Chapter 1: Aerodynamics and Flight Controls

- he pilot can change the aircraft’s attitude, heading, height and forward speed by the the primary control surfaces, (ailerons, elevators and rudder)

1- AILERONS

- What is the aileron’s control ?
- The lateral control .
- About which axis ??
- Longitudinal axis .
- What is the movement ??
- Rolling movement

Elevator

- What is the elevator’s control ?
- Longitudinal control
- About which axis ??
- Lateral axis
- What is the movement ??
- Pitching movement (nose up and nose down).

Rudder

- What is the rudder’s control ?
- Directional control
- About which axis ??
- Normal or vertical axis
- What is the movement ??
- Yaaaaawwwiiiiiinnnngggg

Spoilers

Figure 4-15. Spoilers reduce lift and increase drag during descent and landing.

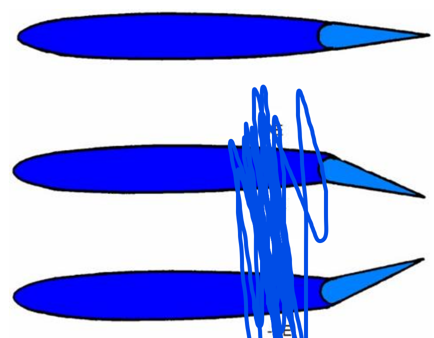
- Spoilers assist the ailerons
  which mean provide rolling movement
- The spoilers are located on the upper surface of each wing.

PRINCIPLE OF OPERATION…

Why is The control surfaces are placed at the maximum distance from the centre of gravity ...???

- to produce the greatest possible turning moment.
  + the greater the length of the moment arm , the less force needed to move the object .

- The control surfaces, when moved, create a convex camber on one side of the main surface and a concave camber on the other side.
- Pressure is reduced on the convex
- Pressure is increased on the concave
- Velocity is increased on the convex
- Velocity is decreased on the concave
- This causes the main surface to move in the opposite direction to which the control surface is moved.



+ The pilot moves the cockpit control in the direction the aircraft is desired to fly.

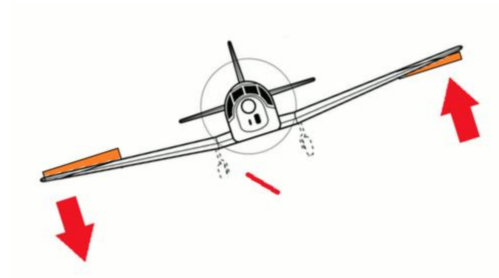
CONTROL SURFACE RANGE OF MOVEMENT…

The range of movement is the same in both directions of the control surfaces

- In practice it is necessary for structural reasons to limit the angular range of movement of the control surfaces.
- To achieve this, mechanical stops are placed at both the control surface

Section 2: Roll Control

- Lateral or rolling control on the longitudinal axis is provided by the ailerons.
- Ailerons located on the rear or trialing edge of the mainplanes
    1- When the control column is moved to the right or the control wheel is turned clockwise,
    2- the ailerons move in opposite directions.
    3- Which means control column is moved to the right
    4- The right aileron will move up
    5- The lift aileron will move down
    6- The right wing will move down
    7- The left wing will move up
    8- The aircraft will roll to the right and the opposite



AILERON DRAG…

- The aileron which moved down the effective angle of attack is increased on this down aileron because the airflow will hit the lower part of the lower aileron which mean the aircraft will yawing on other world ….
  The down-going aileron produces lift and drag, while the up-going one reduces lift and causes less drag. This will tend to yaw the aircraft
- This is known an AILERON DRAG or adverse aileron yaw

TIP STALL

- If the turn is attempted at LOW SPEED
- This may cause the wing tip to stall.
- The aileron drag may sometime response of the tip stall .
- And the loss of lift is the main point to stall

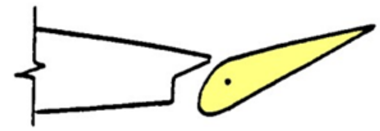
The methods for reduce the effect of aileron drag and may also reduce the possibility of a tip stall…???

1- Differential aileron.
2- Frise type aileron.
3- Slotted aileron.
4- Spoilers.
5- Wing tip washout.

1-DIFFERENTIAL AILERON

- The aileron designed to make the ‘down’ travel is less than the ‘up’ travel.

2- FRISE TYPE AILERON

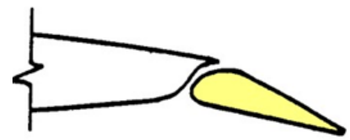


- the leading edge of the upgoing aileron protrudes below the wing, creating more drag.

+because as we know the up-going aileron reduce lift and produce less drag while the down-going aileron produce lift and more drag than the up aileron

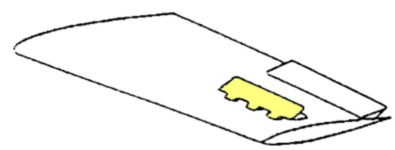
This is why we protrude the leading edge of the upgoing aileron to equalize the drag on both ailerons

3- SLOTTED AILERON



- this type when it is lowered, a slot is formed between the wing and the leading edge of the aileron.
- Air from the lower surface accelerates through the slot and reduces turbulence over the aileron (increase lift and reduce drag)
- It also reduces the possibility of a tip stall at low speed when banked turn is attempted.

4- SPOILERS



Aileron drag may be reduced by fitting a spoiler on the top surface of the wing in front of the aileron.

How is the spoilers work ..??

- When roll to the right the right aileron will go up
  and the right spoiler will go up to assist and the left spoiler is flush

+ some type of aircraft have no ailerons those use spoilers

5- WASHOUT

- Washout, the reduction of wing incidence towards the wing tip may also be used to reduce the possibility of tip stall.

