

AIRCRAFT STRUCTURES

ENAS 413

Lecture : 3
Tutorial : 1
Practical : 3/2

Year : IV
Part : I

Course Objectives:

The objective of this course is to provide students a sound knowledge of aircraft structure design criteria and in-depth knowledge of the design process. After completion of this course the students will be able to understand the intricate technical details of fixed-wing as well as rotary-wing aircraft.

- 1 Aircraft Structural Design (6 hours)**
 - 1.1 Structural layout of the airplane and components
 - 1.2 Structural design V-n diagram
 - 1.3 Loads acting on major components: Wing; Fuselage; Tails; Landing gear
 - 1.4 Concept of allowable stress and margin of safety
- 2 Unsymmetrical Bending (4 hours)**
 - 2.1 Bending stresses in beams of unsymmetrical sections
 - 2.2 Bending of symmetric sections with skew loads
 - 2.3 Product of inertia and principal axes of inertia
 - 2.4 Deflection of beams under unsymmetrical bending
 - 2.5 Temperature and initial curvature effects on bending stress
 - 2.6 Bending of thin-walled open sections - idealized boom models
- 3 Shear Flow in Open Sections (5 hours)**
 - 3.1 Thin walled beams
 - 3.2 Concept of shear flow
 - 3.3 Shear center, elastic axis with one axis of symmetry
 - 3.4 Shear center with wall effective and ineffective in bending
 - 3.5 Unsymmetrical beam sections
- 4 Shear Flow in Closed Sections (8 hours)**
 - 4.1 Bredt-Batho formula
 - 4.2 Single and multi-cell structures
 - 4.3 Approximate methods
 - 4.4 Shear flow in single and multi-cell structures under torsion

- 4.5 Shear flow in single and multi-cell under bending with walls effective and ineffective

5 Buckling of Plates (6 hours)

- 5.1 Rectangular sheets under compression
- 5.2 Local buckling stress of thin walled sections
- 5.3 Crippling stresses by Needham's and Gerard's methods
- 5.4 Thin walled column strength
- 5.5 Sheet-stiffener panels
- 5.6 Effective width, inter-rivet and sheet wrinkling failures

6 Joints and Fittings (8 hours)

- 6.1 General theory for the design of fittings
- 6.2 Estimation of fitting design loads
- 6.3 Design of riveted, bolted and welding joints
- 6.4 Post buckling of structures
- 6.5 Concept of effective width

7 Stress Analysis in Wing and Fuselage (5 hours)

- 7.1 Shear and bending moment distribution for semi cantilever and other types of wings and fuselage
- 7.2 Thin webbed beams with parallel and non-parallel flanges
- 7.3 Shear-resistant web beams
- 7.4 Tension-field web beams (Wagner's)

8 Design Considerations (3 hours)

- 8.1 Design criteria with safety factor
- 8.2 Design life criteria
- 8.3 Life assessment procedures
Design principle: Future airworthiness requirements, Two bay crack criteria, widespread fatigue damage

Tutorial (15 hours)

- 1. Shear center calculations (Open sections): Determination of the shear center for C-channel, unsymmetric I-section, and idealized multi-boom sections, including the physical distinction between shear center and elastic axis and its impact on aeroelastic divergence.
- 2. Shear flow in closed sections: Calculation of shear flow distribution under combined bending and shear for single-cell and two-cell wing boxes, along with a comparative analysis of open versus closed section stiffness for identical cross-sectional geometries.

3. V-n diagram generation: Generation of the maneuvering flight envelope and gust envelope overlay using aircraft performance parameters to verify structural margins of safety.
4. Plate buckling analysis: Determination of critical buckling stress, crippling stress, and effective width for thin plates, including combined local and global column buckling strength using the Johnson–Euler transition.
5. Joints, fittings and fatigue design: Analysis of riveted joints and bolted fittings for structural integrity, including S-N curve application, damage tolerance evaluation, and inspection interval estimations using safe-life and fail-safe design philosophies.

Practical

(22.5 hours)

1. V-n Envelope and Structural Load Distribution: Generate flight envelope boundaries and compute semi-span shear and bending distributions to identify critical load cases for structural sizing.
2. Two-Cell Wing Box and Frame Structural Sizing: Size structural members, verify panel buckling resistance, evaluate joint fittings and compute margins of safety under combined structural loads.
3. Safety Assessment and Structural Compliance: Evaluate compliance against airworthiness safety factors, verify fail-safe crack growth limits and compile structural design metrics into a technical report.
4. Wing Box Finite Element Stress Analysis: Build shell and beam finite element models to extract bending stresses and shear flows, comparing numerical outputs directly with hand calculations.
5. Linear Buckling and Stiffener Optimization: Perform linear eigenvalue buckling simulations on panel assemblies to extract critical mode shapes, quantifying structural improvements gained from adding stiffeners.
6. Compressive Load Testing of Stiffened Plates: Test unstiffened and longitudinally stiffened panels under compressive loading, recording out-of-plane deflections and critical buckling loads via optical or mechanical instruments.
7. Post-Buckling Behavior and Load Redistribution: Analyze load-deflection behavior to locate bifurcation points, comparing experimental failure loads against analytical and finite element predictions.

Final Exam

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

Chapters	Hours	Marks distribution*
1, 2	10	12
3, 5	11	12
4	8	12
6	8	12

7, 8	8	12
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Peery, D. J. (2011). Aircraft structures. Dover Publications.
2. Von Mises, R. (1959). Theory of flight (Latest Edition). Dover Publications.
3. Donaldson, B. K. (2008). Analysis of aircraft structures: An introduction. Cambridge University Press.
4. Megson, T. H. G. (2022). Introduction to aircraft structural analysis. Butterworth-Heinemann.
5. Megson, T. H. G. (2022). Aircraft structures for engineering students. Butterworth-Heinemann.