INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal - 500 043, Hyderabad, Telangana

COURSE CONTENT

AIRCRAFT STABILITY AND CONTROL								
V Semester: AE								
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**		
AAED21	**Elective**	**L**	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
		3	0	-	3	40	60	100
Contact Classes: 48	**Tutorial Classes: Nil**	**Practical Classes: Nil**				**Total Classes: 48**		
Prerequisite: Flight Mechanics								

I. COURSE OVERVIEW:

Aircraft Stability and Control is the science that investigates the stability and control of aircrafts and all other flying vehicles. From the advent of the first flight by the Wright Brothers, it was observed that flight without knowledge of stability and control was not viable. Since then, several different concepts for controlling aircraft flight have been devised including control surfaces, deformable surfaces, morphing of wings etc. This course introduces some of these concepts and describes their operation, as well as the degree of stability that these devices can provide. Modern aircraft control is ensured through automatic control systems known as autopilot. Their role is to increase safety, facilitate the pilot's task and improve flight qualities. The course will introduce modern aircraft stability and control and discuss some of its objectives and applications.

II. COURSES OBJECTIVES:

The students will try to learn

I. The fundamental knowledge on static stability of aircraft in multiple directional motions with their relationship for critical applications in flight vehicles.
II. The aircraft equations of motion to correlate qualitatively with potential applications in aircraft stability in different degrees of freedom (DOF).
III. The methods of optimizing the aircraft equations of motion and its derivatives for aircraft dynamic stability in various flight modes
IV. The utilization of advances of flight dynamics and control in design and development of modern airplane control systems.

III. COURSE OUTCOMES:

At the end of the course students should be able to:

CO 1 Describe the contribution of various components to the static longitudinal stability of the aircraft
CO 2 Determine aircraft stability and compute the control deflections and control forces required to trim the airplane in any given flight configuration
CO 3 Construct the mathematical model of aircraft motion in longitudinal, lateral and directional cases for establishing the status of the flight vehicles stability.
CO 4 Categorize different types of dynamic modes in longitudinal, lateral and directional motion of the aircraft and their influence on dynamic stability and safety.
CO 5 Identify stick fixed and stick free conditions for neutral points with an appropriate static margin, control force and CG limitation.
CO 6 Explain qualitatively about motion in three-dimensions, Euler angles and rates, full 6-DOF equations for rigid symmetrical aircraft, state space formulation, and solution in the time domain and flight simulation.

IV. COURSE CONTENT:

MODULE - I Aircraft in Equilibrium Flight- Elevator Angle to Trim- Longitudinal Static and Maneuver Stability (10):

Need for controlled flight. Equilibrium, stability, trim, control- definitions- examples. Longitudinal forces and moments on aircraft in unaccelerated flight- contribution of principal components. Equations of equilibrium- thrust, angle of attack, elevator angle required to trim. Control gradient, total airplane lift curve slope and pitch stiffness. Tailless aircraft and aircraft with foreplanes. Longitudinal static stability- definition, relation to control gradient, pitch stiffness. Stick fixed neutral point- static margin. Effect of flaps and flight speed on force and moment coefficients, aerodynamic derivatives, stability, trim.

Steady, symmetric pull-up maneuvers- equations of motion- pitch rate, pitch damping. Control to trim, trim curves- elevator per g- maneuver point, maneuver margin- relation to static margin. Statutory limits on position of centre of gravity. Determination of neutral and maneuver points by flight testing.

MODEULE- II Estimation of Aerodynamic Force and Moment Derivatives of Aircraft (9):

Significance of aerodynamic derivatives. Derivatives of axial, normal force components and pitching moment with respect to the flight speed, angle of attack, angle of attack rate, pitch rate, elevator angle- dependence on vehicle geometry, flight configuration- effects of flaps, power, compressibility and aeroelasticity.

Lateral directional motion- coupling- derivatives of side force, rolling and yawing moments with respect to the sideslip, rate of sideslip, roll rate, yaw rate, aileron, rudder deflections- dependence on vehicle geometry, flight configuration. Estimation- the strip theory method. Relation between dimension-less and dimensional aerodynamic derivatives.

