

## Chapter 6

### Fuselage and tail sizing - 8

#### Lecture 30

#### Topics

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##### 6.5 Fuel system

The fuel system includes fuel tanks, fuel pumps, fuel lines, vents and fuel flow controls. The fuel tanks are of three types. They are :

(a) Discrete (b) bladder and (c) integral.

Discrete tanks are fuel containers fabricated separately and fixed inside the airplane. These are used for general aviation aircraft and home built airplanes. Bladder tanks consist of rubber bags inserted into the space available for storage of fuel. They are also self sealing – if a bullet pierces the tank; the rubber fills in the hole and prevents large loss of fuel and fire hazard. Integral tanks are cavities within the wing/fuselage which are sealed to form a fuel tank.

Note :

To calculate the space required for fuel, the following guidelines are followed. (Ref.1.18, chapter 10) the weight of the fuel required is known from the consideration of the range. The volume of the fuel can be calculated knowing it's relative density which varies between 0.77 to 0.82; a value of 0.8 can be taken for the first estimate. Decide the type of fuel tank, to arrive at the space for fuel in

the airplane add the volume of the discrete tank to the volume of the fuel. For bladder tank, space available for fuel is about 77% of available space in wing, and 83% available space in fuselage. For integral tank the space for fuel is 83% of wing space and 92% of fuselage space (Ref.1.18, chapter 10) .

## 6.6 Landing gear

Landing gear design is a specialized topic. A brief outline is given here for the sake of completeness. The landing gear is also called undercarriage or alighting gear.

The following three types of landing gears are mainly used on airplanes.

- (i) Tricycle or nose wheel type
- (ii) Tail wheel type
- (iii) Bicycle with outrigger wheels on wings

### 6.6.1 Tricycle type or nose wheel landing gear

This is the most commonly used landing gear. Figure 6.6 shows an airplane with this type of landing gear. The nose wheel is near the nose of the fuselage and the two wheels located on the wings, in this case, form the tricycle arrangement. Sometimes the rear wheels may be attached to the fuselage. ATR-72-200 airplane, shown in Fig.6.7a, has such a configuration. The main wheels and nose wheel are located such that they share roughly 90% and 10% of the airplane weight. The nose wheel is generally steerable. In Fig.6.6 all the three parts of landing gear have a single wheel. However, as the size of the airplane increases, multiple wheels are used. This is called bogie. Figures 6.7a, 1.4a and 1.8b show the bogies.

### 6.6.2 Retractable and non-retractable landing gear

In low speed airplanes the landing gear is fixed to the airplane. Such a landing gear configuration is called non-retractable. This type of landing gear is simple. However, it is exposed to the airstream throughout the flight and increases the

drag of the airplane. The drag of the landing gear is proportional to the square of flight speed and when the cruising speed of the airplane exceeds about 250 kmph the drag of landing gear becomes excessive. Then a retractable landing gear is used. In this case all the wheels of the landing gear are retracted in the respective wheel wells. The nose wheel has the wheel well in the nose (Fig.6.7a). The wheel wells for the main wheels are either (i) in the wing or (ii) in the nacelle attached to wing or (iii) in special pods attached to fuselage (Fig.6.7c). The last alternative for wheel well is used in airplanes with high wing configuration. In this case, retracting the main landing gear in wings or nacelles attached to wing would require long landing gear legs and relatively large wheel well. A retractable landing gear is heavy and increases the complexity of the airplane. As a compromise the airplanes below cruising speed of about 250 kmph have non-retractable landing gear and above that speed they have retractable gear. Sometimes, airfoil shaped fairing is attached to the main wheels of the non-retractable landing gear(Fig.6.17). This fairing reduces the drag coefficient to some extent.



Fig.6.17 Image of an airplane with tail-wheel type landing gear  
with fairing on the main wheels  
(Adapted from pilotfriend.com)

### 6.6.3 Tail wheel type landing gear

In this type of landing gear main wheels are ahead of c.g. and the tail wheel is at the rear end of fuselage (Fig.6.17). This type of landing gear is mainly used on low speed air-planes and is non-retractable. Simplicity is the advantage of this type of landing gear. Tail dragger is an aircraft with tail wheel or tail skid (Ref.1.2).

### 6.6.4 Bicycle type landing gear

In this type of landing gear the front and rear wheel(s) are located on the fuselage centre line. Outrigger wheels are provided on wing tips to prevent the airplane from toppling sideways. Harrier Airplane with vertical take-off and landing (VTOL) capability, built by Hawker Siddley of UK is an example of this type of airplane. Figure 6.18 shows an image of this airplane.



Fig.6.18 Image of an airplane with bicycle type landing gear; the outrigger wheel on right wing is also seen  
(Adapted from 1000aircraftphotos.com)

**Remark:**

Reference 1.18, chapter 11 and Ref.1.24, chapter 9 be consulted for additional information on (i) other types of landing gears (ii) retraction mechanism (iii) tyre sizes and pressures (iv) height of landing gear, wheel base and wheel track and (v) books on landing gear design.

