Chapter 6

Fuselage and tail sizing - 2

Lecture 24

Topics

6.2.3 Features of the fuselage of a military airplane

Figure A 2.1.3 b in Appendix A.1 of chapter 2 shows the schematic side view of a military airplane with engine intakes on the sides of the fuselage. The nose portion, in this case, has the radar. In some older configurations, the engine intake is in the nose. The portion of fuselage marked as cockpit in Fig.A2.1.3 b has the flight deck. The region below the flight deck houses the systems.The engine is located inside the fuselage. The length of the tail cone is mainly dependent on the moment arm needed for the horizontal tail and vertical tail. This brief description of the fuselage of a military airplane is only for the sake of completeness of this section on fuselage. For additional details, the reader is referred to Ref.1.12, part III; Ref.1.15, chapter 4; Ref.1.18, chapter 9 and Ref.1.24, chapter 7.

6.2.4 Desired features of fuselage design

The aim of fuselage design, at this stage of preliminary design, is to obtain the following.

(a) Lengths of nose, cockpit, payload compartment, tail cone and the overall length.

(b) Cross section shape and the heights and widths of nose, cockpit, payload compartment and tail cone.

The desirable features of the design can be listed as follows.

(a) The flight crew, cabin crew and the passengers should have an environment of comfort. The crew should be able to perform their duties effectively. The journey should be pleasant for the passengers.

(b) Loading and unloading of passengers' luggage and cargo should be efficient.The regulating agencies like FAA, prescribe the size, number and locations of emergency exits and equipment for emergency evacuation.

(c) Fuselage drag should be low. The lift produced by the wing – fuselage combination should be close to that possible under ideal conditions.

(d) The tail arms for the horizontal and vertical tails should be long.

(e) The structural weight of fuselage should be low.

6.2.5 Details of the fuselage of a typical four seater general aviation aircraft

Figure 6.5 shows the cutaway drawing of one version of Piper Commanche airplane. This drawing shows the internal details of the airplane. It is a four seater low wing airplane with tractor propeller and tricycle landing gear. Following information about the airplane is obtained from Ref.1.20, chapter 8.

(a) Take-off weight = 1270 kgf

(b) Empty weight   =   725.8 kgf

(c) Overall length   =   7.59 m

(d) Wing span   =   11.0   m

Additional information about the fuselage of Piper Commanche has been obtained for Ref.1.21(1965–66 edition), Ref.1.12, part III, chapter 3, and internet. (www.google.com). It is summarised below. This summary would indicate the typical sizes of the various portions of such a fuselage.

Figures 6.6a,b and c show the three view drawing of the same airplane(Piper Commanche) but a slightly different version.

The following approximate information can be deduced from these figures about the version shown in Fig.6.6.

(i) The propeller diameter is 1.88 m

(ii) The length of the spinner and the boss of the propeller is about 0.41 m which is 21 % of the propeller diameter.

(iii) The length of fuselage is less than the overall length of the airplane, as the top portion of the vertical tail projects beyond the rear end of the fuselage as seen in Fig.6.6a.

The length of fuselage including the spinner and propeller boss is approximately 6.96 m. The length of the fuselage behind the propeller is approximately 6.55 m.