Section 3: Pitch Control

- Longitudinal or pitching control about the lateral axis is provided by the elevators
- Pushing the control column forward causes the elevator to move down.=nosedown
- Pulling the control column back causes the elevator to move up=nose up

STABILATOR is the elevator but is all moving part

- also known as an all moving or all flying tailplane
- The stabilator is hinged to the fuselage
- An anti-balance tab is hinged to the trailing edge of the stabilator
  this tap assist the movement of stabilator and moves in the same direction with the stabilator
- Stabilator controlled by longitudinal

VARIABLE INCIDENCE STABILISER

- During cruise flight the VARIABLE INCIDENCE STABILISER exert a downward force to balance the nose-down effect caused by the centre of lift being behind the centre of gravity.

Section 4: Yaw Control

RUDDER :

Directional or yawing control about the normal or vertical axis is provided by the rudder, which is hinged to the rear or trailing edge of the fin.

- right rudder pedal is moved forward the rudder will move to the right,
  the aircraft will yaw to the right.
- rudder may also produce a rolling movement
- Moving the rudder to the right causes the left wing to move forward faster than the right. Increased left wing speed means increased lift mean roll to the right .
- The roll is usually corrected by interconnecting the rudder and ailerons. Therefore, when the rudder is applied the ailerons are automatically operated.

RUDDUER LIMITER

- At higher speeds large rudder movements could cause large stresses on the aircraft structure.
- Rudder travel can be reduced as the speed increases by:
- • Automatically reducing the hydraulic pressure being supplied to the rudder actuators as the speed of the aircraft increases.
- • Using a ratio changer which reduces rudder travel in relation to rudder pedal travel with increase in forward speed.
- • Using an airspeed sensing device which adjusts the position of the rudder travel stops to reduce the travel of the rudder as the aircraft speed increases.

- THE PROMPLEM THAT THE YAWING ROLLING CALLED DUTCH ROLL

swept wings are subject to DUTCH ROLL

HOW TO PREVENT THE DUTCH ROLL …???

- YAW DAMPING SYSTEM IS USED
- yaw damping system automatically moves the rudder approximately 3º

Control Surface	Desired Effect on Aircraft	Pilot's Action	Control Surface Movement
Aileron	To roll to the right	Control column to the right or control wheel turned clockwise.	Right aileron moves up and left aileron moves down
	To roll to the left	Control column to the left or control wheel turned anticlockwise	Left aileron moves up and right aileron moves down
Elevator	To raise the nose (climb)	Control column or control wheel pulled back	Elevator moves up
	To lower the nose (dive)	Control column or control wheel pushed forward	Elevator moves down
Rudder	Turn (Yaw) to the right	Right rudder pedal pushed forward	Rudder moves to the right
	Turn (Yaw) to the left	Left rudder pedal pushed forward	Rudder moves to the left

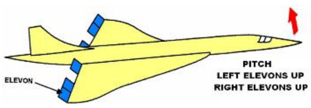
Section 5: Canards

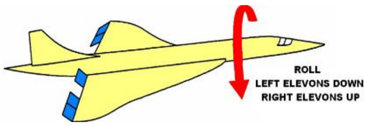
- horizontal stabiliser is in front of the wing
- The canard may also be known as a foreplane or forward wing
- Longitudinal control is provided by elevators hinged to the trailing edge of the foreplane
- - means canard response of pitching movement

The canard layout has additional advantages:

1- the rear fuselage is empty
2- the noise is behind the cabin
3- clear of the propeller slipstream

Section 6: Elevons and Ruddervators

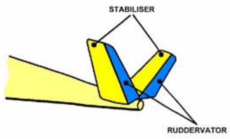




ELEVONS

- On a delta wing aircraft, acts as both aileron and elevator

RUDDERVATORS AND THE BUTTERFLY OR 'V' – TAIL



- combines the rudder and elevator,
- The ruddervators can be moved up or down together using the control column to provide pitching control.
- The ruddervators can be moved opposite to each other to provide yawing
- An advantage of the 'V' tail is less weight and drag due to the smaller number of control surfaces used .
- The V-tail used on light aircraft but it is rarely used

Section 7: High Lift Devices

- Such as flaps, slats and flaperon
- High lift devices will increase the camber of the wing
- As the camber increase the lift coefficient will increase , and lower the stall
- This allows the take-off and landing runs to be shortened

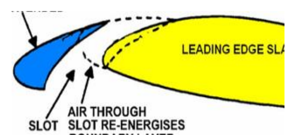
LEADING EDGE DEVICE

- Leading edge high lift devices are designed to delay separation of the boundary layer from the top surface of the wing

  The leading edge devices are:

  - Leading edge slats.
  - Leading edge flap

LEADING EDGE SLATS (increase lift and dely sepertaion and reduce drag)



- small aerofoils attached to the leading edge of the wings.
- slats extend along the complete span of the wing
- extended position a slot is formed between the slat and the top surface of the wing.
- The gap at the front of the slat is much larger than the gap at the rear.
- This allow air to pass through the slot from the high pressure region below the wing into the low pressure region above the wing.
- This delays the separation of the airflow from the top surface of the wing.
- The wing angle of attack may be increased until it is about 6º to 8º above the normal stalling angle.
- The wing stalling angle is increased to between 21º and 23º
- This type of slat can increase the lift as much as 60%.

LEADING EDGE FLAPS

- Lower the flaps will increase the lift at low speed
- It can increase the lift of the basic aerofoil by 50%.

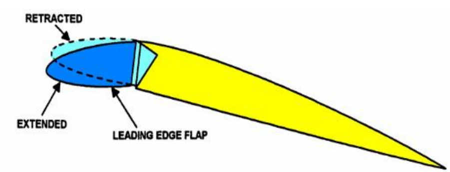
The main types of leading edge flaps in current use are:

• Drooped leading edge flaps .

• Krueger flaps.

