The Hong Kong University of Science and Technology
UG Course Syllabus

Course Title:	Aircraft Structural Analysis
Course Code:	MECH-3650
Number of Credits:	3
Pre-requisites:	CIVL2120 or MECH1907 or MECH1910 or MECH2040
Instructor:	Prof. Jinglei Yang
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Course Description

The components of aircraft structures are subjected to forces and deformed elastically during the life of service. This course covers the general information of aircraft structures and materials, and transfer of external aerodynamic loads into structural internal forces. The focus is to deliver the fundamental knowledge for stresses, deflection, and buckling analysis of these structural components under various static loading conditions including torsion, bending and shear.

There are two main activities in this course. The first is lectures, which emphasize the fundamentals of structural mechanics and analytical approaches for analysis of aircraft structures. The students will learn to derive the theory of linear elasticity and apply it to analyze the components subjected to typical aircraft loading conditions and design requirements.

The second is tutorials, which provide a set of lessons and exercises teaching the concepts and methodology in analysis of aircraft structures. The students will be able to learn and understand the procedure of aircraft structural analysis from following tutorial problem solving exercises with group discussions.

Intended Learning Outcomes (ILOs)

By the end of this course, students should be able to:

1. Visualize the complexity of structural components and materials of the aircraft and understand their functions.
2. Analyze how external aerodynamic loads are transferred to internal stresses and deformations.
3. Apply the theories to analyze various aircraft structural components subject to different loading conditions.
4. Apply energy methods for deformation analysis. Have the capability to assess whether aircraft structural components are able to withstand the applied loads and meet specified performance.

Assessment and Grading

This course will be assessed using criterion-referencing. Grades will not be assigned using a curve. Student performance will be evaluated according to their demonstrated achievement of the intended learning outcomes (ILOs) and course outcomes via in-class participation, homework assignments, a midterm examination, and a final examination. Rubrics and grade descriptors are provided below to clarify the criteria used for evaluation.

Assessment Task	Contribution to Overall Course Grade (%)	Due Date / Timing
Attendance in-class Q&A	5%	Throughout the term
Homework assignments	10%	Throughout the term
Midterm examination	25%	Around Week 8
Final examination	60%	Final examination period

Mapping of Course ILOs to Assessment Tasks

Assessed Task	Mapped ILOs	Explanation

Attendance in-class Q&A	ILO 1, ILO 2,ILO 3, ILO4	In-class participation and Q&A assess students' engagement with the course material.
Homework assignments	ILO 1, ILO 2,ILO 3, ILO4	Homework assignments assess students' ability to apply the theoretical and analytical tools introduced in lectures and tutorials. Through structured problem sets, students visualize the complexity of structural components and materials of the aircraft and understand their functions (ILO 1), analyze how external aerodynamic loads are transferred to internal stresses and deformations (ILO 1), apply the theories to analyze various aircraft structural components subject to different loading conditions (ILO 2), apply energy methods for deformation analysis(ILO 3), have the capability to assess whether aircraft structural components are able to withstand the applied loads and meet specified performance(ILO 4).
Midterm examination	ILO 1, ILO 2,ILO 3	The midterm examination assesses individual achievement of the learning outcomes covered in the first half of the course, including aircraft structural anatomy, materials, and functions (ILO 1), aircraft loads and load-transfer mechanisms (ILO 2), and stress analysis of thin-walled structural components with emphasis on torsion and related section properties up to the specified midterm scope (ILO 3).
Final examination	ILO 1, ILO 2,ILO 3, ILO4	The final examination is cumulative and assesses all intended learning outcomes of the course. Students demonstrate understanding of aircraft structures and materials (ILO 1), analyze aircraft loads and internal force transfer (ILO 2), perform stress analysis for structural components under torsion, bending, shear, idealization, taper, and combined loading (ILO 3), address stability and buckling of thin-walled structures, and apply energy methods to evaluate deformation and structural performance (ILO 4).

Grading Rubrics

The following rubrics describe the general criteria used to assess the major assessment components in this course. More detailed task-specific marking schemes may be provided for individual homework assignments and examination questions.

