



DEPARTMENT OF AERONAUTICAL ENGINEERING

LAB MANUAL

**AE3511-AIRCRAFT STRUCTURES
LABORATORY**

COURSE OBJECTIVES:

- To enable the students understand the behavior of aircraft structural components under different loading conditions.
- To provide the Principle involved in photo elasticity and its applications in stress analysis for composite laminates.
- To obtain the stresses in circular discs and beams using photo elastic techniques

LIST OF EXPERIMENTS

1. Deflection of Beams
2. Verification of superposition theorem
3. Verification of Maxwell's reciprocal theorem
4. Buckling load estimation of slender eccentric columns
5. Determination of flexural rigidity of composite beams
6. Unsymmetrical Bending of a Cantilever Beam
7. Combined bending and Torsion of a Hollow Circular Tube
8. Material Fringe Constant of a Photo elastic Models
9. Shear Centre of a Channel Section
10. Free Vibration of a Cantilever Beam
11. Forced Vibration of a cantilever Beam
12. Fabrication of a Composite Laminate.
13. Determination of Elastic constants for a Composite Tensile Specimen.
14. Determination of Elastic constants for a Composite Flexural Specimen.
15. Tension field beam

Any 10 experiments can be chosen

COURSE OUTCOMES:

At the end of the course students will be able to:

CO1: Evaluate the effects of bending in the aircraft structures.

CO2: Explain the shear centre of the aircraft structures.

CO3: Compare the photo-elastic techniques on the aircraft structures.

CO4: Justify the experimental findings in clear oral and concise report.

EX.NO: 01

DEFLECTION OF BEAMS

AIM

To determine the deflection of beams with various end conditions, experimentally compare with the theoretical values and draw the deflection curve.

APPARATUS REQUIRED

- Dial Gauges
- Weights
- Weights Hanger
- Meter Scale
- Beam Specimen and
- Beam setup

THEORY

The deflection of an Aircraft wing can considerably change the lift distribution on a wing. Hence estimation of deflections and restricting the deflection within the allowable limits are important for Aerospace structural engineer. From the elementary theory of bending, the differential equation of the deflection curve is

$$\frac{d^2y}{dx^2} = -\frac{M}{EI} \quad (1)$$

From the above equation, the deflection curve for a simply-supported beam with a concentrated load at the center is

$$EIy = \frac{PL^2x}{16} - \frac{Px^3}{12} \quad (2)$$

The deflection curve for cantilever beam with a tip load is

$$EIy = \frac{PLx^2}{2} - \frac{Px^3}{6} \quad (3)$$

The above equations are used to calculate the deflection theoretically at various points.

PROCEDURE

1. The beam is simply supported using the knife edges; weight hanger and dial gauge are to be kept at the middle of the beam.
2. Apply the concentrated load of 0.1kg in the beam.
3. Note down the reading from the dial gauge and increase the load by 0.1kg.
4. The deflections at this point are also calculated theoretically using equation (2) and (3).
5. The deflection curve is drawn on a graph sheet with proper scale.
6. The experiment can be repeated by fixing the specimen as cantilever beam.
7. For cantilever beam, note down the length of the beam using meter scale.

TABULATION

FOR CANTILEVER AND SIMPLY-SUPPORTED BEAM

S.No.	Load P (kg)	Dial Gauge Reading δ	Theoretical deflection
1.			
2.			
3.			
4.			
5.			

GRAPH

The draw the graph between loads vs. deflection.

APPLICATION

- I. Aircraft wing is idealized as cantilever beam in the design of Aircraft (Box beam).
- II. Aircraft fuselage is idealized as a free-free beam in the design of Aircraft.

RESULT

Deflection curves are drawn for the given beam. Experimental values are compared with the theoretical values

MODEL TABULATION AND CALCULATION

For Cantilever beam

Let consider,

Length of the beam (L) = 60 cm

Breadth of the beam (b) = 12.5cm

Width of the beam (d) = 6mm

Moment of inertia ($I = \frac{bd^3}{12}$) = 225mm⁴

Theoretical deflection = $\frac{PL^3}{3EI}$

S.No.	Load P (kg)	Dial Gauge Reading δ	Theoretical deflection
1	0.1	150	149
2	0.2	299	298

3	0.3	448	449
4	0.4	597	597
5	0.5	746	747

Calculation

$$\text{Theoretical deflection} = \frac{PL^3}{3EI} = (0.1 \times 9.81 \times 600^3) / (3 \times 210 \times 10^3 \times 225)$$

$$= 1.49\text{mm} = 149$$

For Simply Supported beam (load and deflection at mid point)

Let consider,

Length of the beam (L) = 60 cm

Breadth of the beam (b) = 12.5cm

Width of the beam (d) = 6mm

Moment of inertia ($I = \frac{bd^3}{12}$) = 225mm⁴

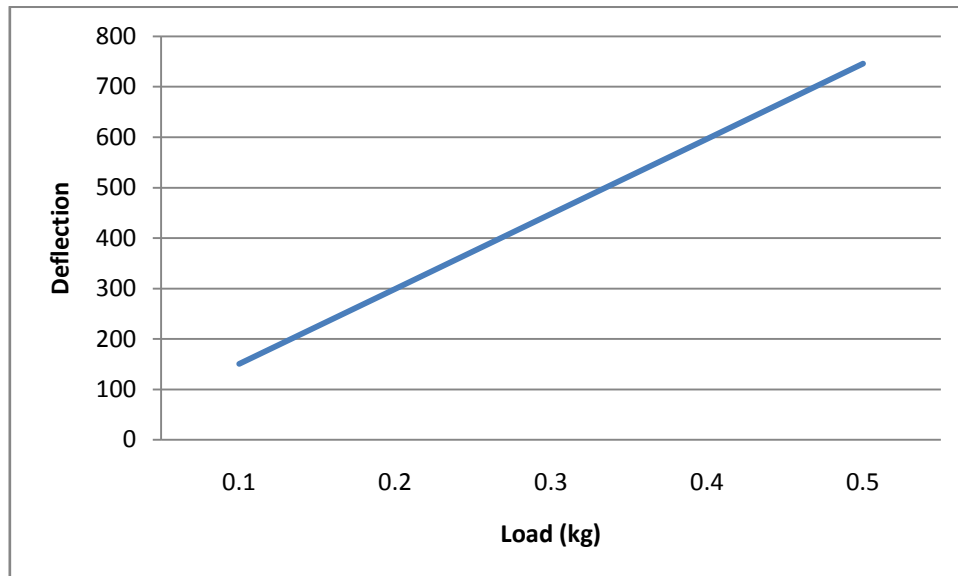
$$\text{Theoretical deflection} = \frac{PL^3}{48EI}$$

S.No.	Load P (kg)	Dial Gauge Reading δ	Theoretical deflection
1	0.1	10	09
2	0.2	18	18
3	0.3	28	28
4	0.4	37	37
5	0.5	46	46

Calculation

$$\begin{aligned}\text{Theoretical deflection} &= \frac{PL^3}{48EI} = (0.1 \times 9.81 \times 600^3) / (48 \times 210 \times 10^3 \times 225) \\ &= 0.09\text{mm} = 09\end{aligned}$$

Model Graph



Maxwell Reciprocal Theorem

Aim: -

To verify clerk Maxwell's reciprocal theorem

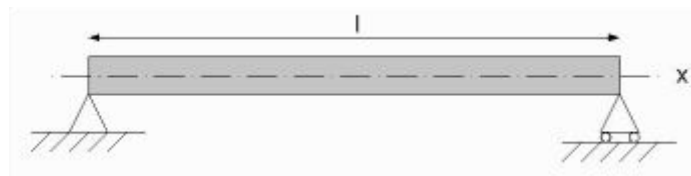
Apparatus Required:

- Maxwell's Reciprocal Theorem apparatus,
- Weights, Hanger,
- Dial Gauge,
- Scale,
- Knife edges

Theory: -

Maxwell theorem in its simplest form states that deflection of any point A of any elastic Structure due to load P at any point B is same as the deflection of beam due to same load Applied at A

It is, therefore easily derived that the deflection curve for a point in a structure is the same as the deflected curve of the structure when unit load is applied at the point for which the Influence curve was obtained.



Procedure: -

1. Apply a load either at the centre of the simply supported span or at the free end of the beam, the deflected form can be obtained.
2. Measure the height of the beam at certain distance by means of a dial gauge before and after loading and determine the deflection before and after at each point separately.
3. Now move a load along the beam at certain distance and for each positions of the Load, the deflection of the point was noted where the load was applied in step1.This
4. Deflection should be measured at each such point before and after the loading, separately.
5. Plot the graph between deflection as ordinate and position of point graph drawn in step 2 and 3.These are the influence line ordinates for deflection of the Beam.

Table:

SINo	Load at A (g)	Deflection at B (mm)	Load at B (g)	Deflection at A (mm)
1	100	.42	100	.42
2	200	.97	200	.96
3	300	1.33	300	1.33
4	400	2.43	400	2.43

Precaution: -

- i) Apply the loads without any jerk.
- ii) Perform the experiment at a location, which is away from any disturbance
- iii) Ensure that the supports are rigid.

Result:

From the results in the Table, it is found that the deflection at A is equal to the deflection at B and Hence the Maxwell reciprocal theorem is verified.

HINGED BAR SUSPENDED BY TWO WIRES OF DIFFERENT MATERIALS

Aim:

To determine the forces in the two wires of different materials attached to the hinged bar experimentally.

Theory:

A statically determinate force system is one in which the values of all the external forces acting on the body can be determined by the equation of statics along more unknown forces than the equations of the equilibrium such a case of the force system is said to be statically indeterminate.

A hinged bar suspended by two wires of different materials in an indeterminate system. It will have one unknown force in each wire and a vertical unknown reaction at the hinged support. To determine the unknown forces 'DETERMINATION Method' is used, in which considers the deformation of the system. The procedure to be followed in analyzing an indeterminate system. Enough equations involving deformations must be written so that the total number of equations from both statics and deformations is equal to the number of unknown forces involved.

The present experiment is aimed at finding these unknown forces using simple dial gauges.

Apparatus required:

Loading frame, hinged bar suspended steel and copper wires of equal length and the diameter, dial gauges (2 Nos.), weights and hook for placing the weights.

Procedure:

The hinged bar is suspended horizontally using spirit level. Two dial gauges are placed exactly below the point of the attachment of each wire. Weights are placed in the weight hanger in steps of 2kgs up to 10kgs and the corresponding dial gauge readings are noted and tabulated as given below.

The load carried by each wire is calculated using the theory from 'strength of materials' as shown below and compared with the values obtained from the dial gauge readings.

Experimental calculations:

$$L_1 = L_2 = L = 577\text{mm} \qquad d_1 = d_2 = 1\text{mm} \qquad A_1 = A_2 = (\pi/4) d^2$$

$$E_1 = 2000\text{Gpa} \qquad E_2 = 100\text{Gpa}$$

S.no	P in kg	Δ_1	Δ_2
1	2	24	11
2	4	37	17
3	6	46	23
4	8	57	30
5	10	68	35

For a load $10 - 2 = 8\text{kg}$ $\Delta_1 = 44$ $\Delta_2 = 23$

$$P_1 = AE_1/L_1\Delta_1 = (\pi \times 100 \times 10^3 \times 44 \times 10^{-2}) / 4 \times 577 = 59.9\text{N} = 6.1\text{kgf}$$

$$P_2 = A_2E_2/L_2\Delta_2 = (\pi \times 200 \times 10^3 \times 23 \times 10^{-2}) / 4 \times 577 = 62.64\text{N} = 6.4\text{kgf}$$

$$P_1/P_2 = 3.99$$

FROM THEORY $P_1 = P/2$ AND $P_2 = P/2$

Hence the ratio of forces from the experiment and theory coincides.