MODULE - III Stick Free Longitudinal Stability (10)

Control Forces to Trim, Lateral-Directional Static Stability and Trim: Elevator hinge moments- relation to control stick forces. Hinge moment derivatives. Stick force to trim in symmetric unaccelerated flight, maneuvering flight. Stick force gradients- effect of trim speed- role of trim tab. Effect of freeing elevator on tail effectiveness, static and maneuver stability. Elevator-free factor. Stick-free neutral and maneuver points, stability margins- relation with stick force gradients. Aerodynamic and mass balancing of control surfaces. Control tabs- types, function, construction.

Lateral-directional static stability, definition, requirements. Equilibrium of forces and moments. Aileron, rudder, elevator and thrust required to trim aircraft in steady sideslip, roll, coordinated turn, engine out condition. Cross wind landings.

MODULE-IV Aircraft Equations of Motion- Perturbed Motion- Linearised, Decoupled Equations (10)

Description of motion of flight vehicle- systems of reference frames- Euler angles, angles of attack and sideslip– definitions- earth to body axis transformation, Rotating axis system- expressions for linear and angular momenta of rigid body, time derivatives- inertia tensor, components of linear and angular velocities, accelerations. Resolution of aerodynamic, gravity forces, moments acting on flight vehicle. Equations of motion- longitudinal and lateral-directional. Relation between angular velocity components and Euler angle rates. Determination of velocities of airplane in earth axis system. Determination of vehicle trajectory- outline of method.

Description of motion as perturbation over prescribed reference flight condition. Equation of motion in perturbation variables. Assumption of small perturbations, first order approximations- linearised equations of motion. Decoupling into longitudinal and lateral-directional motions- conditions for validity- role of symmetry. Linearised longitudinal and lateral-directional equations of perturbed motion.

MODULE- V Longitudinal and Lateral-Directional Dynamic Stability (10)

Linearised longitudinal equations of motion of aircraft - three degree of freedom analysis- characteristic equations- solutions- principal modes of motion- characteristics- time constant, undamped natural frequency and damping ratio- mode shapes- significance. One degree of freedom, two degree of freedom approximations- constant speed (short period), constant angle of attack (long period) approximations- solutions- comparison with three degree of freedom solutions- justification of approximations. Lateral directional equations- three degree of freedom analysis. Principal modes- characteristics- mode shapes- significance, lower order analysis- approximate solutions.

Determination of longitudinal and lateral stability from coefficients of characteristic equation- stability criteria, approximate roots. Special problems in aircraft dynamics- roll coupling, high angle of attack operation. Aircraft spin- entry, balance of forces in steady spin, recovery, pilot techniques..

V. TEXT BOOKS:

1. Yechout, T.R. et al., *Introduction to Aircraft Flight Mechanics*, AIAA education Series, 2003, ISBN 1-56347-577-4.
2. Nelson, R.C., *Flight Stability and Automatic Control*, 2nd edn., Tata McGraw Hill, 2007, ISBN 0-07-066110-3

VI. REFERENCE BOOKS:

1. Pallett, E.H.J., "Aircraft Instruments and Integrated Systems", Longman Scientific &Technical 10th Edition, 1992.
2. Harris, D, "Flight Instruments and Automatic Flight Control Systems", 6th Edition, 2004.
3. Bolton, W., "Pneumatic and Hydraulic Systems, Butterworth-Heinemann.

VII. ELECTRONICS RESOURCES:

1. https://www.amazon.in/Aircraft-Systems-Mechanical-ElectricalIntegration/dp/0470059966.
2. https://www.scribd.com/book/142412367/Aircraft-Systems-Mechanical-Electrical-and Avionics Subsystems-Integration.
3. https://www.scribd.com/document/231235694/n-0447376.

VIII. MATERIALS ONLINE

1. Course template
2. Tutorial question bank
3. Tech talk topics
4. Open end experiments
5. Definitions and terminology
6. Assignments
7. Model question paper – I
8. Model question paper - II
9. Lecture notes
10. E-learning readiness videos (ELRV)
11. Power point presentation