FLIGHT INSTRUCTOR’S HANDBOOK OF EXERCISE BRIEFING MATERIAL

CHAPTER 1

EXERCISE 1

AIRCRAFT SYSTEMS

Progressive instruction should be given so that by the time the student is ready for solo he should be familiar with:

1) The fuel and oil systems.
2) The pneumatic system.
3) The electrical system.
4) The flight and engine instruments.
5) The handling and use of radio/navigation equipment.
6) Fire extinguishing methods.
7) The hydraulic system.
8) The heating and ventilation system.
9) Ice and rain protection –
    a. Engine.
    b. Airframe.
10) Flight an engine control systems.

CHECK LISTS AND DRILLS

The student must learn all check lists and drills thoroughly so that his actions on the ground and in the air become instinctive. He should be able to locate all controls, indicators and switches without having to look for them; to this end the student should seat himself in the aircraft and practice with the aid of pilot’s notes.

EXERCISE 1E

EMERGENCY DRILLS

When teaching emergency drills, emphasize seconds will count when an emergency arises. Do not give the impression that such emergencies are commonplace, and stress the fact that since emergencies are rare, the unexpected nature of the occurrence demands and instinctive drill which needs to be practiced at intervals to ensure that no time is lost through momentary confusion or indecision. The following drills must be thoroughly learned: -

i. Action in the event of fire in the air and on the ground.

ii. Emergency communication procedures.

ACTION IN THE EVENT OF FIRE

1. AIM

Fire is an extremely rare occurrence in the modern aircraft, but it is essential that the pilot has a thorough knowledge of the procedures to be adopted in his particular aircraft to extinguish a fire both on the ground and in the air.

WHAT THE INSTRUCTOR IS TO TEACH

i. Discuss the probable causes for various types of aircraft fires, as well as the technical principles involved in extinguishing those fires.

ii. Ensure that the student has a thorough knowledge in the use of the aircraft’s fire extinguishing equipment.

iii. The ground/air exercise briefing:
   a. Appropriate procedures and checklists.
   b. Engine fire analysis and preventative measures.
   c. Use of fire extinguishing equipment in air and on ground.
   d. Removal of smoke form aircraft cabin.
   e. Side slipping technique to keep flames from cabin area.
   f. Preparation of aircraft and passengers for forced landing.
   g. Appropriate radio call – “May-Day” or “Pan-Pan”.
   h. Engine considerations, safety and airmanship.

iv. De-briefing after simulated exercise on ground and in air.

WHY IT IS BEING TAUGHT

To give the student confidence in his ability to assess the type of fire occurring and to ensure that he carries out the correct firefighting drill, thereby preventing possible damage to the aircraft and injury to occupants.

HOW THE EXERCISE APPLIES TO FLYING

The fire may occur either in the air or on the ground, and may be due to any of the following reasons:

- i. On the ground:
  - a. Over-priming the engine on startup, causing excess fuel to collect in exhaust systems.
  - b. Fractured fuel and oil lines under pressure leaking onto hot exhaust systems.
  - c. During re-fueling operations a fire may occur due to incorrect grounding of re-fueling equipment.
  - d. Fire in electrical system or radio equipment.
  - e. Cockpit/cabin interior fire due to electrical fault/passenger smoking.

- ii. In the Air:
  - a. Fractured fuel and oil lines under pressure leaking onto hot exhaust systems.
  - b. Internal mechanical damage to the engine causing a fire in the exhaust manifold.
  - c. Fire in the induction system of the engine.
  - d. Fire in the electrical system or radio equipment.
  - e. Cabin fire.

2. PRINCIPLES INVOLVED

- i. Explain what causes fires.
- **ii.** Discuss the various types of fire extinguishers and their application.

3. DESCRIPTION OF THE GROUND/AIR EXERCISE

APPLICABLE PROCEDURES AND CHECKLISTS

DEMONSTRATION **OBSERVATION**

A. ON THE GROUND

i. Simulate an engine fire during start up.

THROTTLE	Closed
MIXTURE	Idle Cut-off (ICO)
FUEL SELECTOR	Off
FUEL PUMP	Off
IGNITION	Off
ENGINE FIRE EXT.	Operate (If installed)
RADIO CALL	Inform ATC
PARK BRAKE	On
BATTERY MASTER	Off
PASSENGERS	Evacuate
HAND FIRE EXT.	Operate

ii. Simulate a cabin or electrical fire whilst taxying. Carry out the same drill as above, after stopping the aircraft and applying the park brake.

B. IN THE AIR

i. Simulate an engine fire during flight.

a. Propeller which can feather (VP)

THROTTLE	Closed
PROPELLER	Feather
MIXTURE	Idle Cut-Off (ICO)
FUEL SELECTOR	Off
FUEL PUMP	Off
IGNITION	Off
ENGINE FIRE EXT.	Operate If applicable
RADIO CALL	Inform ATC
CABIN AIR SUPPLY	Closed
BATTERY MASTER	Off
EXTINGUISH FIRE	
FORCED LANDING PROCEDURES	Complete

b. Fixed Pitch Propeller

THROTTLE	Closed

LOWER THE A/C NOSE TRIM FOR BEST GLIDE SPEED (Then proceed with same drill as above from "MIXTURE idle cut off")

NOTE: In modern aircraft with the exhaust outlets situated below the engine and out of sight of the pilot, it may not be possible to assess whether the engine fire is an induction or exhaust fire.

It may then be advisable to use the exhaust fire extinguishing method which has been detailed above. However, should an induction fire be identified, OPEN THE THROTTLE FULLY during the engine shut down, procedure to use up the fuel in the carburetor and fuel lines as quickly as possible.

The above procedures are representative of most aircraft but the PILOT MUST FOLLOW THE PROCEDURES DETAILED IN THE PARTICULAR AIRCRAFT MANUAL.

ii. Simulate a cabin and/or electrical fire whilst in flight

Cabin smoke or fire: determine source of smoke

a. If electrical:

ELECTRICS	All off
FIRE EXT.	Use applicable type
CABIN VENTS	Open to remove smoke
ATC PROCEDURE	Carry out com failure

LAND AS SOON AS POSSIBLE

b. If not electrical:

FIRE EXT.

CABIN VENTS

RADIO CALL

LAND AS SOON AS POSSIBLE

EXERCISE 2

PREPARATION FOR FLIGHT AND ACTION AFTER FLIGHT

1. AIM

To learn thorough preparation for flight and action after flight.

2. INSTRUCTIONAL GUIDE

a) FLYING CLOTHING

The importance of wearing the appropriate flying clothing must be impressed on the student. Any discomfort will affect his flying.

b) FLIGHT AUTHORIZATION AND AIRCRAFT ACCEPTANCE

The use of the authorization book must be explained and the student should be shown how to complete these documents before and after flight. At this stage the student should not be overburdened with pre-flight planning details and only the more important points, such as the weather, aerodrome control requirements and the aircraft state should be mentioned.

c) EXTERNAL CHECKS

The instructor should point out:-

i. The positioning of the aircraft for starting – state of ground, direction in relating to buildings, other aircraft and wind direction and speed, etc.
ii. The precautionary presence of fire extinguishers.
iii. Chocks in position (if required).
iv. The importance of checking the immediate taxying path for obstructions which cannot be seen from the cockpit.
v. A detailed pre-flight check of the aircraft is carried out, as prescribed in the aircraft manual. The instructor should supervise all pre-flight checks of the aircraft, as the instructor is legally pilot-in-command of the aircraft.

d) INTERNAL CHECKS

On entering the cockpit, check that the student knows how to fasten and adjust his safety harness and see that he then adjusts his seat and rudder pedals to the most convenient positions so that he can apply full rudder and/or brake without having to strain. If unable to reach his rudders fully, ensure that the pupil uses a back cushion throughout his training. After these preliminaries the internal checks, as listed in the aircraft manual, should be done. During these checks the student should be kept actively engaged; this helps him to learn the internal checks, and make him more familiar with the cockpit.

e) STARTING AND WARMING UP

When demonstrating the startup procedures, the signals between the pilot and ground crew should be explained and the various safety precautions emphasized, where applicable. The student should be allowed to start the engine for his first flight, as this small achievement can make him more receptive to further instruction. During the warm-up period the student should be kept aware of the engine instrument readings and alert to any activity in the immediate vicinity of his aircraft.

f) POWER CHECKS

When carrying out power checks:-

i. The aircraft should, whenever possible, be headed into wind and at all times if the wind exceeds 15 knots.

ii. The control column or wheel should be held as applicable for the aircraft type.

iii. Power and systems check as per recommended procedure.

g) RUNNING DOWN AND SWITCHING OFF

It should be pointed out that the handling of High-performance engines necessitates a correct running down and stopping procedure to prolong the life of the engine and ensure reliability. Carry out the running down and stopping procedure as laid down in the expanded checklist. Explain to the student the danger of leaving the ignition and master switches on.

h) LEAVING THE AIRCRAFT

Explain the use of flying control locking mechanisms and point out the advisability of leaving the door or windows closed in wet weather and slightly open in extremely hot or cold weather. Explain the reason for releasing the parking brake after the chocks have been inserted. After vacating the cockpit, carry out a post flight inspection of the aircraft and explain that this is done to check for any signs of leaking fluid or other indications of unserviceability (bird strikes, etc.) Propellers should be dressed.

i) COMPLETION OF AUTHORIZATION BOOK AND FLYING RECORDS

Make sure the student knows how to record his flying times in the Authorization Book and the method of reporting defects.

