Influence of aileron connection stiffness on aileron effectiveness

Table of Contents

1. Aircraft layouts

Aircraft layouts:

Normal layout

Canard configuration

T-tail layout

Flying -wing layout

The different layouts of aircraft will have the different aileron configurations.

Types of Ailerons

The ailerons can be roughly divided into four categories according to their functions:

1) Conventional ailerons (Normal airplane)

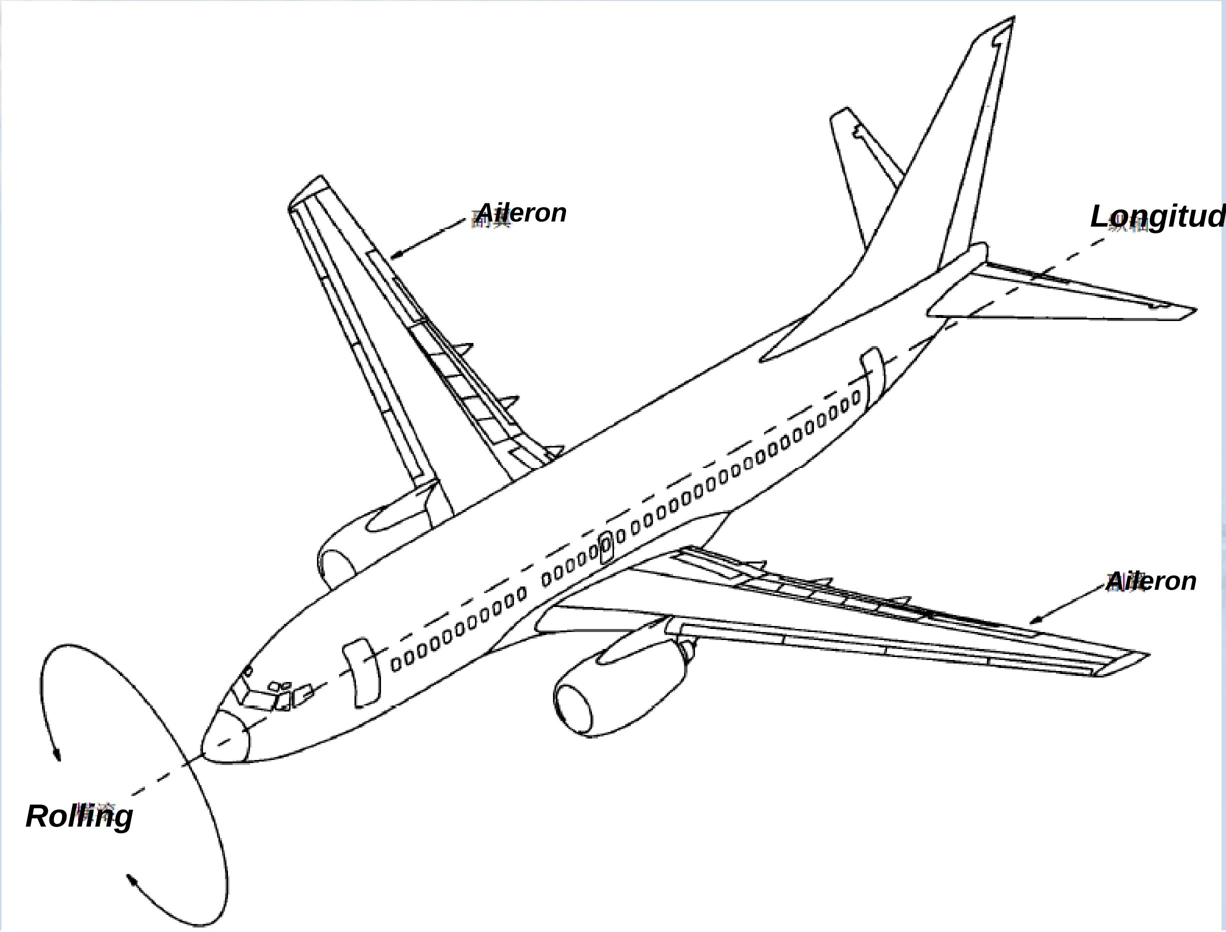
2) High-speed aileron (flying-wing airplane)

3) Elevon (delta-winged aircraft)

4) Flaperon (some commercial aircraft)

Location of Ailerons

A conventional aileron is a small piece of the movable airfoil mounted outside the trailing edge of the wing tip.



Location of Ailerons

The inner ailerons are generally called **high-speed ailerons**.

It is a small movable airfoil located inside the trailing edge of the wing tip.

