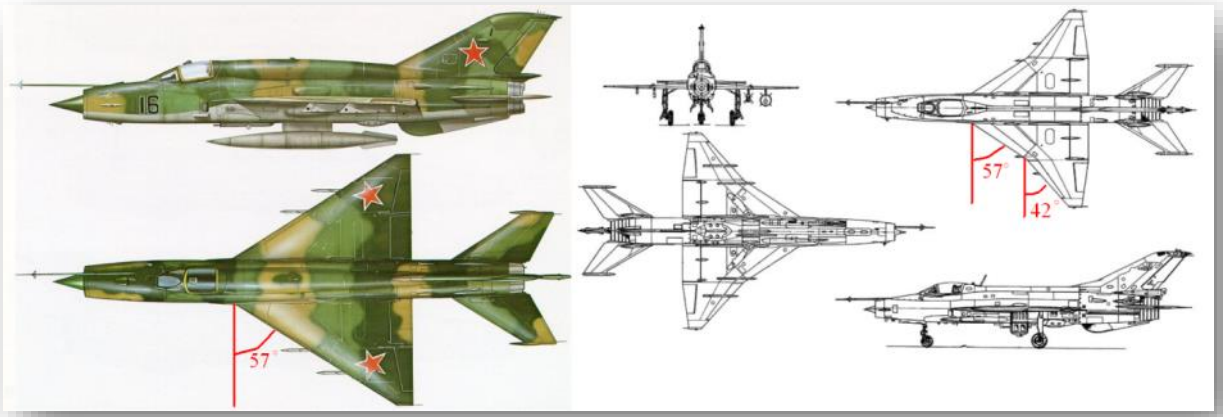
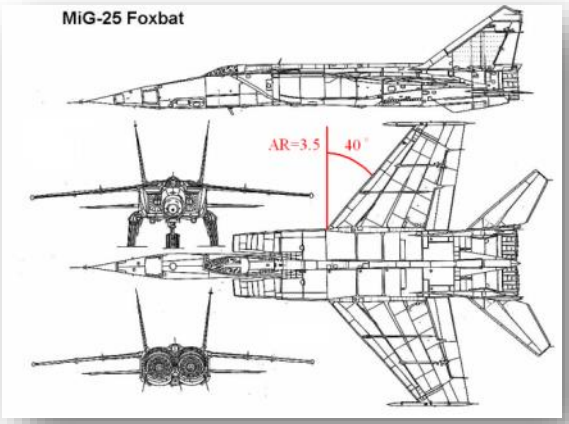
Introduction to aeronautics

Part 4. The era of the jet-propelled airplane

4.4 The design for breaking sound barrier

- **Reduce the wave drag**
  - **Delta wing and trapezoidal wing**



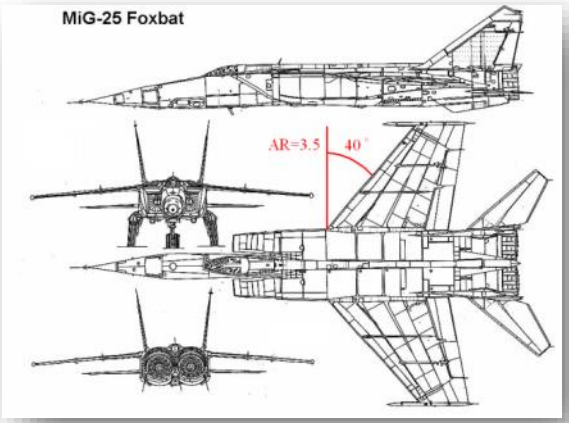


- **Subsonic leading edge：the leading edge lies in the Mach cone. The flow at the leading edge is subsonic**

- **Supersonic leading edge： the leading edge lies out of the Mach cone. The flow at the leading edge is supersonic**

4.4 The design for breaking sound barrier

- **Reduce the wave drag**
  - **Delta wing and trapezoidal wing**



- **Advantage of delta wing:**
  - **Light weight**
  - **Low wave drag at supersonic speed**
- **Disadvantage of delta wing:**
  - **Poor subsonic performance**
    - **Very low maximum lift with high stall AOA**
    - **High induced drag**