BUCKLING OF COULMNS

Aim:

To determine a critical load of column using south well plot.

Theory

The need to make use of materials with high strength-to-weight ratio in aircrafts design has resulted in the use of slender structural components that fail more than often by instability than by excessive stress. The simplest example of such structural component is a slender column. Ideal column under the small compressive equilibrium position returns to it original equilibrium position. Further increase the load does not alter the situation. Until a stage is reached. This is neutral equilibrium position for the column position also. The column is said to have failed due its instability. The load beyond which the column is unstable is called the Euler load or the critical load.

In an ideal column deflection appear suddenly at the critical load whereas in actual column due to imperfections present the deflection starts appearing as soon as the loads are applied. South well shown that there exists a relation between a compressive load. Later deflations which can be utilized profitably to determine the critical load and the eccentricity of the column by the graphical procedure without actually destroying the test specimen.

The well known formula for critical load of an uniform slender column is

$$P_{cr} = C (\pi^2 EI) / L^2$$

Where C is constant depending on the end conditions of the column, E is the youngs modulus of the material of the column, I is the least moment of inertia of the section and L is the length.

As mentioned earlier the lateral deflection of the ideal column is indeterminate at the critical load. But for the deflections ‘ Δ ’ of a simple supported column at its midpoint due to load P can be written as

$$\Delta = e \left[\frac{P_{cr}}{P} - 1 : \begin{array}{c} \dots \\ \vdots \\ \dots \end{array} \right]$$

Rewriting the equation in the following form,

$$\Delta = P_{cr}(\Delta/P) - e$$

It is seen that the plot of the ratio (Δ/P) against Δ is a straight line and that its inverse slope gives the critical load and the intercept on the Δ – axis gives the magnitude of the eccentricity.

Apparatus required:

1. Column testing apparatus as shown in the figure.
2. Specimens
3. Dial gauge
4. Venire calipers
5. Weights

Procedure:

The ends of the given column specimen are carefully prepared to provide knife-edge supports. The specimen is then mounted on the column testing apparatus. The columns should be placed with the longitudinal axis aligned vertically at the mid-point of the given column, a dial gauge is placed.

Loads are then gradually applied. A plot of Δ/p versus Δ is obtained. This is called the south well plot, which should be a straight line. The inverse of

the slope of this line will be indicated the value of the critical buckling load, P_{cr} of the given hinged- hinged column as shown in the theory.

Table:

Specimen dimensions' = $L =$ $d =$

s.no	P	Δ	Δ/P
1			
2			
3			
4			

$$P_{cr} = \pi^2 EI / L^2$$

Result

The critical load of column using

$P_{theo} =$ $P_{exp} =$

SOUTH WELL PLOT

Model Calculation

LOAD FRAME WEIGHT = 4kg

s.no	P	Δ	Δ/P
1	4+1=5	12	2.4
2	4+2=6	16	2.6
3	4+3=7	20	2.8
4	4+4=8	27	3.3
5	4+5=9	34	3.7
6	4+6=10	43	4.3
7	4+7=11	55	5
8	4+8=12	67	5.5
9	4+9=13	81	6.2
10	4+10=14	100	7.1

Material: aluminum

$$L = 1$$

$$b = 14.5 \text{ mm}$$

$$d = 8 \text{ mm}$$

$$I = bd^3/12$$

$$I = 618.6 \text{ mm}^4$$

$$P = (\pi^2 EI)/L^2 \quad E = 70 \times 10^9 \text{ Pa}$$

$$P = 432.6 \text{ N}$$

$$P_{\text{cr the}} = 432.6/9.81 = 44.09 \text{ kg}$$

$$P_{\text{cr exp}} = \tan^{-1} \theta = (25.5/1.5) = 17.0 \text{ kg}$$

Model graph:





DEPARTMENT OF AERONAUTICAL ENGINEERING

AE3581-CAD LABORATORY



DEPARTMENT OF AERONAUTICAL ENGINEERING

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by Mr/Ms..... of
Department in the.....
Laboratory and Submitted for University Practical Examination Conducted
on.....At TAGORE ENGINEERING COLLEGE, Chennai -
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Staff In charge

Head of the Department

EXTERNAL EXAMINER

INTERNAL EXAMINER

LIST OF EXPERIMENTS

EX NO	DATE	NAME OF THE EXPERIMENT	SIGNATURE
		INTRODUCTION TO CAD MODELING	
		INTRODUCTION TO SOLID WORKS	
1		COMPUTER AIDED DESIGN OF SUBSONIC DIFFUSERS.	
2		COMPUTER AIDED DESIGN OF SUPERSONIC DIFFUSERS	
3		COMPUTER AIDED DESIGN OF A COMPRESSOR BLADE.	
4		COMPUTER AIDED DESIGN OF CONVERGENT NOZZLE	
5		COMPUTER AIDED DESIGN OF A CONVERGING-DIVERGING NOZZLE.	
6		COMPUTER AIDED DESIGN OF TYPICAL AIRCRAFT WING.	
7		COMPUTER AIDED DESIGN OF TYPICAL FUSELAGE STRUCTURE.	
8		COMPUTER AIDED DESIGN OF A LANDING GEAR.	
9		COMPUTER AIDED DESIGN OF A LAUNCH VEHICLES.	
10		COMPUTER AIDED DESIGN OF A RE-ENTRY VEHICLES.	
11		COMPUTER AIDED DESIGN OF A MISSILES.	
12		COMPUTER AIDED DESIGN OF A SATELLITES	

INTRODUCTION TO CAD MODELING

Computer Aided Drafting is a process of preparing a drawing of an object on the screen of a computer. There are various types of drawings in different fields of engineering and sciences. In the fields of mechanical or aeronautical engineering, the drawings of machine components and the layouts of them are prepared. In the field of civil engineering, plans and layouts of the buildings are prepared. In the field of electrical engineering, the layouts of power distribution system are prepared. In all fields of engineering use of computer is made for drawing and drafting. The use of CAD process provides enhanced graphics capabilities which allows any designer to

- Conceptualize his ideas
- Modify the design very easily
- Perform animation
- Make design calculations
- Use colors, fonts and other aesthetic features.

REASONS FOR IMPLEMENTING A CAD SYSTEM

1. Increases the productivity of the designer: CAD improves the productivity of the designer to visualize the product and its component, parts and reduces the time required in synthesizing, analyzing and documenting the design
2. Improves the quality of the design: CAD system improves the quality of the design. A CAD system permits a more detailed engineering analysis and a larger number of design alternatives can be investigated. The design errors are also reduced because of the greater accuracy provided by the system
3. Improves communication: It improves the communication in design. The use of a CAD system provides better engineering drawings, more standardization in the drawing, better documentation of the design, few drawing errors and legibility.
4. Create data base for manufacturing: In the process of creating the documentation for these products, much of the required data base to manufacture the products is also created.
5. Improves the efficiency of the design: It improves the efficiency of the design process and the wastage at the design stage can be reduced.

APPLICATION OF CAD:

There are various processes which can be performed by use of computer in the drafting process.

1. **Automated drafting:** This involves the creation of hard copy engineering drawings directly from CAD data base. Drafting also includes features like automatic dimensioning, generation of cross – hatched areas, scaling of the drawing and the capability to develop sectional views and enlarged views in detail. It has ability to perform transformations of images and prepare 3D drawings like isometric views, perspective views etc.,
2. **Geometric modeling:** concerned with the computer compatible mathematical description of the geometry of an object. The mathematical description allows the image of an object to be displayed and manipulated on a graphics terminal through signals from the CPU of the CAD system. The software that provides geometric modeling capabilities must be designed for efficient use both by computer and the human designer.

BENEFITS OF CAD:

The implementation of the CAD system provides variety of benefits to the industries in design and production as given below:

1. Improved productivity in drafting
2. Shorter preparation time for drawing
3. Reduced man power requirement
4. Customer modifications in drawing are easier
5. More efficient operation in drafting
6. Low wastage in drafting
7. Minimized transcription errors in drawing
8. Improved accuracy of drawing
9. Assistance in preparation of documentation
10. Better designs can be evolved

11. Revisions are possible
12. Colours can be used to customize the product
13. Production of orthographic projections with dimensions and tolerances
14. Hatching of all sections with different filling patterns
15. Preparation of assembly or sub assembly drawings
16. Preparation of part list
17. Machining and tolerance symbols at the required surfaces
18. Hydraulic and pneumatic circuit diagrams with symbols
19. Printing can be done to any scale

LIMITATIONS OF CAD

1. 32 – bit word computer is necessary because of large amount of computer memory and time
2. The size of the software package is large
3. Skill and judgment are required to prepare the drawing
4. Huge investment

CAD SOFTWARES

The software is an interpreter or translator which allows the user to perform specific type of application or job related to CAD. The following software's are available for drafting.

1. AUTOCAD
2. Pro – E
3. CATIA
4. MS OFFICE
5. PAINT
6. ANSYS
7. MSc.NASTRAN

8. IDEAS

9. SOLID WORKS

10. HYPERMESH

11. FLUENT – GAMBIT

The above software is used depending upon their application.

INTRODUCTION TO SOLID WORKS

The SOLIDWORKS® CAD software is a mechanical design automation application that lets designers quickly sketch out ideas, experiment with features and dimensions, and produce models and detailed drawings. This document discusses concepts and terminology used throughout the SOLIDWORK application. It familiarizes you with the commonly used functions of SOLIDWORKS.

3D Design

SOLIDWORKS uses a 3D design approach. As you design a part, from the initial sketch to the final result, you create a 3D model. From this model, you can create 2D drawings or mate components consisting of parts or subassemblies to create 3D assemblies. You can also create 2D drawings of 3D assemblies. When designing a model using SOLIDWORKS, you can visualize it in three dimensions, the way the model exists once it is manufactured.

EX NO: 1

DATE:

COMPUTER AIDED DESIGN OF SUBSONIC DIFFUSERS

Aim:

To design the subsonic diffusers using computer aided design software (solidworks)

Software required:

- Solid works

Procedure:

The design of subsonic diffuser is a circular element so the following procedure is used for the 3D modelling

- Open the Part Modelling
- Select the XY plane
- Draw the cross sectional view of the subsonic diffuser in one axis and draw the centre line
- Exit Sketch
- Use the Revolve base option and create the revolved structure in 360°
- Using shell command to create the hollow section
- Subsonic Diffuser model is created

Result:

Thus the subsonic diffusers is designed using computer aided design software.

EX NO: 2

DATE:

COMPUTER AIDED DESIGN OF SUPERSONIC DIFFUSERS

Aim:

To design the supersonic diffuser using computer aided design software (solid works).

Software required:

- Solid works

Procedure:

The design of supersonic diffuser is a circular element so the following procedure is used for the 3D modelling

- Open the Part Modelling
- Select the XY plane
- Draw the cross sectional view of the subsonic diffuser in one axis and draw the centre line
- Exit Sketch
- Use the Revolve base option and create the revolved structure in 360^0
- Using shell command to create the hollow section
- Subsonic Diffuser model is created

Result:

Thus supersonic diffuser is designed using computer aided design software.

