Aircraft Design

Code	Credit Hours
AE-451	2-2

Prerequisites

- Aerospace vehicle Performance
- Stability and Control
- Propulsion and Power plants

Course Description

This course deals with the conceptual design of various types and categories of aircraft. Conceptual design is basically the new aircraft concept development process and consists of two major activities: design layout and design analysis. These two phases broadly cover aspects of configuration layout, payload considerations, aerodynamics, propulsion, structures and loads, weights, stability and control, performance and tradeoff studies. As part of this course, the student is required to prepare and present a conceptual design of a complete aircraft based on certain specifications. Extensive use of computers would be made to refine the designed aircraft. The students are encouraged to use software like AAA / RDS / DATCOM / XFLR / PANAIR / ADS / OpenVSP / Matlab / CATIA / Solid edge / Solid works / Pro-Engg PTC Creo/ Sketchup / Inventor / NX etc and explore other online available software for design, evaluation, CAD modeling and optimization of the designs.

Text Book (S):

Textbook:

1. “Aircraft Design: A Conceptual Approach” by Raymer, AIAA Education Series, Latest Available Edition , ISBN 978-1-62410-490-9, 2018.
2. Maintenance Practices by Aviation Maintenance Technician Certification Series, Latest Available Edition
3. TURBINE AEROPLANE STRUCTURES AND SYSTEMS by Aviation Maintenance Technician Certification Series, Latest Available Edition
4. Aircraft Aerodynamics, Structure and Systems by Aviation Maintenance Technician Certification Series, Latest Available Edition

Reference Material:

1. “Aircraft Design – A Systems Engineering Approach” by Mohammad H. Sadraey,Wiley, ISBN 978-1-119-95340-1, 2013.
2. “Fundamentals of Aircraft and Airship Design, Volume 1 : Aircraft Design” byLeland M Nicolai, AIAA Education Series, ISBN 978-1-60086-751-4, 2010
3. “Aircraft Design” by Ajoy Kumar Kundu, Cambridge Aerospace Series, ISBN 978-0-521-88516-4, 2010.
4. “Designing Unmanned Aircraft Systems : A Comprehensive Approach” by JayGundloch, AIAA Education Series, 2nd Edition, ISBN (print): 978-1-62410-261-5, 2014.

ASSESSMENT SYSTEM:

Quizzes	10%
Assignments	10%
Mid Terms	30%
ESE	50%

Lab Part	
Assignments	60 %
Design Presentation (Final Lab + Project)	40%
In order to increase the weightage of final presentations, some assignments' weightage may be shifted to Design presentation	

Teaching Plan

Theory

LecNo	Description	Ref
1	Introduction Conceptual design of various types and categories of aerospace vehicle	Text-1 Ch1,2
2-3	Rough weight sizing of aircraft Airfoil and Wing/Tail geometry selection	Text-1 Ch 3 3.2,3.3,3.4,3.5, 3.6 Reference-1 Ch-3 3.1,3.2,3.3

4-6	Airfoil selection Cl Calculation Stall Characteristicst/c selection Wing Geometry AR calculation Sweep selection Taper Ratio selection Dihedral selection Wing Tip selection Wing vertical location selectionTail configuration selection Tail Geometry (AR and Taper Ratio)	Ch4
7-8	Thrust-to-weight Ratio (T/W) and wingloading (W/S) T/W calculation according to aircraft type Thrust Matching according to mission profileW/S calculation according to mission profile Selection of T/W and W/S	Text-1 Ch 5 5.1,5.2,5.3
9-13	Initial Sizing (Refined weight sizing) Rubber and Fixed Engine sizing Fuel weight estimation according to missionprofile GTOW calculation through iterations (MATLABor any other suitable Software) Geometry SizingFuselage Wing Tail volume coefficientControl surface sizing	Text-1 Ch 6 6.1,6.2,6.3,6.5
14-15	Configuration / Design layout and lofting Conic lofting Conic fuselage developmentButtock plane cuts Wing Layout calculationFillets Winglets Wetted area determinationTail layout calculation Volume determination	Text-1 Ch 7 Reference-1 Ch-7
16	Special considerations in configuration	Text-1 Ch 8,9
17	layout Aerodynamics considerations Area Ruling Sear-Hacks Structural considerations Radar Detectability Aural Signature Crew Station, Passengers and Payload considerations Cabin management Gun Installation Bombs/missile station considerations	Text-1 Ch 10 10.3,10.4,10.5
18-19	Propulsion and fuel system integration Engine dimension estimation Inlet geometry Inlet locations Capture area calculations BL Diverter Propeller sizing Propeller location Fuel system Electrical system	Reference-1 Ch-8