NOTE:

The student cannot be expected to remember all the detail involved in this lesson. He should therefore continuously be supervised and checked as unobtrusively as possible, until he becomes proficient.

EXERCISE 3

AIR EXPERIENCE

1. AIM

To introduce the student to the sensation of flying and the totally new aspect of the ground when seen from the air.

2. INSTRUCTIONAL GUIDE

No flying instruction should be given during the exercise, but this does not detract from its potential usefulness. During this flight the instructor can make his initial assessment of the student's in-flight temperament and decide on a tentative manner of approach for subsequent instruction, the student becomes still more familiar with the aircraft and its operation by watching the instructor, and also becomes accustomed to the new environment and the novel sensations associated with flight, the flight should be made in the vicinity of the aerodrome and local flying area so that local prominent landmarks can be pointed out. After the student has settled down and is taking an active interest, his attention can be drawn to items such as the attitude and airspeed. If the student shows signs of becoming airsick, the flight should be discontinued and if he is sick, do not reveal any annoyance or show undue concern, but make light of the incident and assure him that his behaviour is not uncommon in the early stages.

NB. This flight is for the benefit of the student and not a pleasure trip for the instructor. Nor is it an opportunity for the instructor to demonstrate to the pupil his ability to handle the aircraft to its limits.

The impressions of the first flight can have a definite bearing on the student's subsequent interest, enthusiasm and ability to learn.

Many students may have had some form of air experience on some type of aircraft. The instructor should ascertain for himself the amount of experience a student may have acquired and use this period accordingly.

Introduce the importance of keeping a good look-out and reporting the position of other aircraft by the clock-code method.

Hold the student's attention throughout the flight by referring to checks and procedures where applicable.

CHAPTER 2

EXERCISE 4

EFFECTS OF CONTROLS

1. **DEFINITION:**

To introduce the basic controls/movements relationships of an aircraft and the factors that affect these movements.

2. **WHAT IS BEING TAUGHT:**

The primary and secondary effects of controls and factors affecting the effects of basic control movements.

3. **WHY IT IS BEING TAUGHT:**

To give the student a good understanding and thorough knowledge of the principles involved in the use of the basic flight controls.

4. **HOW THE EXERCISE APPLIES TO FLYING:**

these controls are used at all times while flying or even when the aircraft is on the ground and are therefore used in all of the following exercises that you will learn.

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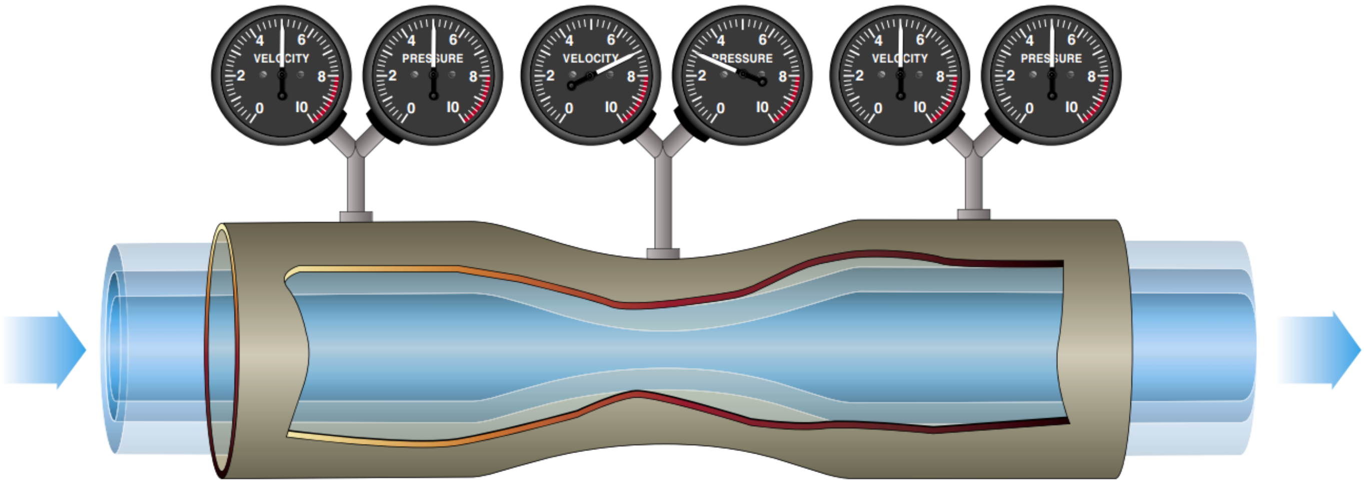
1. Bernoulli’s Principle

Bernoulli's Theorem states that in the streamline flow of an ideal fluid i.e. one which is not viscous, the sum of the pressure energy plus the potential energy plus the kinetic energy will remain constant. In other words, the total energy of a particle in motion is constant at all points on its path in steady flow. Because of the insufficient change of height of the fluid to have any appreciable effect on the potential energy, only pressure and kinetic energy will be considered. Therefore, if the velocity (kinetic energy) increases, then the pressure energy must decrease to keep the sum of energies constant and vice versa. The visible proof of this phenomenon is the airflow through a venturi tube.

1. THE VENTURI TUBE



Air pressure decreases in a venturi tube.

Fig. 2-1: The Venturi Effect

An interesting example of Bernoulli's Theorem is provided by the venturi tube. This is a simple yet effective tube which gradually narrows to a throat, then gradually expands again to the exit. Photographs and drawings of an airflow passing through this venturi show that the fluid streamlines are closer together at the throat of the venturi. See Figure below. This gives the impression that the fluid has been compressed at this point. Not so. A distinguishing feature of subsonic airflow (air moving below the speed of sound) is that when changes in pressure and velocity occur, there are small and negligible changes in density. When the airflow approaches the speed of sound, the flow must now be considered as compressible. Thus in dealing with subsonic airflows, the density is considered to remain at a constant value. Static Pressure and Velocity are the variable quantities.

2. The Aerofoil – Creation of Lift

Lift is defined as that component of the Total Reaction which acts at 90° to the relative airflow.

a) LIFT PRODUCING SURFACES

Early experiments found that a flat plate, inclined at an angle to the air through which it was being moved, produced a force which tried to push the plate upwards and backwards. The upwards force was quite capable of supporting the weight of the plate and was called lift. The backwards force represented a resistance to forward motion and became known as drag. At this stage the sole upwards force was created by the air pressure against the under surface of the plate and this, combined with the flat shape, proved to be very inefficient and unstable.

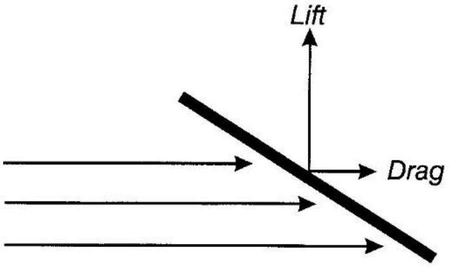


Figure 2-2: Lift and Drag Associated with a Flat Plate

Further development showed that by applying the venturi principle and creating a curved upper surface additional lift could be created since, as the airflow velocity over the upper surface increases, the pressure decreases effectively sucking the wing upwards. The resultant shape was more streamlined, created less drag and became known as an aerofoil. The cross sectional view is called an aerofoil section. See Figure 2-3.