(iv)The airplane uses Lycoming 00-540 engine with a length of 0.916 m.The engine is attached to the fuselage by a frame work called engine mounting. To prevent transfer of heat from the engine to the cockpit, the engine
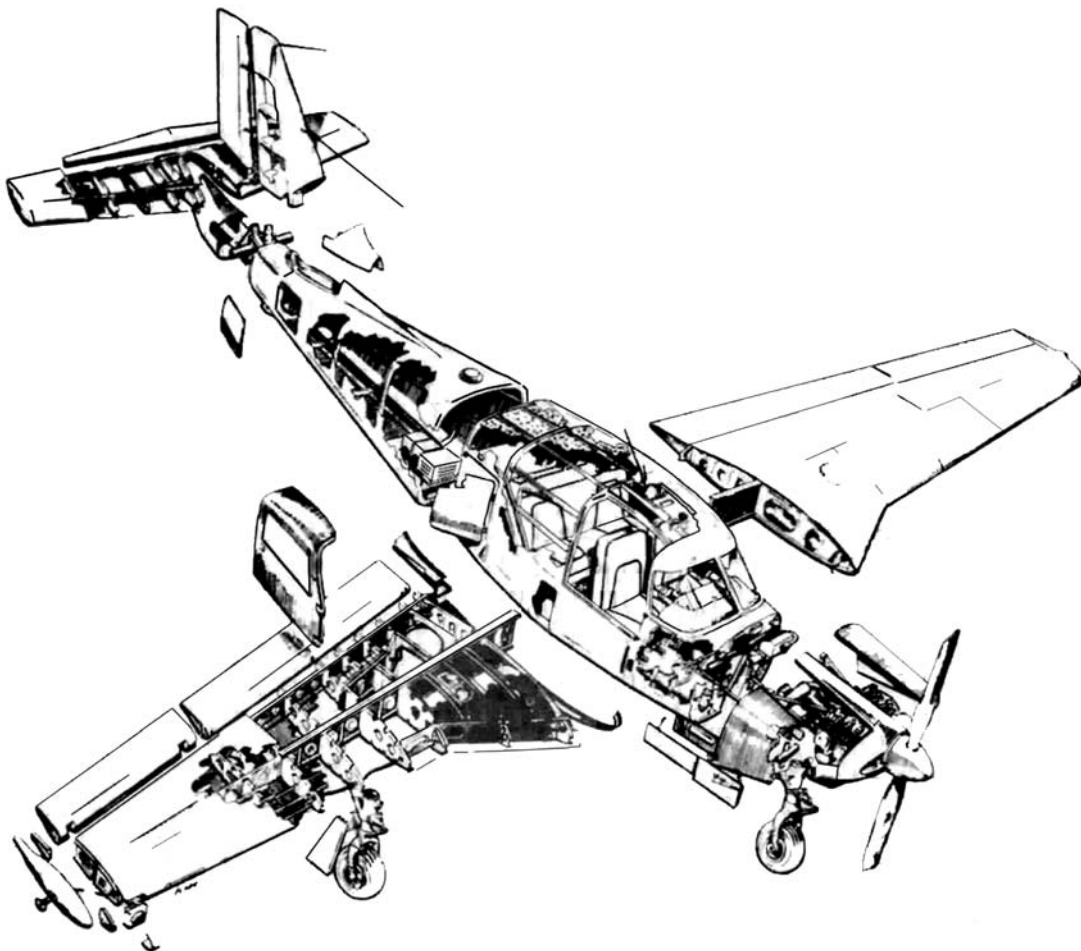

