DESIGN OF PASSENGER AIRCRAFT

AIRCRAFT DESIGN PROJECT II REPORT

Submitted by

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BONAFIDE CERTIFICATE

Certified that this project report titled "**PASSENGER AIRCRAFT**" is the bonafide work of "**CH.NARAHARI(0019101153**) **, K.VIKAS CHARAN (0019101140) , N.RAJU KUMAR (0019101151)**" who carried out the project under authorized supervision. Certified further to the best of my knowledge that the work reported here does not form a part of any other project/research work on the basis of which a degree or reward was conferred on an earlier occasion on this or any other candidate

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INTERNAL EXAMINER

EXTERNAL EXAMINER

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LIST OF SYMBOLS & ABBREVIATIONS

S.NO	SYMBOLS/ABBREVIATIONS	DESCRIPTION
1.	b	Semi span
2.	C	Chord of the Airfoil (m)
3.	C_{root}	Chord at Root (m)
4.	C_{tip}	Chord at Tip (m)
5.	Y_1	Linear lift distribution
6.	Y_2	Ellipitical distribution
7.	y	Schrens apporiximation
8.	C_x	Chord at any point at a distance x from the root
9.	W_w	Weight of the wing
10.	k	Constant
11.	Y_0	Mean coordinate
12.	L_{tip}	Lift at tip
13.	Lroot	Lift at Root

14.	W_W	**Load on single wheel**
15.	R_f	**Deflection**
16.	**w**	**Width**
17.	**d**	**Diameter**

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CHAPTER I
INTRODUCTION

1.1 CONCEPTUAL DESIGN

- Conceptual design includes assumptions of aircraft mission requirements, performance and configuration needed for the company or customer We actually design the aircraft on the concept basis with the help of referring many aircraft and taking some assumption values.
- For designing the fighter aircraft, the following things are to be considered. Mission Requirements
- Configuration
- Performance Characteristics

1.2 MISSION REQUIREMENTS

Table 1.1 Results from aircraft Design Project I

PARAMETERS	**VALUES**
CREW	**3**
ROLE	**PASSENGER**
ENDURANCE	**16.7 HRS**
PAYLOAD	**67.1 TONES**
TYPE OF PAYLOAD	**PASSENGERS**
COMBAT TIME	**NOT COMBAT TYPE**

1.3 CONFIGURATION

Table 1.2 Results from aircraft Design Project I

PARAMETERS	**SHAPES**
FUSELAGE	**SEMI MONOCOQUE**
WING	**ANHEDRAL WITH SWEPT BACK**
TAIL	**T-TAIL**
LANDING GEAR	**SINGLE NOSE LANDING WHEEL WITH FOUR**

	WHEELS WITH TWO AXEL
ENGINE	**TURBOFAN (PRATT& WHITNEY HIGH BYPASS)**

1.4 PERFORMANCE CHARACTERISTICS

Table 1.3 Results from aircraft Design Project I

PARAMETERS	VALUES
MAXIMUM SPEED	0.85 MACH
CRUISE SPEED	908 KM/H
SERVICE CEILING	431000 FT
RATE OF CLIMB	2000 TO 4000 FT/MIN

1.5 SPECIFICATION OF DESIGNED AIRCRAFT

The calculated values of our desired aircrafts as shown in table 1.1

Table 1.4 Results from aircraft Design Project I

DESIGN POINT	PARAMETERS	VALUES
Weight	Overall Weight	448000 kg
	Empty Weight	220000 kg
	Fuel Weight	238610 liters
	Payload Weight	67.1tones
Performance	Cruise speed	908 km/h
	Maximum Speed	0.85 mach
	Range	14320 km
	Thrust Required	30163.89 kg
wing	Area	550 m^2
	Span	64 m

Wing	**Root Chord**	**14.84 m**
	Tip Chord	**3.7 m**
	Aerofoil	**NACA4412**

CHAPTER II

SCHRENK'S CURVE

2.1 WING DESCRIPTION

Lift varies along the wing span due to the variation in chord length, angle of attack and sweep along the span. Schrenk's curve defines this lift distribution over the wing span of an aircraft, also called simply as Lift Distribution Curve.

Schrenk's Curve is given by

$$\boldsymbol{Y = \frac{Y_1 + Y_2}{2}}$$

Where y1 is Linear Variation of lift along semi wing span also named as L1 y2 is Elliptic Lift Distribution along the wing span also named as L2

Data required from ADP I

Parameter	**Value**
Root chord	**14.84 m**
Tip chord	**3.7 m**
Semi span	**32m**
Empty weight/overall weight	**220000kg**

2.2 LINEAR LIFT DISTRIBUTION:

$Lift\ at\ root$

$$L_{Root} = \frac{\rho V^2 C_L c_{root}}{2}$$

Lroot = 331921.2715 (N/M)

Lift at tip

$$L_{Tip} = \frac{\rho V^2 C_L c_{tip}}{2}$$

$$\boldsymbol{L_{Tip}} = \mathbf{82756.65\ (N/m)}$$

By representing this lift at sections of root and tip we can get the equation for the wing.