Rubric for Homework Assignments

Criteria	Excellent	Good	Satisfactory	Marginal	Fail	Map to Course ILOs
Conceptual understanding	Demonstrates clear and accurate understanding of aircraft structures, materials, loads, stress analysis concepts, and physical mechanisms. Correctly identifies structural components and their functions.	Shows good understanding of main concepts, with only minor omissions or imprecision.	Shows adequate understanding of basic concepts but may lack depth or contain some conceptual gaps.	Shows limited understanding ; explanations are incomplete or partially incorrect.	Shows little or no understanding of relevant structural analysis concepts.	ILO 1, ILO 2, ILO 3, ILO 4
Application of structural analysis theory	Selects and applies appropriate elasticity theory, torsion, bending and shear analysis, energy methods, and buckling theory correctly and efficiently.	Applies appropriate methods with mostly correct reasoning and only minor errors.	Applies standard methods to familiar problems but may require clearer justification or contain some procedural errors.	Attempts to apply relevant methods but with significant errors or weak justification.	Fails to apply appropriate structural analysis methods or uses irrelevant approaches.	ILO 1, ILO 2, ILO 3, ILO 4

Mathematical accuracy and problem solving	Solutions are mathematically sound, logically organized, and lead to correct results with appropriate units and notation.	Solutions are generally correct, with minor algebraic, numerical, or unit errors.	Solutions show reasonable effort and partial correctness but include some significant errors.	Solutions are incomplete or contain major mathematical errors.	Solutions are largely absent, incorrect, or not submitted.	ILO 1, ILO 2, ILO 3, ILO 4
Physical interpretation of results	Provides clear interpretation of results, including stress distributions, deflection patterns, buckling modes, and engineering significance. Relates results to aircraft structural design.	Provides reasonable interpretation, though some details may be missing.	Provides basic interpretation but may not fully connect results to physical structural behaviour.	Provides limited or superficial interpretation.	Provides no meaningful interpretation of results.	ILO 1, ILO 2, ILO 3, ILO 4
Clarity of presentation	Work is clear, well structured, legible, and easy to follow, with appropriate diagrams, equations, and explanations.	Work is mostly clear and organized.	Work is understandable but may be disorganized or difficult to follow in places.	Work is poorly organized or hard to follow.	Work is illegible, incoherent, or missing.	ILO 1, ILO 2, ILO 3, ILO 4

Rubric for <u>Midterm Examination</u>

Criteria	Excellent	Good	Satisfactory	Marginal	Fail	Map to Course ILOs
Knowledge of aircraft structures and materials	Clearly and accurately explains aircraft structural components, materials, and their functions. Demonstrates thorough understanding of structural anatomy and material selection.	Provides good explanation of aircraft structures and materials with minor omissions.	Demonstrates adequate understanding of basic structural concepts but with limited depth.	Shows limited understanding of aircraft structural components and materials.	Demonstrates insufficient understanding of aircraft structures and materials.	ILO1
Understanding of loads and forces	Accurately identifies and analyzes loads and forces in aircraft structures. Clearly explains load transfer mechanisms from aerodynamic surfaces to internal structure.	Provides good analysis of loads and forces with mostly correct reasoning.	Demonstrates adequate understanding of basic load concepts but may miss some details.	Shows limited understanding of aircraft loads and force analysis.	Fails to demonstrate understanding of loads and forces at an acceptable level.	ILO 1, ILO 2, ILO 3
Torsion stress analysis of structural components	Correctly applies elasticity theory to analyze torsion in thin-walled structures. Accurately computes stresses,	Applies stress analysis methods mostly correctly with minor errors.	Applies standard stress analysis to familiar problems but has difficulty with more complex configurations.	Shows limited ability to perform stress analysis; significant errors in calculations.	Fails to apply stress analysis methods at an acceptable level.	ILO 1, ILO 2, ILO 3

	shear flow, and section properties.					
Mathematical accuracy and clarity	Work is accurate, logically structured, clearly presented, and uses appropriate equations, units, and notation under examination conditions.	Work is generally clear and accurate, with minor errors.	Work is understandable but may contain errors, omissions, or lack organization.	Work is poorly organized or contains major errors.	Work is incoherent, largely incorrect, or missing.	ILO 1, ILO 2, ILO 3

