AE 462

DESIGN OF AIRCRAFT STRUCTURES

COURSE OUTLINE

INSTRUCTOR: Prof.Dr. Altan Kayran

Room 203, Tel: 4274

COURSE ASSISTANT: No Assistant

COURSE OBJECTIVE:

The objective of the course is to equip the senior year aerospace enginering students with the relevant infrastructure to carry out the design of aircraft sub-structures like wings, fuselages, landing gears etc. The course aims at achieving its objective by introducing the following general concepts used in the design process.

- Introduction of design philosophies like damage tolerance, safe- life, fail-safe
- Establishment of relations between the design requirements and airworthiness regulations
- Introduction of the aircraft data requirements and description of the critical airloads used in the design and analysis of aircraft structures
- Introduction of the aeroelastic stability design constraint
- Overview of the role and lay-out of main structural members used in aircraft structures
- Initial sizing calculations based on design constraints such as deflection, local buckling
- General design considerations used in the structural joints and fittings
- Fatigue failure consideration and its relation with design philosophies, fatigue loads in aircraft operations and fatigue life analysis methods

TEXTBOOK:

No special textbook will be used in the course. However, first four reference books are the ones which are mainly followed in this course.

1- ‘Airframe Structural Design,’ 2nd edition, by M.Niu, 1999, Hong Kong Conmilit Press Ltd., ISBN: 9627128090. (ordered by the library)

2- ‘Aircraft Loading and Structural Layout,’ by Denis Howe, 2004, AIAA Education series.

3- ‘Analysis and Design of Flight Vehicle Structures,’ by E.F. Bruhn, 1973, Tri-State Offset Company, Call number: TL 671.2 .B7
4- ‘Aircraft Structures,’ by D.J. Peery and J.J. Azar, 1982, Mc Graw Hill, ISBN: 0070491968, Call Number: TL671.6 P4

5- ‘Aircraft Structures for Engineering Students,’ by T.H.G. Megson, 1990, 2nd edition, John Wiley Sons, ISBN: 0470216530, Call Number: TL671.6 M36
6- Course notes on ‘Aircraft Design Loads’, AIAA Professional Development Short Course, April 2007, Hawaii.
7- Course notes on ‘Aircraft Structures Design and Analysis,’ University of Kansas, March 2003, Virginia.
8- ‘Airframe Stress Analysis and Sizing,’ by M.Niu, 1999, Hong Kong Conmilit Press Ltd.,ISBN: 9627128082.
9- ‘Analysis of Aircraft Structures,’ by B.K. Donaldson, 1993, McGraw-Hill, ISBN: 007017539X, Call Number: TL671.6.D56
10- ‘Theory and Analysis of Flight Structures,’ R.M. Rivello, 1969, McGraw-Hill, ISBN: 07052985X, Call Number: TL671.6 R53
11- ‘Structural Loads Analysis for Commercial Transport Aircraft: Theory and Practice,’ by Ted L. Lomax, 1995, AIAA Education Series, ISBN: 1563471140, Call Number: TL671.6.L597
8- ‘Understanding Aircraft Structures,’ by J. Cutler, 1999, Third Edition, Blackwell Science, ISBN: 0632050012, Call Number: TL671.6 .88
9- ‘Aeroelasticity,’ by Raymond L. Bisplinghoff, H. Ashley and Robert L. Halfman, 1996, Dover Publications, ISBN: 0486691896, Call Number: TL574.A37B5397
10- ‘Spacecraft Structures and Mechanisms; From Concept to Launch,’ by Thomas P. Sarafin, 1998, Luwer Academic Publishers, ISBN: 188184019, 0792319962, Call Number: TL790.S74
11- ‘Mechanical Engineering Design,’ J.E. Shigley, McGraw Hill Book Company, 2001, Call Number: TJ230.S5
12- ‘Fundamental of Machine Component Design,’ R.C. Juvinall, K.M. Marshek, John Wiley and Sons, 2006, Call Number: TJ230.J88

COURSE SYLLABUS: Total Hours Allocated: 56 class hours

The classes are organized for 3 class hours per week. The fourth hour will be used for general discussion, problem solving and project discussion. However, in the first half of the course, four hours of class will be held to cover as much topic as possible to aid the student in their project assignment.

