Aircraft Flight Mechanics and Control

Introduction

Aircraft is subjected to a wide variety of forces e.g. aerodynamic, propulsive and gravity. Further, to achieve a specific mission, pilot (human or auto) applies additional forces so that aircraft behaves in the desired manner. Further, ircraft, during their service life, go through a variety of manoeuvres that need to be managed either manually or in an autonomous mode. Among these, there are many manoeuvres, which can be adequately described using decoupled LTI models, and, hence, can be dealt with using simple control structures. However, there are many manoeuvres that need special attention due to complexity of motion and inadequacy of LTI models / simple control structures. In all such cases, flight dynamic equations become more complex (i.e. coupled, nonlinear, time varying, uncertain) and there is a need to synthesize control structures for such dynamical systems.

Importance of the Subject

Flight Mechanics and control is the formal study of the way the aircraft responds to the applied forces and is closely coupled to aircraft mission, as it deals with overall flight performance. As a result, analyses of flight mechanics provide direct inputs to the aircraft design process. Flight Mechanic analysis is also critical to the design of flight control system using advanced control design techniques that help in synthesizing the required elements to ensure the desired performance.

Course Objectives

To establish basic concepts of equilibrium, static stability and steady-state control of aircraft.

To study aircraft motion in terms of component modes of the aircraft flight dynamics.

To provide exposure to flight dynamics under various manoeuvres, and realistic control structures.

Course Contents

Definitions, concept of aircraft flight, axes, sign conventions for forces, moments and motion variables. Lift & pitching moment models, concepts of aerodynamic centre, trim and stability of flight & role of horizontal tail. Neutral point as a design attribute. Elevator as longitudinal control, control power. Sideslip, rolling and yawing actions, contributions of vertical fin, dihedral angle & wing position to stability. Rudder as directional & ailerons as lateral control. Frames of references and basic flight dynamic formulation, inertial attitude and velocity, complete flight dynamic equations, forces and moments. Linearized longitudinal and lateral dynamic models, Phugoid and short period approximations, Roll, Spiral and Dutch roll approximations, open loop response to control actuation. Flight envelope as a mission statement, flying & handling quality requirements and design objectives for the flight control systems. Basic longitudinal and lateral stability augmentation systems (SAS) and standard autopilots. Effect of flight conditions on linearized models, high angles of attack & roll rates, inertia cross-coupling, structural flexibility, human pilot model, spherical earth, unsteady aerodynamics. LQR and Eigen structure assignment based controllers, normal acceleration based SAS / autopilots. Robust, LQG and LTR based controllers, actuator saturation and anti-windup controller.

Pre-requisites

Participants should be familiar with basic aircraft flight concepts and nomenclatures e.g. wing, tail, lift, drag, and performance attributes e.g. take-off, cruise, climb, landing, turning etc. Further, familiarity with ordinary differential equations and their solution, MATLAB/SIMULINK will be useful. Lastly, an exposure to basic control concepts e.g. single loop feedback structures, P, PI, PD & PID controllers and their design, linear state-space controllers e.g. pole placement design, LQR controller, multi-loop forms would help in better understanding the FCS related topics.

Text/References

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