Equation of linear lift distribution for starboard wing

$$Y_1 = -mx + c$$

$$Y_1 = (7786.3944)x + 331921.2715$$

Y1 = 581085.892

Equation of linear lift distribution for port wing we have to replace x by –x in general,

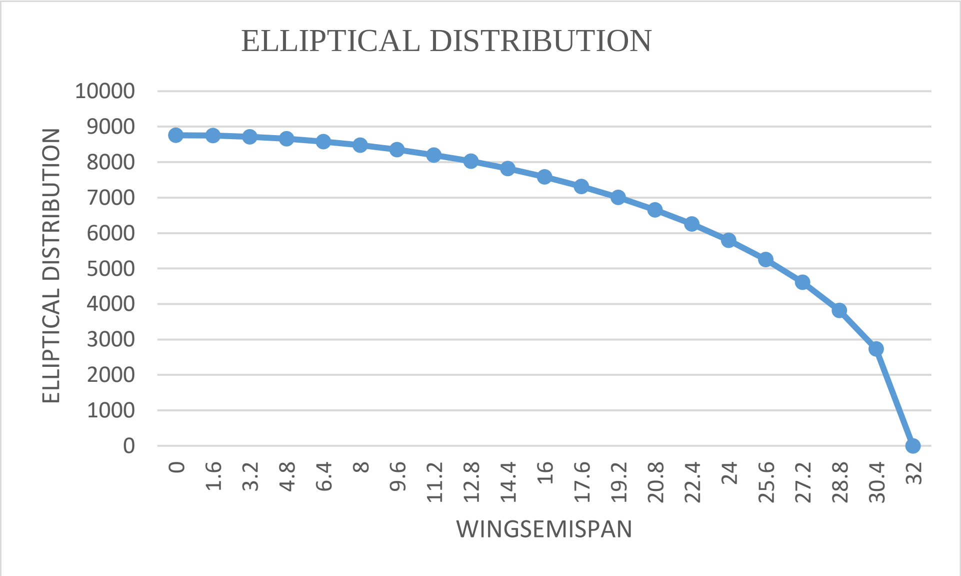


FIG 2.1 GRAPH BETWEEM X (SEMI SPAN) AND LINEAR DISTRIBUTION

2.3 ELLIPTIC LIFT DISTRIBUTION:

Twice the area under the curve or line will give the lift which will be required to overcome weight

Considering an elliptic lift distribution, we get

$$\frac{L}{2} = \frac{W}{2} = \frac{\pi a b_1}{4}$$

$$A = \frac{\pi a b_1}{4}$$

Where b1- is Actual lift at root

And a- is wing semi span

Lift at tip

$$b_1 = \frac{4W}{2\pi a}$$

b_1 = 4378.98

EQUATION OF ELLIPTIC LIFT DISTRIBUTION:

$$Y_2 = \frac{2b_1}{a}\sqrt{(a^2 - x^2)}$$

Y 2 = 273.686305*√(32)^2-X^2

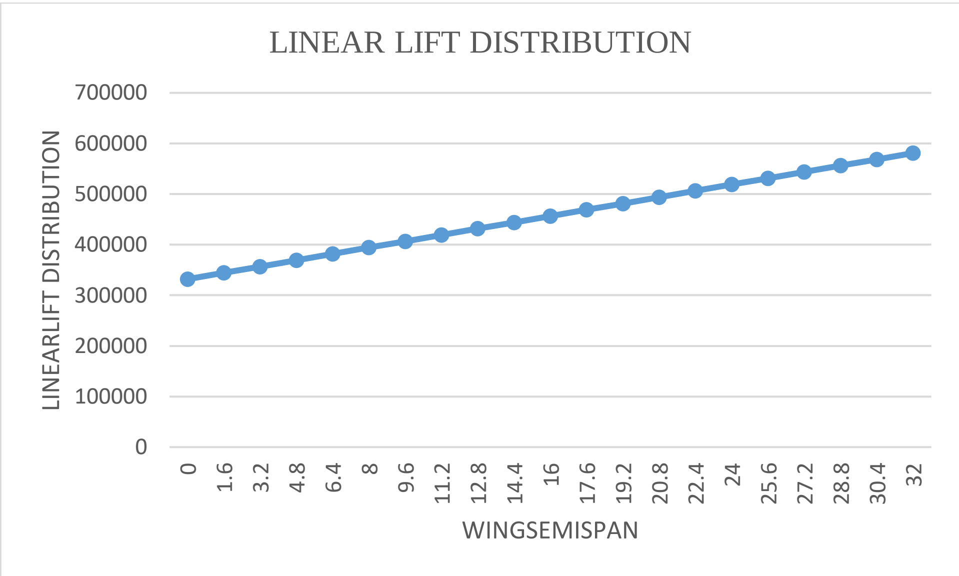


FIG 2.2 GRAPH BETWEEN X (SEMI SPAN) AND ELLIPITICAL DISTRIBUTION

2.4 CONSTRUCTION OF SCHRENK'S CURVE:

Schrenk's Curve is given by

$$Y = \frac{Y_1 + Y_2}{2}$$

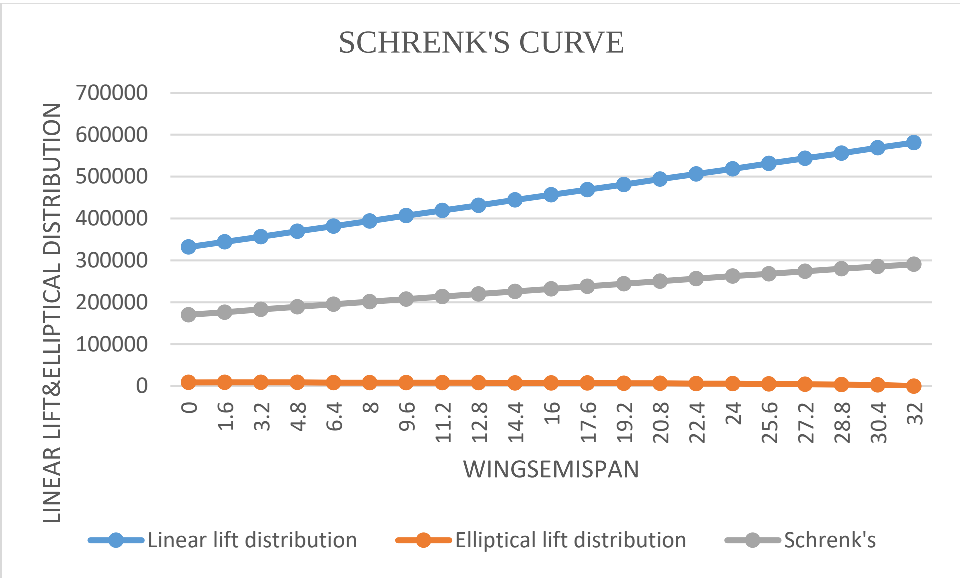
For x = 0 Y= 170339.617

For x = 32 Y = 290542.946

Table 2.1: Lift distribution table along semi span (DIVIDE X INTO 0 TO 10)

X	Y1	Y2	y
0	331921.2715	8757.96176	170339.6166
1.6	344379.5025	8747.007457	176563.255
3.2	356837.7336	8714.061926	182775.8978
4.8	369295.9646	8658.874151	188977.4194
6.4	381754.1957	8581.015	195167.6053
8	394212.4267	8479.860011	201346.1434
9.6	406670.6577	8354.563047	207512.6104
11.2	419128.8888	8204.018049	213666.4534
12.8	431587.1198	8026.80454	219806.9622
14.4	444045.3509	7821.109935	225933.2304
16	456503.5819	7584.61737	232044.0996
17.6	468961.8129	7314.340107	238138.0765
19.2	481420.044	7006.369408	244213.2067
20.8	493878.275	6655.474731	250266.8749
22.4	506336.5061	6254.435709	256295.4709
24	518794.7371	5792.847202	262293.7922
25.6	531252.9681	5254.777056	268253.8726
27.2	543711.1992	4613.542634	274162.3709
28.8	556169.4302	3817.507026	279993.4686
30.4	568627.6613	2734.672683	285681.167
32	581085.8923	0	290542.9462

FIG 2.3 GRAPH BETWEEN WING SEMISPAN AND LINEAR LIFT DISTRIBUTION AND ELLIPITICAL DISTRIBUTION AND SCHRENS APPORIXIMATION



CHAPTER III

LOAD ESTIMATION ON WING

3.1 DESCRIPTION:

The solution methods which follow Euler's beam bending theory (σ/y=M/I=E/R) use the bending moment values to determine the stresses developed at a particular section of the beam due to the combination of aerodynamic and structural loads in the transverse direction. Most engineering solution methods for structural mechanics problems (both exact and approximate methods) use the shear force and bending moment equations to determine the deflection and slope at a particular section of the beam. Therefore, these equations are to be obtained as analytical expressions in terms of span wise location. The bending moment produced here is about the longitudinal (x) axis.

3.2 LOADS ACTING ON WING:

As both the wings are symmetric, let us consider the starboard wing at first. There are three primary loads acting on a wing structure in transverse direction which can cause considerable shear forces and bending moments on it. They are as follows:

- Lift force (given by Schrenk's curve)
- Self-weight of the wing
- Weight of the power plant
- Weight of the fuel in the wing

Change the numerical values according to your calculatoins

STRUCTURAL WEIGHT DISTRIBUTION:

The structural weight is assumed to square of the chord,

$W_S \ \alpha \ (C_x)^2$

$W_S = k \times (C_x)^2$

K –constant

C_x –chord at any point at a distance x from the root.

Since the chord variation is linear along the span, apply boundary conditions

@ x= 0, C_x = a = C_r

@ x= semi span, C_x =C

C_x =a +bx ------------- (1)

Substitute all in eqn (1)

x=0 , C_x =a =C_r = 14.84 m.

x = 32, C_x = C_t = 3.7 m.

C_x = a + bx

3.7 = 14.84 +b (32)

b = - 0.35M

C_x = 14.84 -0.35x

W_w $=k\int_0^{32} (a + bx)\, dx$

$=k \int_0^{32} ((14.84)^2 + (-0.35)^2 * x^2 + 2(14.84)(-0.35))^2\, dx$

=k (8755.446)

112000   =k (8755.446)

k = 12.7920N/m².

$$\textbf{Airload} = \frac{\frac{w}{2}\times Y_0}{Area\ of\ ellipse\ (Schrenk' scurve)}$$

Area of ellipse =$\frac{\pi}{4}\, a\, b$

Where a is x axis and by axis coordinate value

Resultant load =Airload - kC_x^2

CALCULATION OF SHEAR FORCE AND BENDING MOMENTS

Include the table and graph

Table- 3.1:

Section	Stations (X)	Mean cordinates(Y_0)	Cx (m)	kC_x^2 (N)	Air load	Resultant load
1	0	13.686	14.84	2816.68	2122.01	-694.67
2	1.6	13.0017	14.28	2608.11	2015.91	-592.20
3	3.2	12.3174	13.72	2407.56	1909.81	-497.7
4	4.8	11.6331	13.16	2215.04	1803.71	-411.33
5	6.4	10.9488	12.6	2030.54	1697.61	-332.92
6	8	10.2645	12.04	1854.05	1591.51	-262.54
7	9.6	9.5802	11.48	1685.59	1485.41	-200.18
8	11.2	8.8959	10.92	1525.16	1379.30	-145.85
9	12.8	8.2116	10.36	1372.74	1273.20	-99.537
10	14.4	7.5273	9.8	1228.35	1167.10	-61.243
11	16	6.843	9.24	1091.98	1061.00	-30.972
12	17.6	6.1587	8.68	963.629	954.906	-8.7228
13	19.2	5.4744	8.12	843.301	848.805	5.50474
14	20.8	4.7901	7.56	730.994	742.705	11.7104
15	22.4	4.1058	7	626.71	636.604	9.89429
16	24	3.4215	6.44	530.447	530.503	0.05623
17	25.6	2.7372	5.88	442.206	424.402	-17.803
18	27.2	2.0529	5.32	361.987	318.302	-43.685
19	28.8	1.3686	4.76	289.790	212.201	-77.589
20	30.4	0.6843	4.2	225.615	106.100	-119.51
21	32	0	3.64	169.462	0	-169.46

TABLE 3.2

Load at midpoint(in magnitude)	Shear force(N)	Bending moment (N-m)
-102.46	-102.46	-1402.3
-94.446	-94.446	-1227.9
-86.424	-86.424	-1064.5
-78.402	-78.402	-912.06
-70.380	-70.380	-770.58
-62.358	-62.358	-640.08
-54.337	-54.337	-520.56
-46.315	-46.315	-412.01
-38.293	-38.293	-314.44
-30.271	-30.271	-227.86
-22.249	-22.249	-152.25
-14.227	-14.227	-87.623
-6.2057	-6.2057	-33.972
1.81617	1.81617	8.69964
9.83805	9.83805	40.3931
17.8599	17.8599	61.1078
25.8818	25.8818	70.8437
33.9037	33.9037	69.6009
41.9256	41.9256	57.3793
49.9475	49.9475	34.1790
-169.46	-169.46	0

By using the corresponding values of x in appropriate equations we get the plot of shear force.