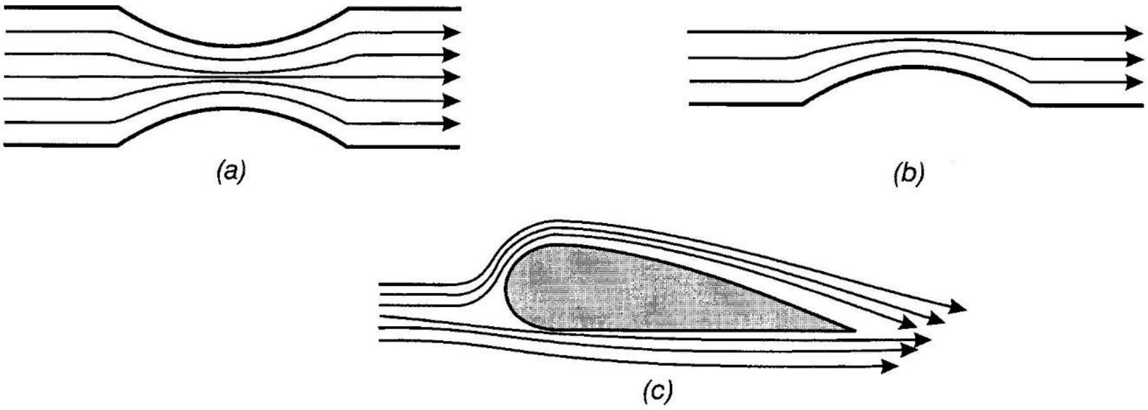


Figure 2-3: Development of Aerofoil Section

The venturi tube at Figure 2-3 (a) is modified by removing the upper portion (b), and creating the aerofoil section (c).

At this point it is necessary to examine the aerofoil section more closely and identify some of the definitions associated with it in order to further explain how lift is created.

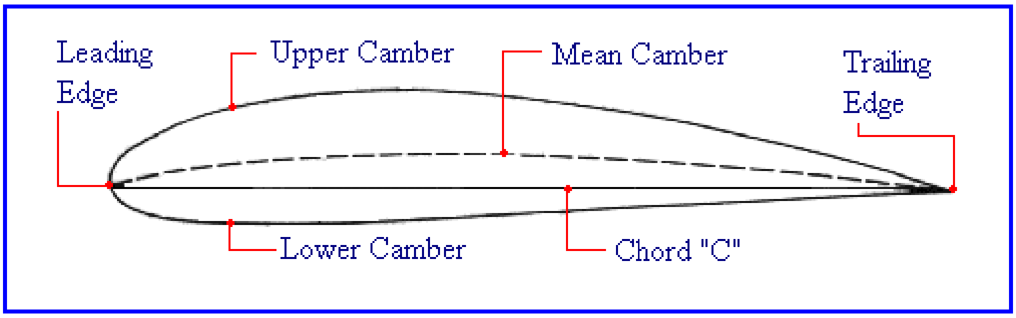


Fig 2-4: The Aerofoil Section

Referring to Figure 2-4, the term **Camber** is used to describe the curved surface of an aerofoil. We should note that it is not only the upper surface of the aerofoil that can have camber, but the lower surface as well. The **Chord Line** is of theoretical value and is represented by a straight line joining the centre of curvature of the leading edge with the trailing edge. The significance of this line is angle it forms with the **Relative Airflow**, the **Angle of Attack**. If we consider how lift is created it becomes easier to understand how it can be varied. Airflow over the upper surface is accelerated by the venturi effect, creating a decrease in pressure.

Definitions:

CHORD LINE

The straight line joining the centres of curvature of the leading edge to the trailing edge.

CHORD LENGTH

The distance between the leading edge and trailing edges measured along the chord.

MAXIMUM THICKNESS

The point where the upper and lower surfaces of an aerofoil section are the furthest apart.

THICKNESS/CHORD RATIO

The maximum thickness or depth of an aerofoil shape expressed as a percentage of chord length. Corresponds to the Fineness Ratio of a streamlined body.

FINENESS RATIO

The ratio of depth to length of a streamlined body.

MAXIMUM EFFECTIVE THICKNESS

The thickness of an aerofoil at the point through which the centre of pressure acts, measured at right angles to the relative airflow.

RELATIVE AIRFLOW

The airflow that is opposite and parallel to the flight path of the aircraft.

ANGLE OF ATIACK

The angle between the chord line and the relative airflow.

ANGLE OF INCIDENCE

The angle formed between the chord line and the longitudinal axis of the aircraft.

MEAN CAMBER LINE

A line joining the leading and trailing edges of an aerofoil that is equidistant from the upper and lower surfaces. When the camber line lies above the chord line, the aerofoil has a positive camber.

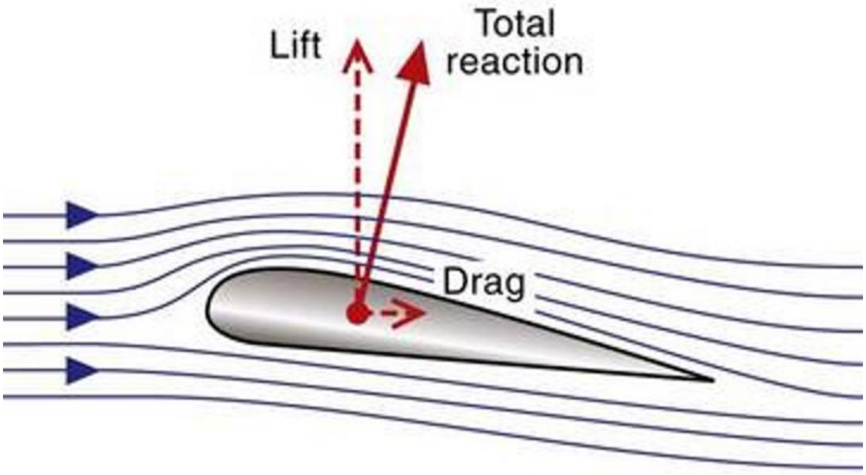
CAMBER

The measure of curvature of the upper surface of an aerofoil and is measured as the maximum distance between the camber line and chord line.

CENTRE OF PRESSURE

The position along the chord line at which the resultant force acts is called the centre of pressure.

TOTAL REACTION



The resultant lift produced from the components of lift and drag.

LIFT

The component of the total reaction which acts at right angles to the relative airflow.

DRAG

The component of the total reaction which acts parallel to the relative airflow.

FREE STREAM FLOW

Air in a region where pressure, temperature and relative velocity are unaffected by the passage of an aircraft through it.

The free stream flow is also called the relative airflow which is the airflow which is parallel to and opposite to the flight path of the aircraft.

WING AREA

Area of the wing projected on a plane at right angles to the vertical axis.

The weight per unit area of the wing – $\frac{\text{weight}}{\text{wing area}}$

ASPECT RATIO

The ratio between the span of a wing and its chord. In the case of swept wings or wings of unusual shape the aspect ratio is equal to -

$$\frac{\text{span squared}}{\text{area}}$$

STREAMLINE

The path traced by a particle in a steady fluid flow.

CENTRE OF PRESSURE

The position along the chord line at which the Total Reaction acts.

b) AIRFLOW AROUND AN AEROFOIL

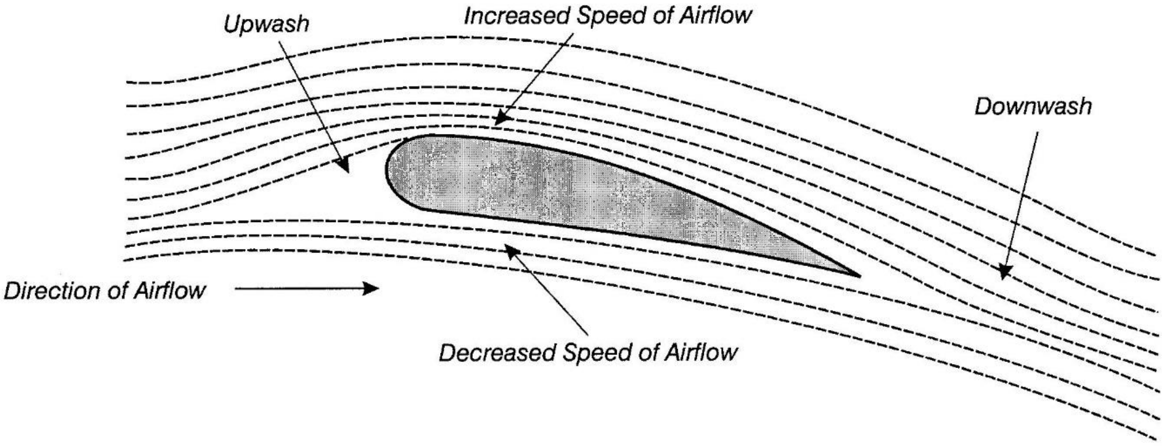


Figure 2-5: Airflow Around an Aerofoil

Figure 2-5 shows the airflow around a typical aerofoil. The following results are noteworthy:

1. There is a slight "up wash" of the airflow before reaching the aerofoil.
2. There is a "downwash" after passing the aerofoil. This is caused by the creation of lift and is an example of Newton's Third Law: To every action there is an equal and opposite reaction. In this case the upward force (lift) which is exerted on the wing exerts an equal force on the air, in this case downwards, which we call the downwash.
3. The streamlines are closer together above the aerofoil (at the thickest part) where the pressure is reduced.