EX NO: 3

DATE:

COMPUTER AIDED DESIGN OF A COMPRESSOR BLADE

Aim:

To design a compressor blade using computer aided design software (solid works).

Software required:

- Solid works

Procedure:

- The design of compressor blade in the Solid works by using following commands
- The compressor blade cross section is aerofoil blades
- Concave aerofoil database is get from the UIUC Aerofoil data site
- Compressor blade root chord and tip chord dimensions derived
- In solid works aerofoil data base are imported and the aerofoil shape is converted as a sketch
- Loft command in solid works which is helps to convert the root chord and tip chord sketch to blade

Result:

Thus a compressor blade is designed using computer aided design software.

EX NO: 4

DATE:

COMPUTER AIDED DESIGN OF CONVERGENT NOZZLE

Aim:

To design a Converging Nozzle using computer aided design software (solid works).

Software required:

- Solid works

Procedure:

The design of convergent nozzle is a circular element so the following procedure is used for the 3D modelling

- Open the Part Modelling
- Select the XY plane
- Draw the cross sectional view of the convergent nozzle in one axis and draw the centre line
- Exit Sketch
- Use the Revolve base option and create the revolved structure in 360°
- convergent nozzle is created

Result:

Thus a Converging Nozzle is designed using computer aided design software.

EX NO: 5

DATE:

COMPUTER AIDED DESIGN OF A CONVERGING-DIVERGING NOZZLE.

Aim:

To design a Converging Diverging Nozzle using computer aided design software (solid works).

Software required:

- Solid works

Procedure:

The design of Converging-diverging nozzle is a circular element so the following procedure is used for the 3D modelling

- Open the Part Modelling
- Select the XY plane
- Draw the cross sectional view of the Converging-diverging nozzle in one axis and draw the centre line
- Exit Sketch
- Use the Revolve base option and create the revolved structure in 360°
- Converging-diverging nozzle is created

Result:

Thus a Converging Diverging Nozzle is designed using computer aided design software.

EX NO: 6

DATE:

COMPUTER AIDED DESIGN OF TYPICAL AIRCRAFT WING.

Aim:

To design a typical Aircraft Wing using computer aided design software (solid works).

Software required:

- Solid works

Procedure:

- The design of aircraft wing in the Solid works by using following commands
- The aircraft wing cross section is aerofoil blades
- Aerofoil database is get from the UIUC Aerofoil data site
- Aircraft wing root chord and tip chord dimensions derived
- In solid works aerofoil data base are imported and the aerofoil shape is converted as a sketch
- Loft command in solid works which is helps to convert the root chord and tip chord sketch to aircraft wing

Result:

Thus a typical Aircraft Wing is designed using computer aided design software.

EX NO: 7

DATE:

COMPUTER AIDED DESIGN OF TYPICAL FUSELAGE STRUCTURE.

Aim:

To design a typical Fuselage Structure using computer aided design software (solidworks).

Software required:

- Solid works

Procedure:

The design of fuselage in the Solid works by using following commands

- The fuselage structure dimensions get from the aircraft data sheet
- Boeing 747 Fuselage structure
- Using sketcher command the shell was designed
- Extrude boss option and Loft options in Solid works to create the fuselage structure

Result:

Thus a typical Fuselage Structure is designed using computer aided design software.

EX NO: 8

DATE:

COMPUTER AIDED DESIGN OF A LANDING GEAR

Aim:

To design a Landing gear using computer aided design software (solidworks).

Software required:

- Solid works

Procedure:

The design of Landing gear in the Solid works by using following commands

- The Landing gear structure dimensions get from the aircraft data sheet
- Nose landing Gear
- Using sketcher command the tyre and other parts are modelled
- Extrude boss option and Loft options in Solid works to create the Landing gear structural components

Result:

Thus a Landing gear is designed using computer aided design software.

EX NO: 9

DATE:

COMPUTER AIDED DESIGN OF A LAUNCH VEHICLES

Aim:

To design a Launch Vehicle using computer aided design software (solidworks).

Software required:

- Solid works

Procedure:

The 3D modelling of the Launch Vehicle in solid works software using following commands

- The Launch Vehicle dimension details get from the various journals
- The outer sketch of the Launch Vehicle is created in Solid works sketcher tool
- Using the revolve boss options main body of the Launch Vehicle is modelled
- The control surface of the Launch Vehicle is designed using Extrude boss option
- The pattern and fillet options used for creating multiple objects and shape of the objects

Result:

Thus a Launch Vehicle is designed using computer aided design software.

EX NO: 10

DATE:

COMPUTER AIDED DESIGN OF A RE-ENTRY VEHICLES

Aim:

To design a Re-entry Vehicle using computer aided design software (solidworks).

Software required:

- Solid works

Procedure:

The 3D modelling of the Re-entry Vehicle in solid works software using following commands

- The re-entry vehicle dimension details get from the various journals
- The outer sketch of the re-entry vehicle is created in Solid works sketcher tool
- Using the revolve boss options main body of the re-entry vehicle is modelled
- The control surface of the re-entry vehicle is designed using Extrude boss option
- The pattern and fillet options used for creating multiple objects and shape of the objects

Result:

Thus a Re-entry Vehicle is designed using computer aided design software.

EX NO: 11

DATE:

COMPUTER AIDED DESIGN OF A MISSILES.

Aim:

To design Missiles using computer aided design software (solidworks).

Software required:

- Solid works

Procedure:

The 3D modelling of the Missile in solid works software using following commands

- The missile dimension details get from the various journals
- The outer sketch of the missile is created in Solid works sketcher tool
- Using the revolve boss options main body of the missile is modelled
- The fins of the missile is designed using Extrude boss option
- The pattern option is used for creating multiple fins

Result:

Thus Missiles are designed using computer aided design software.

EX NO: 12

DATE:

COMPUTER AIDED DESIGN OF A SATELLITES

Aim:

To design a Satellite using computer aided design software (solid works).

Software required:

- Solid works

Procedure:

The 3D modelling of the unfolded satellites view in solid works software using following commands

- Open the Solid works part modelling
- Open the Sketcher part and draw the centre core part top section is draw in the sketcher tools
- After completing the house part move to the Receiver parts
- The section also drawn in the sketcher tool and using Extrude Boss options to make the model
- Satellite model is created successfully

Result:

Thus a Satellite is designed using computer aided design software.



DEPARTMENT OF AERONAUTICAL ENGINEERING

LABORATORY MANUAL

AIRCRAFT DESIGN PROJECT

YEAR / SEMESTER : **III / 06**

DEPARTMENT : **Aeronautical Engineering**

ACADEMIC YEAR : **2023-24**

REGULATION : **2021**

Chapter 1

CHAPTER 1

INTRODUCTION

1.1 Defining a new design

1.2 Design process

1.3 Conceptual design

“A beautiful aircraft is the expression of the genius of a great engineer who is also a great artist.”

Neville Shute,
British Aeronautical Engineer and Novelist,
From, *No Highway*, 1947.

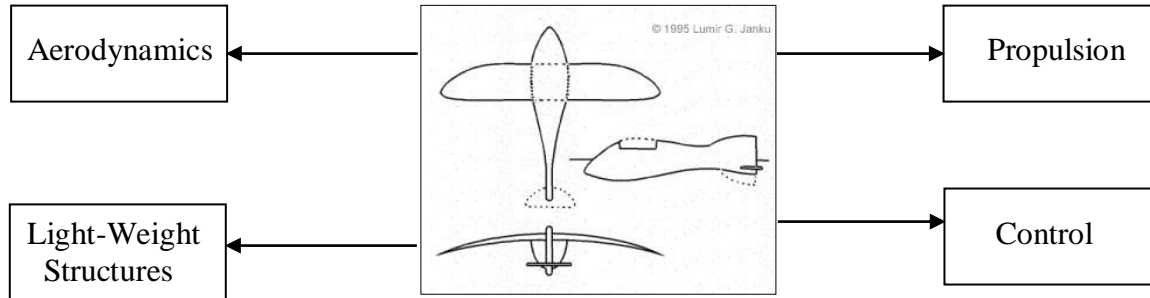
When you look at aircraft, it is easy to observe that they have a number of common features: wings, a tail with vertical and horizontal wing sections, engines to propel them through the air, and a fuselage to carry passengers or cargo. If, however, you take a more critical look beyond the gross features, you also can see subtle, and sometimes not so subtle, differences. What are the reasons for these differences? What was on the mind(S) of the designers that caused them to configure the aircraft in this way?

Airplane design is both an art and a science. In that respect it is difficult to learn by reading a book; rather, it must be experienced and practiced. However, we can offer the following definition and then attempt to explain it. Airplane design is the intellectual engineering process of creating on paper (or on a computer screen) a flying machine to (1) meet certain specifications and requirements established by potential users (or as perceived by the manufacturer) and/or (2) pioneer innovative, new ideas and technology. An example of the former is the design of most commercial transports, starting at least with the Douglas DC-1 in 1932, which was designed to meet or exceed various specifications by an airplane company. (The airline was TWA, named Transcontinental and Western Air at that time.) An example of the latter is the design of the rocket-powered Bell X-1, the first airplane to exceed the speed of sound in level or climbing flight (October 14, 1947). The design process is indeed an intellectual activity, but a rather special one that is tempered by good intuition developed via experience, by attention paid to successful airplane designs that have been used in the past, and by (generally proprietary) design procedures and databases (handbooks, etc.) that are a part of every airplane manufacturer.

1.1 Defining a new design

The design of an aircraft draws on a number of basic areas of aerospace engineering. As shown in the illustration, these include aerodynamics, propulsion, light-weight structures and control.

Each of these areas involves parameters that govern the size, shape, weight and performance of an aircraft. Although we generally try to seek optimum in all these aspects, with an aircraft, this is practically impossible to achieve. The reason is that in many cases, optimizing one characteristic degrades another.



In most cases, the design objectives are not as focused. More often, the nature of an aircraft design is compromise. That is, the goal is to balance the different aspects of the total performance while trying to optimize a few (or one) based on well-defined mission requirements.

There are many performance aspects that can be specified by the mission requirements. These include:

- The aircraft purpose or mission profile;
- The type(s) and amount of payload;
- The cruise and maximum speeds;
- The normal cruise altitude;
- The range or radius with normal payload;
- The endurance;
- The take-off distance at the maximum weight;
- The landing distance with 50 percent of the maximum fuel weight;
- The purchase cost;
- And other requirements considered important;

1.1.1 Aircraft Purpose

The starting point of any new aircraft is to clearly identify its purpose. With this, it is often possible to place a design into a general category. Such categories include combat aircraft, passenger or cargo transports, and general aviation aircraft. These may also be further refined into subcategories based on particular design objectives such as range (short or long), take-off or landing distances, maximum speed, etc. The process of categorizing is useful in identifying any existing aircraft that might be used in making comparisons to a proposed design.

With modern military aircraft, the purpose for a new aircraft generally comes from a military program office. For example, the mission specifications for the X-29 pictured in figure 1.1 came from a 1977 request for proposals from the U.S. Air Force Flight Dynamics Laboratory in which they were seeking a research aircraft that would explore the forward swept wing concept and validate studies that indicated such a design could provide better control and lift qualities in extreme maneuvers.

With modern commercial aircraft, a proposal for a new design usually comes as the response to internal studies that aim to project future market needs. For example, the specifications for the most recent Boeing commercial aircraft (B-777) were based on the interest of commercial airlines to have a twin-engine aircraft with a payload and range in between those of the existing B-767 and B-747 aircraft.