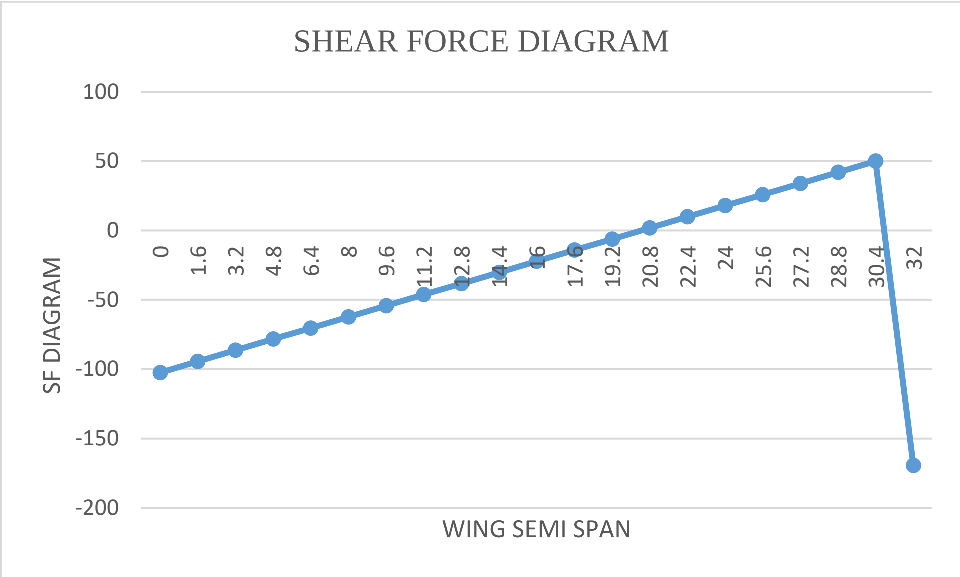


Fig 3.1 Shear Force Acting on wing

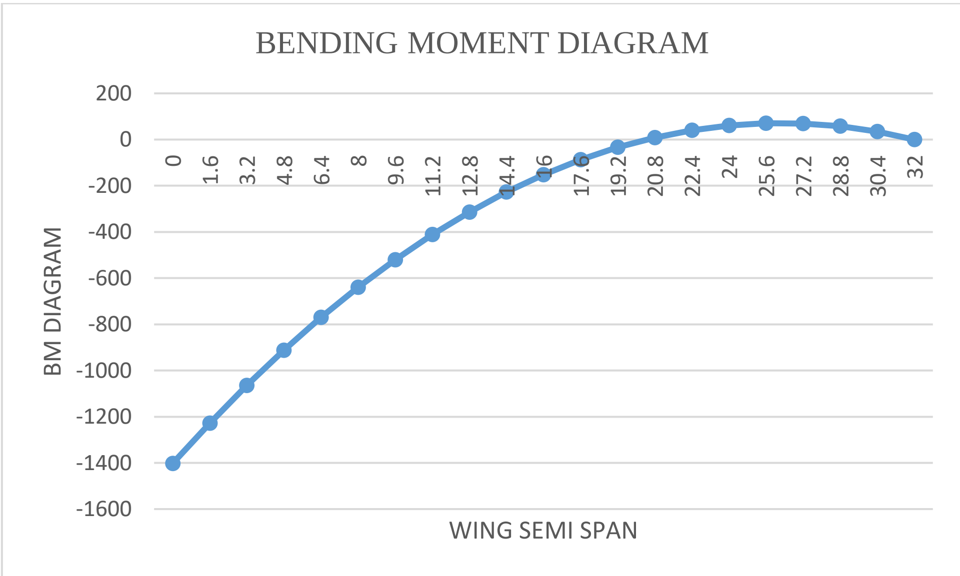


Fig 3.2 Bending moment diagram

CHAPTER IV

LANDING GEAR DESIGN

INTRODUCTION

Another aircraft major component that is needed to be designed is landing gear (undercarriage). The landing gear is the structure that supports an aircraft on the ground and allows it to taxi, take-off, and land. In fact, landing gear design tends to have several interferences with the aircraft structural design. In this lab, the structural design aspects of landing gear are not addressed; but, those design parameters which strongly impact the aircraft configuration design and aircraft aerodynamics will be discussed. In addition, some aspects of landing gear such as shock absorber, retraction mechanism and brakes are assumed as non-aeronautical issues and may be determined by a mechanical engineer. Thus, those pure mechanical parameters will not be considered in this chapter either. In general, the followings are the landing gear parameters which are to be determined in this chapter:

1. Type (e.g. nose gear (tricycle), tail gear, bicycle)
2. Fixed (faired, or un-faired), or retractable, partially retractable
3. Height
4. Wheel base
5. Wheel track
6. The distance between main gear and aircraft cg
7. Strut diameter
8. Tire sizing (diameter, width)
9. Landing gear compartment if retracted
10. Load on each strut

Landing gear usually includes wheels, but some aircraft are equipped with skis for snow or float for water. In the case of a vertical take-off and landing aircraft such as a helicopter, wheels may be replaced with skids. The descriptions of primary parameters are as follows. Landing gear height is the distance between the lowest point of the landing gear (i.e. bottom of the tire) and the attachment point to the aircraft. Since, landing gear may be attached to the fuselage or to the wing; the term height has different meaning. Furthermore, the landing gear height is a function of shock absorber and the landing gear deflection. The height is usually measured when the aircraft is on the ground; it has maximum take-off weight; and landing gear has the maximum deflection (i.e. lowest height).

The common options for landing-gear are shows in figure. The single main gear is used for many sailplanes because of its simplicity. The wheel can be forward of the center of gravity (c.g), as shown here, or can be aft of the c.g. with a skid under the cockpit is also of significant importance and will be employed during calculations. Wheel base is the distance between main gear and other gear (from side view). The landing gear is divided into two sections: 1. Main gear or main wheel1, 2. Secondary gear or secondary wheel. Main gear is the gear which is the closest to the aircraft center of gravity (cg). During the landing operation, the main wheel touches first with the point of contact to the ground. Furthermore, during the take-off operation, the main wheel leaves the ground last. On the other hand, main gear is carrying great portion of the aircraft load on the ground.

