ANALYZING THE PROGRESS IN MICRO AERIAL VEHICLE DEVELOPMENT

Abstract

Micro air vehicles (MAVs) are miniature unmanned aerial vehicles with a size restriction of 5 centimeters, designed for various applications such as boarder surveillance, weather forecasting, pipe inspection, traffic monitoring, fire and rescue. MAVs are primarily used for aerial robotics contests, aerial photography, boarder surveillance, weather forecasting, pipe inspection, traffic monitoring, and fire and rescue. They consist of components like actuators, sensors, communication systems, microprocessors, electric motors, batteries, IC engines, fly wheels, and capacitors. The paper reviews the developmental changes in MAV design and the mechanisms influencing design parameters.

Keywords: MAV, Aerodynamics, Flapping wings, Reynolds Number.

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A brief study on papers related to MAVs was done. Many authors gave different ideas related to their works on micro air vehicles especially on wing structure design. The various design parameters determine the effectiveness. This paper reviews the important works done on MAVs, discusses the contemporary trends and compares various approaches.

Boris Bataille *et. al* [1], explores the potential of fixed-wing Micro Air Vehicles (MAVs) with flying capabilities to enhance their aerodynamic performance. The researchers compared monoplane wing plan forms with biplane concepts using wind tunnel measurements and numerical calculations. They found that a biplane-twin propeller MAV configuration can expressively increase low-speed and high-speed aerodynamic performance. The control in hover flight also aids from the effect of counter-rotating propellers. The authors suggest a control strategy for autonomous transition between forward and hover flights, focusing on hardware and software architectures for real flight. They recommend three design rules for low-speed flight while maintaining good aerodynamic performance in cruise: Plan form, keeping the aspect ratio under 1.7, and reaching a maximum lift-to-drag ratio for moderate camber values.

J.G.Sloan *et. al* [2], emphasized on optimizing airfoil and wing planform for micro air vehicles using response surface methodology. It uses various approaches, including a constant cross-section wing with maximum camber, maximum thickness, and aspect ratio at different Reynolds numbers, a variable cross-section wing defined by root camber and angle of attack, and a fixed-span approach for aircraft subject to steady flight constraints. The third approach balances trade-offs between wing area, aspect ratio, and Reynolds number to determine overall flight efficiency. Optimal airfoils show little change with wing aspect ratio or wing planform location. There is a trend of increasing optimal camber with decreasing Reynolds number. The optimal design favors airfoils with minimum thickness and modest camber, but a higher camber may be better if a higher lift coefficient at minimum power is used as the design goal. Measurements of global and local response surface prediction accuracy and design space refinement help assess the reliability of response surface approximations and optimal design predictions.

Vijayakumar Kolandapaiyan *et. al* [3], discussed the development of foldable wing structures for micro-air vehicles (MAVs), with the goal of creating a mission-based MAV that can be packed in a small volume, unpacked quickly, and deployed in time-critical situations. The article also highlights the canister design's folding wing potential. The authors examine foldable wing profiles, composite material selection, orientation, 3D printing, and component selection. They do structural stress analyses of rectangle and taper wing shapes for CFRP and GFRP materials, build foldable wings and canister designs, and research rapid prototyping techniques. The report also emphasizes the significance of component selection for the overall MAV.

Rajeev Kumar *et. al* [4], investigates the design of insect-inspired micro-air vehicles, with a focus on flapping locust hind wings. Three pairs of artificial wings of variable stiffness are designed, built, and tested. The kinematics of locust wings are characterized in order to construct two transmissions: simply flapping and a combination of active pitching and flapping. Force data for both wings is collected, and stroke-averaged results are discussed. A radio-controlled ornithopter with a 14-cm wingspan has been designed and manufactured, and it has been successfully tested for controlled flight and moderate wind resistance.

Omuzi A. Hudson *e.t al* [5], addressed the design and dynamic simulation of a leaping mechanism for flight initiation in flapping wing aerial vehicles to improve their autonomous mobility. Inspired by bird pilots, a 4-bar linkage is geometrically constructed for take-off manoeuvres, with kinematic dimensions calculated analytically. Because of its compact design and low power consumption, a magnetic latching solenoid actuator and gearbox mechanism are proposed for leaping actuation. The study also highlights the need of keeping the aerial vehicle aloft by providing enough supportive forces at low air speeds. The fluid-structure interaction is investigated using co-simulation in ADAMS and MATLAB/Simulink. The planned legs give an angled take-off of approximately 640 and an initial speed of nearly 2m/s with an angular deflection of 1100 between leg segments. The flight performance is improving.