20	Landing gears and subsystems LG arrangements Tire sizing Shock absorbers LG Retraction geometry	Text-1 Ch 11 Reference-1 Ch-9
21-23	Design Analysis: Aerodynamics Coefficients' determination CD CLα Supersonic lift curve slope CLmax CDo determination Parasite drag determination (Fig 12.34) K- calculation Ground effects Introduction of CFD in determination of drag and lift characteristics XFLRv5 will be used for determination of Airfoil, Aircraft drag estimation	Text-1 Ch 12 12.1,12.2,12.3 12.4,12.5,12.6
24-25	Design Analysis: Propulsion Rubber Engine SizingFixed Engine Sizing Intake Design Propeller Design	Text-1 Ch 13
26-27	Design Analysis: Structures and loads Load categories Structure fundamentalsMaterial selection Truss analysis (Method of joints)Method of shears V-n diagram Gust V-n diagram Weights analysis Moment Balance Methodology for determination of aircraft CG Concept of CG envelope Aircraft statistical weight method	Text-1 Ch 14
	2 Hour Lecture may be arranged as invited guest speaker from Structures Group coveringabove topics	

28-29	Stability, control and handling qualities Introduction Coordinate system and definitions Longitudinal static stability calculationsLongitudinal control calculations Flap effectiveness Downwash and up-wash Thrust effect on longitudinal stabilityTrim Analysis Lateral and directional stability and controlparameters calculations	Text-1 Ch 16 16.1,16.2,16.3 Ref-1 Ch-6 Ref-1 Ch-12
30	Performance estimation and flightmechanics Steady level flight Drag Polar plot Range calculations	Ch 17
31	Endurance CalculationsPs plots Flight envelope Take off distance calculation Landing distance calculations	
32	Sizing & Trade Studies Sizing MatrixCarpet Plot	Ch 19
33	Optimization	Ch 19
	End Semester Exam	

Lab Work

Lab No	Description	Ref	Lab Report
1	Selection of reference aircraft	Ch1,2	1
2-3	Defining Mission profile and Rough weightsizing of aircraft	Ch 3	
4-5	Airfoil and geometry selection	Ch4	
6-8	Calculation of T/W and W/S for differentmission segments	Ch 5	
9	Rubber engine sizing	Ch 6	
10	Initial sizing of aircraft using the parametersselected and wing and thrust loading	Ch 6	

11-12	Lab Assignment preparation	Ch 6	
	(Design Report-1 Submission 15% of Lab Part)		
13-14	Selection of Configuration layout and Payload management. payload positioning, cockpit and crew station layout propulsion and fuel system integration, landing gears and subsystem selection. Drawing of Aircraft and lofting of sketch	Ch 7, 8, 9	1
15	Appropriate selection for Propulsion and fuel systems and their integration with aircraft. Intake design.	Ch 10	
16	Selection of Landing gears and subsystems	Ch 11	
17-20	Aerodynamic analysis including plots of C_{La}, C_{Lmax},C_{D0},K, C_{DI} with varying Mach Nos.	Ch 12	
21-23	Propulsion system analysis including plots of Uninstalled thrust, installed thrust, Inlet drag and Net propulsive power versus Mach No at various altitudes V-n diagram of aircraft with and without gust loads and estimation of maximum speed. weight estimation using Approximate group and Statistical group methods and comparison of the results of the two methods with each other and with previous results of crude estimation. Calculation of resulting fuel weight and to see if the fuel weight is sufficient to carry out the design mission	Ch 13 Ch 14, 15	
24-26	Static stability analysis in pitch, roll and yaw modes. Calculation of contribution of various components (wing, fuselage, tail etc.) towards longitudinal stability and plots of C_{mcg} vs AoA plots. Plot of C_{mcg} vs C_L and estimation of C_{lbeta} and C_{nbeta}.	Ch 16	
Design Report -2 Submission 15% of Lab Part			