Location of Ailerons

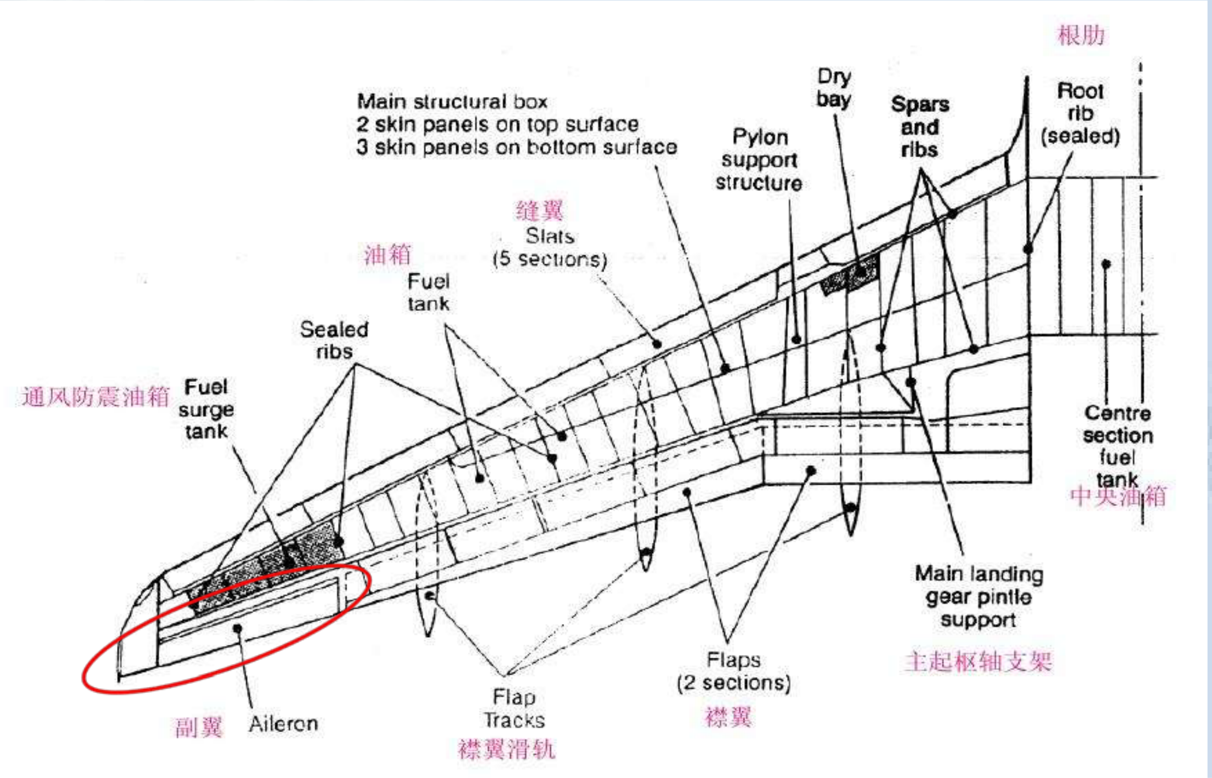
The elevon is a structural form in which the aileron and the elevator are combined.

Location of Ailerons

The flaperons are the control surfaces that combine the flaps and the ailerons.

Four parameters of ailerons

They are aileron planform area, aileron chord/span, maximum up and down aileron deflection and location of the inner edge of the aileron along the wingspan. Based on this statistics, about 5 to 10 percent of the wing area is devoted to the aileron, the aileron-to-wing-chord ratio is about 15 to 25 percent, the aileron-to-wing-span ratio is about 20-30 percent, and the inboard aileron span is about 60 to 80 percent of the wingspan.

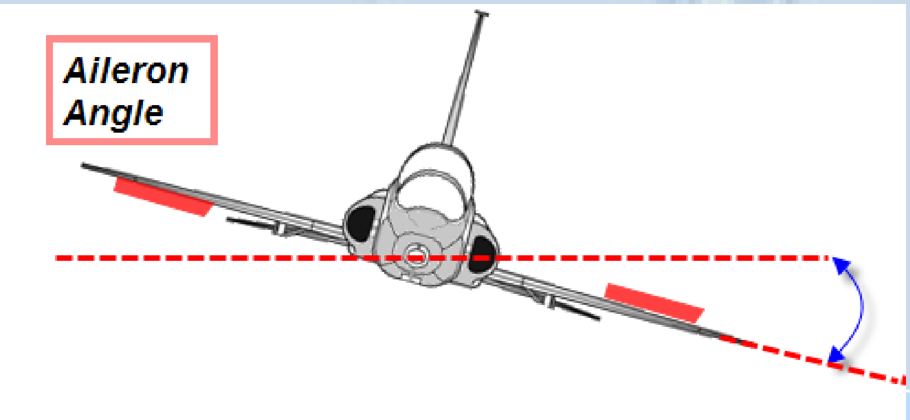


Aileron connectors

The aileron is typically connected to the wing using more than two joints. And it can rotate along the aileron axis.

2. Aileron Functions

The left and right ailerons are always differentially deflected, that is, one upward and the other downward. When the left aileron is up, the right is down. In this way, the left and right wing lifts are not equal and constitute a moment that causes the airplane to roll to the left. Conversely, there is a moment that causes the airplane to roll to the right. To achieve a certain rolling speed or to stop rolling, the aileron needs to provide the necessary torque.



2. Aileron Functions

High-speed aileron is near the wing root. The airflow speed is higher than that in the wing tip, so the moment caused by the ailerons deflecting at the same angle will be greater.

2. Aileron Functions

The elevon the functions of ailerons and elevators at the same time. The left and right ailerons can differentially implement the rolling motion of the aircraft, and the vertical balance can be implemented by simultaneously deflecting up and down.

2. Aileron Functions

The flaperon is used on some high-speed aircraft and acts as a flap when it deflects downward to increase more lift.

2. Aileron Functions

There are two aspects that affect the functioning of the ailerons:

1) Aileron reversal. When the outer aileron is flying at a high speed, the influence of the airflow causes the thinner wing to deform. The operation is supposed to be positive, but the reverse torque is generated, which makes the upward operation downward.