Y. D. Dwivedi *et. al* [6], studied the 2-D panel approach was used to investigate the aerodynamic performance of micro-aerial wing structures at low Reynolds numbers. They studied lift/drag and glide ratio coefficients in a wind tunnel for incompressible flow regimes at two Reynolds numbers and angles of attack. For low angles of attack, the results revealed good agreement between experimental and panel approaches. Corrugated airfoils outperformed NACA0010 in terms of lift coefficient and drag coefficient until 80 degrees of attack. The panel approach was used to validate surface pressure coefficients at 40 angles of attack. The study concluded that corrugated airfoils outperformed NACA0010 in terms of aerodynamic performance, with a strong correlation between experiment data and computational approaches.

T Nakata *et. al* [7], The research looks at the aerodynamics of a hummingbird-inspired bio-inspired flexible flapping-wing micro air vehicle (MAV). It creates a realistic flapping flexible wing model using a computational fluid dynamics (CFD) approach and wind tunnel studies. This model forecasts the four-winged MAV's unstable aerodynamics, including vortex and wake structures and their relationship to aerodynamic force generation. The CFD research also offers a thorough understanding of the aerodynamic effects of clap and flings on the flapping four-winged mechanism, confirming that these processes are most likely used in the current MAV. The study also looks into the effects of body angle, flapping frequency, and forward flow velocity on lift and drag force generation, emphasising the efficacy of the four-wing flapping-wing mechanism and the significance of wing shape.

Hiroto Tanaka and Isao Shimoyama [8] The review centers around the forward trip of swallowtail butterflies, which is restricted to fluttering because of their front wings to some extent covering their rear wings. The scientists conjectured that this flight is accomplished with basic fluttering, requiring little criticism control of the padding point. They made a counterfeit butterfly mirroring the wing movement and state of a swallowtail butterfly and examined its flights utilizing rapid camcorders. The outcomes demonstrated the way that stable forward flight could be accomplished without dynamic padding or input control of the wing movement. The fake butterfly's body moved latently in synchronization with the fluttering, following an undulating flight direction. The level of not entirely set in stone by wing venation. The copy wing with veins produced a higher lift coefficient during the fluttering trip than in a consistent stream because of the enormous body movement. They created an artificial butterfly mimicking the wing motion and shape of a swallowtail butterfly and analyzed its flights using high-speed video cameras. The results showed that stable forward flight could be achieved without active feathering or feedback control of the wing motion. The artificial butterfly's body moved passively in synchronization with the flapping, following an undulating flight trajectory. The degree of deformation was determined by wing venation. The mimic wing with veins generated a higher lift coefficient during the flapping flight than in a steady flow due to the large body motion.

C.K. Kang *et. al* [10], The review investigates the effect of adaptability on the streamlined execution of fluttering wings. It uncovers that harmony wise, length wise, and isotropic adaptability influence force age and propulsive productivity. Various powers, in light of Reynolds number, diminished recurrence, and Strouhal number, are recognized in view of scaling contentions. The additional mass power, connected with wing speed increase, is urgent at Reynolds number systems of O(103 - 104) and O(1). A connection between propulsive power and most extreme relative wing-tip disfigurement boundary (γ) is laid out, which relies upon thickness proportion, St, k, regular and fluttering recurrence proportion, and fluttering plentifulness. The greatest propulsive power is acquired close to reverberation, while ideal proficiency is reached at about portion of the normal recurrence. These scaling connections can give direction to miniature air vehicle plan and execution investigation.

Raymond E. Gordnier [11] The study uses a high-order Navier-Stokes solver and a structural solver to simulate a flexible flapping wing. The results are applied to both rigid and moderately flexible rectangular wing during a pure plunging motion. The study explains the complex interaction between unsteady aerodynamics and flexible wing structural dynamics, and connects the results to enhanced aerodynamic loads for the flexible wing. Comparisons with experimental measurements show good agreement with the computed results.