With reference to point 3 above, the air over the top surface of the aerofoil passed through a bottleneck, similar to a venturi tube. This bottleneck is created between the thickest portion of the aerofoil and the free stream flow. Therefore, the increase in kinetic energy due to the increase in velocity is accompanied by a corresponding decrease in static pressure. Likewise, there is an increase in pressure below the aerofoil (due to ram effect) and the decrease in kinetic energy due to the decrease in velocity.

Because of the two pressure differentials acting on an aerofoil - reduced pressure above and increased pressure below, they are unable to "cancel" each other due to the presence of the aerofoil. In this instance, where a pressure differential exists, the high pressure simply "pushes" the aerofoil into the region of reduced pressure. This upwards force is called - LIFT.

The magnitude of the total reaction is boosted by the value of the decreased pressure above the wing at certain angles; the lift so produced may be as much as 4/5 of the total lift from the top and 1/5 from the bottom.

PRESSURE DISTRIBUTION AROUND AN AEROFOIL

Figure 2-6 shows the pressure distribution around an aerofoil at an angle of attack of about 4 degrees. The following points should be noted:

1. There is a pressure decrease on the upper surface of the aerofoil and a pressure increase below the aerofoil.
2. The pressure is not evenly distributed. The pressure decrease above the aerofoil is greater than the pressure increase below the aerofoil.
3. Both decreased and increased pressures are greatest near the frontal portions of the aerofoil.

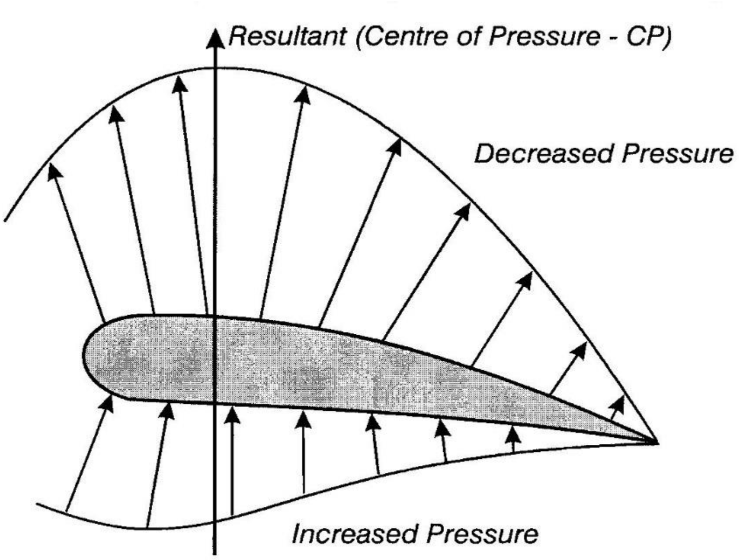


Figure 2-6: Pressure Distribution Around an Aerofoil

It should be remembered that although both surfaces (upper and lower) contribute to lift, it is the upper surface that contributes most to lift.

(a) Therefore, it stands to reason that on highly cambered aerofoils, the airflow is forced to increase its velocity (venturi effect is more pronounced) thereby resulting in a corresponding large decrease in pressure.

(b) By increasing the angle of attack, the aerofoil becomes "effectively thicker" thus giving the airflow a greater acceleration over the upper surface of the aerofoil resulting in a larger pressure decrease with each successive corresponding increase in angle of attack.

Refer to Figure 2-6 again. If all the distributed pressures acting on the aerofoil were replaced by a single resultant force, the position on the chord at which this resultant force acts is called the centre of pressure (CP). Its location is a function of both camber and angle of attack.

7. PRESSURE PLOTTING

As the angle of attack on an aerofoil is altered, lift and drag vary very rapidly due to the pressure distribution changes over the aerofoil. These pressure changes can be clearly demonstrated by a method known as pressure plotting, during which a number of small holes in the surface of an aerofoil are connected to the glass tubes of a manometer. These tubes contain a liquid which reacts to changes in the pressure at the various positions on the aerofoil surface. As the pressure decreases the suction effect causes the fluid to be sucked up the tube. An increase in pressure results in the fluid being compressed in the tube. Figure 2-7 shows the manometer principle.

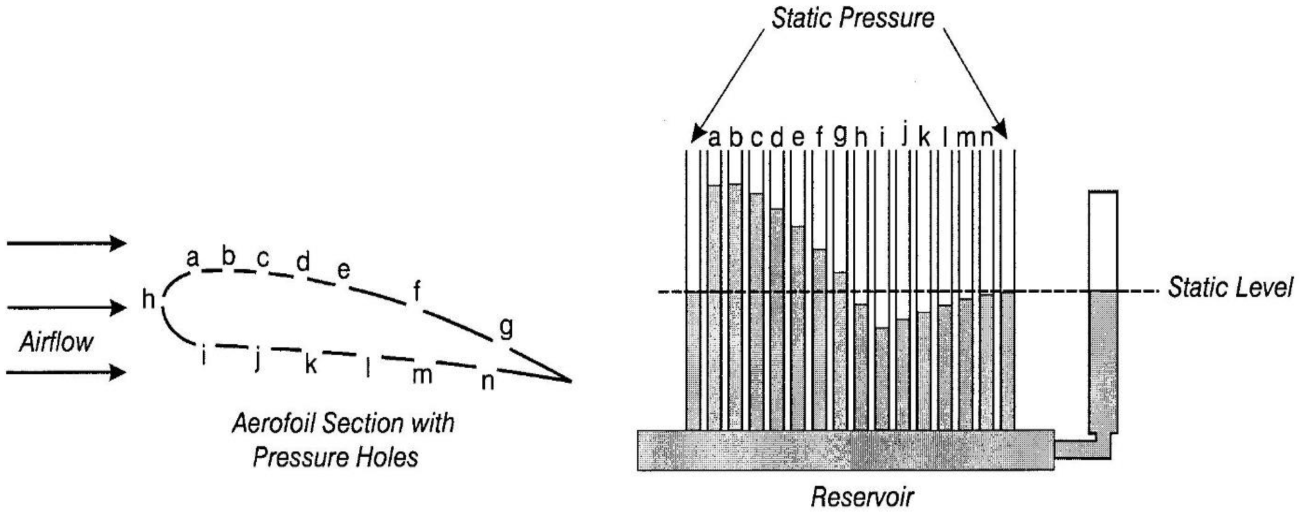


Figure 2-7: Pressure Plotting

In Figure 2-7 an aerofoil is shown at a slight positive angle of attack (approx. +3°). It can be seen that pressure holes a-g on the top surface and the pressure tubes associated with them are all showing a reduction of pressure. Similarly, holes h-p along the bottom surface all show an increase of pressure.

