Chapter 6

Lateral static stability and control - 3

Lecture 21

Topics

6.11 General discussions on control surface

- 6.11.1 Aerodynamic balancing
- 6.11.2 Set back hinge or over hang balance
- 6.11.3 Horn balanace
- 6.11.4 Internal balance or internal seal
- 6.11.5 Frise aileron
- 6.11.6 Tabs – introductory remark
- 6.11.7 Trim tab
- 6.11.8 Link balance tab
- 6.11.9 Servo tab

6.12 Powers boosted and power operated controls and fly-by-wire

6.13 miscelleneous topics

- 6.13.1 Mass balancing of controls
- 6.13.2 All movable tail
- 6.13.3 Elevons
- 6.13.4 V– tail
- 6.13.5 Configuration with two vertical tails

6.11 General discussion on controls

In chapters 2 to 5 and in the previous sections of this chapter, some specific features of elevator, rudder and aileron were considered. In this section some common features of the controls are dealt with.

6.11.1 Aerodynamic balancing

The ways and means of reducing the magnitudes of $C_{h\alpha t}$ and $C_{h\delta e}$ are called aerodynamic balancing.

The methods for aerodynamic balancing are:

1. set back hinge,
2. horn balance and
3. internal balance.

6.11.2 Set back hinge or over hang balance

In this case, the hinge line is shifted behind the leading edge of the control (see upper part of Fig.6.6). As the hinge line shifts, the area of the control surface ahead of the hinge line increases and from the pressure distribution in Fig.3.3 it is evident that $|C_{h\alpha t}|$ and $|C_{h\delta e}|$ would decrease. The over hang is characterized by c_b / c_f .Figure 6.6 also shows typical experimental data on variations of $C_{h\alpha}$ and $C_{h\delta}$ with c_b / c_f. It may be added that the changes in $C_{h\alpha}$ and $C_{h\delta}$ also depend on (a) gap between nose of the control surface and the main surface, (b) nose shape and (c) trailing edge angle (Fig.6.7a and b).