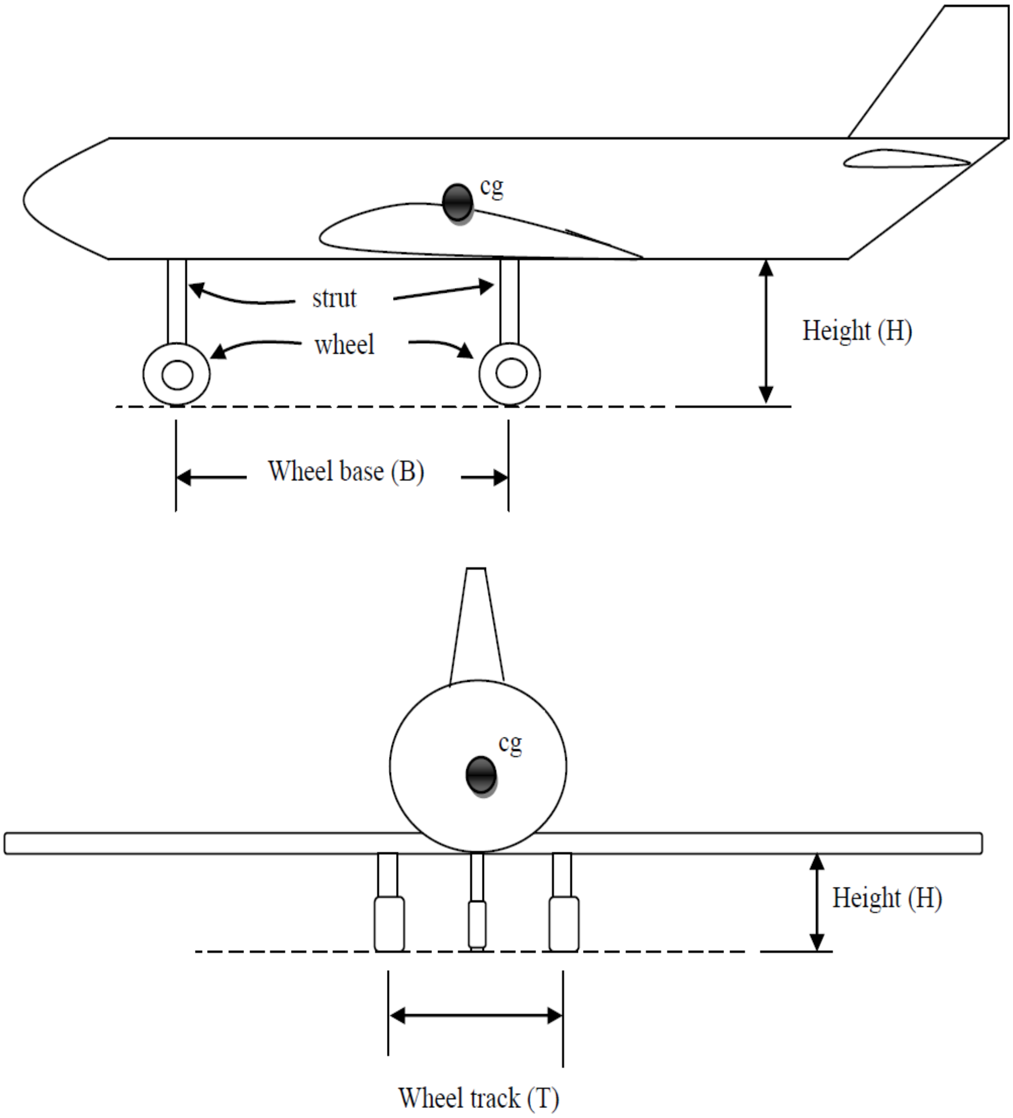


FIG 4.1 Landing gear primary parameters

LANDING GEAR CONFIGURATION

The first job of an aircraft designer in the landing gear design process is to select the landing gear configuration. Landing gear functions may be performed through the application of various landing gear types and configurations. Landing gear design requirements are parts of the aircraft general design requirements including cost, aircraft performance, aircraft stability, aircraft control, maintainability, producibility and operational considerations. In general, there are ten configurations for a landing gear as follows:

1. Single main
2. Bicycle
3. Tail-gear
4. Tricycle or nose-gear
5. Quadricycle
6. Multi-bogey
7. Releasable rail
8. Skid
9. Seaplane landing device
10. Human leg

"Bicycle" gear has two main wheels, fore and aft of the c.g., with small "outrigger" wheels on the wings to prevent the aircraft from tipping sideways. The bicycle landing gear has the aft wheel so far behind the c.g., that the aircraft must take-off and land in a flat altitude, which limits this of gear to aircraft with high lift at low angles of attack (i.e.., high-aspect ratio wings with large camber and/or flaps). Bicycle gear has been used mainly on aircraft with narrow fuselage and wide wing span such as the B-47 .

The "tail dragger" landing gear has two main wheels forward of the c.g. and an auxiliary wheel at the tail. Tail dragger gear is also called conventional landing gear, because it was the most widely used arrangement during the first 40 years of aviation. Tail dragger gear provides more propeller clearance,, has less drag and weight, and allows the wing to generate more lift for rough-field operation than does tricycle gear.

However, tail dragger landing gear is inherently unstable. If the aircraft starts to turn, the location of c.g. behind the main gear causes the turn to get tighter until a "ground loop" is encountered, and the aircraft either drags wingtip, collapses the landing gear, or runs of the side of the runway. To prevent this, the pilot of a tail dragger aircraft must align the aircraft almost perfectly with the runway at touchdown, and "dance" on the rudder pedals until the aircraft stops.

The most commonly used arrangement today is the "tricycle" gear, with two main wheels aft of the c.g. and an auxiliary wheel forward of the c.f., with a tricycle landing gear, the c.g. is ahead of the main wheels so the aircraft is stable on the ground and can be landed at a fairly large "crab" angle (i.e., nose not aligned with the runway). Also, tricycle landing gear improves forward visibility on the ground and permits a flat cabin floor for passenger and cargo loading.

Quadricycle gear is much like bicycle gear but with wheels at the sides of the fuselage. Quadricycle gear also requires a flat takeoff and landing attitude. It is used on the B-52 and several cargo planes where it has the advantage of permitting a cargo floor very low to the ground.

The gear arrangements described above are also seen with two, four, or more wheels in place of the single wheels shown in figure. As the aircraft weights become larger, the requires wheel size for a single wheel capable of holding the aircraft's weight too large. Then multiple wheels are used to share the load between reasonably sized tires.

Also, it is very common to use twin nose-wheels to retain some control in the event of a nose-wheel flat tire. Similarly, multiple main wheels (i.e. total of four or more) are desirable for safety. When multiple wheels are used in tandem, they are attached to a structural element called a "bogey," or "truck," or "axle beam" that is attached to the end of shock-absorber strut.

Typically an aircraft weighing under about 50,000 lb(22,680 kg) will use a single main wheel per strut, although for safety in the event of a flat tire it is always better to use two wheels per strut. Between 50,000 lb (22,680-68,040 kg), two wheels per strut are typical. Two wheels per strut are sometimes used for the aircraft weighing up to about 250,000 lb(113,400 kg).

Between aircraft weights of about 200,000 and 400,000 lb(90,720-181,440 kg) the four-wheel bogey is usually employed; for aircraft over 400,000 lb (181,440 kg) four bogeys, each with four or six wheels, spread the total aircraft load across the runway pavement.

Except for light aircraft and a few fighters, most aircraft use twin nose-wheels to retain control in the event of a flat nose tire. Carrier-based aircraft must use twin nose-wheels at least 19in. (483 cm) in diameter to straddle the catapult-launching mechanism. The massive C-5 employs four nose-wheels to spread to spread the tire load, permitting operation off of relatively soft fields.

