Chapter 2

Lecture 5

Data collection and preliminary three-view drawing - 2

Topic

2.3 Preliminary three-view drawing

Example 2.1

2.3 Preliminary three-view drawing

The preliminary three-view drawing of the airplane gives an idea about the possible shape and size of the proposed airplane and forms the next step after the data collection. To draw the preliminary three-view drawing, requires the approximate dimensions of the wing, fuselage, tail and other components. The following steps are used to get these ballpark values. Example 2.1 illustrates the procedure.

1. The payload is the weight of the items for which the airplane is being designed. This would constitute (a) the weights of passenger & cargo for a transport airplane, (b) the weight of the ammunition/special equipment for a military airplane.

Depending on the number of passengers, range etc., the payload can be estimated. For military airplanes, the payload may be prescribed. Let, the weight of payload be denoted by W_{pay}.

2. From the data collection on similar airplanes, the ratio W_0 / W_{pay}, can be chosen; W_0 being the design gross weight. Then,

$$W_0 = W_{pay} \times (W_0 / W_{pay})$$

Remark:

This weight (W_0) will be refined in the next stage of preliminary design (see chapter 3).

3. From the data collection on similar airplanes, the wing loading (W/S) is chosen.

Then, $S = W / (W/S)$

4. From data collection on similar airplanes the aspect ratio (A) of the wing is chosen. Consequently, the wing span (b) is given by:

$$b = (S \times A)^{1/2}$$

5. The planform of the wing is chosen from the data collection. Let the taper ratio be λ.

Since, $S = b / 2\,(c_r + c_t)$ and $\lambda = c_t/c_r$, yields :

$c_r = 2S / b\,(1+\lambda)$ and $c_t = c_r\,\lambda$

Also the sweep angle(Λ) of the wing can be chosen from the data on similar airplanes.

6. From the data on similar airplanes, choose the ratio (l_f / b);

l_f = length of fuselage. Then:

$$l_f = b \times (l_f / b)$$

7. From the data collection on similar airplanes, choose the cross-sectional size of the fuselage and the position where payload is located. Also find the ratios l_{nose} / l_f , $l_{cockpit} / l_f$ and $l_{tailcone} / l_f$. Obtain l_{nose}, $l_{cockpit}$ and $l_{tailcone}$ as l_f is known from step 6. Obtain the length of the payload section as difference between l_f and the sum of the lengths of l_{nose}, $l_{cockpit}$ and $l_{tailcone}$.

8. From the data on similar airplanes choose the values of S_{ht}/ S, S_{vt} / S. Also choose the values of aspect ratio, taper ratio and sweep for the horizontal and the vertical tails. In this step, the suffixes "ht" and "vt" refer to the horizontal tail and the vertical tail respectively.

Consequently,

$$S_{ht} = \frac{S_{ht}}{S} S \qquad S_{vt} = \frac{S_{vt}}{S} S$$

$$b_{ht} = \sqrt{S_{ht} A_{ht}} \qquad b_{vt} = \sqrt{S_{vt}\, A_{vt}}$$

$$(c_r)_{ht} = \frac{2S_{ht}}{b_{ht}(1+\lambda_{ht})} \qquad (c_r)_{vt} = \frac{2S_{vt}}{b_{vt}\,(1+\lambda_{vt})}$$

$$(c_t)_{ht} = (c_r)_{ht}\lambda_{ht} \qquad (c_t)_{vt} = (c_r)_{vt}\,\lambda_{vt}$$

9.From the data collection on similar airplanes, choose the values of $S_{elevator}$ / S_t, S_{rudder} / S_{vt} , $S_{aileron}$ /S , S_{flap} / S , $c_{elevator}$ / c_{ht} , c_{rudder} / c_{vt}, $c_{aileron}$/ c_{wing} , c_{flap} / c_{wing}. Obtain the areas and chords of elevator, rudder, flap and aileron.

10. From the data collection on similar airplanes, choose the value of T/ W or W/ P; T is the engine thrust and P is the engine power.

Hence, $T = (T / W) \times W$ or $P = W / (W / P)$

Choose the number of engines to be used and obtain the rating of engine (s). Obtain approximate dimensions of the engine and the size(s) of the propellers/intake as appropriate.

11. From the data collection on similar airplanes, choose the locations of the wing, the horizontal tail and the vertical tail on the fuselage.

12. From the data on similar airplanes, choose the landing gear type and obtain (wheel base) / l_f and (wheel tread)/ l_f. Obtain wheel base and wheel tread as l_f is known.