4.4 The design for breaking sound barrier

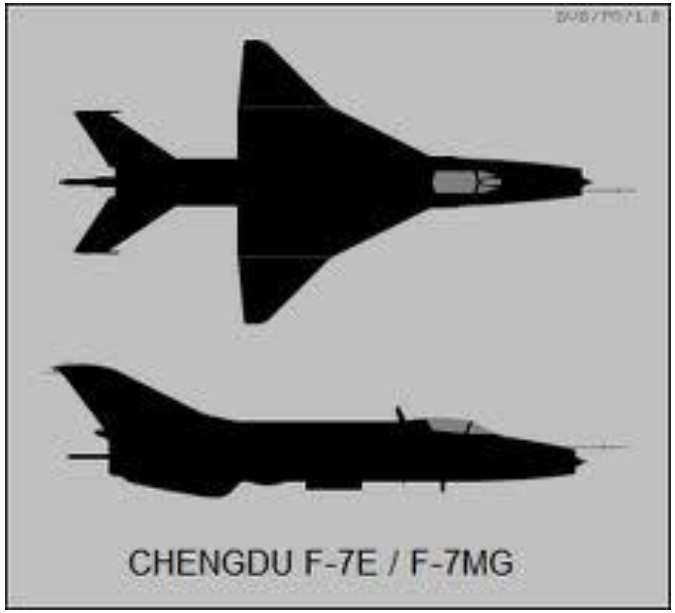
- **Reduce the wave drag**
  - **Delta wing and trapezoidal wing**

4.4 The design for breaking sound barrier

- **Reduce the wave drag**
  - **Delta wing and trapezoidal wing**

4.4 The design for breaking sound barrier

- **Reduce the wave drag**
  - **Compound delta wing**
    - **Increase aspect ratio, improve performance at subsonic region**
    - **Increase lift, improve take off and landing performance**



4.4 The design for breaking sound barrier

- **Reduce the wave drag**
  - **Compound delta wing**

4.4 The design for breaking sound barrier

- **Reduce the wave drag**
  - **Ogival delta wing**

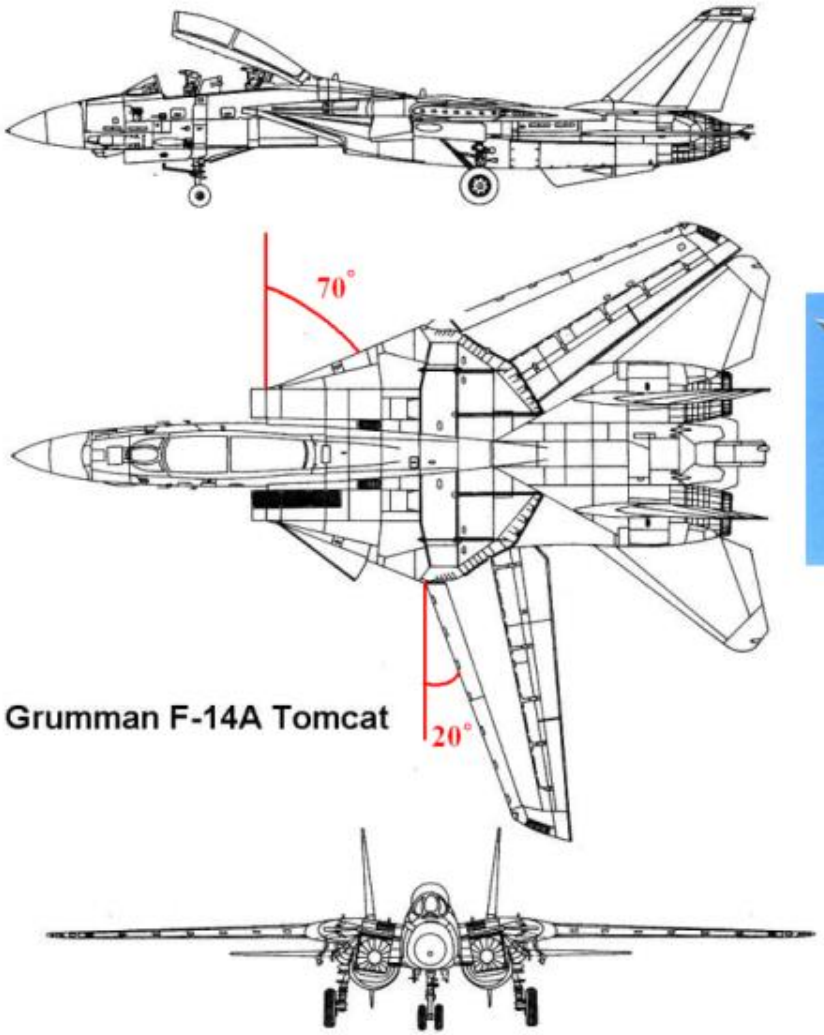
4.4 The design for breaking sound barrier

- **Reduce the wave drag**

- **The delta wing with low aspect radio usually has poor subsonic performance**
- **Variable swept wing provides good performance at both subsonic and super sonic speed, at the cost of structural weight and complexity**