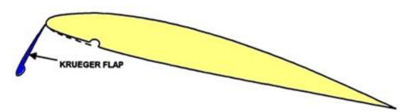
• Variable camber leading edge flaps

1- Drooped Leading Edge Flaps



- It lowerd before take-off because when its lowerd it will increase the camber which will increase the lift force
- lowered and raised by a screwjack

2- Krueger Leading Flaps



- when extended gives an increase in leading edge camber.
- extended and retracted by a screwjack

3- Variable Camber Leading Edge Flap

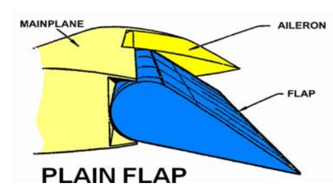
The variable camber leading edge flap is a modified Krueger flap

- It is made from a flexible composite material.
- Both Krueger flaps and variable camber flaps are controlled by using the trailing edge flap selector handle

TRAILING EDGE FLAPS

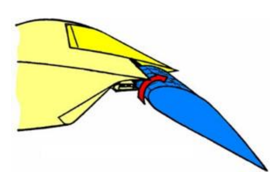
- increasing the lift of a wing at all angles of attack.
- When lowered they increase the camber of the wing section.

1-The Plain Flap



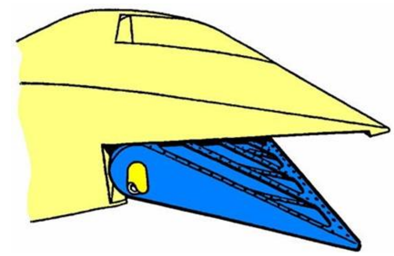
- The Plain Flap is sometimes referred to as the camber flap.
- ncrease in lift, which may be as much as 50%

2-The Slotted Flap



- similar to a plain flap
- when it is lowered, a slot is formed between the flap and the wing.
- Lift is increase by 65%

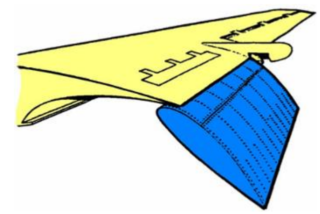
3-The Split Flap



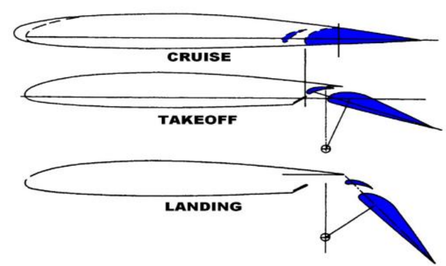
- No change of area and camber on top surface
- On the bottom surface, a concave camber is produced, decreasing the velocity and further increasing the pressure
- produce as much as 60% increase in lift

4-The Extension Flap or Fowler Flap

- is the most widely used type of flap.
- 90% increase in lift
- disadvantage of this type is the large rearward movement of the centre of pressure when the flap is lowered. This causes the aircraft to pitch nose down.



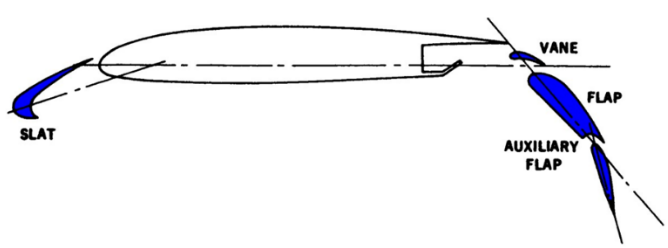
5-The Double Slotted Extension Flap



- similar to the extension flap
- This type of flap will increase lift by 100%
- This type of flap may be found on propeller driven types
- Also this type produce large rear movement of C OF G

- Cruise = straight take-off=half down landing=fully down

- Using a slat and double slotted extension flap will increase the lift of the basic aerofoil by 120%.



GENERAL

IN GENERAL The high lift required for the take-off and landing

Propeller driven types do not normally use leading edge high lift devices.

IF IT USE , IT WILL USE DOUBLE SLOTED EXTENSION FLPAS

- Leading edge slats normally have two extended positions, take-off and landing
- Krueger flaps and variable camber flaps are either retracted of fully extended. They have no intermediate position
- Krueger flaps and variable camber flaps controlled BY TRAILING EDGE FLAPS

PROTECTION OF HIGH LIFT DEVICES

- high lift devices are normally protected against asymmetry

ASYMMETRY PROTECTION

- the difference angles between the two flaps will rolling the aircraft
- The asymmetry protection system stops the movement of the high lift devices.

FLAP LOAD RELIEF

- fully lowered at high airspeeds structural damage may occur.
- An automatic system will retract the flaps if they are lowered at too high a speed then When the airspeed is reduced to a safe value the flaps
- automatically return to their selected position

INDICATIONS

- high lift devices is indicated in the cockpit.
- The position of the high lift devices is indicated by green and amber lamps.
- And on the ECAM OR EICAS

FLAPERONS

- some large transport aircraft there are two sets of ailerons on each wing

Low speed ailerons are mounted near the wing tip (OUTBOARD)

All speed ailerons are mounted NEAR THE ROOT (INBOARD)

FLAPERONS reduces the amount of space available for flaps.

- Flaperons can operate both as flaps and ailerons. Flaperons can be lowered together to act as flaps.
- Spoilers may be fitted to both jet transport aircraft and propeller

Section 8: Drag Inducing Devices

- Spoilers, also known as speedbrakes.
- SPOILERS REDUCE wing lift at landing
- Ground spoilers only use at landing or on the ground
- spoilers are deployed, they rise up, reduce lift and increase drag.
- Located on the upper surface of each wing just in front of the trailing edge flaps.
- control of spoiler panels can be either manual/hydraulic or electric/hydraulic

ROLL SPOILERS…

Spoilers assist the ailerons while rolling .

The down going wing = spoiler up

The up going wing = spoiler SLUSH

SPOILERS AND SPEED BRAKES ARE THE SAME BUT WE SAY SPOILER IN THE PURPSE OF ROLLING ..

