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Design And Computational Analysis of Fixed Wing of Micro Aerial Vehicle

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Abstract

Micro Aerial Vehicle (MAV) whose wingspan is of the order of a few centimeters cannot be physically built or flown today; they can be designed, tested, flown and studied on the computer using numerical simulation technique. While finalizing a design is quite significant in case of MAV, understanding the flow field environment in which MAVs fly is equally a requirement. The flow field environments encountered by Micro Air Vehicles (MAVs) are fundamentally unsteady – whether for fixed- wing, rotary-wing or flapping-wing configurations. High lift generation is typically a result of unsteady fluid flow phenomena in flapping flight of small birds and insects. Along with a good understanding of flow field environment of an MAV the insight into the aerodynamics characteristics of it calls for an investigation. These characteristics greatly influence the design of a prototype of an MAV which can serve the purpose of a specific application.

As a first step towards exploring the flow environment and computing the aerodynamic characteristics of a smaller MAV we have chosen a fixed wing MAV for which a study is attempted considering a three dimensional flow field. In the present study, unsteady aerodynamic analysis of the MAV has been done using commercial CFD solver ANSYS FLUENT. The analysis aim at predicting aerodynamic characteristics such as flow visualization, pressure plots, velocity plots and also stream line over the wing. During the study it is observed that the pressure and velocity are both compared well for the mid-range angle of attacks 0 and 20 degree AOA.

OVER VIEW OF EMBEDDED SYSTEMS

Embedded systems are electronic devices that incorporate microprocessors with in Their implementations. The main purposes of the microprocessors are to simplify the system design and provide flexibility. Having a microprocessor in the device means that removing the bugs, making modifications, or adding new features are only matters of rewriting the software that controls the device. Or in other words embedded computer systems are electronic systems that include a microcomputer to perform a specific dedicated application. The computer is hidden inside these products. Embedded systems are ubiquitous. Every week millions of tiny computer chips come pouring out of factories finding their way into our everyday products.

Embedded systems are self-contained programs that are embedded within a piece of hardware. Whereas a regular computer has many different applications and software that can be applied to various tasks, embedded systems are usually set to a specific task that cannot be altered without physically manipulating the circuitry. Another way to think of an embedded system is as a computer system that is created with optimal efficiency, thereby allowing it to complete specific functions as quickly as possible. Embedded systems designers usually have a significant grasp of hardware technologies. They used specific programming languages and software to develop embedded systems and manipulate the equipment. When searching online, companies offer embedded systems development kits and other embedded systems tools for use by engineers and businesses.

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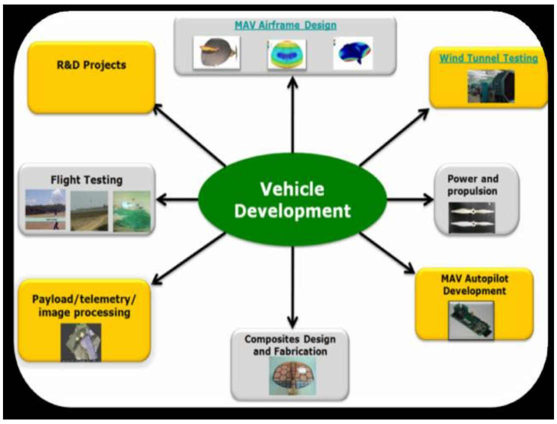
Embedded systems technologies are usually fairly expensive due to the necessary development time and built in efficiencies, but they are also highly valued in specific industries. Smaller businesses may wish to hire a consultant to determine what sort of embedded systems will add value to your organization.

INTRODUCTION TO THE PROJECT

A bird or insect sized flapping wing Micro Aerial Vehicle (MAV) whose wingspan is of the order of a few centimeters cannot be physically built or flown today; they can be designed, tested, flown and studied on the computer using numerical simulation technique. While finalizing a design is quite significant in case of MAV, understanding the flow field environment in which MAVs fly is equally a requirement.