Course Outline:

1- STRUCTURAL DESIGN OVERVIEW (2)
(To spare more time for later sections and project discussion, we will skip this section this year)

Subject	Hours
Fundamental structural concepts	1
Structural design criteria – Limit, ultimate loads Design strategies	
American and European civil and military regulations and design requirements	1

2- AIRCRAFT LOADS (10)

Subject	Hours
2.1. Aircraft data requirements; Structural design speeds, basic load concepts and types of load analyses • Design process of aircraft • Sources of of external loading • Types of loads and stiffness requirements • Structure design criteria • Aircraft Data requirements - Aerodynamic data - Mass, CG, Geometric data - Structural design speeds - Load factor data - Basic load concepts and types of load analyses **HW1**	2
Flight Maneuvering loads, V-N Diagrams • Definition of maneuver • Maneuver V-N diagram • Control system and hinge moment loads • Maneuvers and maneuver critical structure • Maneuver flight loads calculation procedure • Steady maneuver loads calculation • Pitch maneuvers-Checked, unchecked • Roll maneuvers-steady, accelerated • Yaw Maneuvers-Abrupt rudder, Oscillatory rudder motion	2

Gust loads; Discrete gusts • Discrete gust – Evolution of criteria • Tuned gust regulations • Tuned gust output • Gust envelope **Gust loads; Continuous gusts** • Definition of PSD • PSD gust load history • Gust PSD used in design – Von Karman PSD	3
APPLICATION 1 Example problem of calculating wing shears and moments for one unit load condition (Bruhn p.A5.9,A5.10,A5.11)	**Extra hour**
APPLICATION 2: **ESDU 95010:** Description of the computer program for estimation of spanwise loading of wings with camber and twist in subsonic attached flow and Schrenk's approximation **HW2**	**Extra Hour**
Assignment of Part 1 of the project: Calculation of external and internal loads	
Landing and ground handling loads • Requirements, role of conventional landing gear • General introduction and A/C landing attitudes • Shock strut efficiency • Drop test • Shock absorber performance and efficiency • Airframe loads and dynamic effects • Ground handling loads Ground handling analysis Take-off run and taxi Braked roll conditions Turning conditions Nose wheel yaw Pivoting Reversed braking Towing conditions Jacking and mooring conditions Abnormal landing	2

3- STATIC AEROELASTIC CONSIDERATIONS (4)

	Subject	Hours
3.1.	• Basic definition • Load distribution and control effectiveness and reversal	1
3.2.	• Flexible lift coefficent of a 2D wing including inertial effects, Divergence speed • Flexible lift	1
3.3.	• Slender beam model – Divergence instability	1
3.4.	• Control surface reversal of a simple 2D wing • Effects of wing sweep • General aeroelastic equations **HW3**	1

4- INITIAL SIZING OF AIRCRAFT STRUCTURES
EMPHASIS-2008: WING STRUCTURE, HAND CALCULATION (11)

	Subject	Hours
4.1.	• Wing strength requirements and stress analysis methods	0.25
4.2.	• Analysis and design of semi-monocoque structures - Typical structural idealizations - Review of unsymmetric bending and shear flows due to transverse forces - Torsion of closed section box beams, angle of twist - Shear center of closed section box beams, multicell box beams, Beam coordinates- A/C coordinates - Example of 3 flange- single cell wing (Bruhn-p.A19.5-7) - Multicell box beam under torsion- Easy solution method	6
	APPLICATION 3 Calculation of Brazier loading – Crushing load due to wing bending	**Extra hour**
4.3.	• Buckling design constraints - Local buckling of skin panels - Strut/stringer buckling - Compression buckling of thin walled section and stiffened skin panels - Buckling of flat plates under in-plane bending - Buckling of flat plates under combined loading - Effect of curvature on buckling - Optimization of distributed flange-stringer designs	5