## 6.7 Subsystems

An airplane has the following major subsystems.

### i)Hydraulic systems :

These are used for operation of flight controls and actuation of flaps, landing gear, speed brakes and weapon bays.

### ii) Electrical systems :

These are used to supply power to avionics, hydraulic systems, environmental control systems lighting etc. They consist of generators, transformers, rectifiers, controls, circuit breakers and cables. The generator is powered by the airplane engine.

### 3) Auxilliary power unit:

Most commercial transport airplanes and military airplanes use an auxiliary power unit(APU). It has a generator driven by an auxiliary jet engine. APU is used to provide ground power for air conditioning, cabin lighting, engine starting and to supply in-flight emergency power.

### 4) Pneumatic systems:

These are used to supply compressed air for pressurization, anti-icing and sometimes for starting of the engine.

### 5) Avionics:

These are electronic systems which include radios, flight instruments, navigational aids, flight control computers, radars and sensors in the airplane.

**Remarks:**

(i) Passenger airplanes also have entertainment systems, fire suppression system and evacuation system. Military airplanes have ejection seats and

systems for deploying the weapons. Most of the high speed airplanes (civil and military) have autopilot and fly-by-wire systems.

(ii) For further details see Ref.1.10, part IV; Ref.1.18, chapter 11 and Ref.1.24, chapter 7.

### Example 6.3

For the sixty-seater airplane being considered in examples 5.1, 6.1 and 6.2, obtain the tentative locations of the engines and the landing gear.

#### **Solution:**

##### I) Engine location

As mentioned in example 4.16, the power plant tentatively chosen for this airplane consists of two P&W 124B turboprop engines. Each engine has a rating of 1611 kw at sea level. From Ref.1.21 (1999-2000 edition) and internet ([www.google.com](http://www.google.com)) the following approximate features can be deduced for an engine of this category.

Length of engine = 2.13 m

Width of engine = 0.66 m

Height of engine = 0.84 m

Weight of engine = 450 kgf

ATR-72-200 airplane has the same engines which are mounted on each wing half. From the three view drawing of the airplane in Ref.1.21 the following details are observed.

Maximum width of nacelle  $\approx$  1.03 m

Maximum depth of nacelle  $\approx$  1.37 m

The top of the nacelle almost coincides with the upper surface of wing (Fig.6.7a)

The nacelle forms a streamlined fairing around the engine. The lower portion of nacelle extends upto the trailing edge of the wing.

The propeller of diameter 3.93 m has a spinner of about 0.8 m length. The forward end of the spinner is about 2.4 m ahead of the leading edge of the wing.

Taking guidelines from these features the following dimensions are tentatively chosen for the 60 seater airplane under design.

- (a) The nacelle has maximum width of 1.03 m. The spanwise extent of the nacelle ends at the end of constant chord portion of wing i.e. at 9.72 m from FRL.
- (b) The maximum depth of nacelle is 1.37 m.
- (c) The propeller of the airplane has a diameter of 3.95 m(example 4.19)
- (d) The length of the spinner is  $0.2 \times 3.95 = 0.79$  m.
- (e) The forward end of the spinner is at  $0.6 \times 3.95 = 2.37$  m ahead of the leading edge of the wing.

**Remark :**

The actual dimensions of the nacelle are arrived at after the structural design of the engine mount.

**II) Landing gear**

Table 6.3 presents some features of the landing gears of similar airplanes. As the cruising speed is around 500 kmph, all airplanes have retractable landing gear. All of them are of nose wheel type. In case of IPTN, ATR-72 and Antonov 140 the landing gear is retracted in pods located on fuselage. Subsection 6.6.2 points out the advantages of this choice, when the airplane has a high wing configuration.

For the airplane under design, a tricycle landing gear, retracted in pods on fuselage is chosen. Based on data in Table 6.3 ,  $(\text{wheel track}/b) = 0.15$  and  $(\text{wheel base}/l_f) = 0.39$  are chosen. Noting that  $b = 26.49$  m and  $l_f = 25.07$ , yields :  
Wheel track =  $0.15 \times 26.49 = 3.97$  m  
Wheel base =  $0.39 \times 25.07 = 9.78$  m

Designation	XACY-7-100	IPTN-250-100	ATR-72-200	ATR-72-500	ILYU-SHIN Il-114	SAA-B 2000	ANTONOV AN-140	De Havilland Dash 8 Q300
Landing gear								
Type	R.T* In nacelle on high wing	R.T*. In Pods on fuselage	R.T*. In Pods on fuselage	R.T*. In pods on fuselage	R.T*. In nacelle on low wing	R.T*. In nacelle on low wing	R.T*. In Pods on fuselage	R.T*. In nacelles on high wing
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
Wheeltrack / b	0.273	0.146	0.152	0.152	0.28	0.332	0.129	0.287
Wheel base/l <sub>f</sub>	0.326	0.383	0.396	0.396	0.340	0.411	0.354	0.393

\* R.T : Retractable tricycle

Table 6.3 Some features of the landing gears of similar airplanes