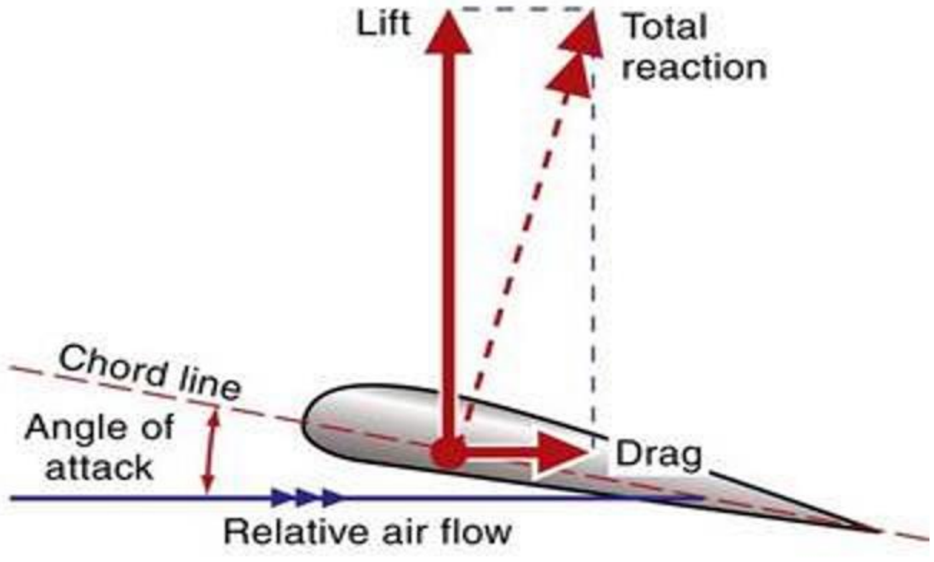
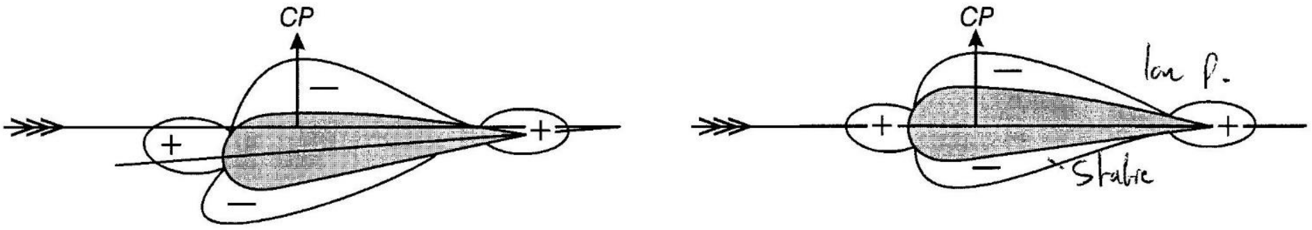


Fig 2-8: Relative Airflow and Angle of Attack

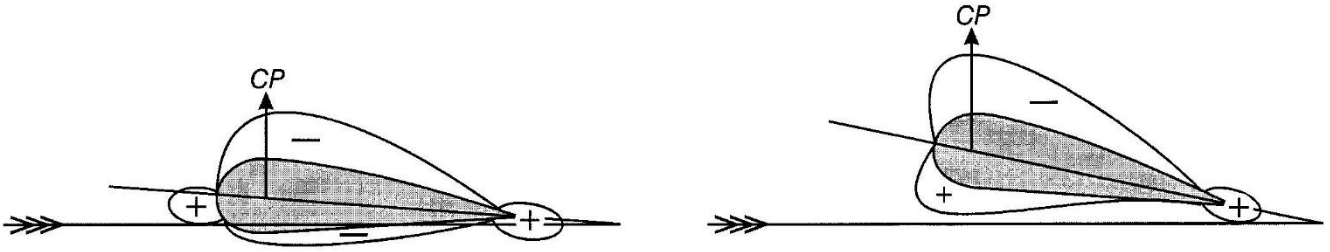
8. CENTRE OF PRESSURE AND ITS MOVEMENT WITH ANGLE OF ATTACK

The pressure distribution above the upper surface and below the bottom surface of an aerofoil section is shown in Figure 2-9, below.



(a) -4° Angle of Attack

(b) 0° Angle of Atttack



(c) +4° Angle of Attack

(d) +8° Angle of Attack

Fig 2-9: Centre of Pressure and Its Movement

Apart from the zero and below zero angles of attack, where the positive pressure area over the upper surface of the leading edge together with a negative pressure under the bottom surface combine with the aft position of the centre of pressure to cause a nose down couple, it can be noted that, as the angle of attack increases, the centre of pressure moves forward because the highest point of curvature (the throat of the venturi) moves forward. This forward movement of the centre of pressure is unstable in that it increases the tendency for the nose to continue rising after an upward displacement in the pitching plane.

This unstable tendency continues until the stall where the sudden decrease of lift over the top surface causes a backward movement of the centre of pressure which tends to make the nose drop and is therefore a stable movement, (see Chapter 6, Stalling). In addition to the movement of the centre of pressure, note that the lift coefficient increases with an increase in angle of attack from a negative angle of between 1 and 4 degrees where there is zero lift, the actual angle at which lift is zero depends on the percentage camber. A symmetrical aerofoil has a zero lift angle of attack of 0° and one with 2% camber has zero lift at _2°; average general purpose aerofoil sections usually have zero lift at _4° angle of attack.

Note also that, because of the venturi effect over the upper surface, an aerofoil is generating lift at a zero angle of attack. In normal flight the angle of attack will vary between 0° and 6° for level flight, climbing and descending, and greater angles of up to 14° during the landing.

However, if the aerofoil is tilted downwards to the airflow until it produces zero lift and a straight line is drawn through the aerofoil parallel to the airflow, it will be the inclination of this line which determines whether or not the aerofoil produces lift.

c) THE LIFT FORMULA

The following formula describes the relationship of the factors that create lift in a wing. As can be seen from fig. 2-3 the flow of air over the airfoil creates a low pressure area over the top of the aerofoil while the bottom of the aerofoil is subject to a higher pressure. The result of the forces create a lifting force. Fig. 2-5 indicates how angle of attack is another factor affecting lift. Let's look at the lift formula:

$$\text{Lift} = C_L \tfrac{1}{2}\rho V^2 S$$

Where:

CL is the coefficient of lift. Or simply, the value of lift for a given **angle of attack**,

ρ is the air density,

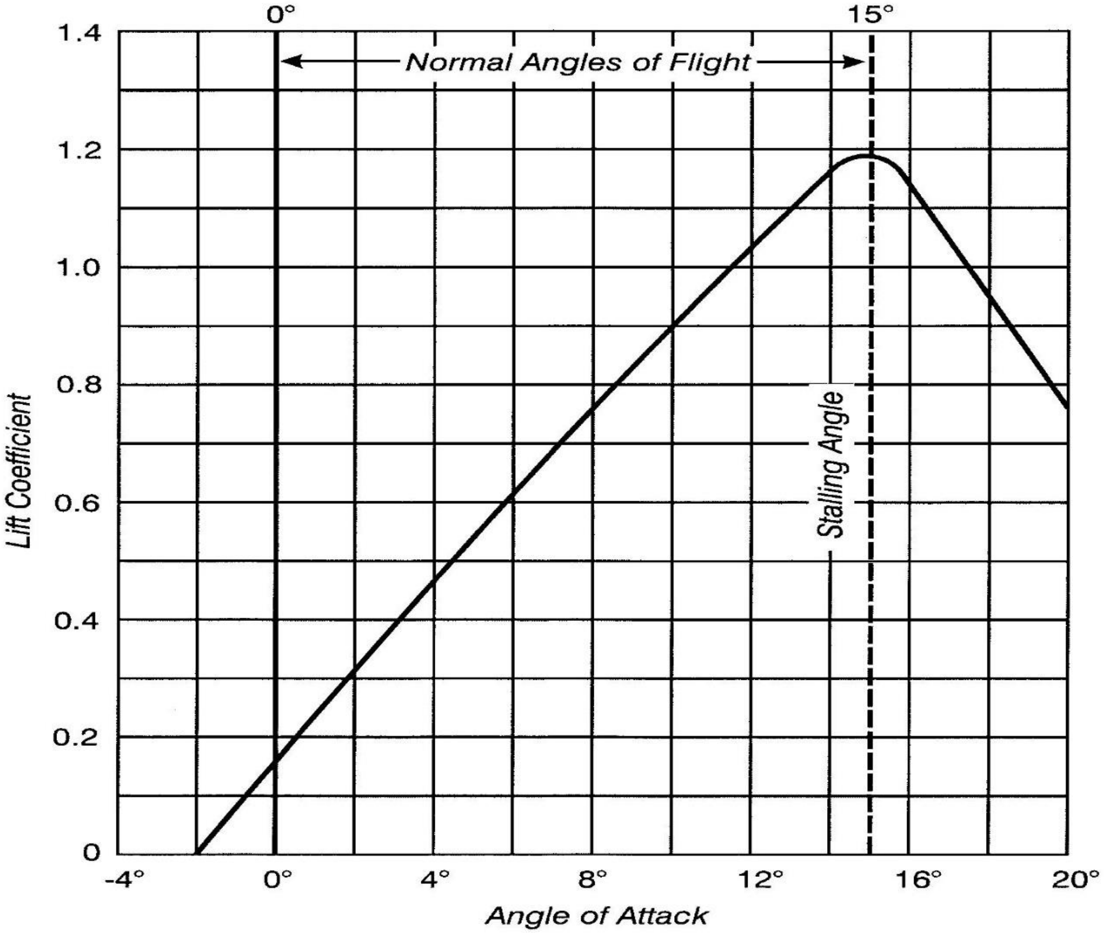
V^2 is the velocity (TAS) in feet or metres per second squared. In other words, if the speed is **doubled**, the lift increases **fourfold**,

S is the surface area of the wings.