The flow field environments encountered by Micro Air Vehicles (MAVs) are fundamentally unsteady – whether for fixed wing, rotary-wing or flapping-wing configurations. High lift generation is typically a result of unsteady fluid flow phenomena in flapping flight of small birds and insects. Micro air vehicles (MAVs) have attracted significant attention since mid-1990 for both civilian and military applications. Micro Air Vehicle (MAV) is defined here as a small, portable flying vehicle which is designed for performing useful work. The desire for portable, low altitude aerial surveillance has driven the development of aircraft on the scale of small birds. Vehicles in this class of small-scale aircraft are known as Micro Air Vehicles or MAVs, and have great potential for applications in surveillance and monitoring tasks in areas either too remote or too dangerous to send human agents. Equipped with small video cameras and transmitters, MAVs can image targets that would otherwise remain inaccessible

Unsteady aerodynamics plays a significant role in MAV flight and stability. Unsteady phenomena may arise due to natural time dependent changes in the flow itself or it may be created by changes in the position or orientation of a body. In many unsteady flows of interest, the important unsteady aspects involve not only the kinematic changes in boundary conditions caused by the motion of a body, but the influence of an unsteady wake, and the changes in the pressure-velocity relationship associated with the unsteady form of Bernoulli's equation. Mechanisms such as rotational circulation, wake capture, and the unsteady leading edge vortex do seem to properly account for the aerodynamics forces. Regarding forward flight, the unsteady leading edge vortex is the only mechanism present to produce the necessary forces. The unsteady leading edge vortex involves leading edge flow separation that reattaches to the wing and forms a separation bubble. The vortex increases the circulation around the wing and creates much higher lift than the steady-state case.



Low Reynolds numbers make the problem of airfoil design difficult because the boundary layer is much less capable of handling an adverse pressure gradient without separation. Thus, very low Reynolds number designs do not have severe pressure gradients and the maximum lift capability is restricted. At very low Reynolds numbers, most or all of the boundary layer is laminar. Laminar separation bubbles are common and unless properly stabilized can lead to excessive drag and low maximum lift. The above discussion on low Reynolds number aerodynamics has generated lot of

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interest to investigate computationally the unsteady aerodynamic phenomenon over a fixed wing of an MAV. The problem is to determine the Aerodynamic characteristic such as Pressure distribution, Lift coefficient, Drag coefficient and Moment coefficient over the fixed wing MAV at different flight conditions. While solving the above problem it is attempted to keep the fulfillment of the following two key objectives.
Instead of traditional sensors and computational devices, which are too heavy for most MAVs, the SFD combined a stereo-vision system with a ground station to control the flight altitude, making it the first flapping-wing MAV under 10 grams that realized autonomous flight.

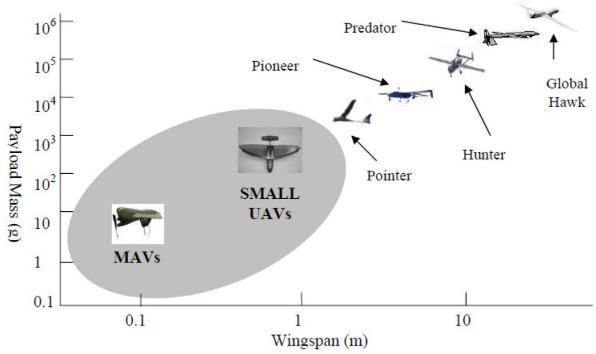
In 2008, the TU Delft University in the Netherlands developed the smallest ornithopter fitted with a camera, the DelFly Micro, the third version of the DelFly project that started in 2005. This version measures 10 centimeters and weighs 3 grams, slightly larger (and noisier) than the dragonfly on which it was modeled. The importance of the camera lies in remote control when the DelFly is out of sight. However, this version has not yet been successfully tested outside, although it performs well indoors. Researcher David Lentink of Wageningen University, who participated in the development of previous models, DelFly I and DelFly II, says it will take at least half a century to mimic the capabilities of insects, with their low energy consumption and multitude of sensors—not only eyes, but gyroscopes, wind sensors, and much more.

