Gust Load Alleviation for Highly Flexible Aircraft in an Integrated Aeroelastic and Flight Dynamic Framework Using Vortex Lattice Method

Mariyam Naseer
Corresponding Author
emma.mary611@gmail.com
National University of Science and Technology, Islamabad, Pakistan

Dr. Haroon Awais Baloch
haroon2301@alum.ceme.edu.pk
National University of Science and Technology, Islamabad, Pakistan

Dr. Muhammad Safdar
msafdar@smme.nust.edu.pk
National University of Science and Technology, Islamabad, Pakistan

An integrated aeroelastic, flight dynamics and control design mathematical model is developed in SIMULINK to account for flexibility effects in flight dynamic behavior during gust encounters and alleviate the wing loadings for the High-Altitude Long Endurance Unmanned Ariel Vehicles. These HALE UAVs are made of light-weight materials like fiber composites and have high aspect ratio wings to cater for high endurance requirements. Hence these structures are highly flexible which requires a robust control system that should make the system stable and controllable. Moreover, the structural flexibility brings the low frequency structural modes close to the rigid body modes which necessitates an approach that unifies both these rigid and flexible motions. Along with this, highly flexible structures require a robust control system that should make the system stable and controllable. This brings all the major subjects related to aircraft design namely structural dynamics, aerodynamics, flight dynamics and controls under one umbrella known as AeroServoElasticity. In order to cater for these requirements , a generic high aspect ratio flexible glider from MSC Nastran example is used to numerically demonstrate a framework which measures flutter margins and limit cycle oscillation behavior for various flight maneuvers and gust encounters and alleviates the wing loadings when required. Structural equations of motion are modelled in SIMULINK based on mass and stiffness matrices obtained from SOL103 of MSC NASTRAN. A structural dynamics block is thus developed which results in time based nodal displacements and its derivatives. Vortex Lattice Method is used to develop aerodynamic model in DynaFlight Software. This aerodynamic model results in Aerodynamic Influence Coefficients and spline matrices. These aerodynamic matrices are imported in SIMULINK and coupled with structural dynamic block. Aeroelastic responses are measured against given flight conditions. Nonlinear equations of motion for Six Degree of Freedom for rigid body dynamics are then coupled with aeroelastic block to incorporate the flexibility effects in flight dynamics. Loads are recovered in the form of shear force and bending moments at wing root. Also, the wing tip displacements are noted for various flight conditions and gust encounters of various speeds and lengths. A control scheme is developed to alleviate the loadings on the wing . A model thus developed results in accurate prediction of inflight loads and alleviation of these loads when deemed necessary for highly flexible structures by unifying all the flight dynamics, gust models and aeroelastic equations in the time domain.

Keywords: Aeroservoelasticity, Aeroelastic, Flight Dynamics, Structural Loading, Unmanned Air Vehicle