With these data a preliminary three-view drawing can be prepared. The procedure is illustrated with example 2.1.

Example 2.1

Obtain the preliminary three-view drawing for the airplane with the following specifications.

Type: Regional transport airplane with turboprop engine.

No. of passengers: 60.

V_{cruise}: Around 500 kmph at around 4.5 km altitude.

Safe range: 1300 km.

Service ceiling: 8000 m.

Balanced field length for take-off : Around 1400 m.

Solution:

The regional transport airplanes are currently in considerable demand and many airplane companies are engaged in their design. These airplanes could be propelled by a turbo-prop engine or a turbofan engine. The later would, have a shorter duration of flight. However, a turboprop engined airplane is more economical than the turbofan powered airplane. A turboprop powered airplane is considered here. The examples of such airplanes are : XAC Y-7-100, IPTN-250-100, ATR-72-200, ATR-72-500, ILYUSHIN Il-114, SAAB 2000, Antonov AN-140 and De Havilland Dash 8- Q300. Details of these airplanes are available in Ref.1.21. Some of the features are summarized in Table 2.1.

Designation	**XAC Y-7-100**	**IPTN-250-100**	**ATR-72-200**	**ATR-72-500**	**ILYUSHIN Il-114**	**SAAB 2000**	**ANTONOV AN-140**	**De Havilland Dash 8 - Q300**
Country	China	Indonesia	International	International	Russian Federation	Sweden	Ukraine	Canada
No.of passengers	48-52	60-68	64-74	68-74	64	50-58	46-52	50-56
Overall dimensions								
Wing span (m)	29.67	28.0	27.05	27.05	30.0	24.76	24.73	27.43
Overall length(m)	24.22	28.12	27.17	27.17	26.88	27.28	22.61	25.68
Overall height (m)	8.85	8.78	7.65	7.65	9.32	7.73	8.035	7.49

Designation	**XAC Y-7-100**	**IPTN-250-100**	**ATR-72-200**	**ATR-72-500**	**ILYUSHIN Il-114**	**SAAB 2000**	**ANTONOV AN-140**	**De Havilland Dash 8-Q300**
Weights								
Operational empty weight(kgf)	14988	15700	12500	12950	15000	13800		10977
Max.fuel (kgf)	4790	4200	5000	6400	6500	4250	4370	
Max.pay load(kgf)	5500	6200	7200	7550	6500	5900	6000	5443
Max. T.0 weight(kgf)	21800	24800	21500	22000	23500	22800	19150	17962
Max. landing weight(kgf)	21800	24600	21350	21850		22000	19100	17690
Max.zero fuel weight (kgf)	19655	21900	19700	20500		19700	17800	16420

Table 2.1 Important data on regional transport airplanes with turboprop engine (contd..)

Designation	XAC Y-7-100	IPTN-250-100	ATR-72-200	ATR-72-500	ILYUSHIN Il-114	SAAB 2000	ANTONOV AN-140	De Havilland Dash 8 - Q300
Performance								
Max.level speed (kmph)	503				500			
Max.cruise speed(kmph)	476 at 6000m	611 at 6100m	526 at 4575m	519	470	682 at 7620m	575 at 7200m	526 at 4575m
Economical cruising speed (kmph)	423 at 6000 m	556 at 6000m	460 at 7010m				520 at 7200m	
Max.Stalling speed poweroff (kmph)		195						
Max.rate of climb at sea level(m/min)	458	564						
Service Ceiling(m)	8750	9140	7620		7600			7620
Balanced field length (m)		1220	1408	1205			1350	1097
Landing Run(m)	620	1220	1125	1067	1300			1052
Range (km)			1195 (safe range)		1000 (safe range)		2100 (no reserve)	1482

Table 2.1 (contd..)

Designation	XAC Y-7-100	IPTN-250-100	ATR-72-200	ATR-72-500	ILYUSHIN Il-114	SAAB 2000	ANTONOV AN-140	De Havilland Dash 8 Q300
Power plant								
Power Plant	Two DEMC WJ5A Turbo prop each rated 2080 kW	Two Allison AE2100C Each 2439 kW Each	Two PW 124B each rated 1611 kW	Two PWC127F each rated 2050kW	Two KLIMOV TV711s Each 1839 kW	Two Allison AE2100A Each 3069 kW	Two AI 30 series each 1839 kW	Two PW 137 engine each 1775 kW
Propeller								
Propeller dia. (m)	3.9	3.81	3.93		3.60	3.81	3.60	3.96
Distance between propeller centres (m)		7.67	8.1				8.2	
Propeller fuselage clearance (m)	0.72		0.82		0.97			0.76
Propeller ground clearance (m)	1.15		1.1		0.5	0.46		0.94

Table 2.1 (contd..)