Density is generally regarded as a constant value over short periods of time and in level flight. The surface area is also regarded as a constant value, although it is possible to increase the surface area of the wings on some aircraft by using flaps, it is not normally a consideration for level, cruising flight. All of which means that we are left with velocity and angle of attack as the variables in lift production. So, assuming that we want to maintain a constant altitude:

(a) If we reduce the speed, the angle of attack must be increased to maintain the same value of lift, and

(b) If we increase the speed, the angle of attack must be decreased to maintain the same value of lift.



d) NEWTON’S LAWS

(i) NEWTON'S FIRST LAW OF MOTION

A body that is at rest, tends to remain at rest. A body that is moving, tends to continue moving at the same rate and in the same direction, unless acted upon by an external force.

(ii) NEWTON'S SECOND LAW OF MOTION

When a force is exerted on a body to change its state of rest or uniform motion, the acceleration so produced is proportional to the applied force and acts in the same direction.

(iii) NEWTON'S THIRD LAW OF MOTION

To every action there is an equal and opposite reaction.

e) FLAP TYPE CONTROLS

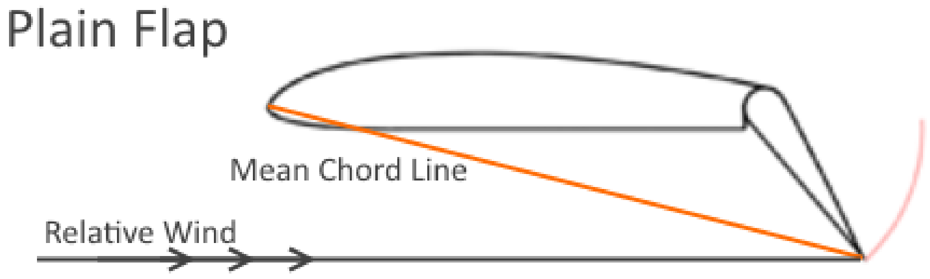


Fig 2-10: Basic Flap-type Control

As we have seen, it is the shape of the aerofoil which affects the lift characteristics. Consider the effect it will have if we are able to change the shape of the wing in flight, and how we can achieve this.

By attaching a hinged surface at the trailing edge of the wing, we obtain a wing in which the tailing edge can move up or down, thus affecting the camber and also the mean chord line of the aerofoil. In its neutral position the flap will line up precisely with the forward part of the wing and thus will have no effect on the aerofoil. However, if we deflect it downward, two things will happen:

1) The *camber* of the upper surface of the wing is increased, thereby increasing the lift, and

2) The *mean chord line* has now changed its angle of attack, thus also increasing the lift.

This is the fundamental method of controlling the three axes of movement of an aircraft in the air.

The result of this movement will depend on where the controls are positioned, the size of the control surface, and the amount of displacement and the speed of the air flow around it.

f) PLANES OF MOVEMENT FOR FLIGHT CONTROLS RELATIVE TO THEIR AXES

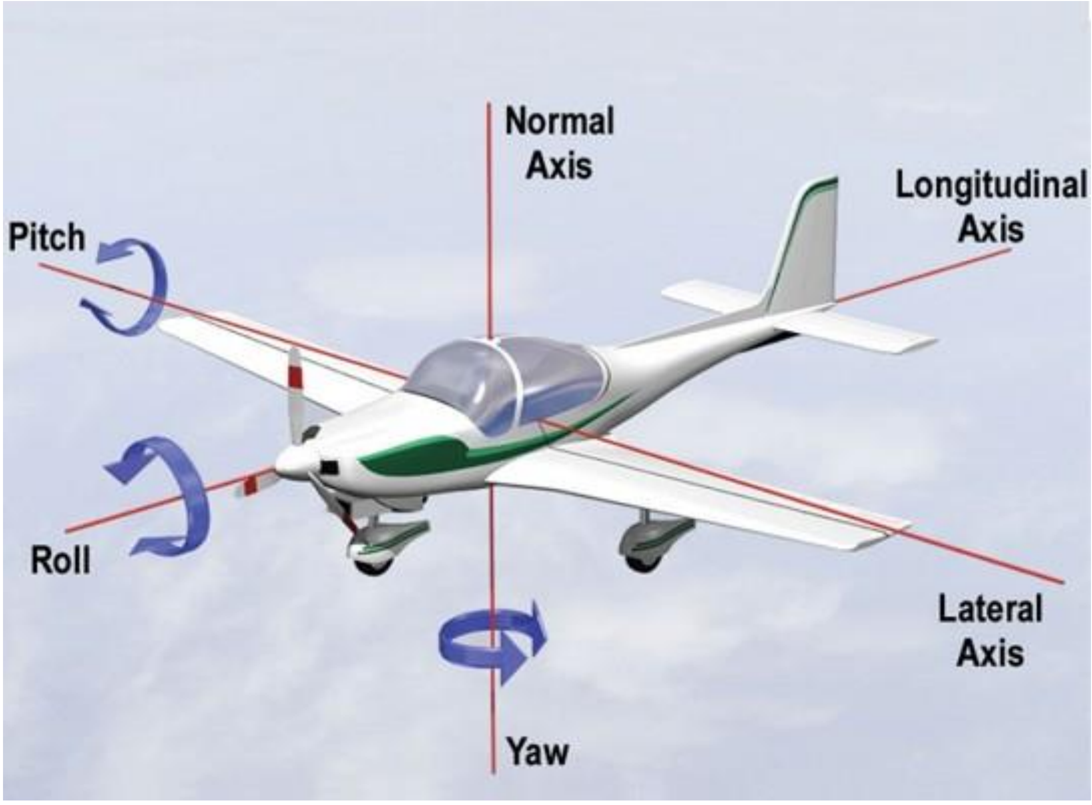


Fig 2-11: The Axes of Movement and Control

INTRODUCTION

An aeroplane has three imaginary planes or axes about which it may move and is controlled about these axes by appropriate controls, either individually or by a combination of all three. All three axes pass through the centre of gravity.

1. THE LONGITUDINAL AXIS

The ***longitudinal*** axis is the axis about which the aeroplane rolls. Ailerons are mounted on the outboard trailing edge of each wing and are used to control the roll.

To the pilot seated in the cockpit, and looking forward, when the control column is moved to the left the left aileron moves up, reducing the lift on that portion of the wing in front of the aileron by reducing the of angle of attack and camber; whilst the down going aileron increases the camber and angle of attack, thus producing greater lift on the right wing, resulting in an imbalance of lift which leads to roll.

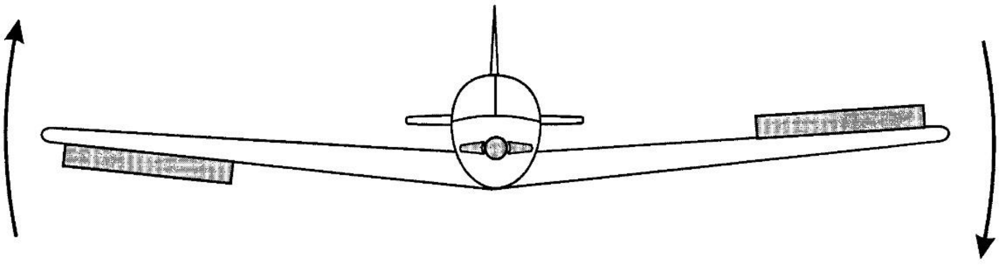


Figure 2-12: Roll

Roll is ***referred*** to as the primary effect, or the initial response, of the aeroplane to the application of ailerons. If the ailerons are applied and no attempt is made to maintain balanced flight a secondary or further effect of ailerons will be noticed. When ailerons are applied the aeroplane will start to roll, the lift force now tilted in the direction of the bank will cause a sideslip towards the lower wing. The resultant airflow striking the fin of the aeroplane provides a weathercock effect and causes it to yaw further in the direction of the sideslip. If not corrected by the pilot a **spiral dive** will result.