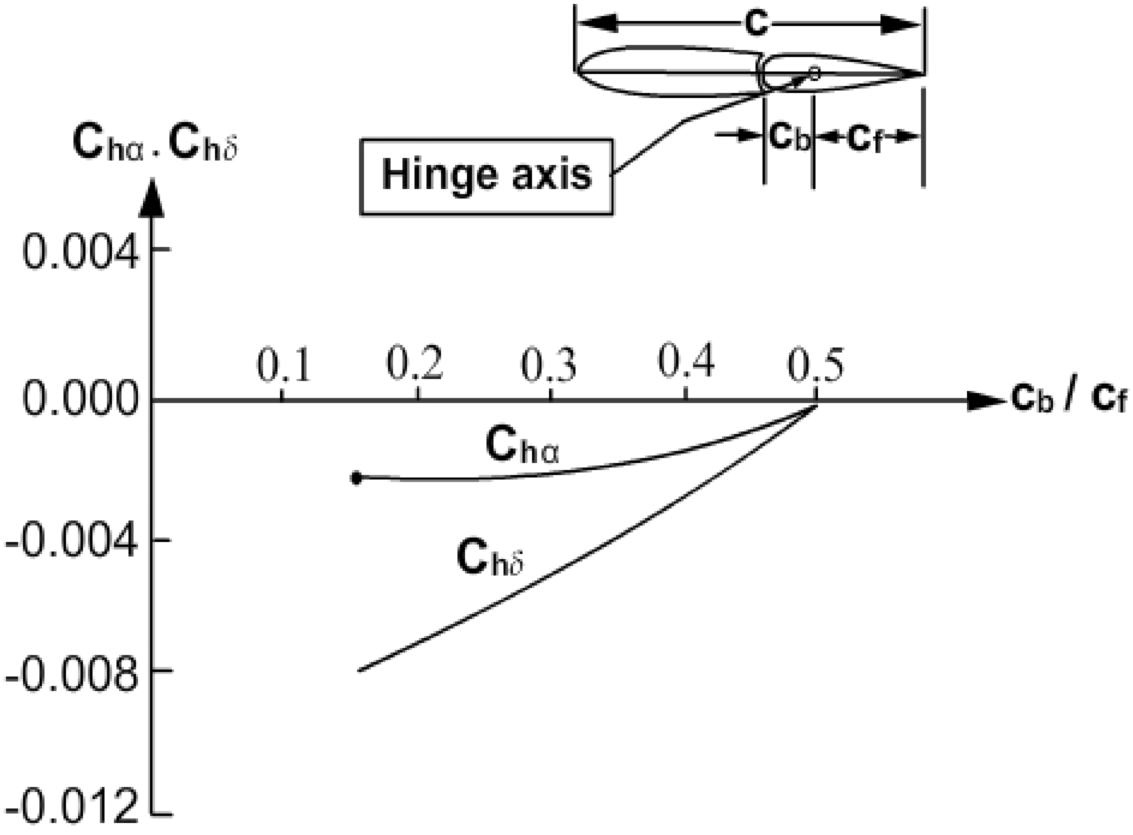


Fig.6.6 Effect of set back hinge on $C_{h\alpha}$ and $C_{h\delta}$ – NACA 0015 Airfoil with blunt nose and sealed gap (Adapted from Ref.6.1)

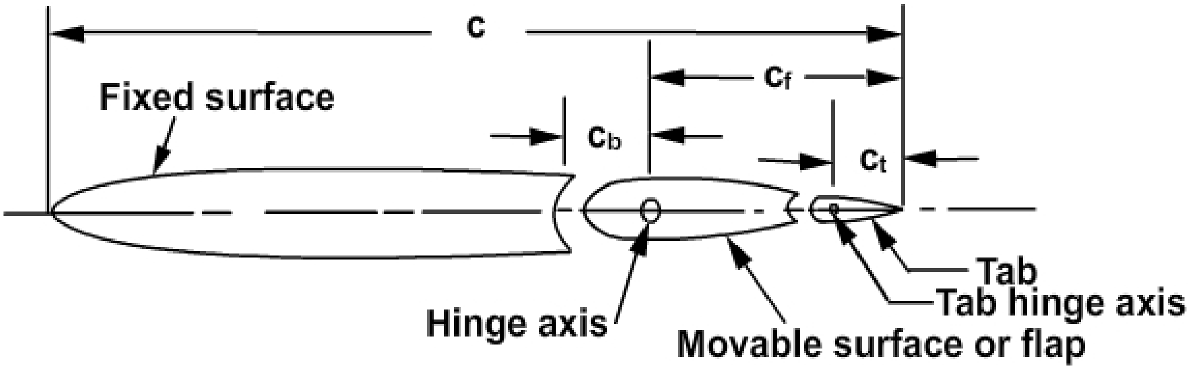
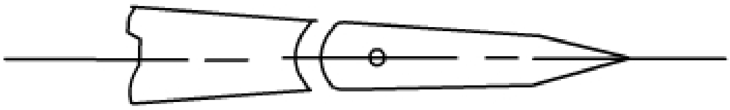


Fig.6.7a Parameters of control surface - chord lengths

(a) Blunt nose (b) Medium nose (c) Sharp nose



(d) Beveled trailing edge

Fig.6.7b Parameters of control surface- shapes of nose and trailing edge

6.11.3 Horn balance

In this method of aerodynamic balancing, a part of the control surface near the tip, is ahead of the hinge line (Fig.6.8a and b). There are two types of horn balances – shielded and unshielded (Fig 6.8a). The following parameter is used to describe the effect of horn balance on $C_{h\alpha}$ and $C_{h\delta}$.

$$\text{Parameter} = \frac{(\text{Area of horn}) \times (\text{mean chord of horn})}{(\text{Area of control}) \times (\text{mean chord of control})}$$

Figure 6.8b shows the areas of the horn and control surface. Figure 6.8b also shows the changes $\Delta C_{h\alpha}$ and $\Delta C_{h\delta}$ due to horn as compared to a control surface without horn. Horn balance is some times used on horizontal and vertical tails of low speed airplanes (see Fig.6.8c).