27-29	Estimation of all required parameters for Performance analysis. Thrust available vs Thrust required plot. Evaluation of range, endurance, climb rate, T/W for climb, time to climb and fuel consumed in climb, instantaneous and sustained turn rate ofaircraft. Ps vs M plots at different load factors, Ps vs Height at different load factors, Trajectory of minimum time to climb and complete operating envelope of your design with all limits clearly shown. Take off and landing performance analysis of design	Ch 17	1
30	Making of sizing matrix for the design for at least 9 different settings of W/S and T/W. Making of sizing matrix cross plot and identification of optimum design point.	Ch 19	
31	Using sizing matrix to make carpet plot of design	Ch 19	
Submission of Design Report-3 as part of Complete Design Report (30% of lab part)			
	Final Design Presentation (40 % of lab part)		

Lab Rubrics (Design Report-1)

Chapter	Requirements	Max Marks	Values / page No
Ch 3 Sizingfrom a Conceptual	Hand Sketch	25	
	Proposed Mission Profile (Demonstrate design characteristics)	25	
	Rough weight sizing according to mission profile	50	
Ch 4 Aerofoil and Wing/ Tail Geometry Selection	Aerofoil selection	25	
	Wing and tail geometric parameters ($C_{Ldesign}$, C_{Lmax}, Mdesign, Stall, AR, Taper ratio, twist, incidence angle, dihedral, vertical locations, tip shape etc)	75	
5 T/W and W/S	Calculate T/W for mission segments (write code as well)	25	
	Calculate W/S for mission segments (Write code as well)	35	
	Selection of design values of T/W and W/S	40	
Design	Introduction of innovative design concepts and highlighting their		
General	significance		
	Presentation	25	
	Analysis and discussion	25	
	Good drawing with labelling	25	

(15% of lab part)

Lab Rubrics (Design Report-2)

Chapter	Requirements	Max Marks	Values / page No
Ch 6 Initial Sizing	Empty Wt Fraction	10	
	Fuel Wt Fractions	10	
	T/O gross Wt Iterations	10	
	Comparison with Rough Wt Sizing	10	
	Comments on results	10	
	Engine sizing	10	
	Fuselage Geometry (Length, fineness ration, diameter, account forpassengers, crew, engines, payload, moment arm for control)	10	
	Revisit Wing Geometry (with new Wo, W/S and T/W info)	10	
	Revisit Tail geometry (AR, Vol Coeff, Moment Arm)	10	
	Control Surface Sizing (Ailerons, Elevators, Rudder etc)	10	
Ch 7 Configuration	Lofted drawing of fuselage (space for crew, payload, passengers,luggage, landing gears, fuel system, engine etc)	25	
layout and lofting	Lofting of wing (AR, TR, Sweep, Dihedral, Thickness, Cords etc)	25	
	Lofting of tail / canards (tips, space for fuel, LG, fillets, Wetted area,	25	
	Proper positioning of wing / tail over fuselage (location of MAC wrt CG	25	
Ch 8 Special consideration inconfig layout	Aerodynamic Considerations	35	
	Structural Considerations	35	
	Other considerations (Stealth, Maintainability)	30	
Ch 9 Crew station, passenger &Payload	Crew station (Space, outside visibility)	25	
	Internal P/L / passengers / Cargo layout	25	
	External P/L (Weapon carriage, launch, gun)	25	
	Good CAD model / drawing with these features	25	
Ch 10 Propulsion sysselection	Engine Selection (justification)	10	
	Engine sizing (Scale Factor, Geometry, wt, Thrust, BPR, SFC – max &Cruise, accessories etc)	20	
	Engine inlet geometry	20	
	Engine inlet location	10	
	Engine Capture area (Subsonic, supersonic)	20	
	BL Diverters	10	
	Fuel tank selection (location, type etc)	10	
Ch 11 LG	Landing gear type and configuration	50	