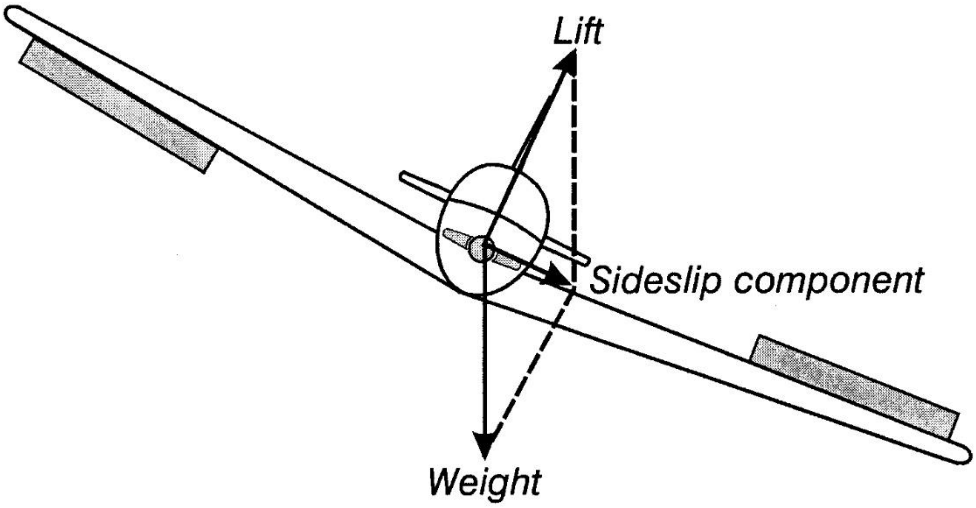


Figure 2-13: Further Effect of Ailerons

2. THE VERTICAL AXIS

The ***vertical*** or ***normal*** axis is the axis about which the aircraft ***yaws***. The ***rudder*** controls the yaw. When the left rudder pedal is depressed, the rudder moves out of symmetry to the left. This causes an effective angle of attack and camber increase which in turn increases the lift and pulls the tail to the right. As viewed by the pilot, the nose yaws left.

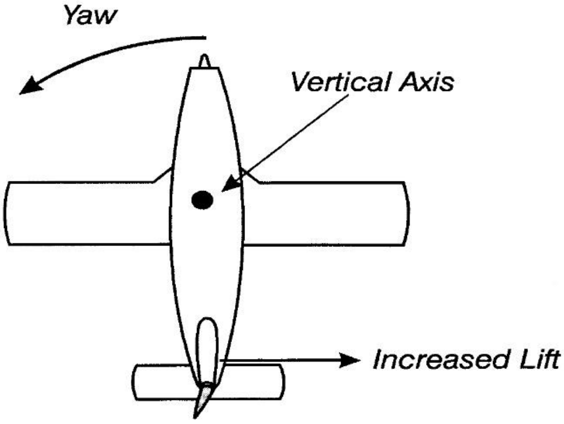


Figure 2-14: Yaw

Yaw is referred to as the ***primary*** effect of the rudder and, as with the ailerons, if rudder is applied without maintaining balance a further effect will be experienced. Following the application of rudder, the outer wing will start to travel faster than the inner wing. Increased speed means increased lift and the aeroplane will start to roll. Even as the aeroplane is rolling it is still yawing, now towards the lower wing and the aeroplane will enter a spiral dive.

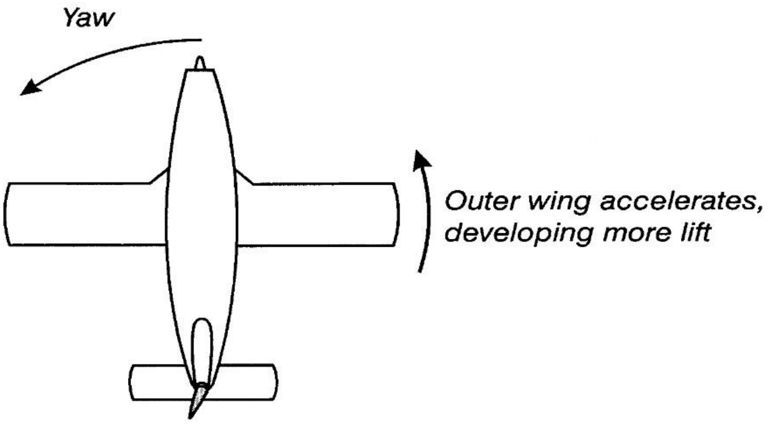


Figure 2-15: Further Effect of Rudder

In both cases, ***recovery*** from the spiral dive is the same:

(a) Close the throttle completely,
(b) Level the wings using both ailerons and rudder,
(c) Ease the aeroplane gently out of the dive with the elevator,
(d) Apply full power ***once the excess speed has bled off*** and there is no danger of over-revving the engine.

3. THE LATERAL AXIS

The ***lateral*** axis is the axis about which the aeroplane ***pitches***. The ***elevator***, mounted on the tail of the aeroplane controls the pitch. When the control column is pushed forward the trailing edge of the elevator moves downwards. This leads to an increase in the angle of attack and camber of the tail plane which increases the lift, producing a lifting force to the tail. With respect to the pilot, the nose is lowered. The reverse applies when the control column is moved backwards.

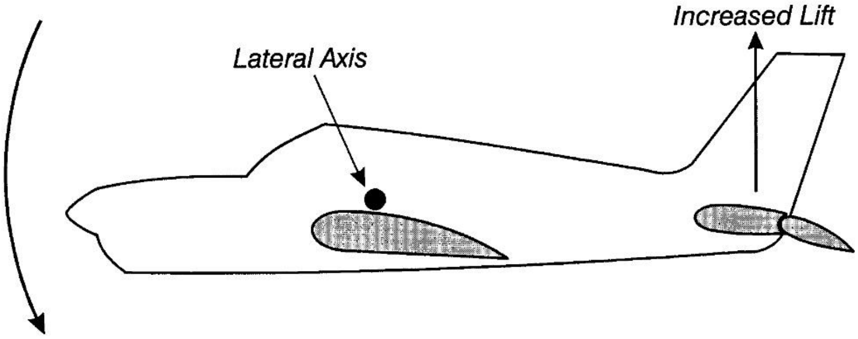


Figure 2-16: Pitch

FURTHER EFFECT OF ELEVATOR:

Except for the change in speed that results from the use of the elevator, no further effects are noted.

NOTE: Occasionally, the effect of two controls are combined in a single set of control surfaces.

These are:

(i) ELEVONS

The effect of ailerons and elevator are combined e.g. Delta wing type aeroplanes.

(ii) RUDDERVATOR

The effect of rudder and elevator are combined. This is found on the 'V" tail installations such as the Beechcraft Bonanza.

The effectiveness of the controls depends on the following:

(i) SIZE OF THE CONTROL.

The control surfaces are lift producing surfaces. If the size, or the camber are increased the surface will produce more lift making the control that much more effective. This is, of course, a design feature and not something that can happen during flight.

(ii) INCREASED SPEED

Lift increases with the square of the speed. Therefore at higher speeds the controls become more effective.

(iii) ANGLE THROUGH WHICH THE CONTROL IS DEFLECTED.

Deflecting a control effectively increases the camber of the area to which it is attached. The greater the deflection the greater the camber, the greater the lift, the more effective the control.

(iv) THE DISTANCE OF THE CONTROL FROM THE CENTRE OF GRAVITY (i.e. moment arm).

The moment arm can be defined as the distance of the control from the centre of gravity. The longer the arm, the more effective will be the force created by the control. This can be related to the principles of weight and balance discussed elsewhere.

g) AILERON DRAG

Aileron drag, sometimes referred to as **adverse aileron yaw**, is an initial yaw in the opposite direction to the applied roll. When an aileron is deflected downwards, its wing experiences an increase in drag.

This is due to the following:

1. The deflected aileron enters an area of high pressure, thus increasing the drag.
2. The camber on that wing is increased, thereby increasing the drag.
3. There is an increase in induced drag as the pressure on the under surface ol the wing increases and hence the spillage of the air around the tips increases (i.e. tip vortices).

However, the 'up aileron" wing experiences a reduction in drag. Thus, due to the changes in the drag force on each wing, a resultant yaw is set up causing the aeroplane to yaw initially in the opposite sense to the applied roll whenever aileron is applied: The effect can be quite marked during low speed, high angle of attack flight when greater aileron deflection is required for control. lt.is, however, of less significance with small applications of aileron or at higher speeds or lower angles of attack.