2) Jam phenomenon. When the aileron uses several joints, the axis of the aileron shaft will also be bent, which will affect the flexibility of the operation. In order to resolve this contradiction, some aircraft use segmented ailerons, each of which is independently attached to the bracket at the trailing edge of the wing, while the spars of each segment are connected with a universal joint that can transmit the torque.

3. Aileron effectiveness under different flight conditions

Definition of aileron efficiency

$$\eta_a = (\partial C_l/\partial \delta_a)_e / (\partial C_l/\partial \delta_a)_r$$

Where: Cl is the rolling torque coefficient of the aircraft;

δa is the aileron declination;

The subscript e indicates elasticity and the subscript r indicates rigidity.

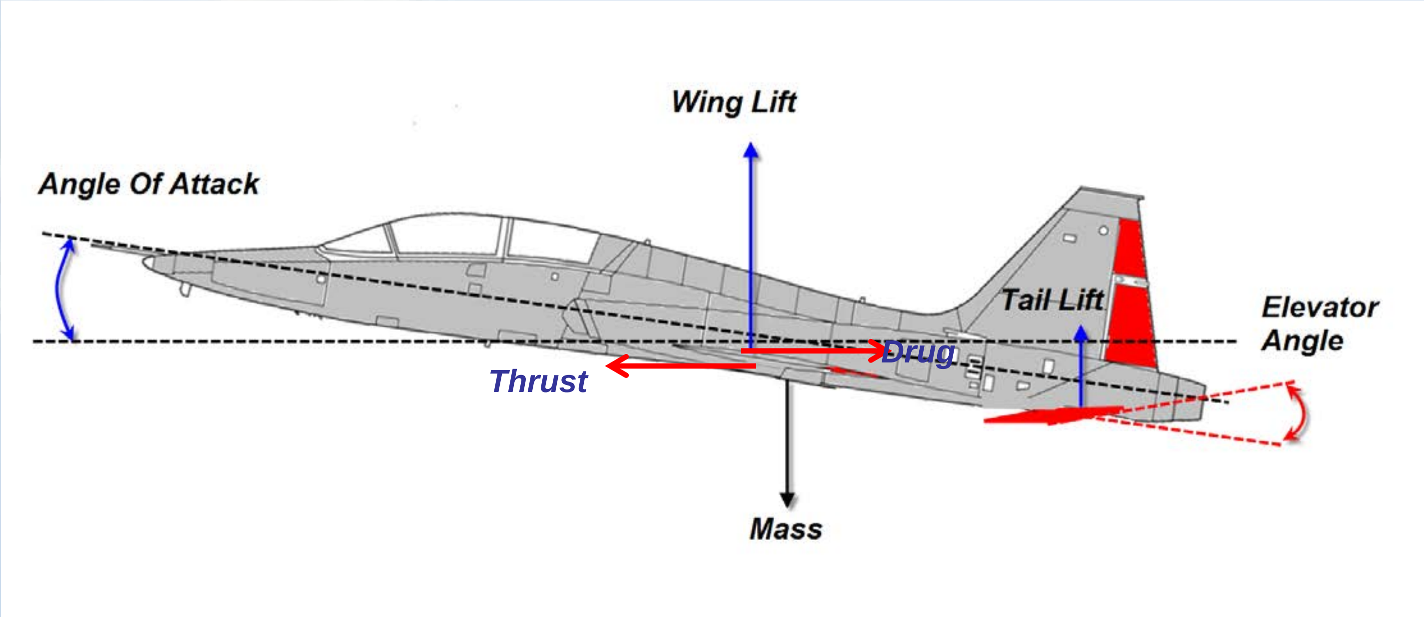
3. Aileron effectiveness under different flight conditions

Definition of the flight envelope of the aircraft – the operating range of the aileron

The aileron's steering force or torque is related to the altitude of the aircraft (air density), the speed of the aircraft's flight, and the overload (acceleration) of the aircraft's flight.