Figure 1.1 X-29

Since it is not usually possible to optimize all of the performance aspects in an aircraft, defining the purpose leads the way in setting which of these aspects will be the “design drivers.” For example, with the B-777, two of the prominent design drivers were range and payload.

1.1.2 Payload

The payload is what is carried on board and delivered as part of the aircraft’s mission. Standard payloads are passengers, cargo or ordnance. The first two are considered non-expendable payload because they are expected to be transported for the complete duration of the flight plan. Military ordnance is expendable payload since at some point in the flight plan it permanently leaves the aircraft. This includes bombs, rockets, missiles and ammunition for on-board guns.

For personal or small general aviation aircraft, the payload includes the pilot as well as passengers and baggage. For business, commuter and commercial aircraft, the payload does not include the flight or cabin crew, only the passengers, baggage and cargo.

1.1.3 Cruise and Maximum Speeds

The mission of an aircraft usually dictates its speed range. Propeller-driven aircraft are usually designed to cruise at speeds between 150 to 300 knots. Jet powered aircraft have higher cruise speeds that are normally specified in terms of Mach number. The typical cruise Mach number for business and commercial jet aircraft is from 0.8 to 0.85. This range of cruise speeds is close to optimum for maximizing the combination of payload weight, range and speed. The few supersonic commercial aircraft designs (1) have supersonic cruise speed as their principle design driver and (2) sacrifice range and payload. The cruise Mach number of the Concorde is 2.02. It will carry 100 passengers with a range of 3740 miles, which is considerably less than the aircraft of normal class, which have high subsonic cruise speeds.

Modern military jet combat and attack aircraft usually have a flight plan that involves efficient cruise at high subsonic Mach numbers. This is usually in

the range from Mach 0.85 to 0.90. The maximum speed is usually specified in the context of an intercept portion of the flight plan. This has a Mach number that is typically in the range of 2.0.

1.1.4 Normal Cruise Altitude

The cruise altitude is generally dictated by the cruise speed, propulsion system and cabin pressurization. An aircraft with an un-pressurized cabin would cruise no higher than 10,000 feet. With propeller-driven aircraft, turbo-charged piston engines can maintain a constant horsepower up to an altitude of approximately 20,000 feet. Higher altitudes are possible with turboprop aircraft, such as the Piper Cheyenne, which have a maximum ceiling from 35,000 to 41,000 feet. The decrease in air density with higher altitude lowers the drag, so that for these aircraft, the cruise range increases with altitude.

At higher subsonic Mach numbers, the turbo-jet engine gives the higher efficiency. For subsonic turbo-jet aircraft, there is an optimum altitude where the fuel consumption is a minimum. This occurs at approximately 36,000 feet. Therefore, it is the best altitude for the most efficient, long range cruise of turbo-jet-powered aircraft.

1.1.5 Range

The range is the furthest distance the aircraft can fly without refueling. In a flight plan, range refers to the distance traveled during the cruise phase. The choice of the range is one of the most important decisions because it has a large (exponential) effect on the aircraft take-off weight. An aircraft that is intended to fly across the United States (New York to Seattle) should have a minimum range of 2500 nautical miles. A range of 3500 nautical miles would be necessary for transatlantic flights from East coast U.S. cities to coastal cities in Western Europe. Shorter range transports that are designed to fly between major cities in a regional area (e.g., Los Angeles to San Francisco) should have a minimum range of 500 nautical miles. Twice that range would allow an aircraft to fly non-stop between most of the major cities along either coast of the United States.

1.1.6 Endurance

Endurance is the amount of time an aircraft can fly without refueling. With a reconnaissance aircraft, endurance is one of the main design drivers. For a commercial aircraft, a flight plan will include an endurance phase to allow for time that night is spent in a holding pattern prior to landing. For operation within the continental United States commercial aircraft are required to be able to hold for 45 minutes at normal cruise fuel consumption. For international operation, the required hold time is 30 minutes.

1.1.7 Take-off Distance

The total take-off distance of the length of a runway needed to accelerate, lift off, and climb to prescribe obstacle height. The obstacle height is 50 feet for military

and small civil aircraft, and 35 feet for commercial aircraft. The take-off distance that is required to accomplish this depends on different factors in the design such as the thrust to weight ratio, the maximum lift to weight ratio and the surface of the air field that affects the rolling friction of the landing-gear wheels.

Table 1.1 Typical ranges for different types of aircraft.

Aircraft Type	Range (nautical miles)
Personal/Utility	500-1000
Regional Turboprop	800-1200
Business Jets	1500-1800
Smaller Jet Transports	2500-3500
Larger Jet Transports	6500-7200

Different designs can fall into standard categories for take-off and landing. A conventional take-off and landing (CTOL) aircraft has distance that is greater than 1000 feet. A short take-off and landing (STOL) aircraft, such as the YC-15 in figure 1.2 can take off and land in under 1000 feet. Both of these would have a ground roll portion during take-off and landing. A vertical take-off and landing (VTOL) aircraft does not require a ground roll.



Figure 1.2 YC-15

Personal and general aviation propeller-driven aircraft, which are intended to operate out of smaller airports, need take-off distances of 1200 to 2000 feet. Larger twin engine propeller commuter aircraft, which operate out of medium to larger size airports, have take-off distances from 3000 to 5000 feet. Business and smaller commercial jets have take-off distances of 5000 to 7500 feet. Larger commercial jet transport aircraft require take-off distances from 8000 to 11000 feet. The take-off distance is a function of the altitude of the airport, although the distance at sea level is usually specified. Table 1.2 lists the altitude and runway lengths of some of the major airports in America.

1.1.8 Landing Distance

The landing distance consists of the length of the runway needed to descend from a specified height of 50 feet, touchdown and break to a stop. Factors that affect the landing distance are the maximum lift to weight and the surface of the air field, which affects the landing-gear wheels' braking friction coefficient. The lift to weight ratio directly affects the slowest (stall) speed at which the aircraft can

fly. The landing touchdown speed is taken to be a small percentage higher than the stall speed.

Table 1.2 Altitude and runway length of major airports in America

City	Airport	Elevation (f)	Runway (f)
Atlanta	Hartsfield	1026	11889
Boston	Logan	20	10081
Chicago	O'Hare	667	11600
Denver	Denver	5431	12000
Los Angeles	Los Angeles	126	12091

For commercial aircraft, in a worst case scenario, the landing distance is determined with half of the fuel weight at take-off remaining and with an additional two-thirds distance to account for pilot variability. Even with these measures, the landing distances are almost always less than the take-off distances. Therefore, with regards to airports with available runway distances, the limiting conditions will generally be set by take-off.

1.1.9 Purchase Cost

The purchase cost of an aircraft involves the cost incurred in the research, development, test and evaluation (RDT&E) phase of the new aircraft design, and the acquisition (A) or production cost of customer-ordered aircraft. The cost of research and development is amortized over an initial fixed number of production aircraft. Therefore, as the number of production aircraft used to distribute this cost increases, the purchase cost per aircraft decreases. The decision on the total number of aircraft to be produced is therefore an important factor in establishing the purchase price. In some cases, this price and customer competition may be the final arbiters that determine if a design is to be built.

The cost estimates are based on “cost estimating relationships” or CERs. These are simple model equations that correlate a few important characteristics of a larger group of aircraft with their cost. The primary characteristics on which these are based are the weight of the structure of the aircraft, which is a fixed percentage of the take-off weight, the maximum speed at best attitude, and the production rate. From these, we expect that larger, heavier aircraft will cost more than smaller, lighter aircraft. Similarly, aircraft with higher cruise speeds are expected to cost more than slower aircraft.

1.1.10 Federal Aviation Regulations

Any aircraft design must consider standards and regulations that are set by government associations. Civil aircraft designed, built and operated in the United States must satisfy the provisions of the Federal Aviation Regulations (FARs). The FARs is continually being updated to incorporate additional requirements that come about due to increased time and experience with existing aircraft. Electronic

listings of the FARs can be obtained through a World Wide Web link to the Flight Standards Service of the U.S. Federal Aviation Association (FAA). The exact link can be found through a search under the keyword FAA.

Sections of the FARs that are of particular interest to designers are Air Worthiness Standards, General Operating and Flight Rules and Operations. Air Worthiness Standards Part 23 and 25 in particular define different categories of aircraft (for example, transport or commuter) based on such characteristics as number of passengers and maximum take off weight.

These categories are important in making comparisons to other aircraft with regard to flight performance, or other design drivers.

1.2 Design Process

The process of designing an aircraft and taking it to the point of a flight test article consists of a sequence of steps, as illustrated in figure 1.3. It starts by identifying a need or capability for a new aircraft that is brought about by (1) a perceived market potential and (2) technological advances made through research and development. The former will include a market-share forecast, which attempts to examine factors that might impact future sales of a new design. These factors include the need for a new design of a specific size and performance, the number of competing designs, and the commonality of features with existing aircraft. As a rule, a new design with competitive performance and cost will have an equal share of new sales with existing competitors.

The needs and capabilities of a new aircraft that are determined in a market survey go to define the mission requirements for a conceptual aircraft. These are compiled in the form of a design proposal that includes (1) the motivation for initiating a new design and (2) the “technology readiness” of new technology for incorporation into a new design. It is essential that the mission requirements be defined before the design can be started. Based on these, the most important performance aspects or “design drivers” can be identified and optimized above all others.

Following the design proposal, the next step is to produce a conceptual design. The conceptual design develops the first general size and configuration for a new aircraft. It involves the estimates of the weights and the choice of aerodynamic characteristics that will be best suited to the mission requirements stated in the design proposal.

The design will make estimates of the total drag and size the power plant. It will determine the best airframe to accommodate the (1) payload and (2) wing and engine placement. This conceptual design will locate principle weight groups in order to satisfy static stability requirements. It will size control surfaces to achieve a desired degree of maneuverability. Finally the conceptual design will estimate the RDT&E and acquisition costs to develop one or more test articles.