Unshielded horn

Shielded horn

Fig.6.8a Unshielded and shielded horn

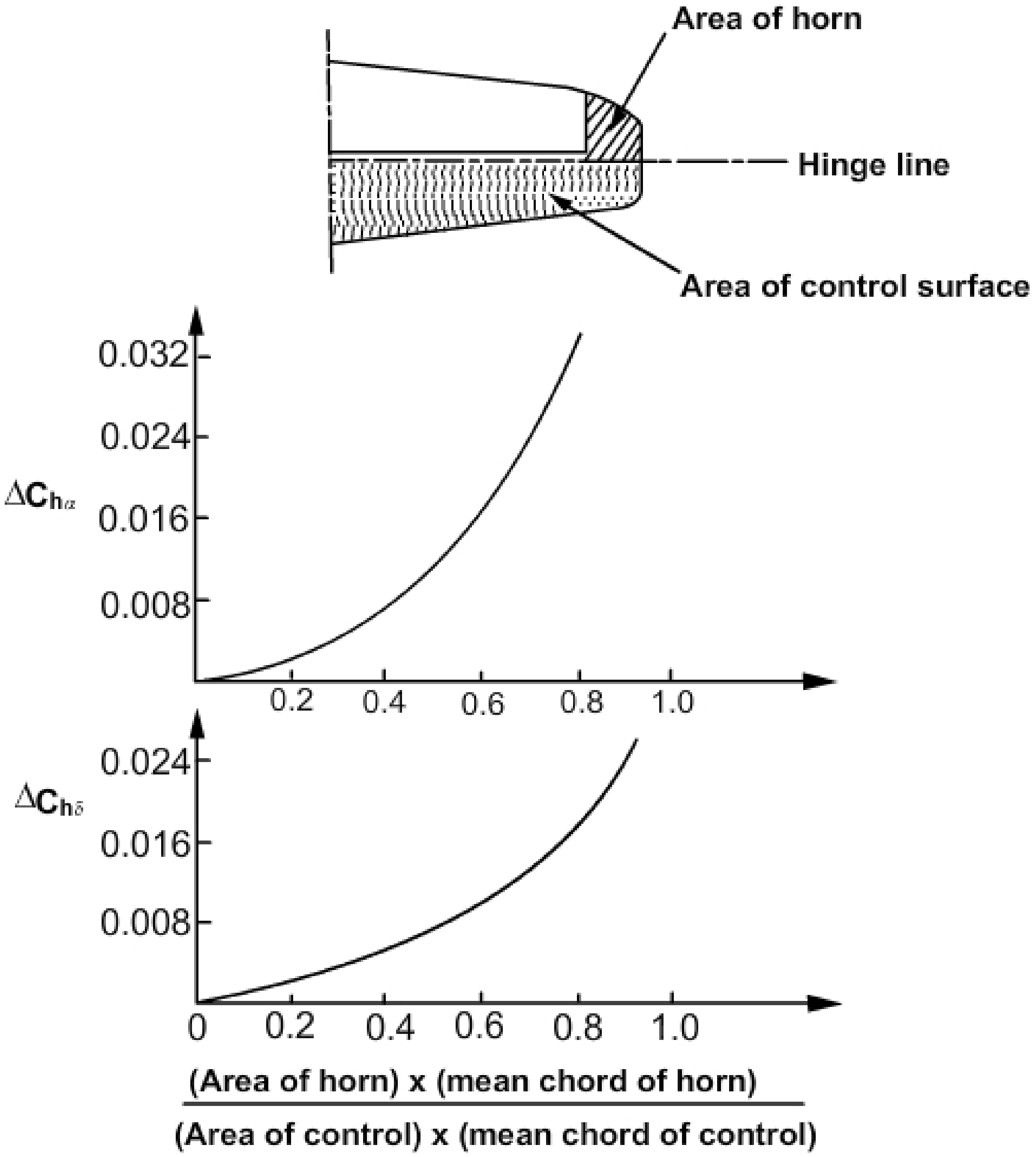
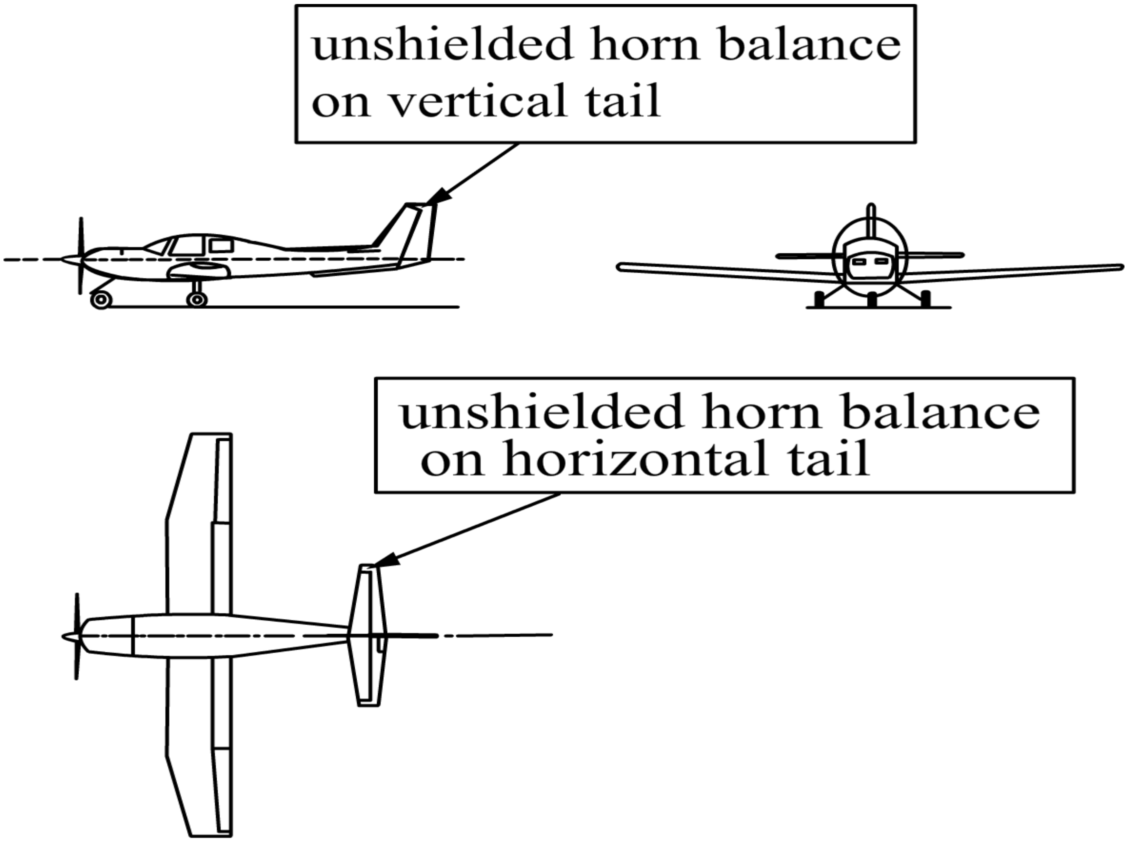