MIDTERM EXAMINATION

5- ROLE AND LAY-OUT STRUCTURAL MEMBERS (5) (Depending on how we progress we may skip sections 5.2-5.5 and do only 5.1)

	Subject	Hours
5.1.	• Basic aims of structural design • Analysis requirements-structural design data Example of unrestrained beam analysis **HW4**	1
5.2.	• Lifting surfaces – wings and stabilizers Overall requirements Main structural components Discrete Booms Built-up skin-stringer construction Integrally machied and moulded construction Multicell construction	1
5.3.	• Chordwise location of spars • Rib location ad direction • Horizontal and vertical stabilizer	1
5.4	• Hinged control surfaces, pivoted control surfaces, high lift systems	1
5.5	• Fuselage General considerations, cross section, basic structural layout Frames and bulkheads	1

6- STRUCTURAL JOINTS AND FITTINGS (4)

Subject	Hours
• Introduction to joints and fittings • General design considerations • Bolted or riveted joints – modes of failure • Eccentric joint analysis • Lug analysis	4
APPLICATION 4 Riveted joint analysis – loads carried by interior rivet lines **HW5**	**Extra hour**

7- FATIGUE FAILURE CONSIDERATION, DAMAGE TOLERANT, FAIL SAFE AND SAFE LIFE DESIGNS (6)

Subject	Hours
• Fatigue failure, Definitions, S-N curves, low-high cycle fatigue • Fatigue strengths for different types of loading • Factors affecting fatigue strength • Reliability analysis • Fatigue under fluctuating stress with a mean	3
• Cumulative fatigue damage and fatigue life prediction-Miner's rule • Fatigue design process:Safe life, fail safe, damage tolerant designs • Fatigue Related specifications	1
• Fatigue loads in aircraft operations, Typical mission profiles - Manuever loads discrete analysis - Exceedances curves and data for maneuver load - Turbulence loads - Landing loads • GAG cycle	2
APPLICATION 5 **Two problems:** **Problem 1-** Factor of safety analysis for a leaf spring under fluctuating stress with a mean **Problem 2-** Determination of fatigue life of an structural part under variable amplitude loading	**Extra hour**

COURSE EVALUATION

5 homeworks (different percentages for the homeworks)	12.5 %
One midterm examination	20 %
Project (50%)	50 %

Progress report (12%)

Document 1 under the "submission documents" list of the Design Project handout. Deadline for the progress report will be announced during the semester.

Project final report (30%)

Documents 2,3, and 4 under the "submission documents" list of the Design Project Handout

Some intermediate deadlines may be announced during the semester for the second part of the project. These deadlines will be announced during the semester. Some of these works may be combined with homeworks. These intermediate assignments will let you prepare for the final project report.

Project presentation (8 %)

Final Examination	20 %
Total	102.5 % (2.5 % bonus)

NOTES :

- Total number of lectures is 56 hours per semester. However, in the first half of the course, four hours of class will be held to cover as much topic as possible to aid the student in their project assignment.
- In case the classes are finished early students will be held free to carry out their study on their assigned projects, and class will meet only for one hour to discuss about the project progress.
- Projects will be assigned to a group of two people or at most 3.
- Projects will be assigned during section 3.
- A project progress report will be written, and submitted. The progress report due time will be announced during the project discussions
- Final project submission should be during the last week before the submiison of grades
- After the submission of the project, there will be project presentations for each design team during that week.

  Each group will present their work. Project presentation is a must item. Students who do not present their project will receive incomplete grade.
- The content and type of the final examination will be announced during the semester. .