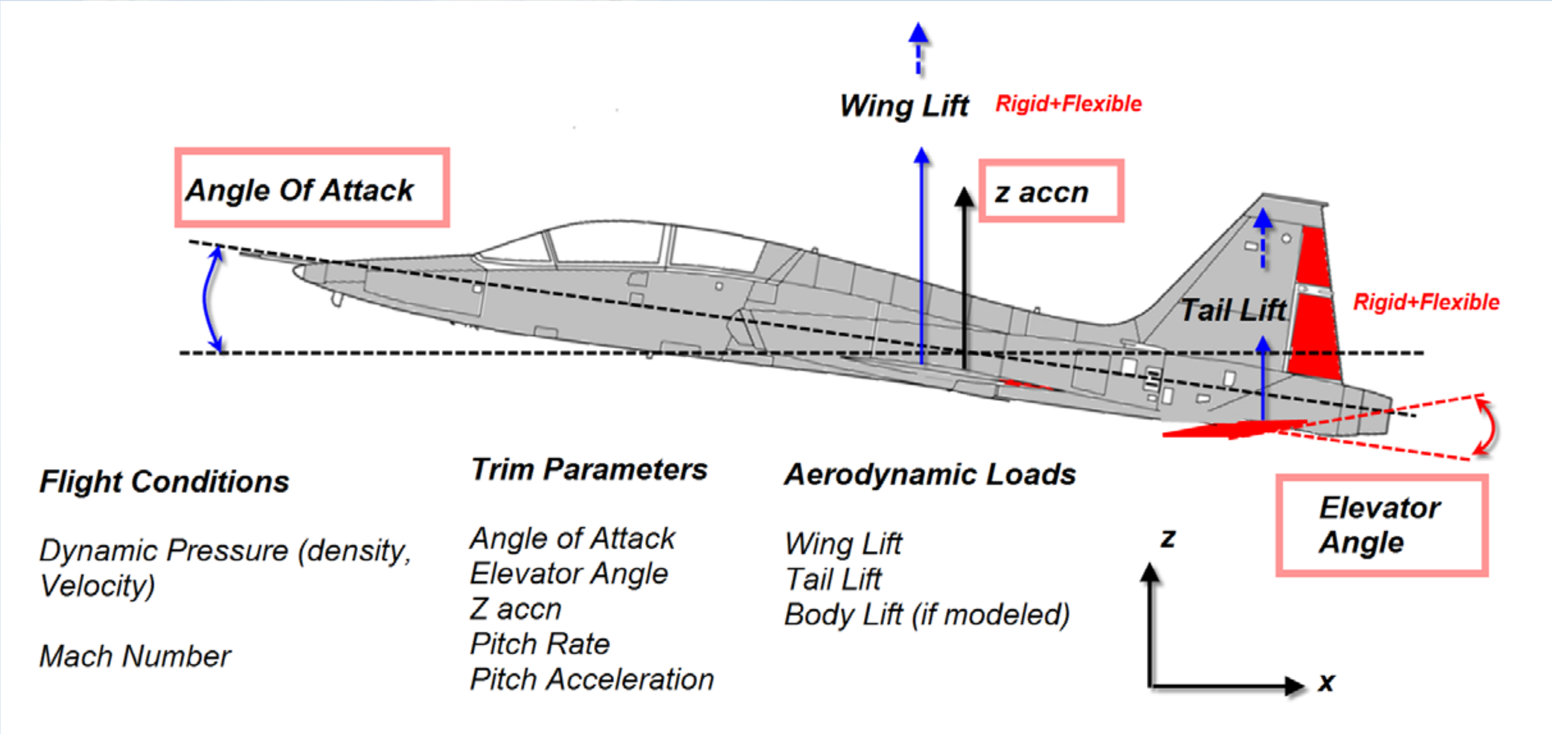
3. Aileron effectiveness under different flight conditions