Fig.6.5 Cutaway drawing of Piper Commanche PA-24 with overall length of
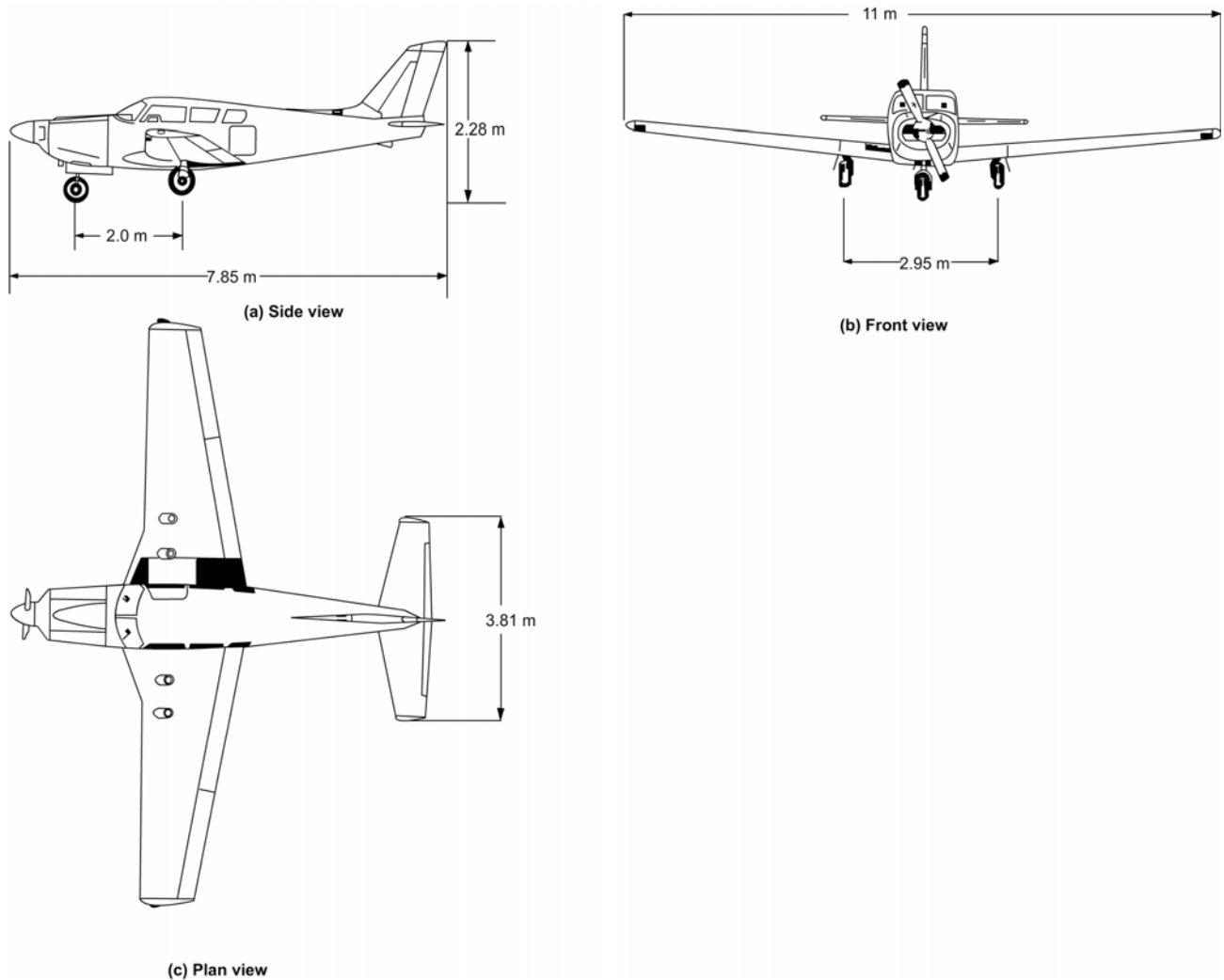24.8 feet (7.54 m)   (With permission from Piper Aircraft Inc.)

Fig.6.6 Three view drawing of another version Piper Commanche PA-24 with overall length of 25' 9.22" (7.85 m)

(a) Side view (b) Front view (c) Plan view

(Adapted from rcgroups.com)

compartment and the rest of the fuselage are separated by a fire wall. From Fig.6.6a it is observed that the length of engine compartment is approximately 1.33 m which is about 1.36 times the length of the engine.

(v) The portion of fuselage after the engine compartment, till the baggage compartment is here referred to as cabin. The cabin includes (a) control stick and pedals (b) instrument panel (c) seating, in the present case for pilot and three passengers, in two pairs of seats and (d) baggage compartment.

It is estimated that the cabin length, from the fire wall to the end of the baggage compartment is about 3.2 m with 0.7 m between thin firewall and the instrument panel.

Based on the data of similar airplanes it is estimated that the maximum height and width of cabin (i.e. internal dimensions) would be 1.14 m and 1.05 m respectively.

