

FIXED WING MORPHING MAV MODELLING USING VAM

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ABSTRACT

The design and implementation of a morphing Micro Air Vehicle (MAV) wing using a smart composite is attempted in this research work. Control surfaces actuated by traditional servos are difficult to instrument and fabricate on thin composite-wings of MAVs. Piezoelectric Fiber Reinforced Composites (PFRCs) are the chosen smart structural materials in the current work for incorporation onto fixed-wing MAVs to simultaneously perform the dual functions of structural load-bearing and actuation of flexure, torsion and/or extension for morphing. Further, PFRC use can be extended towards shape control of a “fixed” wing MAV to meet changing performance requirements. Wings that can warp into desired shapes and/or have variable camber are well-known to exhibit improved efficiency in aerodynamic control. During an entire flight cycle, there are multiple optimal configurations, each of which suits a particular phase of the flight regime. Widely proposed methods of wing morphing include changes in camber, twist, sweep and span. However, camber change during flight is already established, in terms of its potential, as a major factor in improving the aerofoil efficiency and flow separation behavior. Hence, for this work, morphing with camber change is adopted with the goal to better tailor aerodynamic properties.

The fixed wings of an MAV are modeled herein to cater to the morphing concept using PFRCs. The work thus includes the analysis of a PFRC-based wing having a pre-defined initial configuration followed by an extension of the model to allow for the design of a morphing wing. The Variational Asymptotic Method (VAM) is used to model and analyze the piezo-composite wing in an asymptotically correct and yet computationally efficient manner, enabling its applicability for reliable design optimization studies. From amongst the few

standard configurations available for MAV wings, a circular planform is selected with S5010 reflex aerofoil. An initial camber of 3%, which is suitable for the longest duration of a flight phase, is taken up for the baseline analysis. After the application of appropriate electric fields across the inter-digitated electrodes of the PFRC, morphing is achieved. It results in two new camber settings of 6% and 9%. The performance is compared with the actual aerofoil data. Two design cases are further explored. The first design considers the entire laminate to be built out of PFRC while the second proposes a hybrid design consisting of PFRC and Carbon Fiber Reinforced Plastics (CFRP) laminae.

Detailed analysis of the shape change on the MAV during flight is done by considering the aerodynamic loads on a set of airfoils with varying camber. Aerodynamic loads are estimated over the MAV model using CFD. These loads along with external electric fields are applied on the MAV model to analyze the effects of camber change from 3% to 6% and 9%. Finite element analysis of the MAV wing model is done using 3D solid elements in lieu of the wing including its active components. This predicts the actual effect of the active part over and above the aerodynamic loading.

Locations of the active elements over the wing structure are decided mainly by their effectiveness to change the camber of the wing during flight. Optimization studies are carried out with the objective of minimum power consumption while satisfying the constraints of required camber change and positioning of the inflection point. Only the asymptotically leading part of the total strain energy of the structure for a given configuration is considered during the optimization procedure resulting in quick yet hi-fidelity solutions.

The multifunctional composite shell constitutive model is prepared using VAM, which systematically reduces the dimensionality of the problem by taking advantage of the smallness of the thickness of the shell as well as the maximum strains sustained by the PFRC/CFRP employed to construct the shell. The original 3-D problem is thus mathematically split into a 1-D through-the-thickness analysis and a non-linear 2-D mid-surface analysis, accounting for transverse shear deformation, wherever asymptotically required. The results are compared with those of a commercial 3-D finite element analysis to validate the asymptotical correctness of the morphing piezo-composite shell model being presented.