SPEEDBRAKES…..

- the spoilers on each wing are raised together.
- They reach their maximum angle during flight when the lever is in its ‘Flight detent’ position
- Sometimes during flight both speedbrake and roll commands occur together.
- BY OPERATE ONE SIDE FULLY , THE OTHER PARTIALLY
- When spoilers are used as speedbrakes they can be used at any airspeed.

GROUND SPOILERS OR LIFT DUMPERS

- In this mode both the flight spoilers and the ground spoilers rise to their maximum angle on touchdown.

Certain conditions must be met before RISE SPOILERS FULLY ;…???

1- lever in the armed position (AUTO)
2- WOW SENSING
3- thrust levers in their idle positions. (RETRACTED) (BACK)
4- wheels rotating (ensures the aircraft is on the ground)

When the aircraft touches down, an actuator automatically moves the speedbrake lever to the up position

This provides the signal for all the spoiler panels to move up.

+++ UP ANGLE OF SPOILER ON THE GROUND LARGER THAN DURING FLIGHT

When the spoilers are fully raised the flap LIFT WILL ….
- reduced by approximately 80%.

- At the same time the drag more than doubles.

The loss of lift puts the aircraft's weight on to the undercarriage, this:

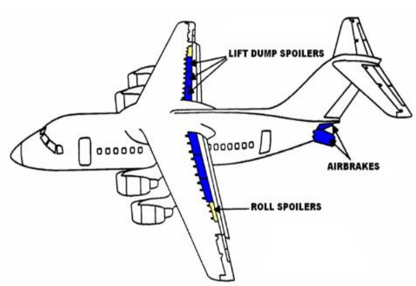
• Increases directional control.

• Improves braking.

• Reduces the risk of aquaplaning on wet runways.

Tail Unit Airbrakes

- Some transport aircraft are fitted with spoilers on the top surface of the wing and separate airbrakes.
- The airbrakes form part of the tail section
  The spoilers and airbrakes are hydraulically



manually controlled using an airbrake/spoiler selector lever

SPOILER ON THE GROUND AUTOMATICALLY BY (ARMED POSITION)

Section 9: Boundary Layer Control

- On a tapered wing the stall starts near the wing tips

STALL WEDGES or spoiler strip : fitted on the leading edge near the root

Why is STALL WEDGES or spoiler strip near the root and on the leading edge ?

- ensures that the root of the wing stalls before the tip
- the turbulence created on the wedges stall or spoiler strip will strike the tail section and this will resulting vibration warning to the pilot of an approaching stall.

+ The spoiler strip need not be wedge shaped.

+ Inverted triangles approximately 2mm thick used to produce similar results.

BOUNDARY LAYER CONTROL

- when boundary layers get thicker airflow ,the turbulence will happened then the drag will increase (the turbulence happened due the separation)

how can we reduce that drag caused by separations ...????

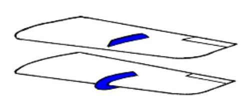
Vortex generators are fitted along the top surface of an aerofoil in spanwise rows.
The purpose of the vortex generators is to speed up the boundary layer.

Speed up the boundary layers will dely the separation .

+vortex generator prevent separation and reduce drag

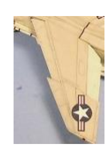
Do we have other ways to prevent separation and reduce drag ..???

1- Wing Fence – This produces a vortex which rotates in the opposite direction to the wing tip vortex.



2- Vortilon and engine pylon This is a small fence like surface attached to the under-surface and extending in front of the wing.

3- Saw Tooth Leading Edge extending forward the leading edge sudden change of chord



Section 10: Operation and Effect of Trim Tabs

The purpose of trimming tabs is to correct for flying faults

flying fault is a tendency of the aircraft to yaw,nose or tail heavy or one wing low.

Flying faults can be caused for example by:

- Changes in weight and centre of gravity due to the consumption of fuel.
- • Varying positions of passengers and cargo.
- • asymmetric power conditions. (yawing)
- • Pitch changes caused by lowering the flaps.

There are two types of trim tabs :

• Fixed tabs.
• Controllable Tabs.

+ both located on the trialing edge of the control surfaces .

+ each primary control surfaces have trim taps for correction faults

1- Fixed trim taps :

- adjusted by threaded rod
- The fixed tab only corrects flying faults at one speed, usually cruising speed
- Used on light aircraft

2- the controllable trim taps

- Controllable trim taps Correct flying fault at all speed
- fixed trim taps Correct flying fault at one speed

How is the controllable trim taps operated or adjusted ..??

By cabels , chain , push pull rod or electric .

+++ Control surfaces move in the opposite direction of the trim taps
+++ some aircraft the trim tabs moved electrically instead of mechanically.

Aileron trim taps

Aircraft left wing low the correction of trim tap is ????
(trim tap UP) (insted of aileron down)

Elevator trim taps

- Forward movement of trim wheel = trim taps up = elevator down = nose down
- rearward movement of trim wheel = trim taps down = elevator up = nose up
- Aircraft heavy tail then the corrections of trim is ..??
- Trim tap up

Rudder Trim tab

- To provide nose right trim the trim wheel is rotated in the clockwise direction. The trim tab moves to the left and the rudder moves to the right.
- To provide nose left trim the trim wheel is rotated anti-clockwise. The trim tab moves to the right and the rudder moves to the left.

When irreversible power controls are used, a trim tab is ineffective.

Pcu will control trimming haydraulically without using trimming
this is known as control surface bias

FLYING FAULTS

A flying fault is a tendency the aircraft may have to yaw, fly nose or tail heavy or one wing low

A tendency of the aircraft to yaw may be caused by…???

1- Slipstream effect on single engined propeller
2- asymmetric power conditions.

+++ slipstream is the air exist from the propeller and strike the tailsection (rudder) which will providing yawing

Nose or tail heaviness may be caused by: …????