and Sub-systems	Tire and shock absorber sizing	50	
Ch 12 Aerodynamic analysis	Lift Curve Slope (Supersonic, subsonic), fuselage lift factor, C_{la} Vs Mach number	15	
	Max Lift – clean (effects of AR, Sweep) C_{lmax} Vs Mach No	10	
	AOA for Max Lift	5	
	Change in Max Lift due HLD (Flaps, LEX, slots, slats, flap area)	5	
	Change in zero lift AOA with HLDs	5	
	Parasite Drag (Eq skin friction method & component build-up method, Cfc, FFc, Qc, Cdmisc, Cdl&p, Wave D)	10	
	Comparison of two methods for Parasite Drag	5	
	Plot of Parasite drag vs Mach No	10	
	Induced Drag – lift (Oswald Efficiency method & LE Suction method)	10	
	Comparison of two methods	5	
	Plot of induced drag Vs Mach No	10	
	Plot of Complete Drag Vs Mach No	10	
Ch 13 Propulsion analysis	Uninstalled thrust Vs M No	20	
	Installed Thrust Calculations (Inlet pressure recovery, bleed air) Vs Mach	40	
	Installed Propulsive Force (Inlet drag, Nozzle drag, Trim Drag) Vs Mach	40	
Ch 14 Structures and loads	Separate Vn diagrams for high g manoeuvre and gust loads with labelling of important curves and parameters (max +, - load, dive speed,	50	
	Combines Vn Diagram	30	
	Discuss various aspects of V-n diagram and behaviour of your design	20	
Ch 15 Weight Analysis	Approximate Group Weight Method (Gp Wt Statement)	20	
	Statistical Group Weight Method (Gp Wt Statement)	20	
	Comparison among the two methods as well as previous crude	20	
	Calculate resulting fuel weight	20	
	Comment if the fuel weight is sufficient to carry out the design mission	20	
Ch 16 Stability Analysis	Contribution of wing to stability	15	
	Contribution of tail to stability	15	
	Contribution of engine to stability	15	
	Location of Neutral point and static margin Vs Mach No	15	
	Plot C_{mcg} Vs CL for various trim settings	15	
	Calculate C_{lB} and C_{nB}	15	

	Comments in stability of your design	10	
	Formatting	25	

General	Presentation	25	
	Analysis and discussion	25	
	Good drawing with labelling	25	

(15% of lab part)

Lab Rubrics (Design Report-3)

Chapter	Requirements	Max Marks	Values / page No
Ch 17 Performance and Flt Mech	Present Thrust available vs Thrust required plot.	10	
	Evaluate range, endurance, climb rate, T/W for climb, time to climb and fuel consumed in climb, instantaneous and sustained turn rate	35	
	Present Ps vs M plots at different load factors, Ps vs Height at different load factors, Trajectory of minimum time to climb and complete operating envelope of your design with all limits clearly shown	35	
	Carry out complete take off and landing performance analysis of yourdesign.	10	
	Comment on performance of your design viz-a-viz the designrequirements	10	
Ch 19 Sizing and Trade Studies	Make sizing matrix for your design for at least 9 different settings of W/Sand T/W	10	
	Make sizing matrix cross plot and identify the optimum design point.	35	
	Use same sizing matrix to make carpet plot for your design.	35	
	Analyse your results and discuss the findings	20	
General	Formatting	25	
	Presentation	25	
	Analysis and discussion	25	
	Good drawing with labelling	25	

(15% of lab part)

*Note: The course has 0-2 credit hours as lab part allowing the students ample time to apply the knowledge imparted during lectures into their designs. The lab wise breakdown provides requirements as well as guidelines to the students to complete their design in discrete steps. The lab work of aerospace vehicle design falls under the C-6 cognitive domain unlike other lab courses where the lab work usually falls under the psychomotor domain. The lab assessments may be considered as Complex Engineering Problem instead of Open-Ended Labs as the students are designing an aircraft with complex engineering requirements and no lab equipment is required for this course.