Load of aircraft in flight



3. Aileron effectiveness under different flight conditions

Longitudinal symmetrical balance of the elevator



Defined Trim: 3g pull up
30 degrees per second pitch rate
0 pitch acceleration

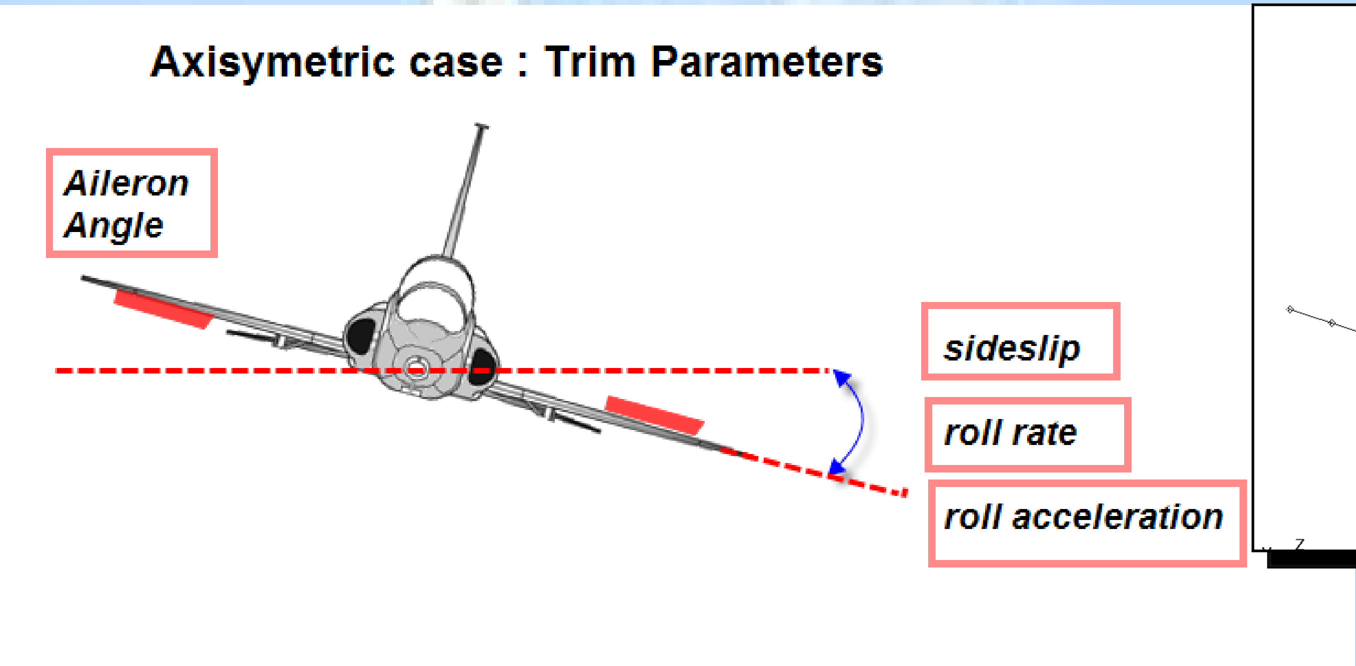
Mach 0.7
Altitude 30000 ft

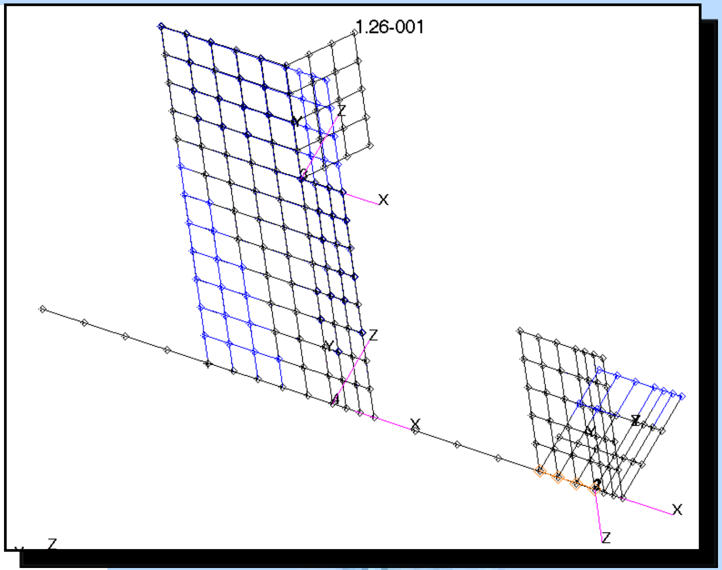
Free Trim:

Angle of Attack
Elevator Angle

3. Aileron effectiveness under different flight conditions

AntiSymmetric Rotational trim-steady roll





Defined Trim: 1g level
0 roll acceleration
Aileron Angle (Linked)

Mach 0.7
Altitude 20000 ft

Free Trim:

Roll rate
Sideslip

3. Aileron effectiveness under different flight conditions

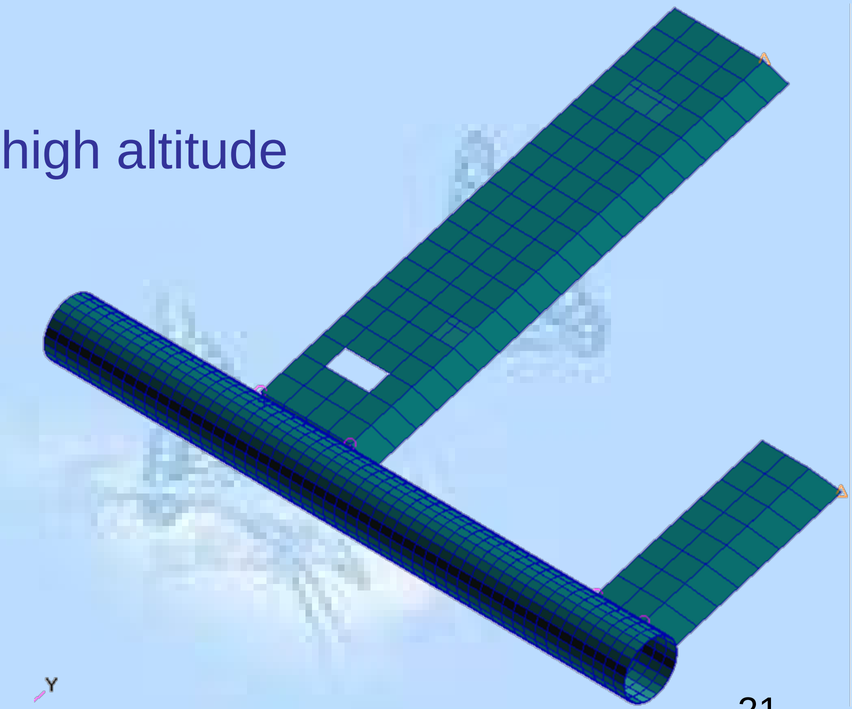
Aileron-elevator longitudinal different trimming conditions