- Changes in weight and centre of gravity position (and this caused by …?????)

1- The consumption of fuel.
2- The seating arrangement of passengers.
3- The positioning of cargo.

+++++ Attitude changes caused by the lowering of flaps.

Various defects may cause one wing low flying faults.

1- aircraft is flying one wing low and that the control wheel moves towards the low wing. This indicates that the fault is due to the (ailerons).

2- If control wheel does not move towards the low wing then the fault is not caused by the (aileronsm).

The fault could be caused by one of the following:

1- Damage flaps
2- flap drooping on the high wing
3- incidence could be too great.
4- Uneven fuel consumption
5- de-icing boot failing to deflate properly.

Elevators

FAULT	ROTATE HANDWHEEL	TAB MOVES	ELEVATORS MOVE	FORCE ON TAILPLANE
Nose Heavy	Rearward	Down	Up	Down
Tail Heavy	Forward	Up	Down	Upward

Rudder

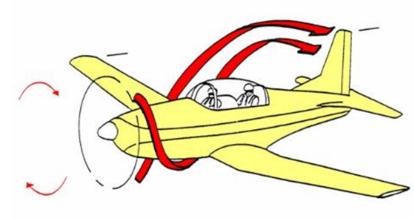
FAULT	ROTATE HANDWHEEL	TAB MOVES	RUDDER MOVES	AIRCRAFT NOSE MOVES
Yaw to Right	Anticlockwise	Right	Left	Left
Yaw to Left	Clockwise	Left	Right	Right

Ailerons

FAULT	ROTATE HANDWHEEL	TABS WILL MOVE	AILERONS MOVE
Right Wing Low	Anticlockwise	Up on Right Aileron Down on Left	Down on Right Wing Up on Left
Left Wing Low	Clockwise	Down on Right Aileron Up on Left	Up on Right Wing Down on Left

SLIPSTREAM EFFECT

On a single engined aircraft the slipstream from the propeller forms a helical path



The slipstream meets the fin (tail section)

The slipstream causes yawing

tends to make the aircraft yaw and may be compensated for by..?

- controllable or fixed trim tap on the radar (tail section)

Section 11: Aerodynamic Balance of Control Surfaces

what does Aerodynamic balance is a means..???

- reducing this effort, making it easier for the pilot to operate the controls.

If the stick forces are too light the control surface must be(loaded)
to increase the opposing moment.

the control surfaces are aerodynamically balanced using one or more of the following methods: mean the following metode will reduce the effort .

• Horn balance (horn tip).

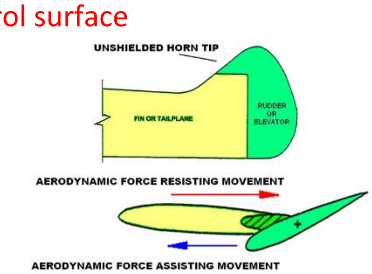
• Inset hinge.

• Internal balance panels.

• Various types of tab.

1- HORN BALANCE OR HORN TIP .

- Usually we use the horn tip or horn balance for the rudder and elevators.
- This the way reduce the effort and make easier for the pilot to move the control surface
- A horn tip is an extension at the tip, in front of the hinge line



2- INSET HINGE

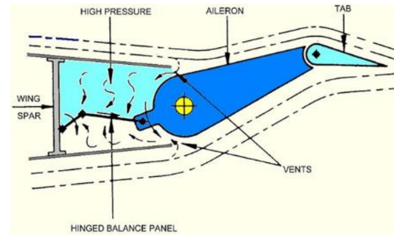
- This works on the same principle as the horn tip.
- it extends in front of the hinge line.
- This the way reduce the effort and make easier for the pilot to move the control surface

3- INTERNAL BALANCE TABS OR BALANCE TAB PANELS

- It has two vent = one upper the other lower

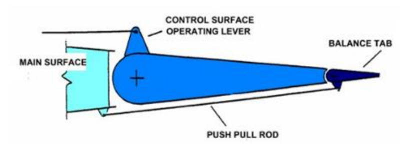
  -This type depending on the aerodynamic pressure above high and lower low

- - This the way reduce the effort and make easier for the pilot to move the control surface



4- BALANCE TAB

- It looks like the trim tap but its not,because the trim tap controlled by the pilot and automatic but balance tap onle controlled automatic .
- hinged into the trailing edge
- When the control surface moves in one direction, the tab automatically moves in the opposite direction and its not controlled by the pilot .
- -This type depending on the aerodynamic pressure
- This the way reduce the effort and make easier for the pilot to move the control surface



- ANTI-BALANCE TAB

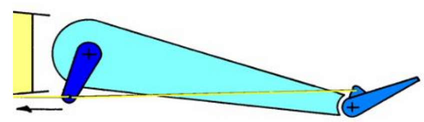
They move in the same direction as the control surface to increase the stick force. For example control surface up, tab up.

Its used with elevator + stabilator

GEARED BALANCE

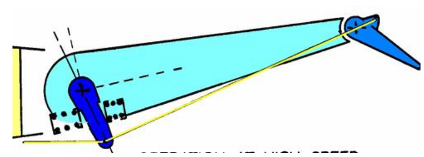
On some aircraft the operation of control surface balance tabs is geared.

This allows the balance effect to be varied in proportion to control surface deflection.



SERVO TAB

- hinged into the trailing edge
- directly controlled by the pilot.
- less effort is required to move the tab into the airflow than would be required to move the main control surface.
- The aerodynamic force acting on the tab makes the control surface move in the required direction until a position of equilibrium is reached.



SPRING TAB

The spring tab is similar to the servo tab but servo is better

- the aerodynamic force acting of the main control surface will overcome the spring and the tab will be operated

Section 12: Mass Balance of Control Surfaces

What is the thing that prevent fluttering and vibrations …???