The distance between the instrument panel and the back of the front row of the seats is around 0.84 m. The seat pitch is also around 0.84 m. The length of the baggage compartment is around 0.82 m. The baggage compartment would be slightly tapered. The average height and width of the baggage compartment are approximately 0.94 m and 0.90 m respectively. The length is about 0.8 m. The baggage volume is about 0.68 m^3 i.e. 0.17 m^3 per person. The cabin door height and the width are 0.91 m and 0.89 m respectively. The height and width of the baggage compartment door are 0.51 m and 0.56 m respectively (Ref.1.21, 1965-66 edition)

The maximum height and width of the fuselage shell (i.e. external dimensions) are around 1.39 m and 1.30 m respectively.

(vi) The length of the fuselage aft of the baggage compartment is :

6.96 – (0.41 + 1.33 + 3.2) = 2.02 m.

It is seen in Figs. 6.6a and c that the tail cone tapers down to zero width in the plan view(Fig.6.6c). In the side view (Fig.6.6a) the height of the tail cone at the rear is approximately 0.4 m. In this airplane the horizontal tail is an all moving tail with a servo tab(Reference 1.21, 1965-66 edition). The tab extends beyond the rear end of the fuselage. Hence, a certain thickness for the fuselage is needed at the rear end of the fuselage to accommodate the attachment of horizontal tail structure and the control linkage. It may be pointed out that the portion of the

fuselage below the vertical tail also increases the effective area of vertical tail.
Subsection 6.3.6 be referred for explanation. For information on servo tab,
Ref.3.1, chapter 6 be consulted.

Remark:

Following data about the wing and horizontal tail of Piper Commanche are
obtained from Ref.1.21, (1965-66 edition) and Fig.6.6.

Wing : Area(S) = 16.53 m^2, Span(b) : 11 m

Root chord (c_r) = 2.16 m, tip chord = 0.99 m

Horizontal tail :

Area(S_{ht}) = 3.04 m^2, Span (b_t) : 3.8 m

c_{rt} = 1.064 m, c_{tt} = 0.532 m

Based on wing planform, the mean aerodynamic chord of the wing ($\bar{c}$) is
obtained as 1.57 m. The mean aerodynamic chord of tail ($\bar{c}_t$) is obtained as
0.828 m.

From the three view drawing (Fig.6.6), the distance between the quarter chords
of mean aerodynamic chords of the wing and the tail is estimated as 3.93 m. This
distance is generally close to l_t, which is the distance between the airplane c.g.
and the aerodynamic centre of the horizontal tail.

Thus, $l_t/\bar{c} \approx 3.93 / 1.57 = 2.5$. This value $l_t/\bar{c}$ is in the range of values mentioned
at the end of section 6.2.1

6.2.6 Guidelines for sizing fuselage of general aviation aircraft

As mentioned in the remark at the end of subsection 1.4.1, the general aviation
aircraft are categorized as normal, utility, aerobatic and agricultural . Before
carrying out the fuselage sizing, the following points are noted.

(i) At the start of the preliminary design, the category of the airplane has already
been chosen.

(ii) The preliminary design of the wing has been done and the wing parameters
like span, mean aerodynamic chord are known.

(iii) The engine has been tentatively chosen and the diameter of the propeller has
been arrived at.

(iv) From the data collection on similar airplanes, the following ratios are known.

(a) l_f /b ; where 'l_f' is length of fuselage and 'b' is wing span

(b) $l_{engine\ compartment}$ / l_f

(c) l_{cabin} / l_f and

(d) $l_{tail\ cone}$ / l_f

Based on the above data the following steps are suggested for fuselage sizing
for single engined airplanes in this category.

(1) Choose l_f /b from data collection. Since 'b' has been obtained (chapter 5),
the first estimate of l_f is given by :

l_f = b x (l_f /b)   (6.3)

(2) The propeller diameter (d) is known (chapter 4). Hence, the length of spinner
($l_{spinner}$) is approximately given as

$l_{spinner} \approx 0.2\ d$ (6.4)

(3) The engine has been tentatively chosen. Hence, the length of the engine
(l_{engine}) and width of the engine (w_{engine}) can be obtained from sources like
Ref.1.21. Consequently,

$l_{engine\ compartment}$ = 1.5 l_{engine} and   (6.5)

$w_{engine\ compartment}$ =1.2 w_{engine} (6.6)

The length of the engine compartment would be fine tuned after the design of
the engine mount. This is done during the structural design of the fuselage.