Fig.6.8b Unshielded horn and the changes $\Delta C_{h\alpha}$ and $\Delta C_{h\delta}$ as compare to control surface without horn (Adapted from Ref.6.1)



Note : The curve representing propeller is circular. Please adjust the resolution of your monitor so that the curve looks circular.

Fig.6.8c Airplane with horn balance on horizontal tail and vertical tail

(Based on drawing of HAMSA-3 supplied by

National Aerospace Laboratories, Bangalore, India)

6.11.4 Internal balance or internal seal

In this case, the portion of the control surface ahead of the hinge line, projects in the gap between the upper and lower surfaces of the stabilizer. The upper and lower surfaces of the projected portion are vented to the upper and lower surface pressures respectively at a chosen chord wise position (upper part of Fig.6.9). A seal at the leading edge of the projecting portion ensures that the pressures on the two sides of the projection do not equalize. Figure 6.9 also shows the changes $\Delta C_{h\alpha}$ and $\Delta C_{h\delta}$ due to internal seal balance. This method of aerodynamic balancing is complex but is reliable. It is used on large airplanes to reduce $C_{h\alpha}$ and $C_{h\delta}$.

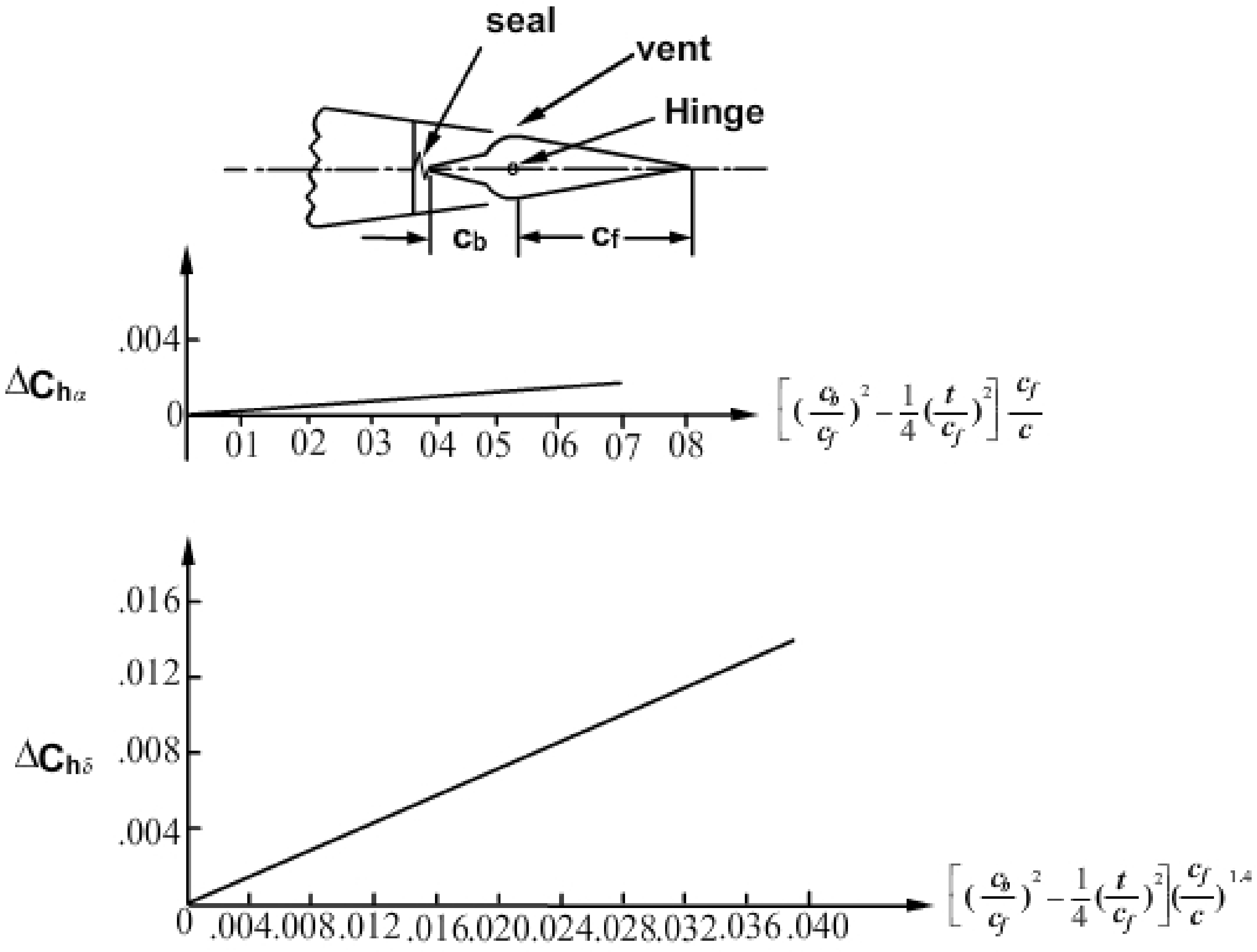


Fig.6.9 Internal seal and the changes $\Delta C_{h\alpha}$ and $\Delta C_{h\delta}$ as compared to control surface with $C_b / C_f = 0$ (adapted from Ref.6.1)

Remark:

Tab is also used for aerodynamic balancing. See section 6.12.