Designation	XAC Y-7-100	IPTN-250-100	ATR-72-200	ATR-72-500	ILYU-SHIN Il-114	SAAB 2000	ANTONOV AN-140	De Havilland Dash 8 Q300
Wing								
Wing span(m)	28.93* (29.67 over winglets)	28.00	27.05	27.05	30.00	24.76	24.73	27.43
Wing gross area (m^2)	75.26	65.00	61.00	61.00	81.9	55.74	90.00	56.21
Aspect ratio	11.7	12.1	12	12	11	11		13.4
Wing chord at root c_r (m)	3.5	2.8	2.57	2.57				2.46*
Wing chord at tip c_t(m)	1.1	1.45	1.59	1.59				1.23*
Taper ratio c_t/c_r (wing)	0.31	0.52	0.62	0.62			0.36	0.50
Constant chord central section	Upto 0.25 of semi-span*	Upto 0.29 of semi-span*	Upto 0.36 of semi-span*					Upto 0.323 of semi-span*
Quarter chord sweep of outboard wing	6.9^{o*}	4.8^{o*}	3.1^{o*}					3.6^{o*}

* Estimated value

Table 2.1 (contd..)

Designation	**XAC Y-7-100**	**IPTN-250-100**	**ATR-72-200**	**ATR-72-500**	**ILYU-SHIN Il-114**	**SAAB 2000**	**ANTONOV AN-140**	**De Havilland Dash 8 Q300**
Wing Location	High wing	High wing	High wing	High wing	Low wing	Low wing	High wing	High Wing
Twist (degrees)		3						
Dihedral (degree)		3	3	3		7	6	2^o 30‘
Anehedral (degree)	2^o12‘							
Incidence (degree)	3	2	2			2		
Airfoil		MS(1)-0317 at root MS(1)-0313 at tip						18% at root 13% at Tip
Type of flap		Fowl-er flap	Two segme-nt double slotted	Two segme-nt double slotted		Single slotted		Fowler Flap
Trailing edge flaps area(m^2)	14.81		12.28	12.28				
Spoiler area(m^2)			1.34	1.34				
Aileron area(m^2)	5.48		3.75	3.75				

Table 2.1 (contd..)

Designation	**XAC Y-7-100**	**IPTN-250-100**	**ATR-72-200**	**ATR-72-500**	**ILYUSHIN Il-114**	**SAAB 2000**	**ANTONOV AN-140**	**De Havilland Dash 8 Q300**
Fuselage								
Fuselage length (l_f) (n)	24.22	26.78	27.17	27.17	26.20	27.28	22.61	24.43
Fuselage max.width (m)	2.9	2.9	2.865	2.865	2.86	2.31		2.69
Fuselage max.depth (m)	2.5	2.9			2.86	2.31		3.04
Cabin length(m)	10.5	13.23	19.21			16.7	10.5	13.83
Cabin Max.width (m)	2.76	2.68	2.57		2.64	2.16	2.6	2.49
Cabin Max.height (m)	1.9	1.925	1.91		1.92	1.83	1.9	1.88
Cabin Volume (m^3)	56		76			52.7	65.5	
Height of belly of fuselage above ground	0.74*	0.73*	0.70*		1.17*	1.27*	0.80*	0.80*

Table 2.1(contd..)

Designation	XA CY-7-100	IPTN-250-100	ATR-72-200	ATR-72-500	ILYU-SHIN Il-114	SAAB 2000	ANTONOV AN-140	De Havilland Dash 8 Q300
Empennage								
H.tail area (m^2)	17.3	16.31	11.73	11.73		18.35		
H.tail span (m)	9.08	9.04			11.1	10.36		7.33
H.tail taper ratio	0.5	0.54	0.54	0.54			0.483	0.70
Elevator area(m^2)	5.14	6.34	3.92	3.92				4.97
V.tail area (m^2)	18.49 (fin = 13.38)	14.72	16.48			13.01		14.12
V.tail taper ratio	0.33	0.667	0.27£					0.7
Rudder area (m^2)	5.11	4.41*	4.0	4.0				4.31
Dorsal fin Area (m^2)	2.88	3.08*	1.05*					2.64*

£ - See remark in Table 6.2

Table 2.1(contd..)