Rubric for Final Examination

Criteria	Excellent	Good	Satisfactory	Marginal	Fail	Map to Course ILOs
Shear stress analysis of structural components	Correctly and independently applies elasticity theory to analyze shear in thin-walled structures. Handles idealized sections, tapered beams, and combined loading with confidence.	Applies stress analysis methods mostly correctly with minor errors.	Applies standard stress analysis to familiar problems but has difficulty with more complex configurations.	Shows limited ability to perform stress analysis; significant errors.	Fails to apply stress analysis methods at an acceptable level.	ILO 1, ILO 2, ILO 3
Bending stress analysis of structural components	Correctly and independently applies elasticity theory to analyze bending in thin-walled structures. Handles idealized sections, tapered beams, and combined loading with confidence.	Applies stress analysis methods mostly correctly with minor errors.	Applies standard stress analysis to familiar problems but has difficulty with more complex configurations.	Shows limited ability to perform stress analysis; significant errors.	Fails to apply stress analysis methods at an acceptable level.	ILO 1, ILO 2, ILO 3
Energy methods for deformation analysis	Correctly applies energy methods, including strain energy, virtual work. Demonstrates clear understanding of the principles and their engineering application.	Applies energy methods mostly correctly with minor errors.	Demonstrates adequate ability to solve standard energy method problems.	Shows limited or fragmented understanding of energy methods.	Fails to apply energy methods at an acceptable level.	ILO 1, ILO 2, ILO 3, ILO 4
Mathematical accuracy, organization, and clarity	Work is accurate, logically structured, clearly presented, and uses appropriate equations, units, notation, and diagrams under examination conditions.	Work is generally clear and accurate, with minor errors.	Work is understandable but may contain errors, omissions, or lack organization.	Work is poorly organized or contains major errors.	Work is incoherent, largely incorrect, or missing.	ILO 1, ILO 2, ILO 3, ILO 4

Final Grade Descriptors

Grade	Short Description	Elaboration on Subject Grading Description
A	Excellent Performance	Demonstrates an excellent command of aircraft structural analysis. Understands structural components, materials, and load transfer mechanisms thoroughly. Applies elasticity theory accurately and insightfully to analyze stresses in thin-walled structures under torsion, bending, and shear. Performs stability/buckling analysis and energy method applications confidently. Assesses structural integrity with sound engineering judgement. Work is accurate, well organized, and shows strong physical insight.
B	Good Performance	Demonstrates good understanding of the main concepts in aircraft structural analysis. Applies most stress analysis methods correctly and shows good ability to handle torsion, bending, shear, buckling, and energy method problems. Solves standard and moderately challenging problems with generally sound reasoning. Homework and examination submissions are clear and technically competent, with only minor weaknesses.
C	Satisfactory Performance	Demonstrates adequate understanding of core structural analysis concepts and can apply standard methods to familiar problems. Shows satisfactory ability to analyze stresses, apply energy methods, and solve buckling problems. Some errors or gaps in reasoning may be present, and physical interpretation may lack depth, but the main learning outcomes are achieved at an acceptable level.
D	Marginal Pass	Demonstrates threshold understanding of basic structural analysis concepts but has difficulty applying theories consistently or accurately. Can attempt standard calculations involving torsion, bending, shear, buckling, and energy methods, but work may contain significant errors, incomplete reasoning, or weak physical interpretation. There is sufficient evidence of partial achievement of the course learning outcomes, but performance is limited.
F	Fail	Demonstrates insufficient understanding of fundamental aircraft structural analysis concepts. Is unable to apply stress analysis methods to structural components, does not adequately perform buckling or energy method calculations, or cannot assess structural integrity at an acceptable level. Work contains major conceptual and mathematical errors, is incomplete, or does not demonstrate achievement of the intended learning outcomes.

Course AI Policy

The use of artificial intelligence (AI) tools is permitted in this course for learning support, brainstorming, checking understanding, improving writing clarity, and assisting with coding or software-related tasks. However, students remain fully responsible for the accuracy, originality, and integrity of all submitted work.