1G level low speed （M0.6）high altitude （40,000ft）

1G level supersonic （M1.2）low altitude （1,000ft）

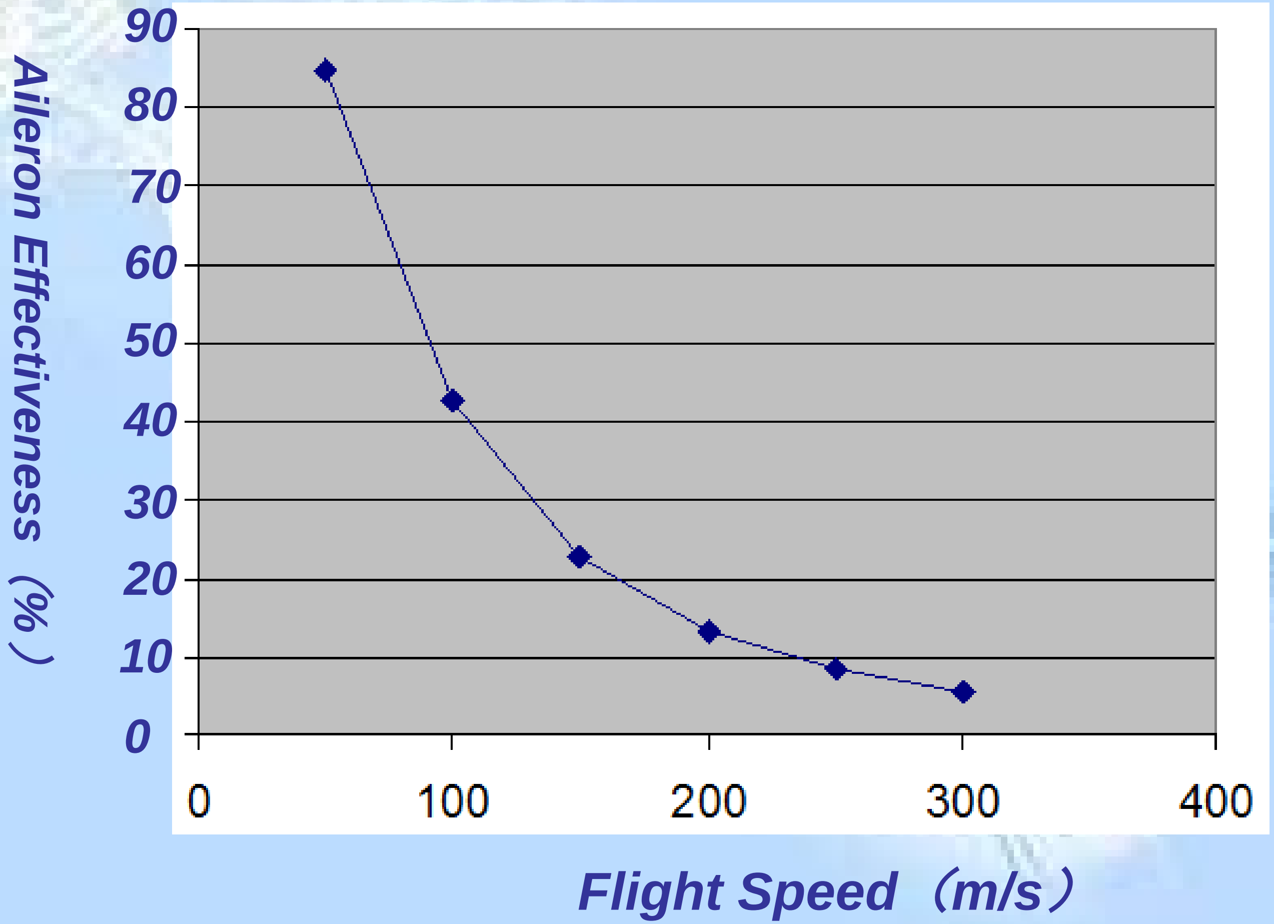
1G level supersonic high altitude

4G （Pull up maneuver） supersonic high altitude



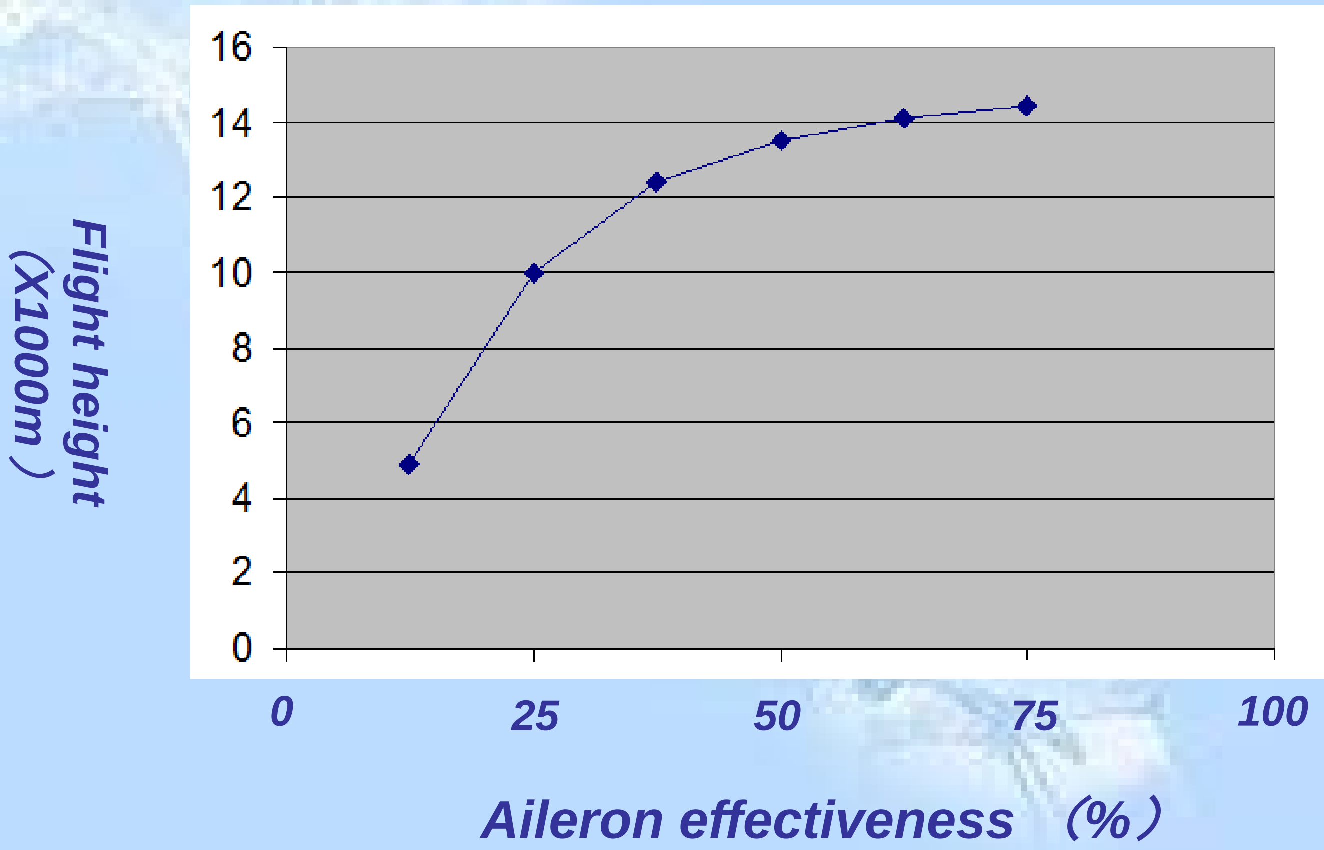
3. Aileron effectiveness under different flight conditions