Designation	**XA CY-7-100**	**IPTN-250-100**	**ATR-72-200**	**ATR-72-500**	**ILYUSHIN Il-114**	**SAAB 2000**	**ANTONOV AN-140**	**De Havilland Dash 8 Q300**
Landing gear								
Type	Retr-acta-ble, tric-ycle €	Retract-able, tricycle $	Retrac-table, Tricy-cle $	Retra-table, tricy-cle $	Retra-ctable, tricy-cle £	Retract-able, tricycle £	Retract-able, tricycle $	Retract-able, tricycle €
Wheel track (m)	7.9€	4.1$	4.1$	4.1$	8.4£	8.23£	3.18$	7.87€
Wheel base (m)	7.9	10.26	10.77	10.77	9.13	11.22	8.01	9.6

€ - Retracted in engine nacelle on high wing

$ - Retracted in pods on fuselage

£ - Retracted in engine nacelle on low wing

Ratios								
W/S kgf/m^2	289.7	381.5	352.5	360.6	286.94	409.04		319.6
l_f/b	0.82	0.956	1.004	1.004	0.873	1.10	0.914	0.891
S_{flap}/S	0.20		0.20	0.20				
S_{ht}/S	0.23	0.25	0.19	0.19		0.33		
S_{vt}/S	0.18	0.23	0.20	0.20		0.23		
$S_{elevator}/S_{nt}$	0.30		0.33	0.33				
S_{rudder}/S_{vt}	0.38		0.32	0.32				
Power Loading (P/W) (kW/N)	0.0195	0.0201	0.0153	0.019	0.016	0.0274	0.0196	0.0201

Table 2.1 Important data on regional transport airplanes with turboprop engine

Remark:

In the case of the jet airplane considered in Appendix 10.2, the details like design philosophy are also discussed. Here, it is assumed that the aforesaid specifications have already been arrived at.

i) Estimate of gross weight (W_0):

The number of passengers and the range mainly decide the gross weight. The number of passengers is 60. The safe range is 1300km. Hence, the gross still air range would be around 1950 km. Table 2.1 shows that the specifications of the airplane to be designed are close to those of ATR-72-200. Hence, gross weight $(W)_0$, is taken as 21500 kgf (210,915 N).

ii) Wing loading (W_0 / S):

Based on the data in Table 2.1, W / S = 350 kgf / m^2 is chosen.

Hence, wing area(S) = 21500/350 = 61.43 m^2.

iii) Other parameters of the wing :

(A) Wing aspect ratio (A): Based on Table 2.1, A=12 is chosen.

Hence, wing span (b) is given by:

$$b = \sqrt{A \times S} = \sqrt{12 \times 61.43} = 27.15 \text{ m}$$

(B) Wing taper ratio (λ): Based on Table 2.1, λ = 0.5 is chosen.

Hence, root chord (c_r) is given by:

$(c_r) = 2S / \{b(1+ \lambda)\}$ = 3.02 m and tip chord (c_t)= 3.02 × 0.5 = 1.51 m.

(C) Flap area (S_f) : From Table 2.1 $S_{ft} / S \approx 0.2$.

Hence, $S_f = 0.2 \times 61.93 = 12.3$ m^2.

(D) Wing sweep back (Λ): At this stage an unswept wing is chosen i.e. Λ = 0.

(E) Wing location: High wing location is the preferred choice for such airplanes.

iv) Fuselage parameters:

The length of fuselage (l_f) depends mainly on the number of passengers and the number of seats in a row. From Table 2.1 it is clear that a 60 seater airplane would have $l_f \approx 27$ m. This value of l_f would give l_f / b of 27 / 27.15 ≈ 1.00. This ratio is also close to the value of l_f / b for ATR-72-200.

(A) Cabin size:

From Table 2.1 it is noticed that the cabin size for such an airplane (4 abreast seats) would be: width ≈ 2.6 m, height = 1.9 m.

(B) The fuselage outer dimensions would be: maximum height = 2.8m, maximum width = 2.8 m. Note fuselage depth includes the height of cabin, the height of cargo compartment and the structural thickness.

(v) Horizontal tail parameters :

From Table 2.1 the following parameters are chosen.

S_{ht} / S = 0.21, aspect ratio of H. tail (λ_{vt}) = 5.0, taper ratio of H.tail (λ_{ht}) = 0.6, and ratio of elevator area to tail area (S_e / S_{ht}) = 0.3.

Consequently,

(A) Horizontal tail area = S_{ht} = 0.21 × 61.43 = 12.9 m^2.