6.11.5 Frise aileron

The frise aileron is shown in Fig.6.10. The leading edge of the aileron has a specific shape. The downward deflected aileron has negative $C_{h\delta}$ and the upward deflected aileron has positive $C_{h\delta}$. This reduces the net control force. Further, owing to the special shape of the leading edge, the upward deflected aileron projects into the flow field and increases the drag. This reduces adverse yaw.

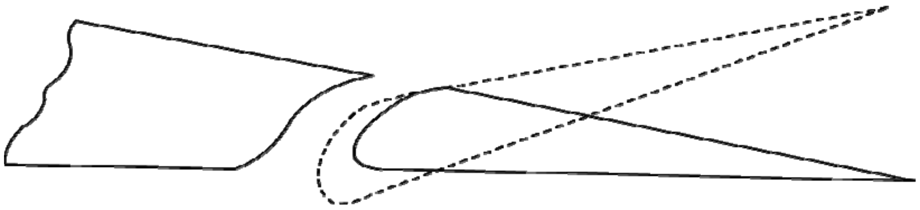


Fig.6.10 Frise aileron

6.11.6 Tabs – introductory remark

The methods of aerodynamic balancing described earlier are sensitive to fabrication defects and surface curvature. Hence, tabs are used for finer adjustment to make the hinge moment zero. Tabs are also used for other purposes. A brief description of different types of tabs is given in the following subsections.

6.11.7 Trim tab

It is used to trim the stick or bring C_h to zero by tab deflection. After the desired elevator deflection (δ_e) is achieved, the tab is deflected in a direction opposite to that of the elevator so that the hinge moment becomes zero. Since the tab is located far from the hinge line, a small amount of tab deflection is adequate to bring C_{he} to zero (Figs.2.16a and b). As the lift due to the tab is in a direction opposite to that of the elevator, a slight adjustment in elevator deflection would be needed after application of tab. Though the pilot subsequently does not have to hold the stick all the time, the initial effort to move the control is not reduced when this tab is used.

6.11.8 Link balance Tab

In this case the tab is linked to the main control surface. As the main surface moves up the tab deflects in the opposite direction in a certain proportion (Fig.6.11). This way the tab reduces the hinge moment and hence it is called ‘Balance tab’.