Calculate and analyze the changing trend of the aileron efficiency with the flight speed (the aileron declination δa is constant) as shown below



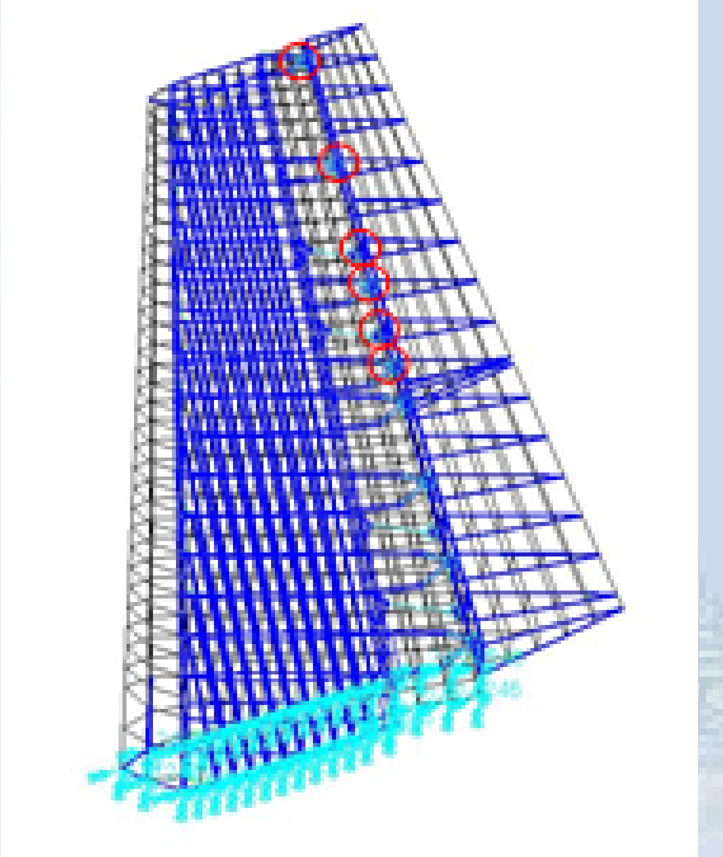
3. Aileron effectiveness under different flight conditions

Calculate and analyze the changing trend of the aileron efficiency with the flight height (the aileron declination δa is constant) as shown below



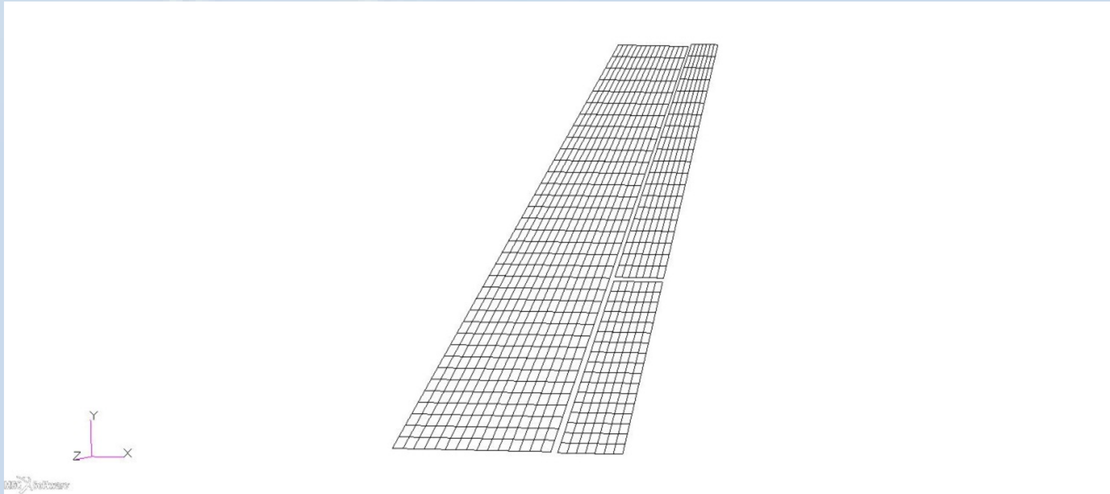
4. Influence of different wing-Aileron connection positions on aileron effectiveness

Suppose the wing-aileron has a pitching trim, which is like elevon's function. The root of the wing was symmetrically supported (in this model, we constrained 2, 4 and 6 directions), when static aeroelastic trim was performed.