For homework submissions, students may use AI tools to support their learning, but they must ensure that the final submitted work reflects their own understanding and reasoning. Students should not submit AI-generated solutions without verification, explanation, and independent judgement. Any use of AI that contributes substantively to submitted work should be acknowledged where appropriate.

During the midterm and final examinations, the use of AI tools is not permitted.

Communication and Feedback

Assessment marks for individual assessed tasks will normally be communicated via Canvas. Homework will be marked and returned to students within 4 days after submission. Feedback may include written comments, annotated solutions, marking rubrics, sample solutions, in-class or tutorial discussion, or verbal feedback during tutorial sessions.

Homework feedback will focus on the correctness of methods, mathematical execution, physical interpretation, and clarity of presentation. Examination feedback will address understanding of structural analysis concepts, accuracy of calculations, and quality of reasoning.

Students who have questions about feedback or marks should contact the instructor or teaching assistant within two weeks after the feedback is released.

Late Submission Policy

To ensure fairness to students who submit work on time, late submissions for homework assignments will be subject to the following penalty schedule:

- 1st day late: -20% of the attained mark
- 2nd day late: -40% of the attained mark
- 3rd day late and thereafter: -100% (no marks awarded)

These penalties apply unless prior approval has been granted by the instructor or valid supporting documentation is provided.

Required Texts and Materials

Primary textbook:

- An Introduction to Aircraft Structural Analysis, 2nd Ed. by T.H.G. Megson.

The textbook is available online via the HKUST Library.

Reading list (optional):

- Analysis of Aircraft Structures: An Introduction, 2nd Edition, Bruce K. Donaldson, Cambridge University Press, 2012.
- Aircraft Loading and Structural Layout, Denis Howe, Professional Engineering Publishing, 2004.
- Airframe Structural Design: Practical Design Information and Data on Aircraft Structures, Michael Chun-Yung Niu, Conmilit Press, 1999.

Lecture notes, tutorial handouts, homework assignments, and supplementary resources will be provided via Canvas.

Academic Integrity

Students are expected to uphold HKUST's Academic Honor Code and maintain the highest standards of academic integrity. The University has zero tolerance for academic misconduct, including plagiarism, cheating, fabrication of data, and misrepresentation of work.

Students may discuss course concepts, homework strategies, and problem-solving approaches with classmates, the instructor, and teaching assistants. However, submitted work must be the student's own unless a task is explicitly designated as group work. Students must ensure that all calculations, derivations, analysis, and interpretation are conducted honestly and that any external assistance, including the use of AI tools, is acknowledged where appropriate.

Students should refer to the HKUST Academic Registry for the University's definitions of academic misconduct and guidance on academic integrity.

Course Outline

1. Introduction to Aircraft Structural Analysis [Week 1-2]

- Fundamentals of aircraft and structures; course briefing
- Aircraft anatomy and terminology; assembly and suppliers; aircraft components and functions; structural tests
- Aircraft materials; accidents due to structural failures

2. Major Aircraft Loads, Forces, and Simple Analysis [Week 2-3]

- Loads and forces in aircraft structures
- Aircraft loads transfer and simple analysis

3. Review of Stress, Strain, and the Theory of Elasticity [Week 3-4]

- Thin-walled structures; stress, strain, and elasticity concepts

- Sectional properties, failure theories, energy methods

4. Mechanics of Structural Components [Week 4-9]

- Torsion of thin-walled structures I: Basics and single closed cell
- Torsion of thin-walled structures II: Multiple closed cells, slat, hybrid sections
- Torsion of thin-walled structures III: Warping
- Bending of symmetric beam structures
- Bending of unsymmetrical beam structures
- Shear of thin-walled structures under bending I and II

5. Practical Stress Analysis of Aircraft Components [Week 9-11]

- Stress analysis in simplified thin-walled pressure vessels
- Structural idealization and bending stresses in idealized sections
- Shear stresses in idealized open and closed sections
- Wing spar beam with single-taper effect; fuselage/wing with double-taper effect
- Practical analysis of wing and fuselage sections under torsion, shear, and bending

6. Deflection of Beams and Stability of Columns with Energy Methods [Week 11-13]

- Bending and shear deflection of beams
- Energy methods used in deformation analysis
- Stability and buckling analysis
- The principle of stationary/minimum total potential energy