- Is the mass balance

Flutter is prevented by fitting a weight in front of the control surface hinge

This weight is made from…??? 1- LEAD 2- TUNGSTEN

These additional weights are usually attached:

• Internally along the leading edge of the control surface.

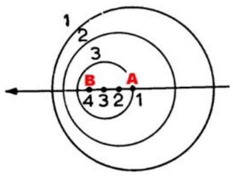
• Inside the horn balance.

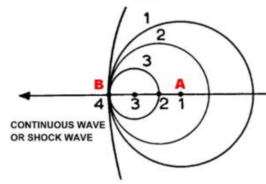
• On an arm attached to the surface.

Chapter 2: High Speed Flight

- sound waves they travel at about 339m/sec (760 mph) in air at a sea level temperature at 15ºC.
- In the Stratosphere at a temperature of about -60°C, the speed of sound is about 660 mph. 40,000 ft
- As the airflow approaches the nose of the aircraft it slows down and the pressure increases.
- At speed of sound air is compressed
- The effect of this increased pressure is transmitted at the speed of sound
- At low speeds air is not compressed , air is compressed at speed of sound

THE SPEED OF SOUND





- An object A is moving in the direction of the arrow (to position B) at a speed less than the speed of the waves.
- As the object (moves to position B) approaches the speed of sound, the pressure waves accumulate in front of the object and form a continuous wave.
- The speed of A is now the same as the pressure waves
- The air gets no ‘warning’ that A is approaching,
  the waves pile up and form a shock wave.
- The density and pressure of this wave are both greater than that of the surrounding atmosphere.

MACH NUMBER

Mach number is the ratio of the true speed of the aircraft to the speed of sound

- If an aircraft is flying at half the speed of sound, the Mach number is 0.5.
- If it is flying at the speed of sound, the Mach number is 1

- Subsonic is no shockwaves form. Is less than the speed of sound
- If the Mach number increases, the airflow over the wing continues to accelerate to reaches the speed of sound at the point of maximum camber

- critical Mach number means 1 mach or less

- The waves pile up one behind the other and form a shock wave. This is knows as an incipient shock wave

- The incipient shock wave occurs when the aircraft is moving at about three quarters of the speed of sound i.e. Mach 0.75.

- However, as the airflow passes through the shockwave the following changes take place:
  1- sudden rise in pressure, density and temperature
  2- airflow is slowed down by the shock wave
  3- boundary layer become turbulent
  4- rapid rise in drag (as much as ten times increase).
  5- There is a loss of lift
  6- control surfaces might become less effective.

SHOCK STALL

- as Mach 0.82 a weak shock wave also forms on the lower surface of the win

Mach number approaches the speed of sound the areas of supersonic flow continue to grow.

- BOW WAVE
- At speeds above the speed of sound another shock wave appears in front of the wing called a bow wave

SUBSONIC

speeds below a Mach number of 0.8.

TRANSONIC

The transonic region is from Mach 0.8 to Mach 1.2. (MAXIMUM DRAG)

SUPERSONIC

The supersonic region is above Mach 1.2

Section 2: Transonic Flight and Raising the Critical Mach Number of the Aircraft

- Raising the Critical Mach Number of an aircraft allows it to fly faster before it encounters the shock stall.

The following design features can be used to increase the critical Mach number

1- SLIMNESS The aerofoil sections, the fuselage, the engine nacelles and tail unit are made as slim as possible.
2- SWEEPBACK When the wings and tail unit are swept back, the CRITICAL MACH NO. is increased.
3- SUPERCRITICAL WINGS

- Those at speeds faster than Mach 1.0 are referred to as supercritical.
- Aerofoils travelling at speeds lower than Mach 1.0 are called subcritical.

  ADVANTAGES OF SOPERCRITICAL WINGS :…???

  1- reducing both weight and drag.
  2- The aerofoil is thicker, so the wing structure can be lighter.

CONTROL AT TRANSONIC SPEED

- control surface loses effectiveness at transonic speeds.
- shock wave often forms at the elevator hinge.
- the elevator will be in the turbulent airflow behind the shock wave and will be almost ineffective
- the shock wave INDUCED SEPERATION AND MOVE back over the elevator, causing it to become immovable.
- To overcome these problems, the power operated all-moving or slab tailplane may be used. The whole tailplane then becomes a primary control surface
-
- Another problem encountered at transonic speeds is reversal of the aileron controls due to distortion of the wing structure.
- This problem may be overcome by using spoilers on the top surface of the wing OR All speed ailerons may also be used.
- TRANSONIC EFFECT ON AIRCRAFT TRIM AND STABILITY During transonic flight the stability of the aircraft is determined by the nature of the airflow behind the shockwave.

Longitudinal Stability Longitudinal stability (NOSE UP,DOWN)

is affected by:

• Movement of the centre of pressure.

• Changes in the lift of the wing.

• Downwash acting on the tailplane.

In straight and level flight at low subsonic speeds the centre of pressure acts behind the centre of gravity.

- NOSE DOWN MOMENT CAUSED BY REARWARD MOVEMENT OF CENTRE OF PRESSURE IS BALANCED BY THE TAILPLANE(STABILATOR),(ALL MOVING)

This results in a nose-down 'tuck under'.:>>>>>>>>>

1- the lift behind the shockwave is reduced and the tailplane becomes covered in disturbed airflow.
2- There is now no downwash acting on the tailplane
3- NOSE WIL PITCH DOWN

IS THE PROCSSES TO PITCH DOWN THE AIRCRAFT ('tuck under')

Tuck under will occur when :..???

1- Low subsonic speed
2- During acceleration from sub to supersonic

Lateral Stability (ROLLING)

The shock waves on the wings may not form at the same time on opposite wings. The difference in lift about the two wings may cause to fly one wing low.

Directional Stability

This may result in differences in drag on opposite wings.

For example if a shock wave forms first on the right wing,
the increase in drag on the right will cause the aircraft to yaw to the right.