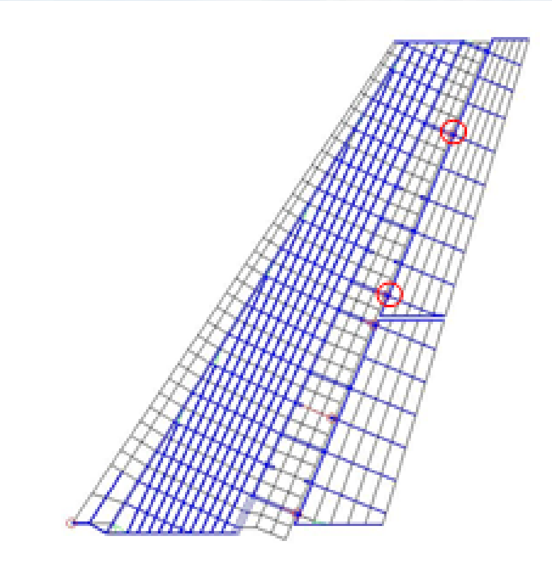
4. Influence of different wing-Aileron connection positions on aileron effectiveness

The aerodynamic meshes of the main wing surface, the aileron, and the flap were established in the following picture, which were coupled with the corresponding structures. The rotation axis and operating surface of the aileron were also defined.

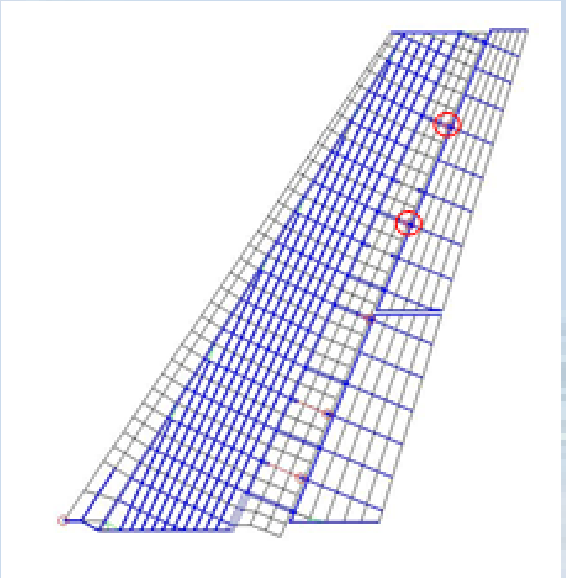


4. Influence of different wing-Aileron connection positions on aileron effectiveness

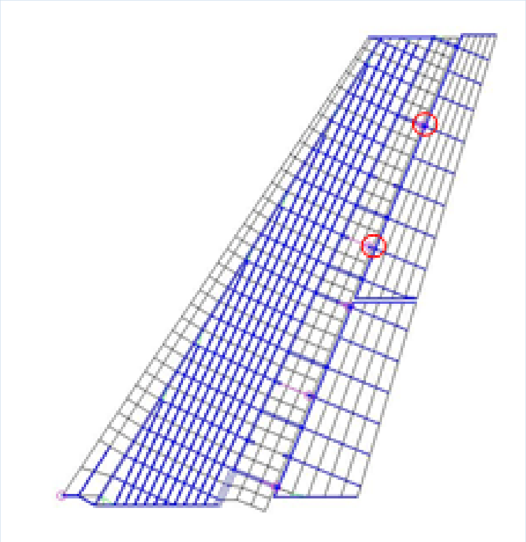
According to the following three cases, to simplify the calculation and analysis, the aileron deflection was 5^0, and the static aeroelastic pitching trim was carried out. The loads and moments of the rigid and elastic ailerons were obtained, and the aileron effectiveness was calculated, which is listed in the following table.



Case 1



Case 2



Case 3

4. Influence of different wing-Aileron connection positions on aileron effectiveness

Table 1 Comparison of aileron effectiveness

Cases	Aileron effectiveness η_a（%）
1	34.58
2	88.29
3	71.25

5. Conclusions

From the previous introduction, we can see that the conventional aileron is placed on the outer side of the wing. The wing is long and the chord is short. When the large angle of attack or the incoming flow speed is high, the control surface is easily deformed so that **aileron reversal** appears. To avoid the emergence of it, the following measures are generally adopted:

1) Adjust the size of the airfoil structure to increase the stiffness of the aileron, but increase the weight of the aileron;

2) Multi-joint fixed ailerons can be used to increase the stiffness. However, if the wing is deformed during flight, the axis of the aileron shaft will be bent, which will affect the flexibility of handling and even jam.

3) The large transport aircraft adopts segmental ailerons to avoid the jamming phenomenon, but the processing and manufacturing procedures are added, and more than one set of operating mechanisms, in addition to the complicated design, one more weight.

5. Conclusions

It can be seen from the longitudinal trimming example introduced in this paper that the method of changing the position of the wing-aileron joint to improve the aileron support stiffness and thus the aileron efficiency is on rise.

1) According to the different flight conditions, the alternative of the wing-aileron joint position is used to change the wing-aileron connection (support) stiffness to make the wingload redistribution, and also reduce the aileron deformation, and therefore improve aileron efficiency;

2) A method of changing the connection position of the wing-aileron joints to increase the stiffness, compared with changing the size of the ailerons to improve the aileron stiffness to prevent the aileron reversal, is a lighter aileron design;

3) The wing-Aileron joint adopts a modified two-point connection, which improves the flexibility of handling and avoids jamming.

Thanks !

More valuable advice!