4.4 The design for breaking sound barrier

- **Reduce the wave drag**
  - **Variable sweep back wing**



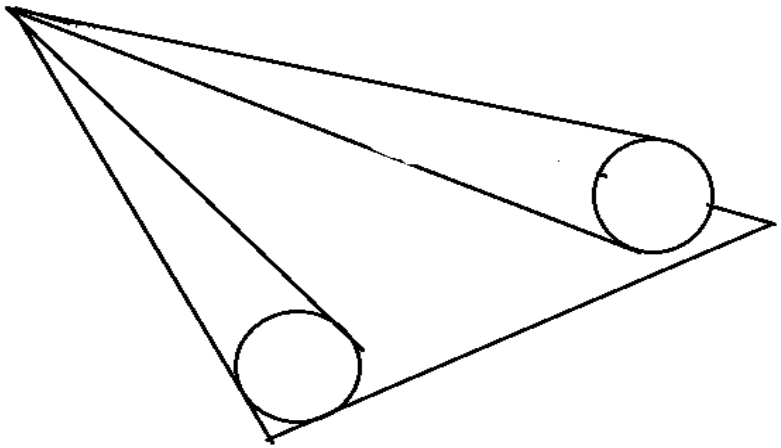
B-1

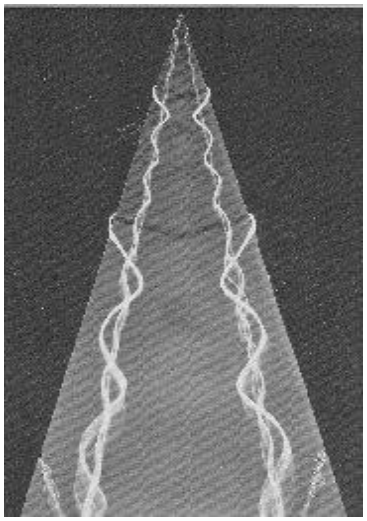
Tu-160

Tornado

4.4 The design for breaking sound barrier

- **Reduce the wave drag**
  - **Variable swept wing is complex and heavy, it is replaced by LEX combined with trapezoidal wing**
  - **Delta wing with sharp leading edge and high sweep back angle can induce very strong leading edge vortex (LEV)**





4.4 The design for breaking sound barrier

- **Reduce the wave drag**
  - **LEX (Leading edge extension): The ultimate solution to the contradiction of the subsonic flight and supersonic flight**
    - **LEX reduces wave drag**
    - **The wings can be designed with larger aspect ratio**
    - **LEX will generate very strong LEV at high AOA, hence increase lift and postpone the stall**

4.4 The design for breaking sound barrier

- **Reduce the wave drag**
  - **LEX (Leading edge extension): The ultimate solution to the contradiction of the subsonic flight and supersonic flight**

4.4 The design for breaking sound barrier

- Reduce the wave drag
  - The area rule
    - The theoretical wave drag of an aircraft at Mach 1.0 is identical to the wave drag of a body of revolution with the same volume-distribution plot.
    - The Sears Haak cross section distribution has the lowest wave drag

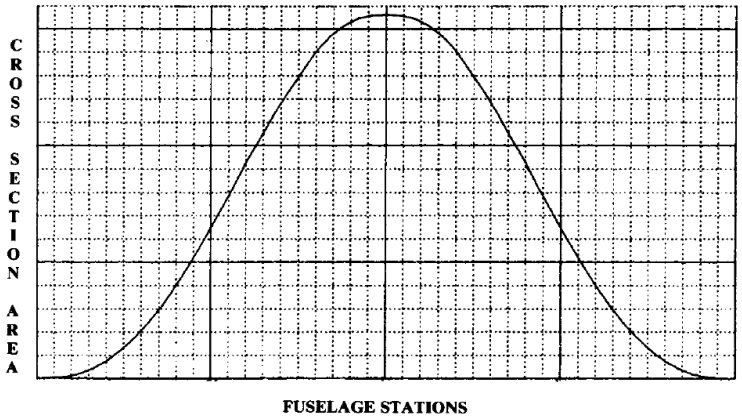
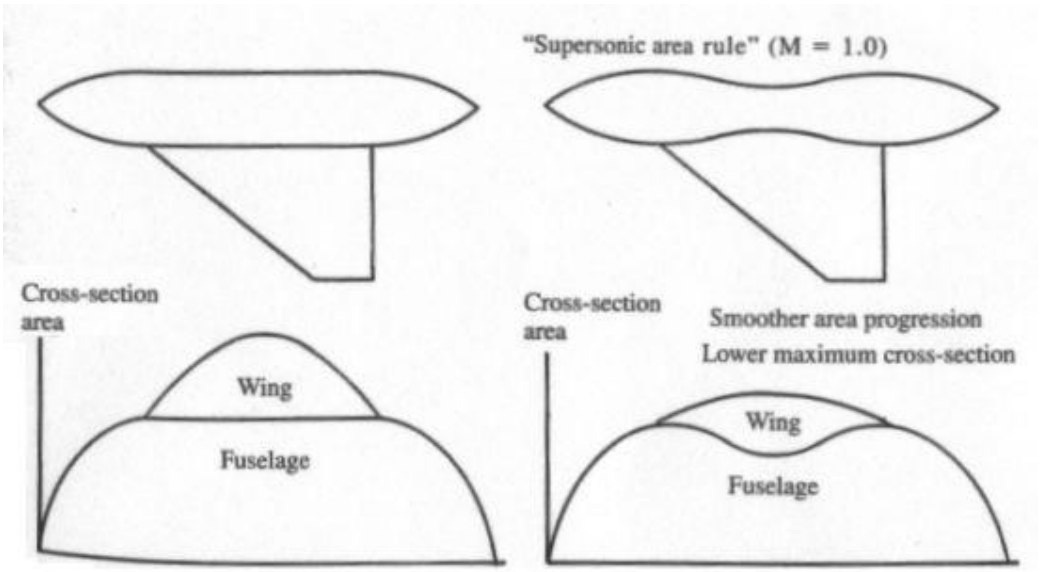


