FLIGHT DYNAMICS

ENAS 353

Lecture	**: 3**	**Year : III**
Tutorial	**: 1**	**Part : II**
Practical	**: 3/2**	

Course Objectives:

The objective of this course is to introduce the fundamentals of aircraft performance, stability, and control. Emphasis is placed on mathematical modeling and analytical techniques for evaluating aircraft motion and flying qualities, including equations of motion, configuration aerodynamics, and longitudinal, lateral, and directional dynamics, with a brief discussion to guidance and navigation concepts.

1 Introduction (5 hours)

- 1.1 Mathematical preliminaries
  - 1.1.1 Flight dynamics
  - 1.1.2 Basic flight principles
- 1.2 Point-Mass dynamics and aerodynamic forces
  - 1.2.1 The atmosphere
  - 1.2.2 Equation of motion for a particle (Point mass)
  - 1.2.3 Introduction to lift and drag
  - 1.2.4 Equations of motion with aerodynamics and thrust

2 Configuration Aerodynamics (8 hours)

- 2.1 Low-speed aerodynamics
  - 2.1.1 2D aerodynamic lift and drag
  - 2.1.2 Effect of sweep angle on lift
  - 2.1.3 Thin aerofoil theory
  - 2.1.4 Description of aircraft configuration
  - 2.1.5 3D aerodynamic lift and drag
  - 2.1.6 Wing twist effects
  - 2.1.7 Effect of aspect ratio on 3D wing lift slope coefficient
  - 2.1.8 Longitudinal control surfaces
- 2.2 Induced drag and high-speed aerodynamics
  - 2.2.1 Induced drag
  - 2.2.2 Mach number effects
  - 2.2.3 High-angle-of-attack lift and drag
- 2.3 Aerodynamic moments
  - 2.3.1 Spanwise lift distribution of 3D wings
  - 2.3.2 Moments of the airplane
  - 2.3.3 Airplane balance

2.3.4 Pitching moment of the airplane
2.3.5 Lateral-directional effects of sideslip angle
2.4 Rotorcraft control and dynamics

3 Flight Performance (16 hours)

3.1 Cruising flight performance
3.1.1 Flight in vertical plane
3.1.2 Steady, level flight
3.1.3 Flight envelops
3.1.4 Cruising flight
3.2 Gliding, climbing and turning flight performance
3.2.1 Gliding flight
3.2.2 Climbing flight
3.2.3 Optimal climbing flight
3.2.4 Maneuvering envelope
3.2.5 Turning flight

4 Flight Stability (8 hours)

4.1 Longitudinal stability
4.1.1 Stability criteria
4.1.2 Wing, fuselage, tail and propulsion contributions
4.2 Lateral stability
4.2.1 Stability criteria
4.2.2 Wing, fuselage, tail and propulsion contributions
4.3 Directional stability
4.3.1 Stability criteria
4.3.2 Wing, fuselage, tail and propulsion contributions
4.3.3 Lateral-directional coupling
4.3.4 Effects of wing geometry
4.3.5 Concept of stick-free stability
4.4 Factors affecting aircraft stability and design configurations

5 Dynamic Stability (8 hours)

5.1 Linearized equations of motion
5.1.1 Linear, time-varying (LTV) approximation of perturbation dynamics
5.1.2 Separation of equation of motion into longitudinal and lateral directional sets
5.1.3 Decoupling approximation for small perturbations from steady, level flight
5.2 Linearized longitudinal equations of motion
5.2.1 Fourth-order hybrid equations of motion
5.2.2 Dimensional stability and control derivatives
5.2.3 Comparison of 2nd and 4th order model response

5.3 Linearized lateral-directional equations of motion
- 5.3.1 Linearized lateral-directional equation of motion in steady, level flight
- 5.3.2 Stability axis representation of dynamics
- 5.3.3 2nd order approximate modes of lateral-directional motion
- 5.3.4 Comparison of 4th and 2nd order dynamic models

Tutorial **(15 hours)**

1. Calculations of flight performance in different phases of flight:
   - i. Gliding
   - ii. Climbing
   - iii. Cruise
   - iv. Turning
   - v. Decent
2. Performing static stability tests

Practical **(22.5 hours)**

The practical will involve design and flight dynamical estimations of aircraft designed by students in typically groups of four. The tests conducted will be on:
1. Longitudinal stability: Long period/phugoid and short period modes
2. Lateral-directional stability: Dutch roll and spiral mode
3. Perform tests, plot and present stability data as explained in the lab manual

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Mark distribution*
1	5	8
2	8	8
3	16	24
4	8	12
5	8	8
Total	**45**	**60**

* There may be minor deviation in marks distribution.

References

1. Pamadi, B. N. (2004). Performance, stability, dynamics, and control of airplanes. Reston.
2. Stengel, R. F. (2004). Flight dynamics. Princeton University Press.
3. Etkin, B., Reid, L. D. (1995). Dynamics of flight: Stability and control (Latest Edition). John Wiley & Sons.
4. Babister, A. W. (1980). Aircraft dynamic stability and response (Latest Edition). Pergamon Press.
5. Dommasch, D. O., Shelby, S. S., Connolly, T. F. (1981). Aeroplane aerodynamics (Latest Edition). Isaac Pitman.