flying objects whose size are smaller than 15 cm. In this paper a mathematical modelling of insect-like flapping wings for application to MAVs is presented. To this aim, the first part of the paper gives a brief review of unsteady aerodynamics for flapping wing flight and the most important physical features of the flow are identified. Then a simulation of comprehensive nonlinear MAV model based on quasi-steady method is developed. This model enables us to investigate the influence of each parameter change in flight force generation.

Gabriel Torres and Thomas J. Mueller [4] "Micro Aerial Vehicle Development: Design, Components, Fabrication, And Flight-Testing" Gabriel Torres and Thomas J. Mueller, University of Notre Dame,2010

The design of micro aerial vehicles (MAVs) is currently hindered by the lack of a thorough understanding of the flow physics of very small aircraft flying at low speeds. Trial and error has been the most effective design tool in many cases, often leading to lengthy and costly design processes. The unavailability of complete analytical methods and the computational expense of numerical methods make an empirically-based design optimization approach a practical alternative. This paper will describe the use of wind tunnel data in the implementation of such a procedure for the design of a micro aerial vehicle. This MAV was the University of Notre Dame's entry for the fourth annual Micro Aerial Vehicle Student Competition, held at Fort Huachuca, AZ in May 2000. Restrictions imposed by the use of COTS components, as well as issues in fabrication and durability will be discussed. Key features of the final MAV prototype will be outlined and a summary of test flights will be presented.

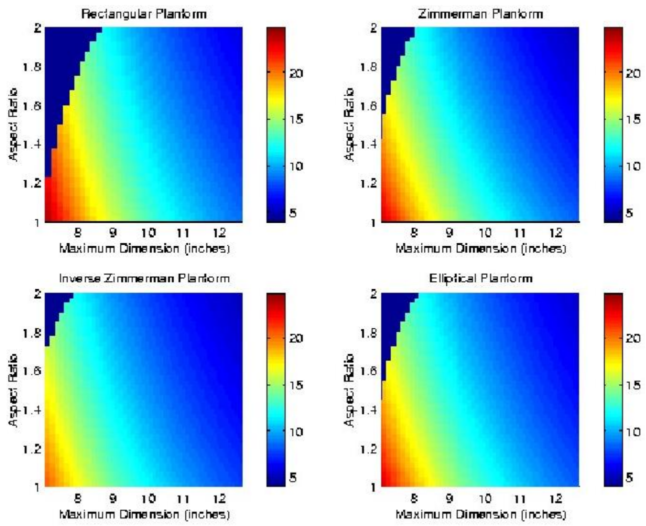

Figure 2Angle of Attack Needed to Achieve CL, req. as a function of Maximum Dimension and AR

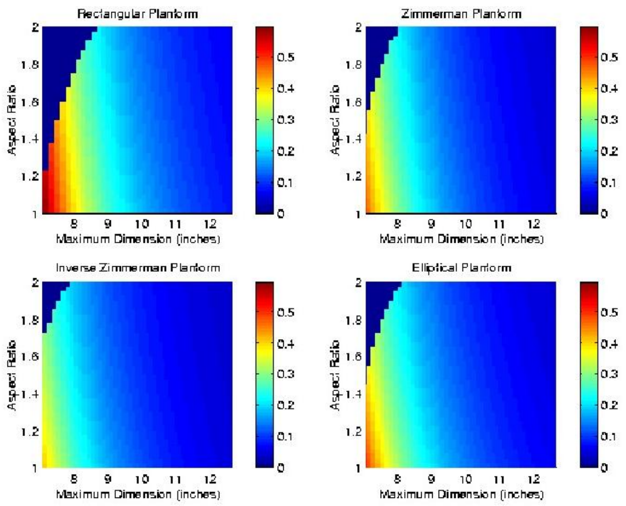

Figure 3Drag Coefficient at CL, req. as a function of
Maximum Dimension and AR

AriefSuhariyono, Jong Hyun Kim, Nam Seo Goo HoonCheol Park, KwangJoon Yoon [5] "Design of Precision Balance And Aerodynamic Characteristic Measurement System For Micro Aerial Vehicles"sciencedirect,2005

This paper presents the design and validation of a measurement system for the aerodynamic characteristics of micro aerial vehicles. Micro aerial vehicles are very small, have a wingspan of about 100–150 mm, and operate at relatively low Reynolds numbers. A precision aerodynamic balance was designed in order to measure the lift, drag, rolling-moment, and pitching-moment of micro air vehicles, as these parameters are too small to be determined by general-purpose aerodynamic measurement systems. During the design process, the aerodynamic balance was analyzed with the finite-element method in order to produce an optimal design and was calibrated as well. The calibration results and the finite element analysis results were compared and found to be in good agreement and the final design was determined to be acceptable. In addition, a computer- based data acquisition system has been developed to acquire measurement data from the aerodynamic balance. Wind tunnel tests of a 2D airfoil were performed to validate the aerodynamic measurement system. Results of the wind tunnel tests were compared with references and found to be in good agreement. Finally, we measured aerodynamic characteristics of MAV wing model used in Batwing with the developed aerodynamic measurement system.