Practical Implementations

In January 2010, the Tamkang University (TKU) in Taiwan realized autonomous control of the flight altitude of an 8-gram, 20-centimeter wide, flapping-wing MAV. The MEMS Lab in the TKU has been developing MAVs for several years, and since 2007 the Space and Flight Dynamics (SFD) Lab has joined the research team for the development of autonomous flight of MAVs.

Background

Propeller theory dates back to Rankine's 1865 study of marine propellers.8 His theory modeled the fluid momentum equations of an 'actuator disk,' or a rotor with an infinite number of blades. In 1878 W. Froude introduced blade element theory, which considered a propeller's geometry and modeled the blade as the sum of independent two-dimensional airfoil sections.9 further progress was made in the early 20th century when Prandtl' swing lifting line theory introduced the concept of the vortex sheet. This was applied to propellers to optimize and predict performance. Classical vortex theory was developed by Betz,10 Prandtl,11 Goldstein,12 Theodorsen,12 and others. In 1919, Betz identified the conditions for minimum induced loss, known as the "Betz condition," which calls for a prescribed "rigid" vortex sheet of constant pitch in the trailing wake of the propeller. Prandtl developed a closed-form approximation for the flow around this helicoidal wake based on two-dimensional flow



LITERATURE SURVEY

Types of Micro Aerial Vehicles

- Fixed Wing Type
- Flapping Wing Type
- Rotary Wing Type

Fixed wing type micro aerial vehicles.

VISION-BASED CONTROL

MAVs seem to fit the bill for the type of flight operations described above, but there is currently no sensor or navigational hardware small enough to make this possible. Steps are however being made to make

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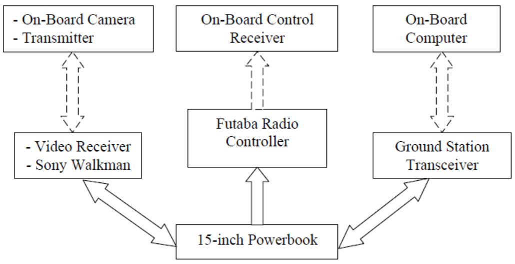
these lacking pieces available to the autonomy flight puzzle. An autopilot system is currently being developed by the University of Florida that utilizes a vision-based horizon tracking system combined with waypoint navigational software and hardware.

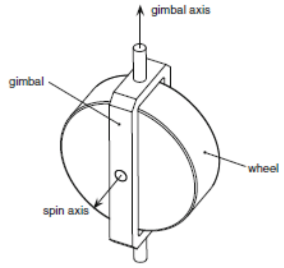
The control loop, shown in Figure, starts with collecting all the sensor and video data, and they are streamed back to the ground station from on-board computer. After these data are processed, control commands will be sent back to the airplane by a custom interface and the trainer function on a Futaba RC controller, which allows switching between computer and human control instantaneously



Practical Limitations

Although there are currently no true MAVs (i.e., truly micro scaled flyers) in existence, DARPA has attempted a program to develop even smaller Nano Air Vehicles (NAVs) with a wingspan of 7.5 centimeters. However, no NAVs meeting DARPA's original program specification were forthcoming until 2009 when Aero environment demonstrated a controlled hovering of DARPA's flapping-wing NAV4 Control Moment Gyroscopes

Momentum Exchange Devices (MEDs) are commonly employed to reorient spacecraft such as the International Space Station (ISS), satellites, and robotic space systems. Their main component is a spinning wheel or rotor that is used to exert internal torques on the vehicle for attitude control.



Avionics & Integration

CommerciallyofftheShelfcomponentslikeMotor,Propeller,ESC,Servomotor,Battery,Autopilot,DataModem,Camera (payload),VideoTransmitter are tested and qualified for performance and then integrated with the Micro Air Vehicle for Autonomous flight operations.