(4) The length of cabin. This item includes (a) portion between firewall and
instrument panel (b) the seating arrangement for pilot and the passenger(s) and
(c) baggage compartment. For agricultural airplane the length of the tank carrying
pesticides can be included in the cabin. In trainer airplanes the accommodation
for trainee in side-by-side or tandem arrangement be considered.

The length and the width of the cabin can be estimated from the cabin length and
width of similar airplanes. If some special features like more spacious
accommodation, larger cargo compartment, are desired then chapter 3, part III of
Ref.1.12 be consulted.

The outer dimensions of cabin can be obtained by adding suitable wall thickness
to the internal dimensions of the cabin.

(5) The general aviation aircraft with upto 4 seats generally have elevator and / or rudder extending beyond the rear end of the fuselage. At this stage of preliminary design, the dimensions of horizontal and vertical tail be chosen from data collection.Then, the parameters like ($l_{tail\ cone}$ / l_f), height and width of real fuselage, can be chosen based on data on similar airplanes.

Consequently, $l_{tail\ cone}$ = ($l_{tail\ cone}$ / l_f) x l_f (6.7)

(6) The total length of fuselage (l_f) is given by:

l_f = $l_{spinner}$ + $l_{engine\ compartment}$ + l_{cabin} + $l_{tail\ cone}$ (6.8)

Using the values from steps (1) to (5) the length of fuselage (l_f) can be calculated. If the length obtained from Eq.(6.8) is significantly different from that obtained from Eq.(6.3), then a correction to $l_{tail\ cone}$ would be needed as it was based on l_f from Eq.(6.3). Recalculate $l_{tail\ cone}$ based on the l_f from Eq.(6.8) and obtained the value of l_f.

Remarks:

 (i) The utility aircraft in general aviation category, have between 6 to 19, passangers. Some of them would have two engines mounted on wings. The cabin in these airplanes would have a portion with constant cross-section (see three-view drawings of airplanes like Aerospace Ae 270 W, Beriev BE – 32 in Ref.1.21 or on net). It may be pointed out that the airplanes with four or less seats do not have the constant cross section portion in cabin. The utility aircraft would generally have a tailcone which is tapering in both planview and sideview similar to that shown in Fig.6.2. To carry out the sizing of the fuselage of utility aircraft, as a first step the parameters like (l_f/b), (l_{nose} / l_f), ($l_{cockpit}$ / l_f), ($l_{mid\ fuselage}$ /l_f), ($l_{tail\ cone}$ / l_f) be obtained for similar airplanes. Using these data the first estimate of l_f be obtained. Subsequently the lengths, l_{nose} , $l_{cockpit}$ and $l_{tail\ cone}$ be obtained. The value of l_{cabin} would depend on the number of passengers and seating arrangement.

(ii) The trainer airplanes under general aviation category, generally have side-by-side seating arrangement. Some airplanes may have tandem (trainee behind the instructor) seating arrangement. The side-by-side arrangement has the advantage that the trainee and the instructor have better communication.

However, this type of airplane has higher fuselage width than the tandem arrangement and hence higher drag. In tandem arrangement the c.g. of the airplane can be adjusted to lie below the seat of the trainee. In this way there is no c.g. shift in the event of the trainee not being present.

(iii) Sizing of the fuselage for a 60 seater airplane with turboprop engine is illustrated using example 6.1.

(iv) Sizing of the fuselage of a jet airplane is carried out in Appendix 10.2.

(v) In this course the attention is focused on subsonic airplanes. For sizing of the fuselage of military airplanes Ref.1.12, part III; Ref.1.15, chapter 4; Ref.1.18, chapters 7 and 9; Ref.1.20, chapter 8 and Ref.1.24, chapter 7, be consulted.