MACH TRIM

To correct for nose tuck under in transonic flight we use the mach trim .

- A Mach trim system is provided to position automatically an all moving tailplane or variable incidence tailplane.

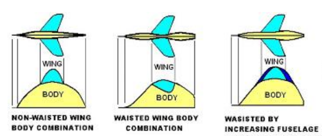
  During acceleration from subsonic to supersonic speed what will happen and what will we do …???

- Nose down occur
- We will transferring fuel from a front trim tank to a rear trim tank.

During deceleration from supersonic to subsonic speeds what will happen and what will we do …???

- Nose up will occur
- the fuel is transferred from the rear trim tank to the forward trim tank.

AREA RULE



- reduce drag at high subsonic and transonic speeds.
- The cross sectional area of the aircraft should increase gradually from the nose, reaching a maximum about midway along the length.

AERODYNAMIC HEATING

- During flight at supersonic speeds, heat is generated by friction between the air and the surface of the aircraft
- Aluminium alloys are suitable for flying up to Mach 2.

Section 3: Supersonic Flight

SHOCKWAVE PATTERNS

symmetrical aerofoil at zero degrees angle of attack.

shock wave appears on both top and bottom surfaces at the same time.

As the speed of the aircraft increases, the shock wave tends to move backwards, and the turbulence behind it increases.

As the speed is further increased the bow wave becomes attached to the leading edge. Bow wave attend above the speed of sound = above critical mach number

At this stage the angles between the shock waves and the surfaces become more acute.

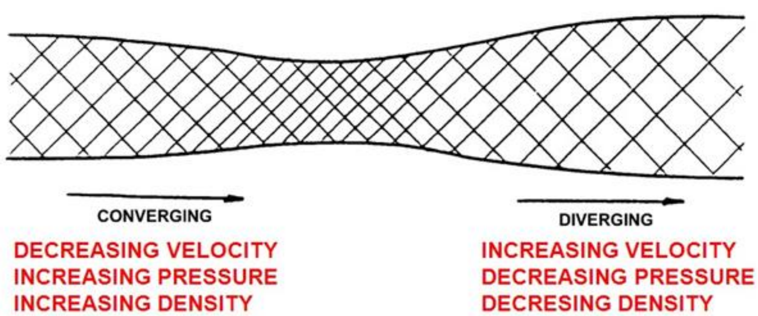
When the airflow meets a shock wave, it loses speed and changes direction.

There is a sudden increase in pressure, density and temperature.

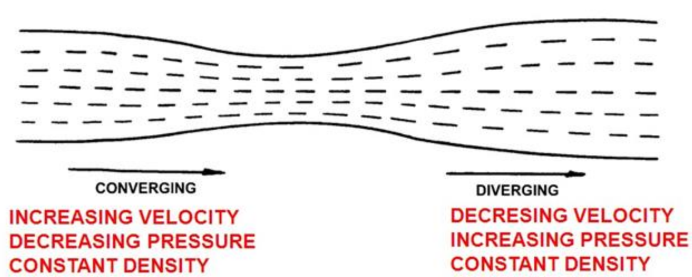
The shock wave is the cause of the new kind of drag called Wave Drag.

Wave drag attend at supersonic

COMPRESSIBLE FLOW (SUPERSONIC)



INCOMPRESSIBLE FLOW (SUBSONIC)



- The angles of the shock waves become more acute as the speed increases.
- The wave formed depends upon the airflow and the shape of the object causing the flow change.

There are three types of waves formed in a supersonic flow.

• The oblique shock wave (compression wave).

• The normal shock wave (compression wave).

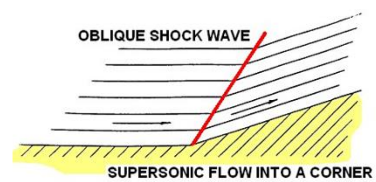
• The expansion wave.

1- THE OBLIQUE SHOCK WAVE

- The supersonic airflow is turned into a corner.

A shock wave forms at the corner and the following changes take place:

• The airflow is slowed down.



• The airflow direction is changed

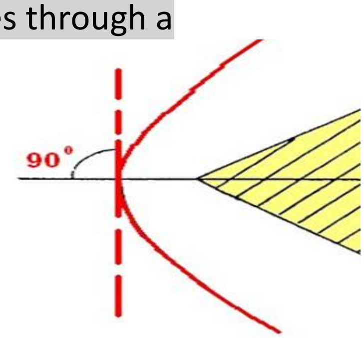
• The pressure, density and temperature behind the shock wave is increase due to convex shape , the airflow speed is increase and pressure ,temp , density is decreased

The wave that change the direction of airflow and slow down the speed OBLIQUE SHOCK WAVE

2- NORMAL SHOCK WAVE

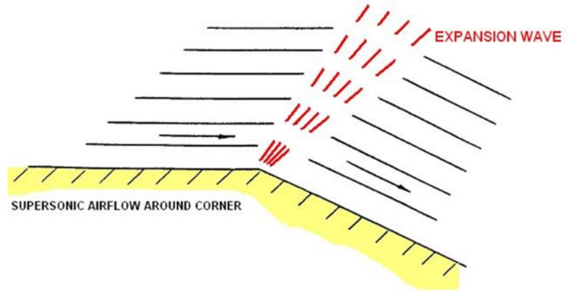
When a shock wave forms perpendicular to the airflow, it is called a ‘normal’ shock wave

- The speed of the airflow behind the shock wave depends on the shape of the nose and the Mach number of the free airflow.
- The following changes take place when a supersonic airflow passes through a normal shock wave:
- airflow is slowed
- airflow direction behind the wave is unchanged.
  (because the airflow is perpenduclar to the shock wave)
- The pressure, density and temperature of the airflow behind the shock wave is increased.