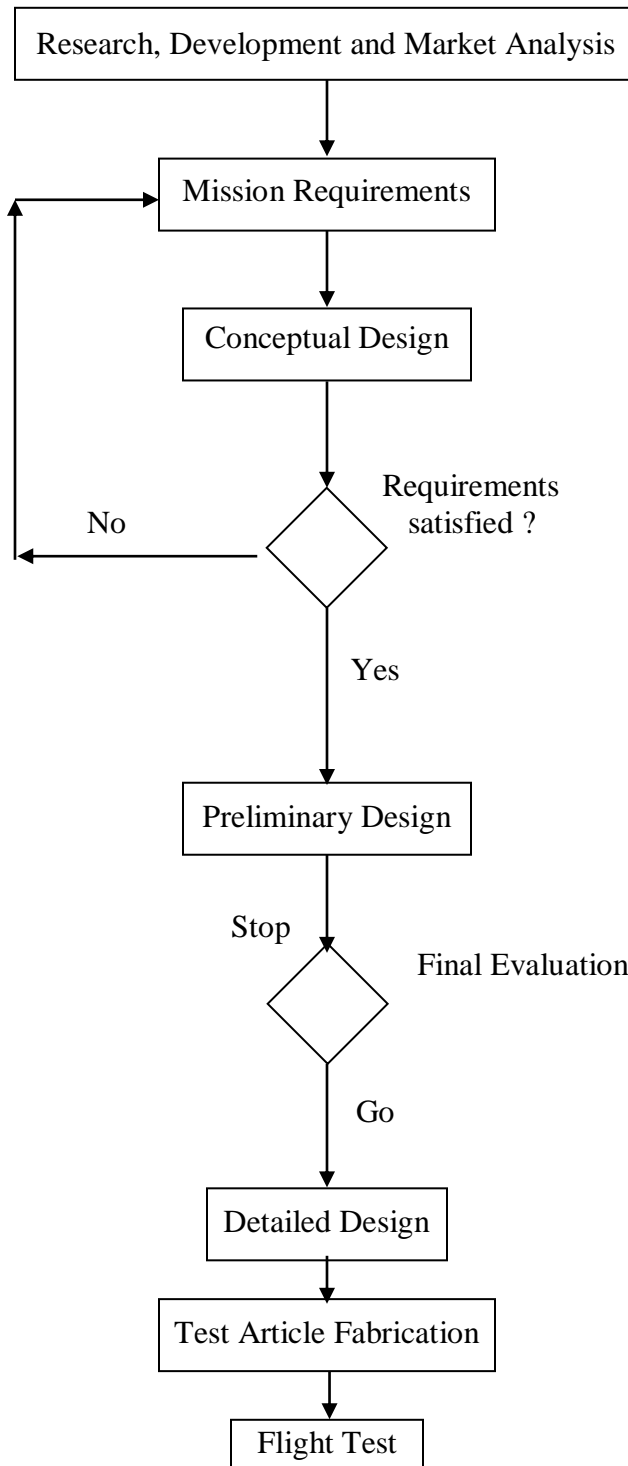


Figure 1.3 Design Process flow chart

The conceptual design is driven by the mission requirements, which are set in the design proposal. In some cases, these may not be attainable so that the requirement may need to be relaxed in one or more areas. This is shown in the iterative loop in the flow chart. When the mission requirements are satisfied, the design moves to the next phase, which is the preliminary design.

DESIGN PROPOSAL

LONG RANGE-HIGH SPEED SUBSONIC BUSINESS JET

We propose to design a long range high speed subsonic business jet. It is intended to have a cruise Mach number of 0.85 and a cruise altitude of 13000 m. Its range will be 10000 km with a full payload followed by 1 hour loiter and reserves equal to 25 % of required mission fuel. Also it should fly 300 km to alternate descent. Its nonexpendable payload would consist of passengers and baggage, with a maximum total weight of 950 kg. Depending on the internal layout, this will comfortably accommodate from 4-6 passengers (excluding crew members). The maximum take off weight is estimated 35000 kg. Other features of the design include a swept back wing configuration with winglets, split type flaps with highly efficient aerodynamic wing and body and a very light weight structure. The most critical technology readiness issue is the propulsion system and the body design. It should have a L/D ratio of above 16 to meet the long range and the engine should have the specific fuel consumption of 0.4 or below. An existing engine that has been selected as a reference engine for the design is the GE-CF-34 series engines. Based on the drag estimate at cruise conditions, the aircraft would require two of these engines.

This aircraft would be one among the long range series which has been manufactured by Bombardier, Dassault, Boeing, Gulf Stream, Cessna etc. Hence it has so many competitors. But still due to its unique fuel consumption and light weight structure it has to attract the customer and develop a good market. Figure 1.4 shows an artist's rendition of the proposed design. The characteristics of this jet are listed in the table that follows. Since there are so many equivalent aircrafts are there, comparisons can be made to optimize the values and also for initial data acquisition. It is evident that all of the aircrafts that has been selected for the literature survey are currently in service.

The primary design drivers are light weight, high L/D and less fuel consumption. The secondary design considerations include moderate take-off and landing distances which are comparable to existing high speed subsonic business jets. An important note is that most of the control systems should be of basic type (like split flap etc.) in order to make the aircraft available at a cheap rate but at a reliable condition.



Figure 1.4 Conceptual Design

The preliminary design is a fine tuning of the conceptual design made through parametric wind tunnel tests of scale aircraft models of the design. Some of the more difficult aspects to predict are tested in this phase. This includes the (1) engine inlet interaction with the fuselage and wing and (2) wing interaction on control surfaces.

The preliminary design also involves a more detailed analysis of the aerodynamic loads and component weights. Based on this, the structural design is further refined. Aero elastic motion, fatigue and flutter are considered at this stage. Additional confirmation of estimates may require building and testing some of the proposed structural components. At the completion of this stage, the manufacturing of the aircraft is given serious consideration and the cost estimates are further refined. At the end of this step, the decision is made whether to build the aircraft. With the decision to build the aircraft, the design is “frozen.”

The detailed design involves generating the detailed structural design of the aircraft. This involves every detail needed to build the aircraft. Sometimes component mock-ups are built to aid in the interior layout. However, the present use of computer aided design (CAD) software can substantially minimize the need for mock-ups by providing realistic 3-D views.

1.3 Conceptual Design

This article deals with the steps involved in the conceptual design of an aircraft. It is broken down in to several elements, which are followed in order. These consist of,

1. Literature survey
2. Preliminary data acquisition
3. Estimation of aircraft weight
 - a. Maximum take-off weight
 - b. Empty weight of the aircraft
 - c. Weight of the fuel
 - d. Fuel tank capacity
4. Estimation of critical performance parameters
 - a. Wing area
 - b. Lift and drag coefficients
 - c. Wing loading
 - d. Power loading
 - e. Thrust to weight ratio
5. Engine selection
6. Performance curves
7. V-n diagram
8. 3-view diagram

The development of these elements is illustrated in the upcoming studies that consist of ‘long range high speed subsonic business jet defined in the preceding design proposal. The mission requirements of this design are relatively difficult to achieve; therefore, it is a good example in which compromise is needed.

Chapter 2

DATA AQUISITION

Chapter 3

CHAPTER 3

ESTIMATION OF AIRCRAFT WEIGHT

3.1 Aim

3.2 Equipments and methods used

3.3 Procedure

3.4 Specification Chart

3.5 Mission Profile

3.6 General Outline

3.7 Detailed Procedure

3.8 Iteration

3.9 Conclusion

3.1 Aim:

To estimate the gross take off weight, fuel weight and empty weight of the aircraft in the designing process through various through numerical steps.

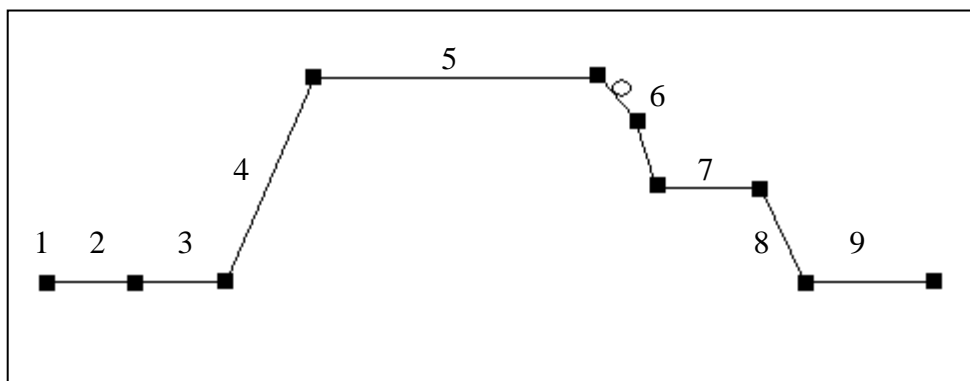
3.2 Equipments and methods used:

1. Fuel fraction method
2. Tables and charts from Ref:- books
3. Survey details
4. Results of Ex-01

3.3 Procedure:

1. Describe the mission specification elaborately in a sheet.
2. Draw the mission profile part clearly.
3. With the help of the above two charts work out the rest through the fuel fraction method to achieve the objective.

3.5 Mission Profile:



Description:

Phase 1	:	Engine start and warm-up
Phase 2	:	Taxiing
Phase 3	:	Take-off
Phase 4	:	Climb to cruise altitude and accelerate to cruise speed
Phase 5	:	Cruise
Phase 6	:	Loiter
Phase 7	:	Flying to alternate field
Phase 8	:	Descent
Phase 9	:	Landing, taxiing & shut-down

Chapter 4

CHAPTER 4

ESTIMATION OF CRITICAL PERFORMANCE PARAMETERS

4.1 Aim

4.2 Equipments and methods used

4.3 Maximum Lift coefficient

4.4 Wing Loading

4.5 Thrust to weight ratio

4.6 Engine Selection

4.7 Design Data

4.8 Conclusion

4.1 Aim:

To estimate the Critical performance parameters like,

1. $(C_L)_{MAX}$
2. L/D
3. W/S
4. T/W

These parameters will be determined by such aspects as maximum speed, range, ceiling, rate of climb, stalling speed, landing distance and take-off distance.

4.2 Equipments and methods used:

1. Regulae – False Method
2. Airfoil sections references
3. Specification chart
4. Jet airplane performance equations
5. Graphs and tables from references
6. Previous exercise results

Procedure:

4.3 Maximum Lift Co-efficient: $(C_L)_{MAX}$

This is the stage in the design process where we make an initial choice for the airfoil shape for the wing. As from the references obtained from the literature survey and through web most of the business jets avail NACA 6 digit airfoil sections – the laminar flow series.

NACA 6 DIGIT SERIES

- | | | |
|---|---|---|
| 6 | - | SIXTH SERIES |
| 3 | - | LOCATION OF MIN C_P in $(1/10)^{th}$ OF CHORD |
| 2 | - | IDEAL C_L IN TENTHS |

After the six-series sections, airfoil design became much more specialized for the particular application. Airfoils with good transonic performance, good maximum lift capability, very thick sections, and very low drag sections are now designed for each use. Often a wing design begins with the definition of several airfoil sections and then the entire geometry is modified based on its 3-dimensional characteristics.

The NACA six digit airfoils have been particularly favored by the general aviation industry in the United States. Though we have introduced the primary airfoil families developed in the United States before the advent of supersonic flight, we haven't said anything about their uses. So let's briefly explore the advantages, disadvantages, and applications of each of these families.

Advantages:

1. High maximum lift coefficient
2. Very low drag over a small range of operating conditions
3. Optimized for high speed

Disadvantages:

1. High drag outside of the optimum range of operating conditions
2. High pitching moment
3. Poor stall behavior
4. Very susceptible to roughness

Applications:

1. Piston-powered fighters
2. Business jets
3. Jet trainers
4. Supersonic jets

For many airplanes, including some general aviation aircraft, one airfoil section is used at the wing root, and another airfoil shape is used at the wing tip, with the airfoil sections between the root and tip being a linear interpolation between the root and tip sections. Since the survey details for the airfoils of business jets are maintained secretly, we can choose our own airfoil which will meet the requirements.