Flapping Wing Studies

UnsteadyAerodynamicCharacterizesfromforcemeasurementsandFlowfieldmeasurementsinwindtunnel.Planformgeometries,wingmaterialproperties,flexuralstiffnessontheAerodynamicperformanceofflappingwingMAV.Designofgearandtransmissionsystems

Antenna Tracking System

Tracks MAV to receive video signal without any interruption based on the GPS data. The GPS locationoftheMAVistransmittedtothetrackerandtheservo systempositiontheantennatherebyensuringahighsignalstrength.Thesystemisunderfieldtrailsandwillsoonbeavailabletotheusers.

Product Engineering

Productengineeringconcepthasbeenbroughtintothedesignofthe MAVsforeasyassebly,testing,transportationandcrashresistantproofandrobustnessandreliability.Lightweight highstrengthmaterials,multifunctionalconnectorsandcomponentsareusedinthisdesign.

DESIGN METHODOLOGY

Introduction to Catia

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Assault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Assault Systems product lifecycle management software suite.

CATIA competes in the CAD/CAM/CAE market with Siemens NX, Pro/E, Autodesk Inventor, and Solid Edge as well as many others.

Scope of Application

Commonly referred to as 3D Product Lifecycle Management software suite, CATIA supports multiple stages of product development (CAx), from conceptualization, design (CAD), manufacturing (CAM), and engineering (CAE). CATIA facilitates collaborative engineering across disciplines, including surfacing & shape design, mechanical engineering, equipment and systems engineering

Mechanical Engineering

CATIA enables the creation of 3D parts, from 3D sketches, sheet metal, composites, and molded, forged or tooling parts up to the definition of mechanical assemblies. It provides tools to complete product definition, including functional tolerances, as well as kinematics definition.

Equipment Design

CATIA facilitates the design of electronic, electrical as well as distributed systems such as fluid and HVAC systems, all the way to the production of documentation for manufacturing.

Systems Engineering

CATIA offers a solution to model complex and intelligent products through the systems engineering approach. It covers the requirements definition, the systems architecture, the behavior modeling and the virtual product or embedded software generation. CATIA can be customized via application programming interfaces (API).

Aerospace

The Boeing Company used CATIA V3 to develop its777 airliner, and is currently using CATIA V5 for the787 series aircraft. They have employed the full range of Dassault Systems' 3D PLM products — CATIA, DELMIA, and ENOVIALCA — supplemented by Boeing developed applications.

- The development of the Indian Light Combat Aircraft has been using CATIA V5.
- Chinese Xian JH-7 A is the first aircraft developed by CATIA V5, when the design was completed on September 26, 2000.
- European aerospace giant Airbus has been using CATIA since 2001.

Automotive

Many automotive companies use CATIA to varying degrees, including BMW, Porsche, Daimler AG, Chrysler, Honda, Audi, Jaguar Land Rover Volkswagen, Bentley Motors Limited, Volvo, Fiat, Benteler AG, PSA Peugeot Citroën, Renault, Toyota, Ford, Scania, Hyundai, Skoda Auto, Tesla Motors, Valmet Automotive, Proton, Tata motors and Mahindra & Mahindra Limited. Goodyear uses it in making tires for automotive and aerospace and also uses a customized CATIA for its design and development

COMPUTATIONAL FLUID ANALYSIS

Introduction to Computational Fluid Dynamics (Cfd)

Fluid dynamics deals with the dynamic behavior of fluids and its mathematical interpretation is called as Computational Fluid Dynamics. Fluid dynamics is governed by sets of partial differential equations, which in most cases are difficult or rather impossible to obtain analytical solution. CFD is a computational technology that enables the study of dynamics of things that flow. The Physical aspects of any fluid flow are governed by three fundamental principles: Mass is conserved; Newton's second law and Energy is conserved. These fundamental principles can be expressed in terms of mathematical equations, which in their most general form are usually partial differential equations. Computational Fluid Dynamics is the science of determining a numerical solution to the governing equations of fluid flow whilst advancing the solution through space or time to obtain a numerical description of the complete flow field of interest.