3- EXPANSION WAVE

- The flow around a corner does not cause sharp sudden changes in the airflow and does not form a shock wave.
- Separation doesn't occur
- The following changes take place when a supersonic airflow passes through an expansion wave:



- Airflow is greater
- The flow direction is changed
- the pressure and density of the airflow behind the wave is decreased
- due to convex shape , the airflow speed is increase and pressure ,temp , density is decreased

+ at supersonic THE C OF P = 50% of the chord

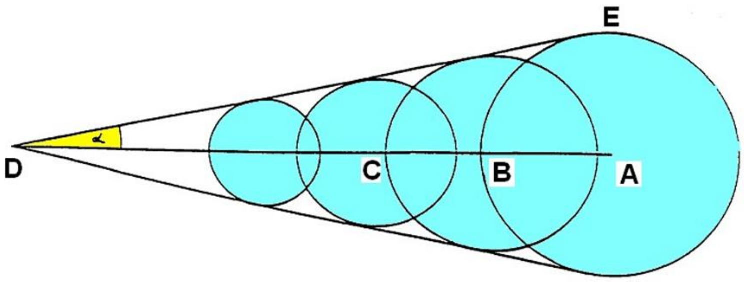
+ at subsonic THE C OF P = 25% of the chord

Which means …

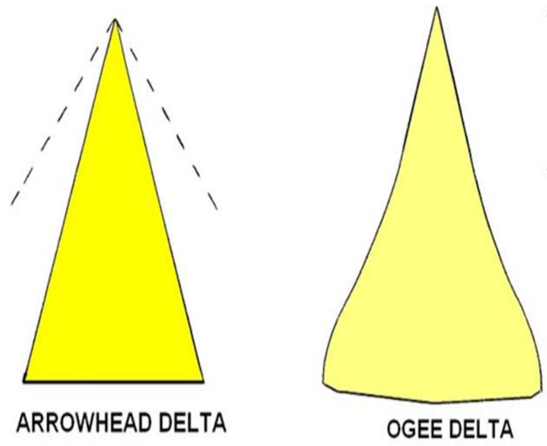
At transonic and supersonic the attend of aircraft is nose heavy

THE MACH CONE..

- The more speed = the more acute angle
- The angle ADE is called the Mach angle
- The greater the Mach number, the more acute the angle.
- If the moving point is the nose of an aircraft, a complete cone will be formed. This is called a Mach cone.
- Point D is faster than the speed of sound



DELTA WING..



- The delta wing used for supersonic
- large chord gives a very low ratio of thickness to chord, so wave drag is low
- delta wing give the strength and structural stiffness.

The ogee delta planform…

- The stalling angle is large
- because the shape of the wing produces leading edge vortices
- This produces greater pressure difference between the upper and lower surfaces of the wing
- This helps to provide the high lift required for take-off and landing.

THE ALL FLYING OR ALL MOVING TAILPLANE…

hinged to the trailing edge of a surfaces loses effectiveness at transonic speeds.

- shock wave often forms at the elevator hinge and make it ineffective
- To overcome these problems, the hydraulically operated all-flying or all-moving tailplane is used
- The whole tailplane becomes a primary control surface, so that full and accurate control can be retained at all speeds and Mach numbers.

Section 4: Factors Affecting the Airflow in The Engine Intakes of High Speed

- The performance of a gas turbine engine depends upon the efficiency of the air intake
- The gas turbine needs large amounts of air to operate efficiently

The air intake must be designed to provide air to the engine with minimum pressure loss due to :…????

- Losses due to friction within the airflow causing it to become turbulent.
- Losses caused by separating

The air must reach the compressor at a uniform pressure.

The air must also be slowed to subsonic speed.

The pressure increase as the forward speed increase .

The increase in intake pressure will increases the mass of air entering the engine. Thus increase the thrust of the engine.

THE IDEAL AIR INTAKE CONDITIONS

- The air entering the engine compressor should be subsonic.
- Intakes are designed to decelerate the airflow to subsonic .
- The kinetic energy of the airflow must be converted into pressure with a minimum of losses.
- At high speeds, shockwaves form at the intake entrance
- The most efficient intakes convert the airflow velocity into pressure with the minimum increase in temperature.

AIRFLOW SPEED AND PRESSURE BEHIND THE SHOCKWAVES

- At flight transonic speed range the simple Pitot type intake is suitable
- For speeds above Mach 1.4 the intakes designed to produce oblique shocks
- These give smoothest deceleration of the airflow with minimum rise in temperature.

AIR INTAKE SHAPE FOR SUBSONIC SPEEDS

At subsonic speeds a diverging intake duct is required to slow down the airflow and increase the pressure.

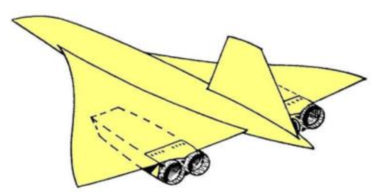
At supersonic speeds a converging duct is required to slow the airflow and increase the pressure.

The simple Pitot intake is suitable for speeds up to Mach 1.4.

Supersonic Speeds

In supersonic cruise conditions, the compression ratio of the intake will be much greater than the engine compressor

- At high Mach numbers it is necessary to have an intake that has a variable throat area. Spill valves or doors are also required to control the changing volumes of air
- As the speed increases above Mach 1 the ramps are lowered to reduce the throat area. For purpose of shock waves to don't reach .
- The air bleed duct is operated by signals from pressure sensors positioned on either side of the normal shockwave.
- If an engine has to be shut down in supersonic flight:
- • Air is spilled overboard through the spill door in the floor of the intake.
- • The ramps are lowered to their maximum down position.



THE PROBLEMS OF SUPERSONIC INTAKE DESIGN

1- intakes of supersonic aircraft usually have sharp edges, which can lead to problems at low speeds. Such a stall engine .
2- At the high angles of attack which are necessary at low speeds, the airflow entering the intake may stall. This may cause the engine compressor to surge.

- The more rounded intakes on subsonic aircraft are less likely to stall the airflow