(B) H.tail span (b_{ht}) = $(12.9 \times 5)^{1/2}$ = 8.03 m

(C) H.tail root chord (c_{rht})

= 2 ×12.9 / {8.03 (1+0.6) } = 2.0 m

(D) H.tail tip chord (c_{tht}) = 0.6 × 2 = 1.2 m

(E) Elevator area (S_e) = 0.3 × 12.9 = 3.87 m^2.

vi) Vertical tail parameters:

From Table 2.1 the following parameters are chosen.

S_{vt} / S = 0.20, aspect ratio of V. tail (A_{vt}) = 1.5, taper ratio of V.tail (λ_{vt}) = 0.3, and ratio of rudder area to V.tail area (S_r / S_{vt}) = 0.35.

Consequently, Area of vertical tail (S_{vt}) = 0.2 × 61.43 = 12.3 m^2

(B) Height of vertical tail (h_{vt}) = $(12.3 \times 1.5)^{1/2}$ = 4.3 m

(C) Root chord of vertical tail (c_{rvt}):

= 2 × 12.3 / {4.3 (1 + 0.3)} = 4.4 m

(D) Tip chord of vertical tail (c_{tvt}):

= 0.3 × 4.4 = 1.32 m

(E) Area of rudder (S_r) = 0.35 × 12.3 = 4.3 m^2

vii) Power plant :

Two wing mounted engines is the current trend. From Table 2.1, each engine would have sea level static power output of about 1600 kW.

Modern propeller with 3.9 m diameter is suggested by data in Table 2.1.

viii) Landing gear:

Retractable tricycle landing gear with main wheels retracted in pods on fuselage is chosen to avoid excessive height of landing gear. A wheel track of 4.1 m is chosen. The wheel base of 10.8 m is selected.

ix) Overall height:

Based on Table 2.1, an overall height of 7.7 m is chosen which is typical of airplane with landing gear retracted in fuselage.

The preliminary three-view is shown in Fig.2.1.

Remark:

Chapter 1 of Appendix 10.2 illustrates the above process for a medium range jet transport. It also contains information on design philosophy and data collection on airplanes in that category.

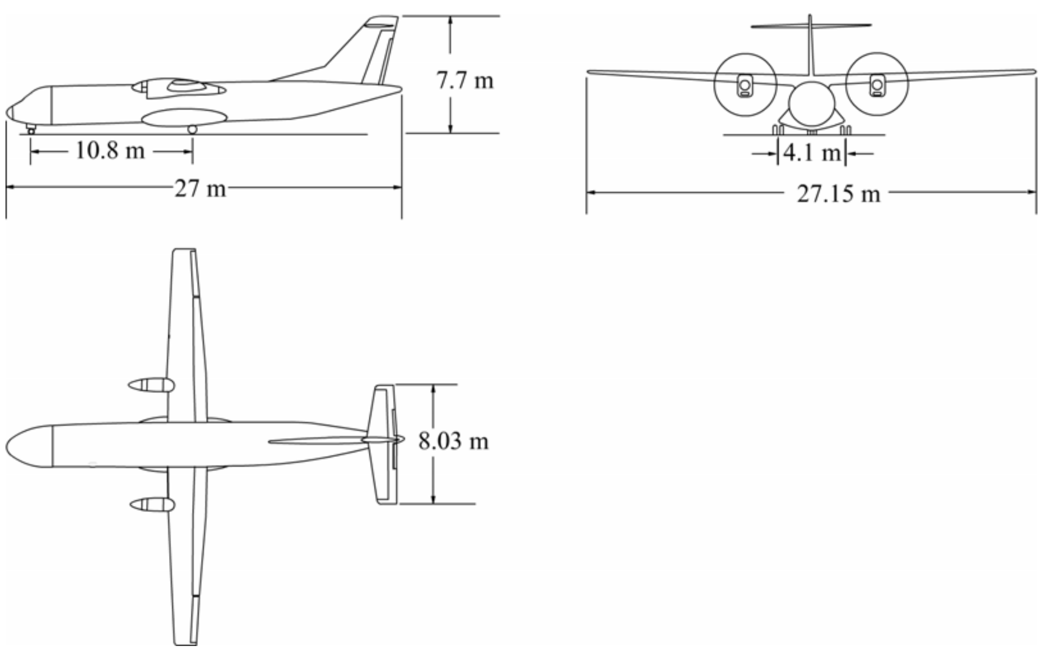

Fig.2.1 Preliminary three-view