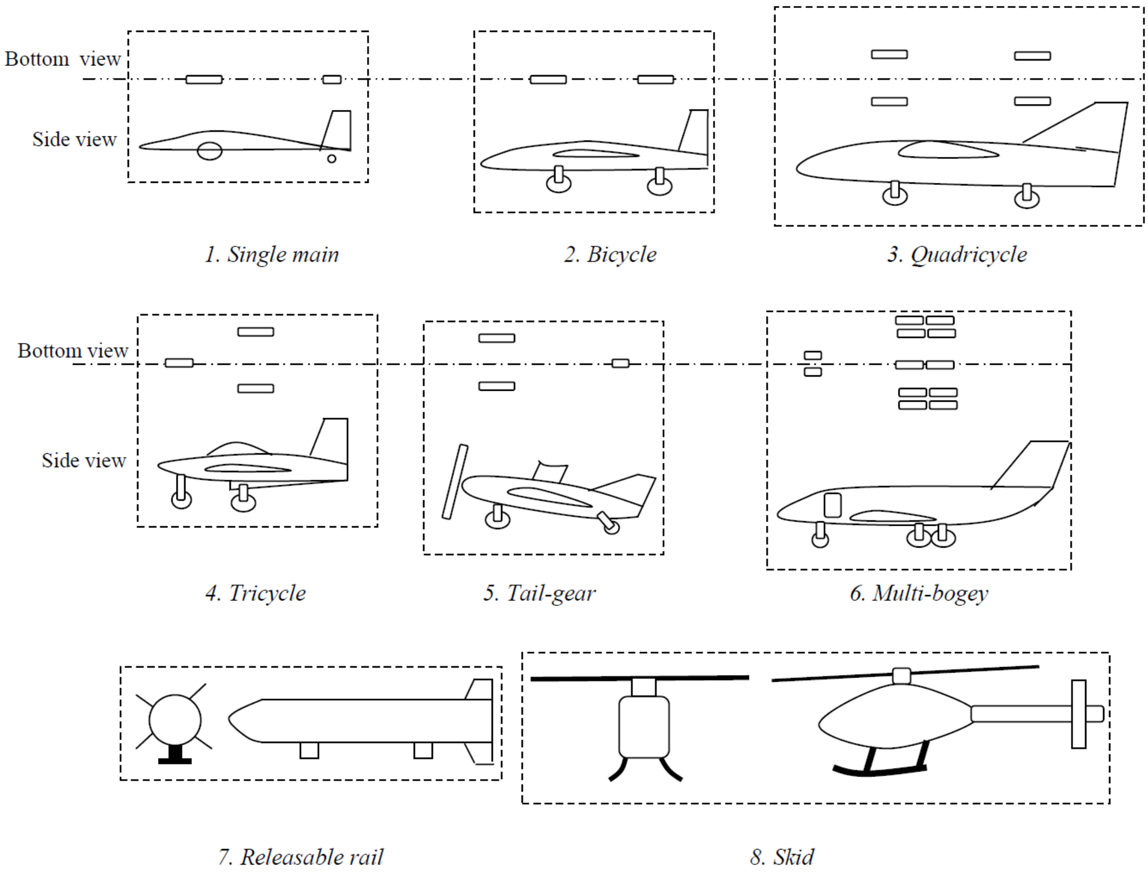


FIG 4.2 Landing gear arrangements

Guidelines for layout of a bicycle landing gear are shown in figure. The c.g. should be aft of the midpoint between the two wheels.The requirements for tail dragger gear are shown in figure. Te tail-down angle should be about 10-15 deg with the gear in the static position(i.e., tires and shock absorbers compressed the amount seen when the aircraft seen when the aircraft is stationary on the ground at takeoff gross weight).The c.g. (most forward and most aft) should fall between 16-25 deg back from vertical measured from the main wheel location. If the c.g. is too far forward the aircraft will tend will tend to nose over, and if it is too far back it will tend to ground loop.To prevent the aircraft from overturning the main wheels should be laterally separated beyond a 25 deg angle off the c.g., as measured from the rear in a tail-down attitude.

1. DIAMETER OR WIDTH OF THE WHEEL

D=A$W_W{}^B$

Where,

A&B is constant,

W_w =load on single wheel.

For main wheel that value is 90% of the total aircraft weight and for auxiliary wheel it is 10% of total aircraft weight this for the business jet it may differ for different aircraft. So,

W_w for main wheel = 0.9 × W_O

=0.9 × 220000

= 198000 (for single wheel of main landing gear it contains 15 extra)

= 198000/16 = 12375kg

W_w for auxilary wheel = 0.1 × W_O

=0.1 × 220000 =22000kg

Diameter of main wheel

D=A$W_W{}^B$

The constants from RAMER book becomes,

A=0.066m

B=0.0063m

We are choosing a tricycle configuration .so, two main wheels and one auxiliary wheel. So, for one main wheel W_w is 12375.

$$D = 0.066 \times 12375^{0.0063}$$

$$= 0.070036 \text{ m.}$$

Diameter of auxiliary wheel

$$D = 0.066 \times 11000^{0.0063}$$

$$= 0.06998\text{m.}$$

2. WIDTH OF THE WHEELS

For main wheel(w)=A${W_W}^B$

Where,

A=0.0279m

B=0.0054m

W=0.0279× $12375^{0.0054}$

=0.029356.