S. Heathcote, Z. Wang, I. Gursul [12], discussed on the effect of spanwise adaptability on fluttering wing impetus was led in a water burrow. The investigation discovered that presenting a level of spanwise adaptability was valuable, as it prompted a little expansion in push coefficient and a decline in power-input necessity, bringing about higher effectiveness. Notwithstanding, presenting a more noteworthy level of spanwise adaptability was impeding, causing a huge stage postponement of the wing tip uprooting, prompting a frail and divided vorticity design. This diminished push coefficient and effectiveness. The investigation additionally discovered that the scope of Strouhal numbers for which spanwise adaptability offered benefits covers with the reach found in nature, which is 0.2oSro0.4. The discoveries propose that birds, bats, and bugs might benefit efficiently from the adaptability of their wings, and that adaptability might help Miniature Air Vehicles both efficiently and in the inborn softness of adaptable designs.

S. Heathcote *et. al* [13], studied on adaptable fluttering airfoil impetus at zero free stream speed, pertinent to floating birds and bugs, examined the impact of airfoil firmness. Molecule picture velocimetry and force estimations were taken for three airfoils with relative bowing stiffnesses 1:8:512 in a water tank. The twisting of the adaptable airfoils delivers an approach that fluctuates occasionally with a stage point regarding the plunging movement. The plentifulness and period of this consolidated plunging/pitching movement assume a significant part in the flowfield and push age. The strength of vortices, their parallel dividing, and the time-averaged velocity of the induced jet depend on the airfoil flexibility, plunge frequency, and amplitude. Direct force measurements confirmed that the thrust coefficient of the airfoil with intermediate stiffness was greatest at high plunge frequencies. The authors suggested an optimum airfoil stiffness for a given plunge frequency and amplitude.

Zongxia Jiao *et. al* [14], proposed a nonexclusive scientific push force model for fluttering wings, coordinating lengthened body hypothesis into actuator circle hypothesis. This strategy straightforwardly relates wing math and kinematics to prompted speed, wiping out the requirement for periodical tension throb adjustment factor estimation. The technique is less complex than precarious streamlined features or computational executions, staying away from complex multi boundary advancement at the early plan stage. Hypothetical deviation of the proposed push model is assessed utilizing mathematical reproductions, and a remedy term is proposed. The remedied strategy is approved through air stream tests and past investigations over enormous boundary ranges. The outcomes show the strategy is legitimate for fluttering wing cycle-normal push assessment over a large number of factors. The technique is additionally talked about for application in both latent and dynamic contorting fluttering wing plans. Be that as it may, an enormous hypothetical deviation is seen when applied to negative-push producing cases, where fluttering wings function as energy extractors.

Kodali D *et. al* [15], presented a two-way coupled aeroelastic model of a plunging spanwise adaptable wing, assessing its exhibition in forward flight. The streamlined features are demonstrated utilizing a two-layered, flimsy, incompressible potential stream model, taking into account cross over removal as the successful dive under the unique equilibrium of wing inactivity, flexible reestablishing force, and streamlined force. The push is a consequence of the cooperation between wing misshapening upgrade and instigated drag. The outcomes for a simply plunging spanwise adaptable wing line up with exploratory and high-loyalty mathematical outcomes. The examination recommends that the wing viewpoint proportion of preoccupied passerine and goose models compares to the ideal aeroelastic reaction, producing the most elevated push while limiting fold power.

Deepa Kodali and Chang-kwon Kang [16], studied a scientific model for chordwise adaptable fluttering wings in forward flight. The streamlined presentation of natural flight is impacted by the liquid construction communication of the fluttering wing and the encompassing liquid. The review determined an insightful liquid construction collaboration model for a two-layered airfoil, including a dive movement on the inflexible driving edge (LE) and dynamic disfigurement of the adaptable tail. The precarious aeroelasticity is demonstrated utilizing the Euler-Bernoulli-Theodorsen condition, with the two-way coupling thinking about following edge deformity as aloof pitch. The wing disfigurement and streamlined execution, including lift and push, concur well with high-loyalty mathematical outcomes. A novel aeroelastic recurrence proportion is inferred, which scales with wing misshapening, lift, and push. The concentrate likewise lays out the powerful closeness between fluttering in water and air.

I. CONCLUSION

From the above revealed writing many writers investigated and created wing outline structures proficiently. Different insightful, computational and trial concentrates on fluttering wing trip of bugs, hummingbirds, and MAVs have been conveyed. However, a few trial of genuine scale MAV wings have been performed, very little consideration has been paid to confining the streamlined powers from different burdens. Parcel of trial studies should have been conveyed in utilizing different plan boundaries alongside lightweight underlying materials as they are fundamental in various applications, for example, biomedical applications, ground vehicles and airplane to improve its productivity and cost.

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