Fig. 8.2 Sears-Haack volume distribution.

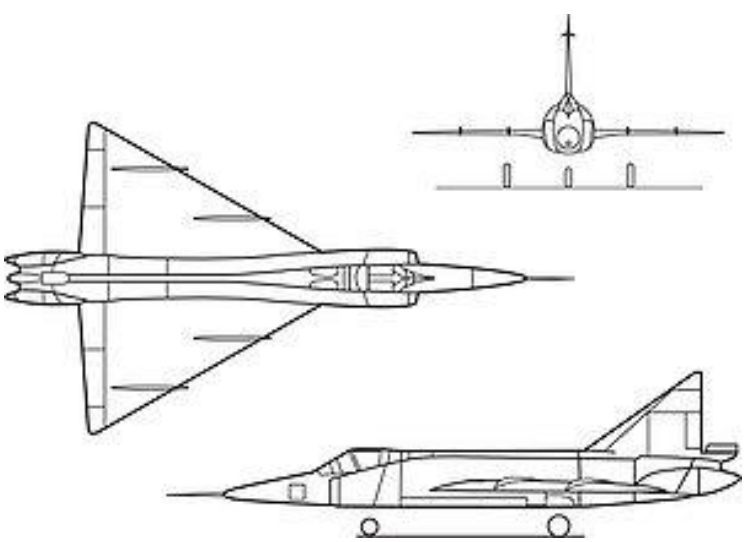
4.4 The design for breaking sound barrier

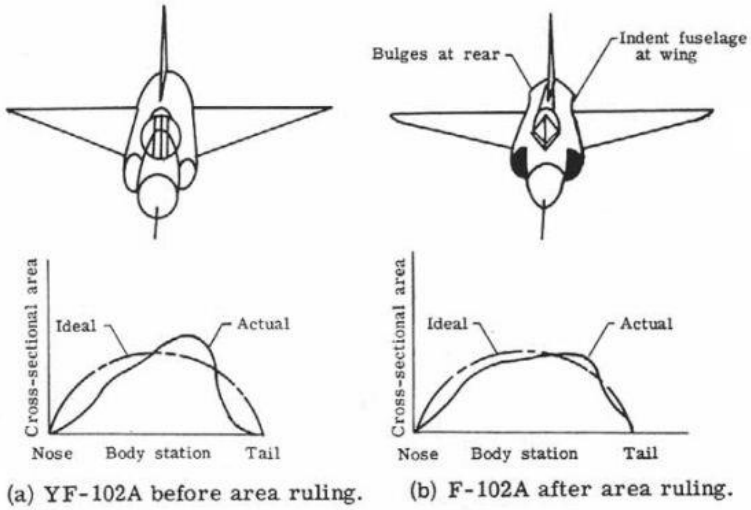
- Reduce the wave drag
  - The area rule
    - The fuselage and wing shall be designed such that the cross section distribution matches Sears Haak distribution as much as possible



4.4 The design for breaking sound barrier

- **Reduce the wave drag**
  - **The area rule**





(a) YF-102A before area ruling. (b) F-102A after area ruling.

F-102（The first aircraft broke sound barrier with the help of area rule）

4.4 The design for breaking sound barrier

- Reduce the wave drag
  - The area rule

4.4 The design for breaking sound barrier

- Reduce the wave drag
  - The area rule

F-22

F/A-18E/F

The vertical tail is placed between the wing and horizontal tail to match the area rule

4.4 The design for breaking sound barrier

- Reduce the wave drag
  - The area rule

Boeing 747 is designed with larger front fuselage to match the area rule

4.4 The design for breaking sound barrier

- **Reduce the wave drag**
  - **The area rule**

A380 is designed with appropriate airfoil thickness distribution to match the area rule