Mr T. Spoerry1, Dr K.C. Wong [6] "DESIGN AND DEVELOPMENT OF A MICRO AIR VEHICLE (µav) CONCEPT: PROJECT BIDULE" University of Sydney NSW 2006

This paper presents an analysis of the concept of Miniature Air Vehicles and Micro Air Vehicles mainly carried out through the development of a mAV prototype called "Bidule", which was first successfully flown in 1998. The final objective of the project is to reduce the size of this miniature demonstrator to a micro sized vehicle. This paper presents the initial work done to achieve this goal with a particular interest in the aerodynamics of the present vehicle. In keeping with the context of a vehicle's size reduction, a preliminary quantitative approach of the concept shows that the tiny size of mAVs and UAVs creates a strong coupling between the different design fields and requires a high degree of integration. Therefore, reducing the size of an aerial vehicle has major consequences on the performance, especially in terms of endurance. Conserving the operational capabilities of the "Bidule" then requires considering the interactions between the different design parameters, with a particular attention being paid to the wing loading and a high maximum lift. The wind tunnel testing of a propelled model of the "Bidule" prototype shows that the basic design benefits from the prop-wash effect in terms of increased lift. In the context of size reduction to the present vehicle, the results suggest keeping the idea of a wing body immersed in a propeller slipstream, providing that the destabilising effects due to the power system and the prop-wash can be kept to an acceptable level.

Lung-Jieh Yang, Cheng-Kuei Hsu, Jen-Yang Ho, Chao-Kang Feng [7] "Flapping Wings With Pvdf Sensors To Modify The Aerodynamic Forces Of A Micro Aerial VEHICLE" sciencedirect,2007

The flight of birds or insects has fascinated scholars and physicists for many centuries. Flapping motion, as shown by many nature flyers, is the most efficient way of flying objects whose size are smaller than 6 in. In this paper, we used MEMS technology to fabricate the flapping wings. They are composed of a pure parylene right wing and a PVDF–parylene composite left wing. In the wind-tunnel test, the lift signals from both PVDF (polyvinylidene fluoride) and the load-cell have similar qualitative behavior. (fig 2)The PVDF sensor could only export the lift signals from the left wing. By comparing to the total lift signal picked by the load-cell from the wind-tunnel facility, we can calculate out and separate the lift contributions by left and right wing, respectively. Therefore, we found a new design methodology to adjust the aerodynamic performance of MAV by changing the phase lag between the two flapping wings by fine tuning of the mechanism linkages. After integrating lithium battery into the MAV, it can perform a free flight with a range of 10–15 m. Finally, the MAV had a successful flight via wireless control with a range of 40 m and a total flight time of 10 s.

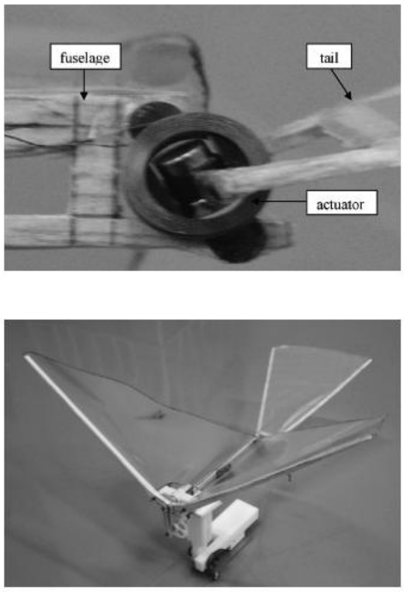

Figure 4The appearance of modified MA V with the configuration of Wing.

HarijonoDjojodihardjoaa, AlifSyamimSyazwanRamlib and SurjatinWiriadidjajac [8] "Kinematic And Aerodynamic Modelling Of Flapping Wing Ornithopter" International Conference on Advances Science and Contemporary Engineering 2012

A generic approach is carried out to model the kinematics and aerodynamics of ornithopter to mimic flapping wing to produce lift and thrust for hovering and forward flight, by considering the motion of a three-dimensional rigidthin wing in flapping and pitching motion with phase lag. Basic Unsteady Aerodynamic Approach incorporating salient features of viscous effect and leading-edge suction will be utilized. Parametric study is carried out to reveal the aerodynamic characteristics of ornithopter flight characteristics and for the analysis of various selected simple models in the literature, in an effort to develop a flying ortnithopter model. Further considerations will be given to other important parameters such as flapping frequency and wing geometry for well-conceived formulations with realistic and workable assumptions and limitations.

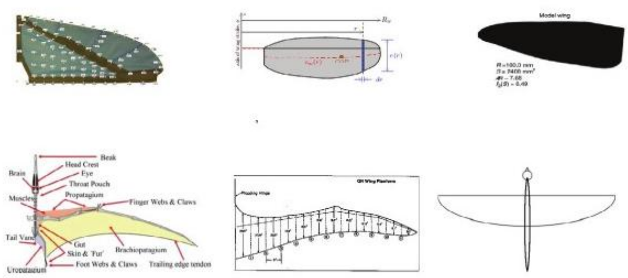

Figure 5: A generic semi-elliptical ornithopter s wing planform with the backdrop of various wing-planform geometries

Results and Discussion

The advantage of the wing twist modulation mechanism is that it is fully independent on the flapping mechanism. It acts at the wing root bar ends, where thereaction forces, that it needs to hold, are relatively small (compared to the secondsolution). This is advantageous as it permits the use of smaller and lighter actuators.Moreover, the use of flexible root bars instead of universal joints greatly reduces themechanism complexity. On the other hand, the wing twist modulation concept re-quires a specific wing design, whose lift force varies approximately linearly with theroot bar deformation. This requires that the wing at the nominal bar position isoperated below its maximal lift.resulted in savings in computational time, core memory requirement and cost of analysis

IV. CONCLUSIONS

We have given a brief overview of the This research offers a perspective into progress and challenges associated with the design of micro air vehicles and investigates the flapping flight dynamics of the MAV's forward flight. The research attempts to systematize the available scientific information for MAV development. Also, it presents a new experimental approach for the development ofMAVs that can also be used in other areas of engineering where dynamic results arerequired. Finally, the research utilizes a fully nonlinear finite element analysis coupledwith the aerodynamic solution technique to investigate the deformation of the wing during flapping flight.

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