4.8 Conclusion:

Thus after performing so many rigorous steps of mathematical analysis we concluded that our aircraft is having the above data. And,

1. Maximum Lift Coefficient $(C_L)_{MAX}$	= 2.43
2. Maximum Lift to Drag ratio $[L/D]_{MAX}$	= 16
3. Wing Loading $[W/S]$	= 392.996 kg/m ²
4. Power Loading $[W/T]$	= 496.5 kg/kN

References:

1. Airplane design by Roskam [Tables & charts]
 2. Aircraft Design by Raymer [Tables & charts]
 3. Aircraft Performance and design by John. D. Anderson
 4. Aerodynamics, Aeronautics and Flight Mechanics by Mc Cormick
 5. Survey sheets
 6. Previous exercise results
 7. <http://www.hq.nasa.gov/office/pao/History/SP-468/ch14-3.htm>
 8. <http://www.aerospaceweb.org/question/airfoils/q0041.shtml>
 9. Theory of Wing Sections by Abbott & Albert
-

Chapter 5

CHAPTER 5

PERFORMANCE CURVES

5.1 Aim

5.2 Graph & Calculations

- a. Graph
- b. Calculations
- c. Summary

5.3 Result

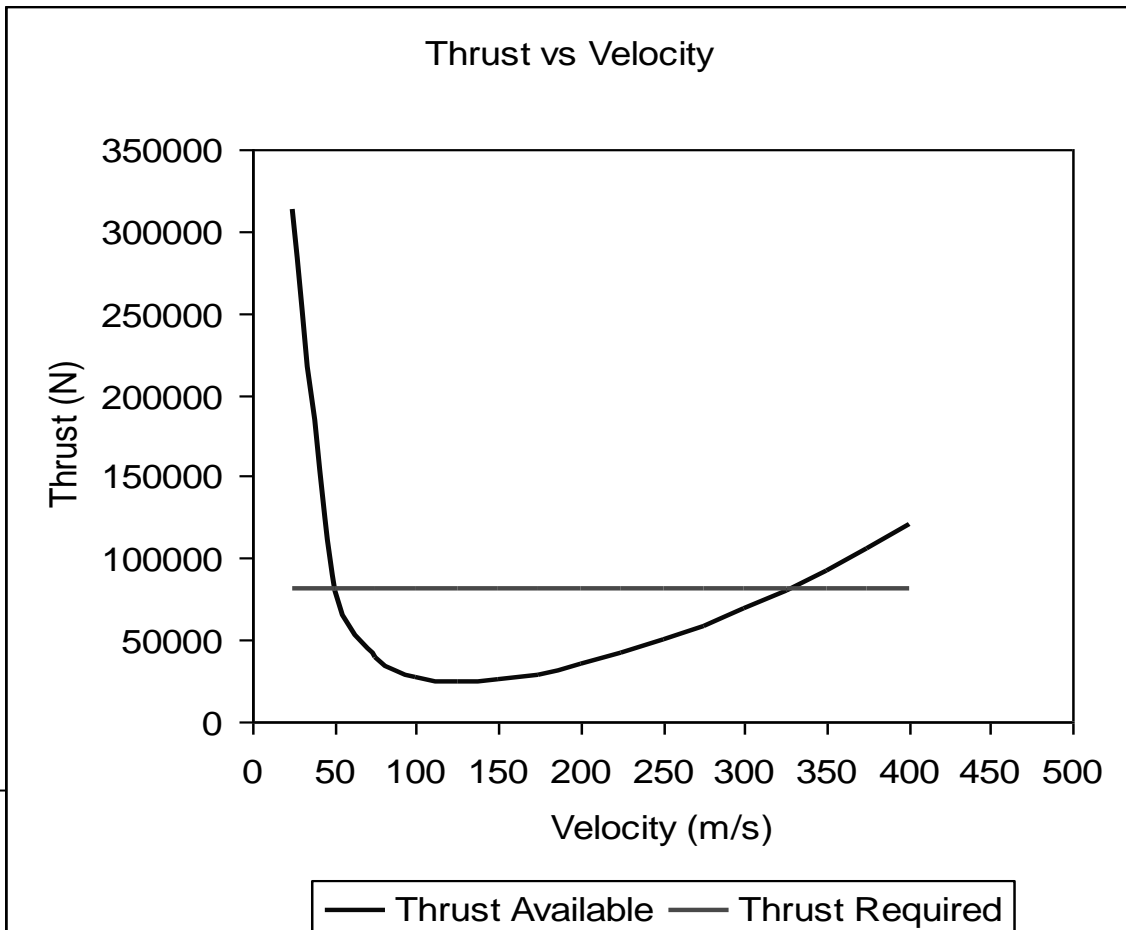
5.1 Aim

To draw the various graphs to estimate the performance parameters of the aircraft that is being designed.

5.2 Graph & Calculations

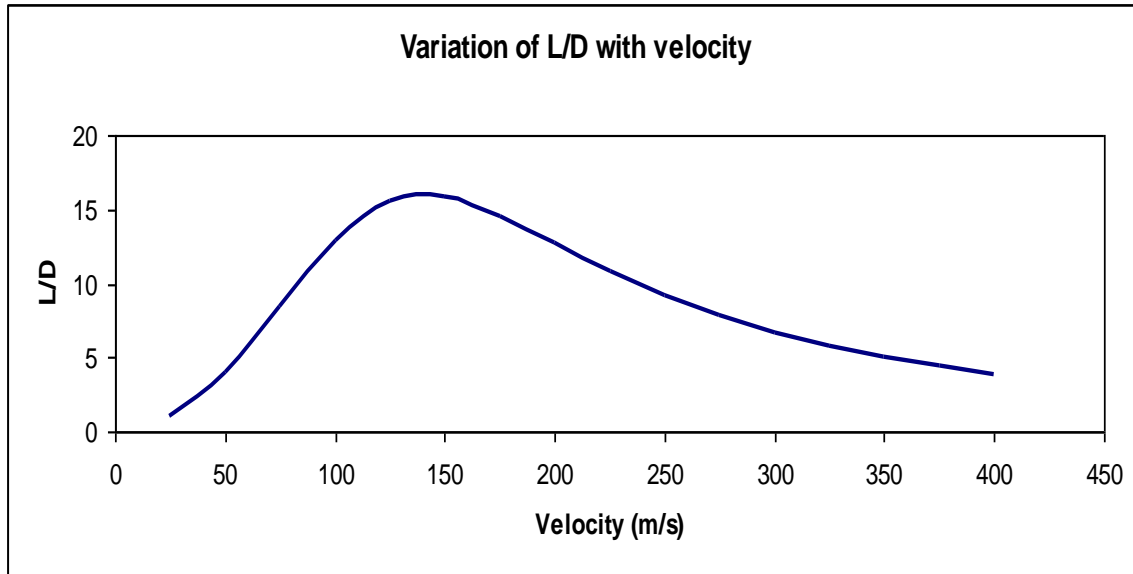
1. Thrust Vs Velocity

Graph:



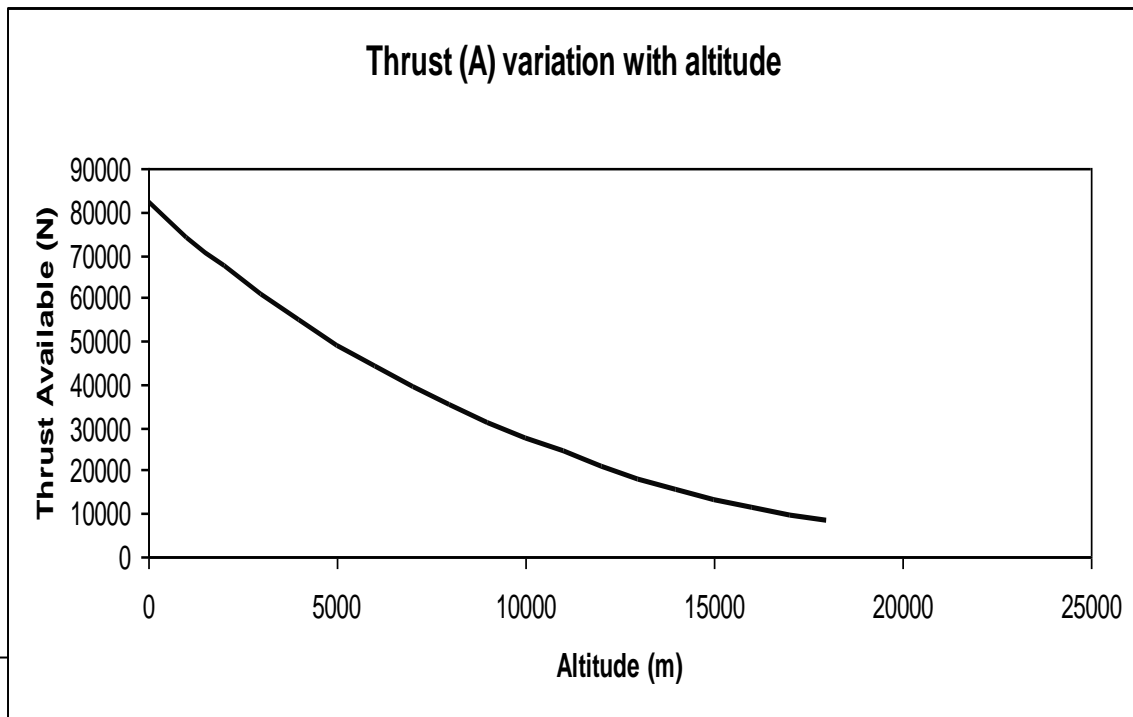
2. Variation of L/D Vs Velocity

Graph:

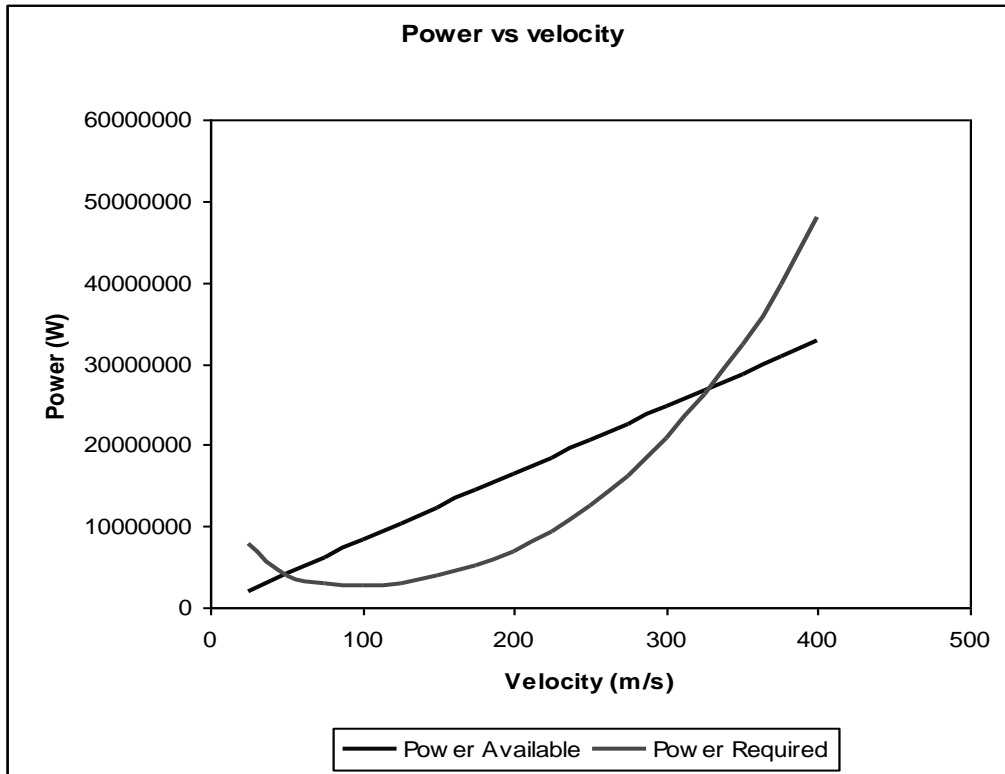


3. Thrust available [T_A] Vs Altitude

Graph:

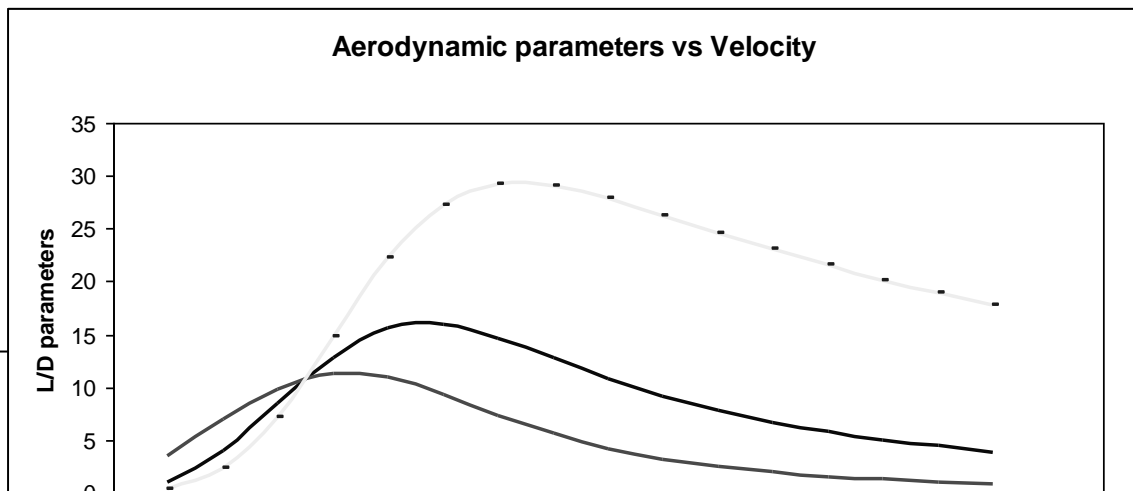


Graph:



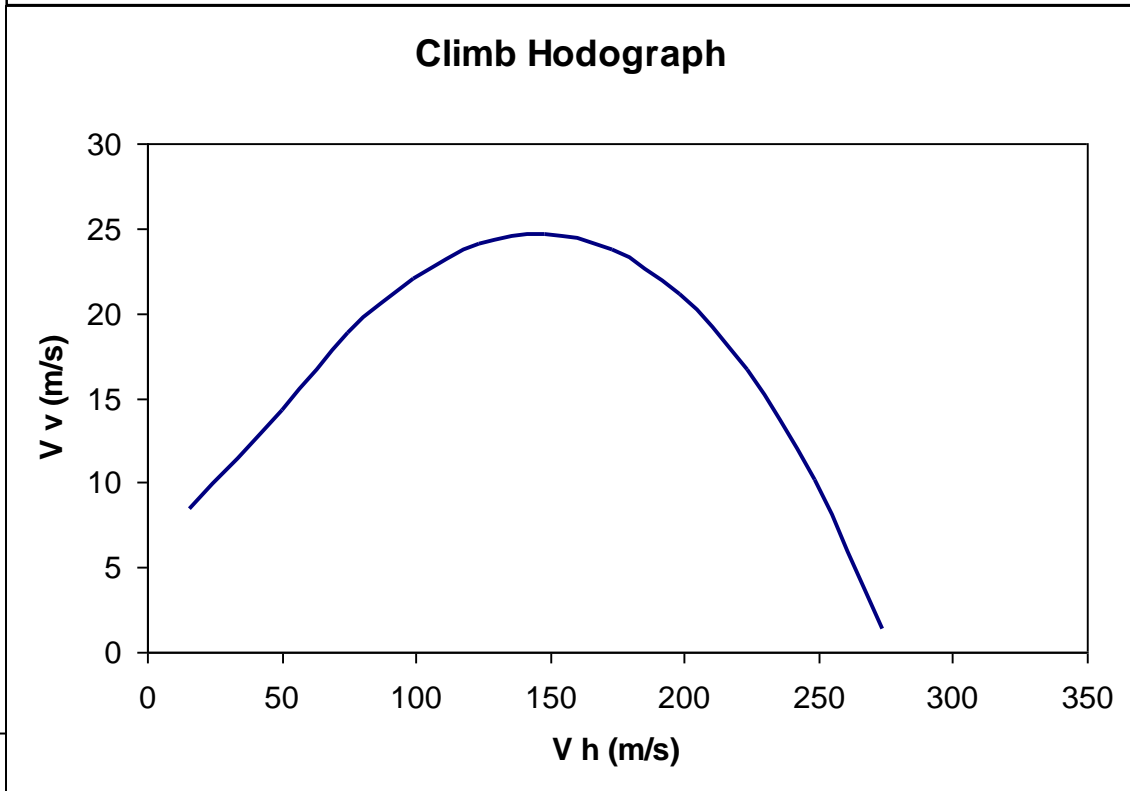
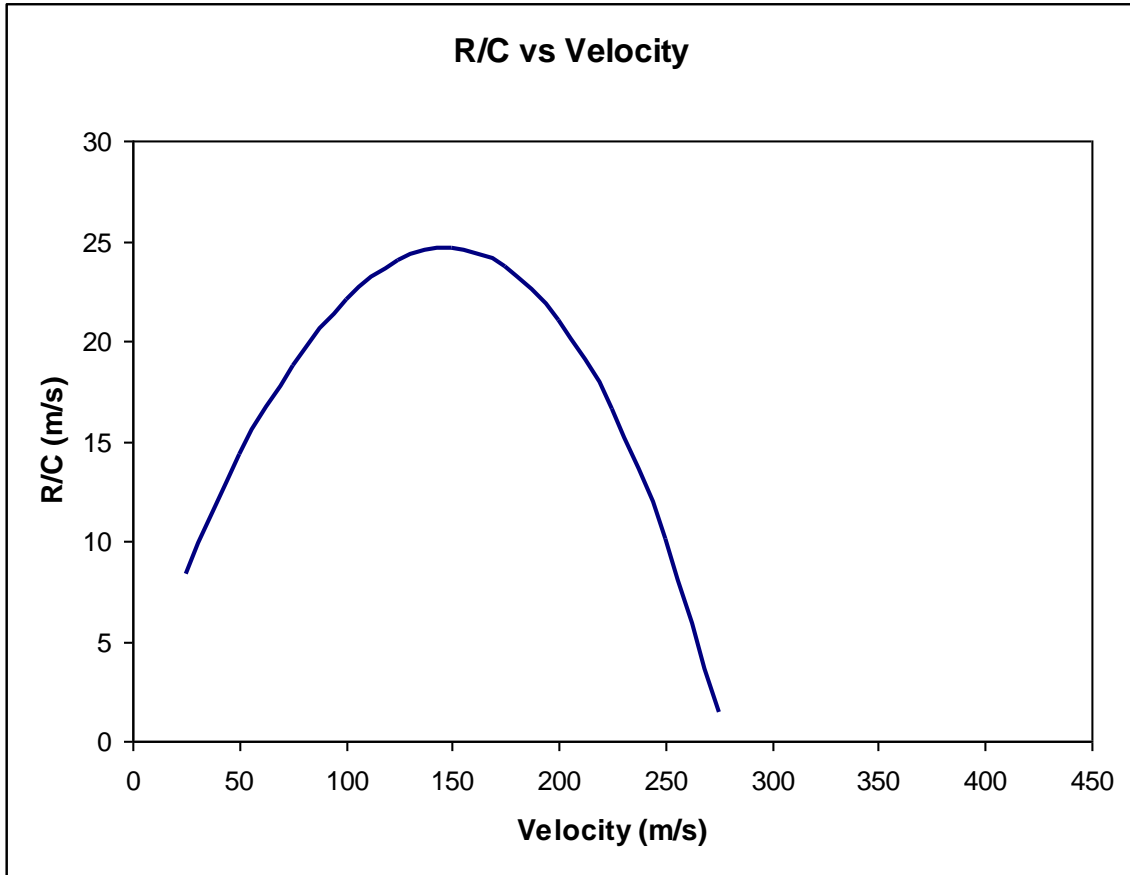
4. Aerodynamic Parameters

Graph:



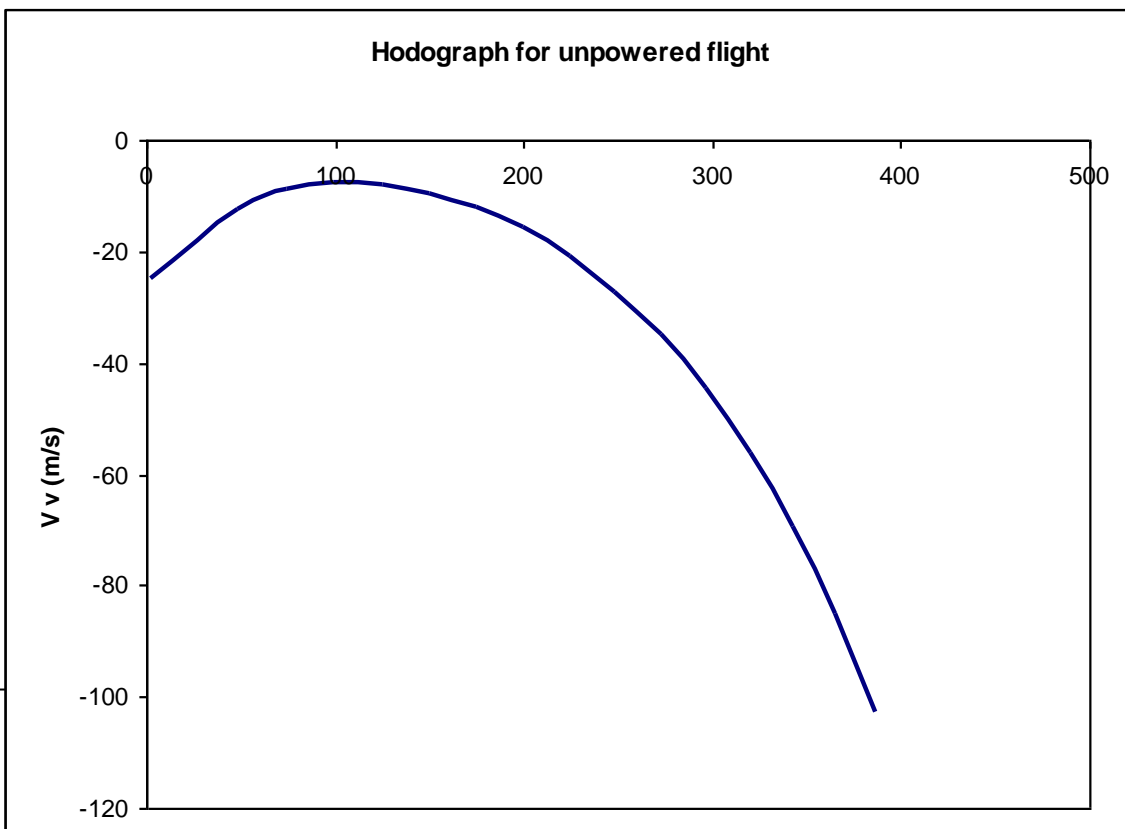
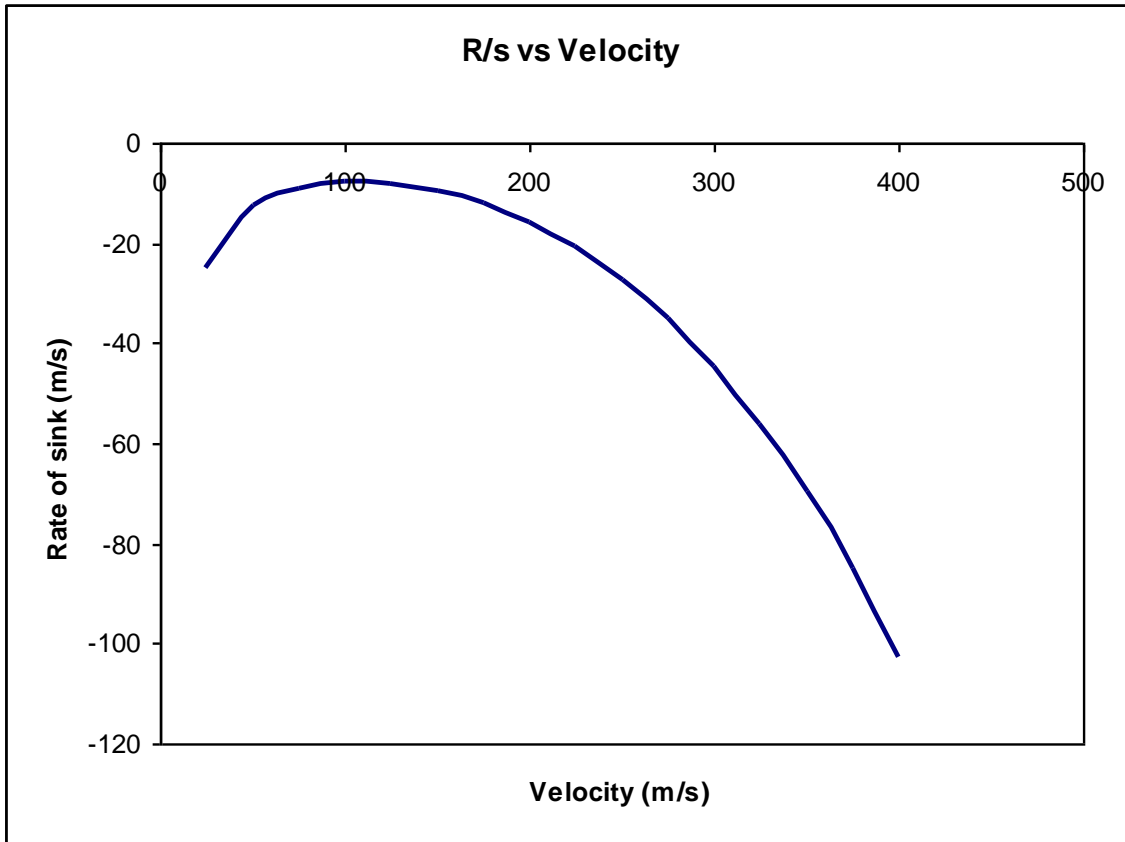
5. Climb Hodograph:

Graph:



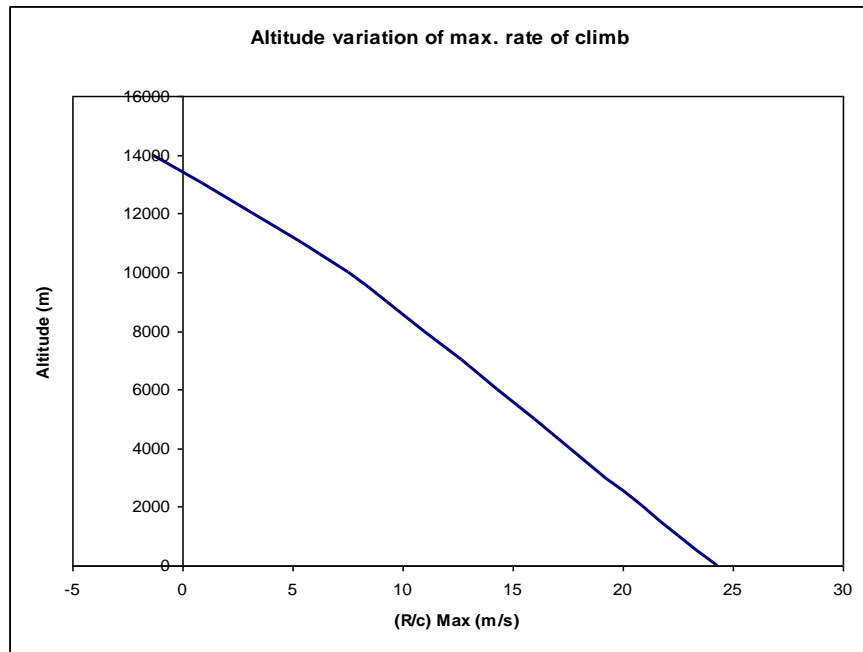
Calculations:

Graph:



6. Altitude Vs $[R/c]_{MAX}$:

Graph:



Chapter 6

CHAPTER 6

V-n DIAGRAM

6.1 Aim

6.2 Formula Used

6.3 Diagram

6.4 Model Calculation

6.5 Table

6.6 Conclusion

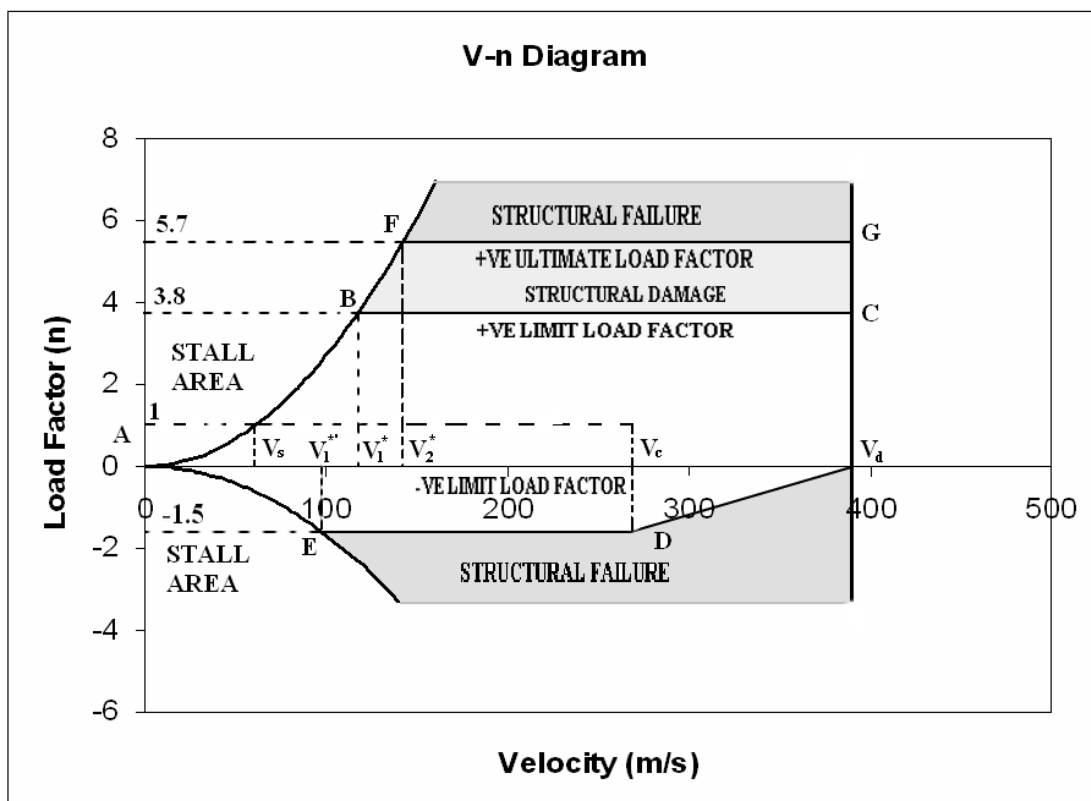
6.1 Aim

To draw the V-n diagram for the long range high speed subsonic business jet.

6.2 Formula Used

- $$n = \frac{L}{W} = \frac{C_{L-MAX}(1/2)\rho V^2 S}{W}$$
- $$V^* = \sqrt{\frac{2nW}{C_{L-MAX}\rho S}}$$

6.3 Diagram



Chapter 7

CHAPTER 7

3-VIEW DIAGRAM

7.1 Aim

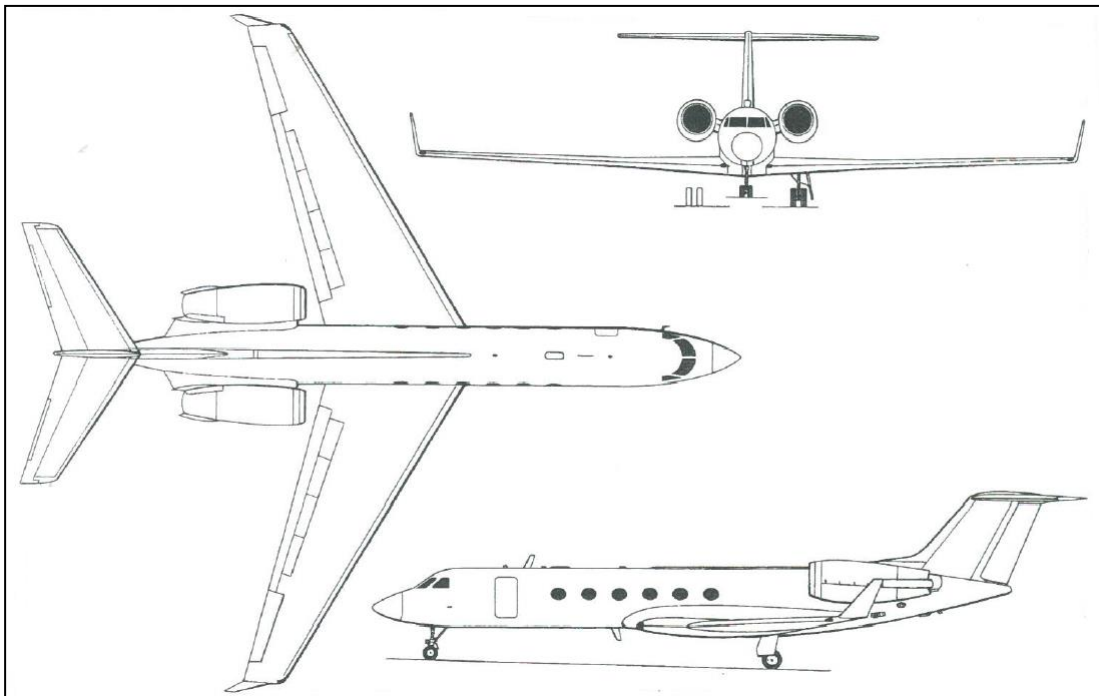
7.2 Diagram

7.3 Conclusion

7.1 Aim

To draw the 3-view diagram of the aircraft which has been designed.

7.2 Diagram



7.3 Conclusion

Thus the 3-view diagram of the aircraft that has been designed to meet the proposed requirements is drawn.

Chapter 8

CHAPTER 8

DESIGN SUMMARY

8.1 Table

8.2 Result

Table 8.1 Comparison Chart

Sl. No.	CONTENTS	ACQUIRED DATA	FINAL DATA
01.			
02.			
03.			
04.			
05.			
06.			
07.			
08.			