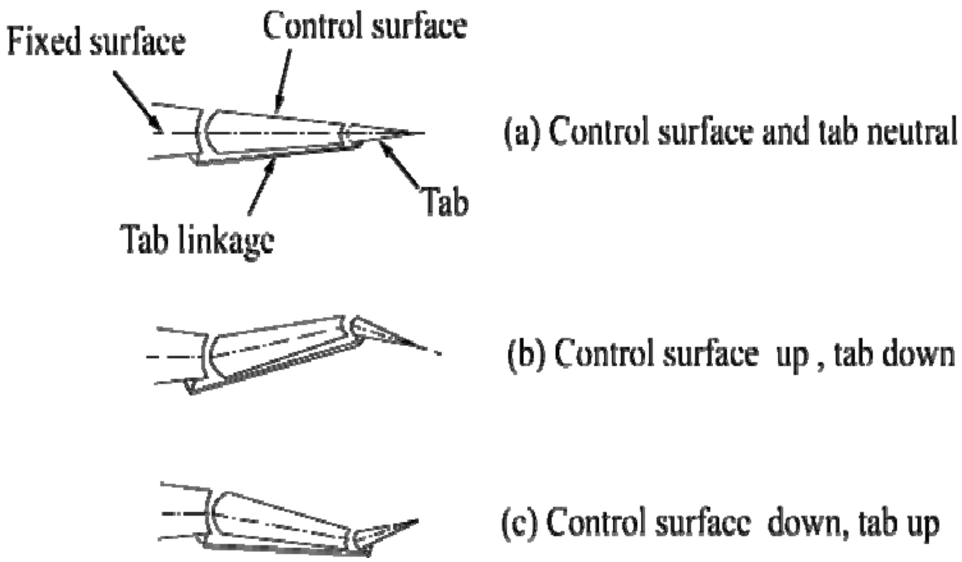


Fig.6.11 Link balance tab

6.11.9 Servo tab

In this case the pilot does not move the main surface which is free to rotate about the hinge. Instead the pilot moves only the tab as a result of which the pressure distribution is altered on the main control surface and it attains a floating angle such that C_h is zero .The action of the tab is like a servo action and hence it is called “Servo tab”. This type of tab is used on the control surfaces of large airplanes.

6.12 Power boosted and power operated controls and fly-by-wire

As pointed out earlier (section 3.4.1) the control force increases in proportion to the cube of the linear dimension of the airplane and to the square of the flight velocity. Consequently, a low value of $C_{h\delta}$ is required, to restrict the control forces within human limits. It may be as low as 0.0002. This is not achievable consistently due to sensitive dependence of $C_{h\delta}$ on uncertainty in fabrication. The alternative systems for operation of controls are as follows.

(a) Hydraulic power boosted systems in which the effort of the pilot is boosted by a hydraulic system. (b) Power operated systems in which the movements of the pilot alter settings of electrical/ electronic systems which in turn cause the movement of the controls. This led to fly-by-wire system wherein the aircraft motion (e.g. velocity, angular rates, acceleration, incidence and sideslip) are sensed by appropriate transducers. Then, optimum response of the airplane is computed and the control surfaces are actuated to give desired results. This system requires artificial feel system to give the pilot, an appreciation of the result of the stick/ pedal movements by him and also to prevent inadvertent excess movement of control surfaces. This system also needs multi-plexing i.e. alternate systems to take over if one of the systems fails.

Remark:

(i) Subsection 1.2.2 may be referred to for brief descriptions of the relaxed static stability and the control configured vehicle (CCV).

(ii) Fly-by light :

In early fly-by wire systems the signals, from flight computer to the control surface actuators, were sent through wires. Presently, the signals are sent through fibre optic cables. Hence, the fly-by-wire system is now called “Fly-by-light” (Ref. 6.2 Chapter 12)

6.13 Miscellaneous topics

6.13.1 Mass balancing of control

This ensures that the c.g. of the control surface lies ahead or on the hinge line.

6.13.2 All movable tail

In some military and large civil airplanes the entire horizontal tail is hinged and rotated to obtain larger longitudinal control.

6.13.3 Elevons

In a tailless configuration (e.g. concorde airplane) the functions of the elevator and the aileron are combined in control surfaces called elevons. Like ailerons they are located near the wing tip but the movable surfaces on the two wing halves can move in the same direction or in different directions. When they move in the same direction, they provide pitch control and when they move in different directions they provide control in roll.

6.13.4 V– tail

In some older airplanes the functions of horizontal and vertical tails were combined in a V-shaped tail. Though the area of the V-tail is less than the sum of the areas of the horizontal and vertical tail, it leads to undesirable coupling of lateral and longitudinal motions and is seldom used.

6.13.5 Configuration with two vertical tails

At supersonic speeds the slope of the lift curve ($dC_L/d\alpha$) is proportional to $1/(M_\infty^2-1)^{1/2}$, where M_∞ is the free stream Mach number. Thus, $C_{L\alpha}$ and in turn the tail effectiveness decreases significantly at high Mach numbers. Hence some military airplanes have two moderate sized vertical tails instead of one large tail. For example see MiG-29M (Fig.6.12). Reference 1.13, chapter 5 mentions that for this configuration the quantity $\eta_V (1+\frac{d\sigma}{d\beta})$, mention in Eq.(5.19) and (5.20), has a higher value as compared to the configuration with single vertical tail located in the plane of symmetry.

Fig.6.12 Airplane with two vertical tails MIG-29M

(Adapted from: http://www.defenseindustrydaily.com)