Energy Equation

$$\frac{\partial}{\partial t}\left(\rho e+\frac{1}{2}\rho v^2\right)+\frac{\partial}{\partial x}\left(\rho ue+\frac{1}{2}\rho uv^2\right)+\frac{\partial}{\partial y}\left(\rho ve+\frac{1}{2}\rho vv^2\right)+\frac{\partial}{\partial z}\left(\rho we+\frac{1}{2}\rho wv^2\right)=$$
$$k\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial xz^2}\right)-\left(u\frac{\partial p}{\partial x}+v\frac{\partial p}{\partial y}+w\frac{\partial p}{\partial z}\right)+$$
$$\mu\left[u\frac{\partial^2 u}{\partial x^2}+\frac{\partial}{\partial x}\left(v\frac{\partial v}{\partial x}+w\frac{\partial w}{\partial x}\right)+v\frac{\partial^2 u}{\partial y^2}+\frac{\partial}{\partial y}\left(u\frac{\partial u}{\partial y}+w\frac{\partial w}{\partial y}\right)+w\frac{\partial^2 u}{\partial z^2}+\frac{\partial}{\partial z}\left(u\frac{\partial u}{\partial z}+v\frac{\partial v}{\partial z}\right)\right]$$
$$+2\mu\left[\frac{\partial^2 u}{\partial x^2}+\frac{\partial u}{\partial y}\frac{\partial v}{\partial x}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial v}{\partial z}\frac{\partial w}{\partial y}+\frac{\partial^2 w}{\partial z^2}+\frac{\partial w}{\partial x}\frac{\partial u}{\partial z}\right]+\rho ug_x+\rho vg_y+\rho wg_z$$

Steps involved in solving problem

- First create the grid of appropriate dimensions and with appropriate step length to specify the problem domain in Ansys modeler workbench.
- Create geometries like Vertices at appropriate grid points.
- Create lines joining two vertices.
- Create Areas selecting all the lines.
- Create Boundary Mesh around the cylinder.
- Create Face Mesh to rest of the model.
- Give the Boundary Conditions for entire domain.
- Save it and export it to mesh file.
- Read the file in CFX and check the mesh and scale the model.
- Enter values for boundary conditions, operating conditions etc.
- Selecting the appropriate solver to solve the problem.
- Solve the problem by initializing from velocity inlet and specifying the number of iterations.
- Solve the problem and note down the results.

The Advantages of CFD

Basically, the compelling reasons to use CFD are these three:

Insight: There are many devices and systems that are very difficult to prototype. Often, CFD analysis shows parts of the system or phenomena happening within the system that would not otherwise be visible through any other means. CFD gives a means of visualizing and enhanced understanding of your designs. Foresight: Because CFD is a tool for predicting what will happen under a given set of circumstances, it can answer many ‘what if?’ questions very quickly. Provided the variables it gives you outcomes. In a short time, CFD can predict design performance, and hence number of variants can be tested until optimal result is found.

GLOBAL POSITIONING SYSTEM (GPS)

The Global Positioning System (GPS) is a space-based global navigation satellite system (GNSS) that provides reliable location and time information in all weather and at all times and anywhere on or near the Earth when and where there is an unobstructed line of sight to four or more GPS satellites. It is maintained by the United States government and is freely accessible by anyone with a GPS receiver. When people talk about "a GPS," they usually mean a GPS receiver.

The Global Positioning System (GPS) is actually a constellation of 27 Earth-orbiting satellites (24 in operation and three extras in case one fails). The U.S. military developed and implemented this satellite network as a military navigation system, but soon opened it up to everybody else. Each of these 3,000- to 4,000-pound solar-powered satellites circles the globe at about 12,000 miles (19,300 km), making two complete rotations every day.