For auxiliary wheel (w) =A${W_W}^B$

$$= 0.0279 \times 11000^{0.0054}$$

$$= 0.006998\text{m.}$$

3. PAVEMENT OR CONTACT AREA

$${W_W}^B = P A_P$$

A)Main wheel landing gear, mm/cm/m

TABLE 4.1 LANDING WHEEL PARAMETERS FOR CALCULATION

INFLATION	DIAMETER	WIDTH	RIM DIAMETER	DEFLECTION
205 PSI	**49 inch**	**19 inch**	**22 inch**	**16.17**

Semi major axis (a) = $\sqrt{(d/2)^2 - (R_F)^2}$

= √(24.5)^2 – (8.08)^2

= 23.127 inch

semi minor axis (b) = w/2

= 19/2

= 9.5inch

Where foot print = A_P = 2.3 × $\sqrt{w.d}\ (\frac{d}{2} - R_F)$

R_F = deflection

w =width

d=diameter

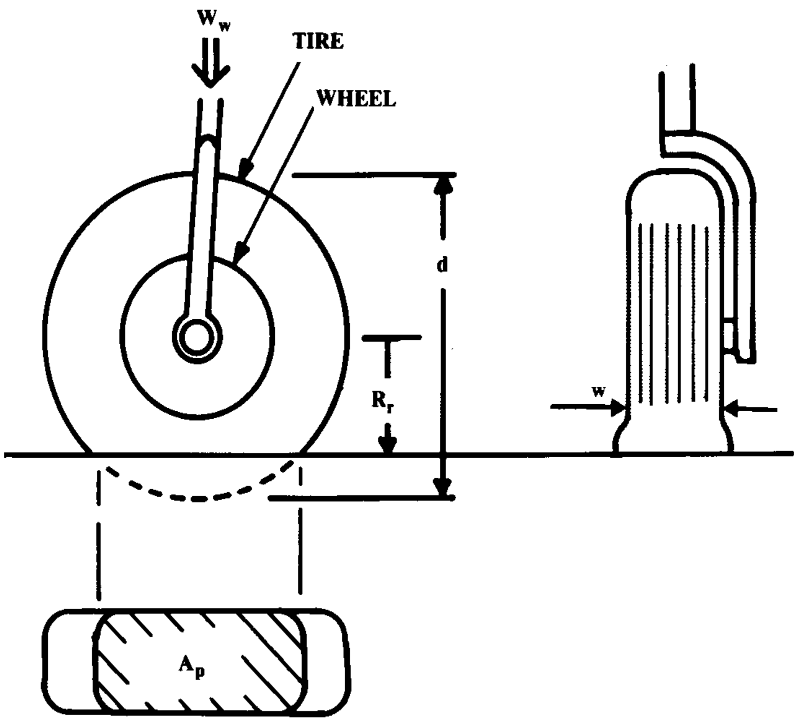


FIG 4.3 Landing gear area / foot print calculation

For major business airfield P=205 psi = 144129.3 kg/m^2

Contact area = ∏×a×b = 3.14×23.127 × 9.5 = 690.33 inch

Foot print(A_P) $= 2.3 \times \sqrt{19 \times 49}\,(\frac{49}{2} - 16.17)$

$= 4092.08$ inch

B) Auxiliary wheel (Nose wheel landing gear) mm/cm/Mm

TABLE 4.2 LANDING WHEEL PARAMETERS FOR CALCULATION

INFLATION	DIAMETER	WIDTH	RIM DIAMETER	DEFLECTION
205 psi	**49 inch**	**19inch**	**22inch**	**16.17inch**

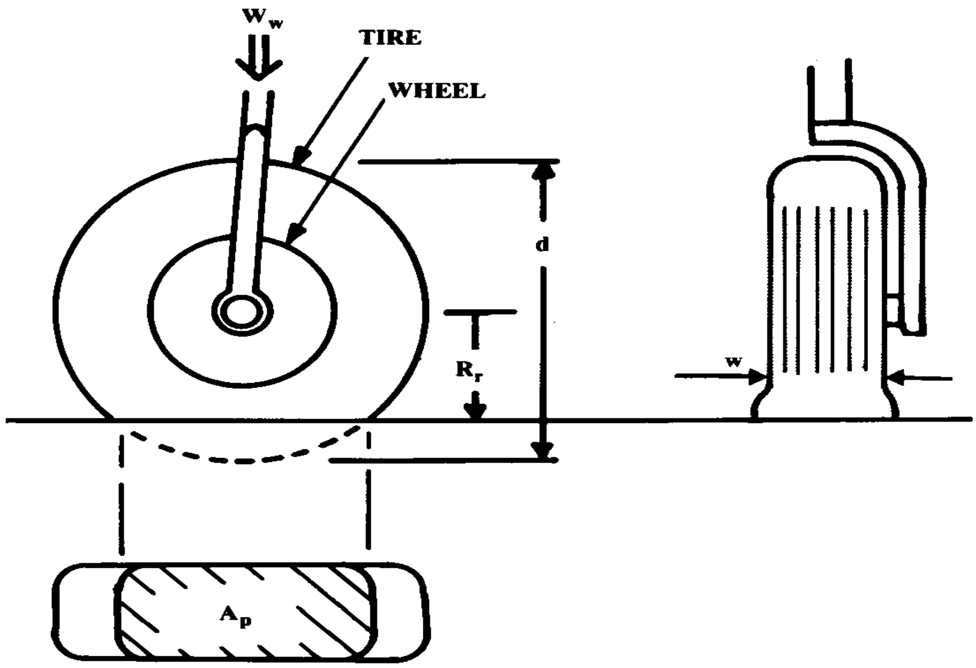


FIG 4.4 Diagram for Landing gear area / foot print calculation

Semi major axis (a) $= \sqrt{(d/2)^2-(R_F)^2}$

$= \sqrt{(49/2)^2 - (16.17)^2}$

$= 23.17$inch

semi minor axis (b) = w/2 = 19/2

= 9.5inch

Contact area = ∏×a×b = 3.14×23.127×9.5 = 690.22 INCH^2

Foot Print (A_p) = $2.3 \times \sqrt{19 \times 49 \times} \left(\frac{49}{2} - 16.17\right)$

= 4092.08 inch