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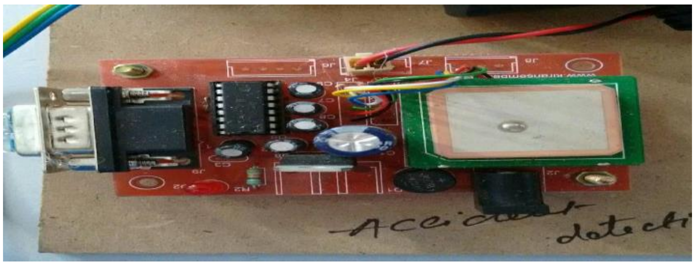
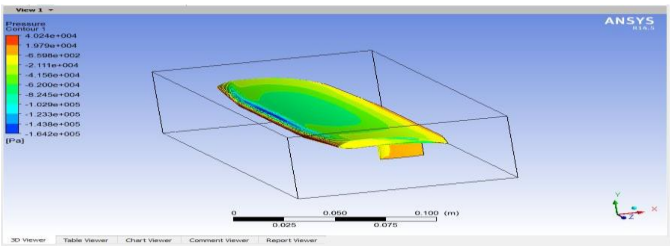
GPS Device



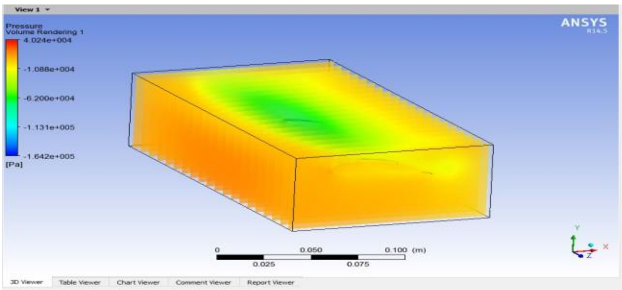
Pressure Contour Result

In this pressure contour plot we are getting the pressure values for the zero angle of attack for the micro aerial vehicle wing, In this the minimal pressure acts upper edge of the wing i.e. -1.642 e^{+005} Pa . And maximum pressure value for the lower edge of the wing i.e. 4.024 e^{+004}.Pa.



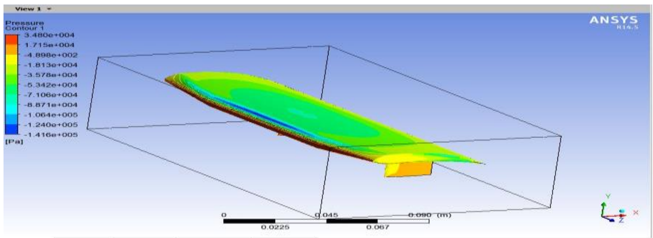
Pressure Volume Rendering

In this volume rendering the pressure and velocity volume rendering is shown in the following figure.



Pressure Contour Result

In this pressure contour plot we are getting the pressure values for the zero angle of attack for the micro aerial vehicle wing, In this the minimal pressure acts upper edge of the wing i.e. -1,416 e^{+005} Pa . And maximum pressure value for the lower edge of the wing i.e. 3.480 e^{+004}Pa.



Pressure Volume Rendering

Angle of attack	Pressure(Pa)		Velocity(ms^-1)	
	min	max	min	max
α =0⁰	-1.642e^005	4.024e^004	1.528	4.852e^002
α =20⁰	-1.416e^005	3.480e^004	2.340	4.555e^002

Angle of attack	Pressure volume rendering (Pa)		Velocity volume rendering(ms^-1)	
	min	max	min	max
α =0⁰	-1.642e^005	4.024e^004	0	4.764e^002
α =20⁰	-1.416e^005	3.480e^004	0	4.435e^002

Conclusion and Future scope

By this concluding that the flow visualization are shown over the micro aerial vehicle wing. And the pressure values of contour plots calculated over the wing at two angle of attack at 0 and 20 degrees. The pressure values are also changing by the change of angle of attack. And the velocity streamlines over the wing are plotted at two different angle of attack, due to changes of angle of attack the velocity values are also changes.

By this original model may vary because the model we tested is a smaller in size.

It may or may not be exits because the size. The model is designed in computationally. The future scope of this project may useful for the analysis of micro aerial vehicle in different areas of use.

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