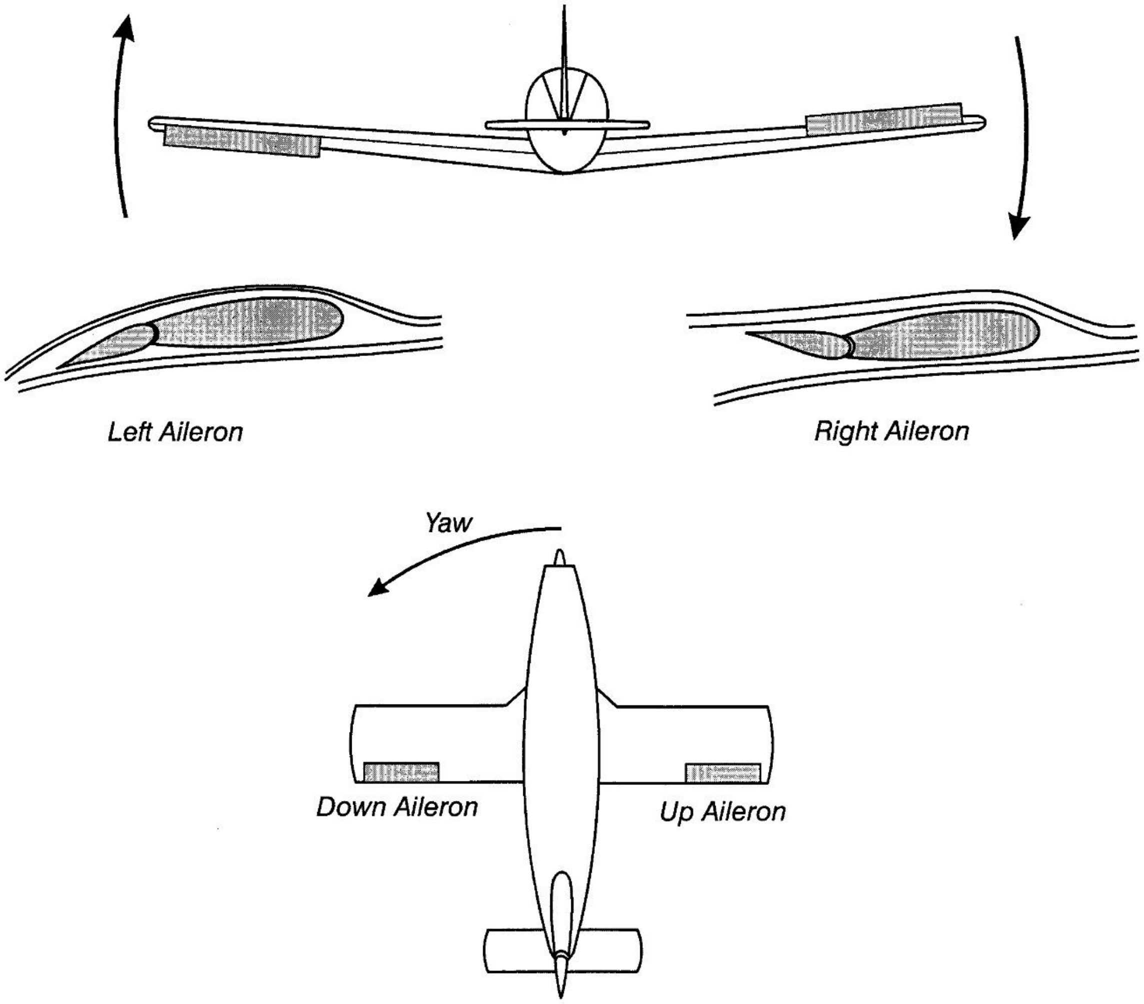
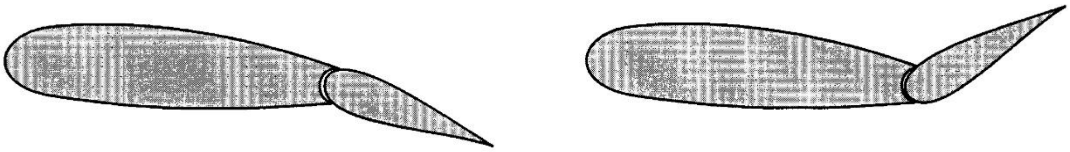


Figure 2-17: Aileron Drag

The following design features are incorporated to reduce aileron drag:

1. DIFFERENTIAL AILERONS

For a given control column deflection, the up going aileron moves through a greater arc than the down going aileron. Thus, the drag so produced by each aileron is nearly equal and almost eliminates the differential drag so set up, which would otherwise lead to adverse yaw. This system is used in the Piper Cherokee series.


(a) Full downward movement

(b) Full upward movement

Figure 2-18: Differential Ailerons

2. FRISE AILERONS

In this case the ailerons are hinged at a point slightly aft of their leading edges. When the ailerons are deflected from their neutral position this allows the leading edge of the up going aileron to protrude into the airflow below the wing, (high pressure), whilst the leading edge of the down going aileron remains below the upper surface of the main plane. In theory the combined drag of the up going aileron is balanced by the drag experienced by the down going aileron.

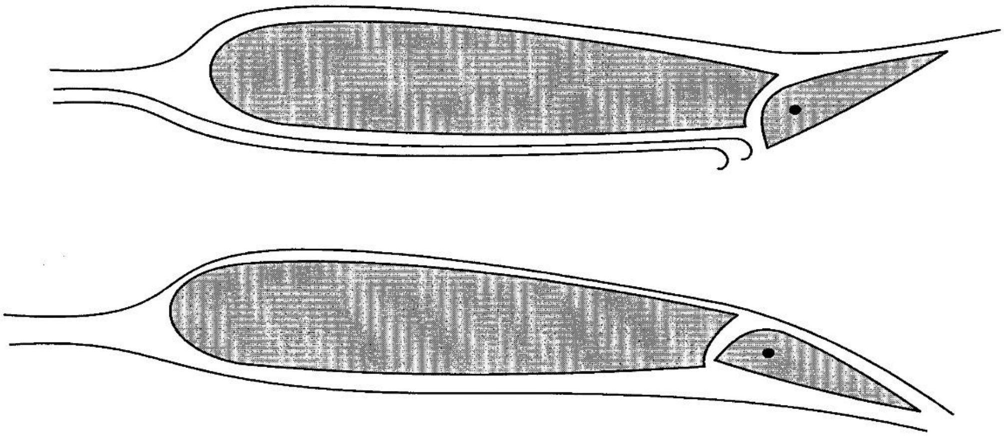


Figure 2-19: Frise Ailerons

3. SPOILERS

As the name implies, spoilers are devices used to spoil or disturb the airflow thus creating drag. They are long, narrow metal plates which, in normal flight, lie flush with the surface of the aerofoil. In addition to being used as air brakes, they can be incorporated into the aileron system so that as the aileron moves up the outboard spoiler on the same side is raised into the airflow decreasing the lift, increasing the drag and correcting the adverse yaw. This type of system is more commonly used on high performance aeroplanes.

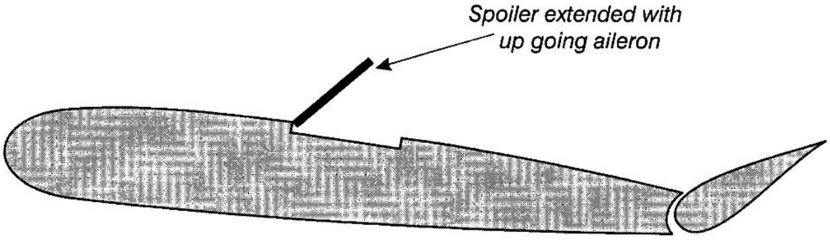


Figure 2-20: Spoiler

4. COUPLED CONTROLS

Some aeroplanes employ a system which couples the ailerons and the rudder. Any aileron deflection automatically activates the rudder, which moves to produce an opposite yawing moment.

5. SLOT-CUM-AILERON CONTROL

This method utilises slots which are located on the outboard leading edge of the wings in front of the ailerons. The slots may be either automatic or interconnected to the aileron so that, as the aileron moves downwards, the slot opens. The slot remains closed when the ailerons are in the neutral or raised position. This means that the down going aileron will increase the lift on that wing, while the slot will lessen the effect of eddy formation. Thus a greater roll tendency is obtained while the yaw tendency is greatly reduced.

6. CONTROL CO-ORDINATION

Although the systems just discussed go a long way in minimising aileron drag, it is **impossible to eliminate it altogether** and the pilot will still have to do some work. Given that the by-product of roll is yaw, the obvious control to use to **counteract aileron drag is the rudder**. **Co-ordination** between ailerons and rudder inputs is essential to maintain balanced flight.

h) EFFECTS OF AIRSPEED

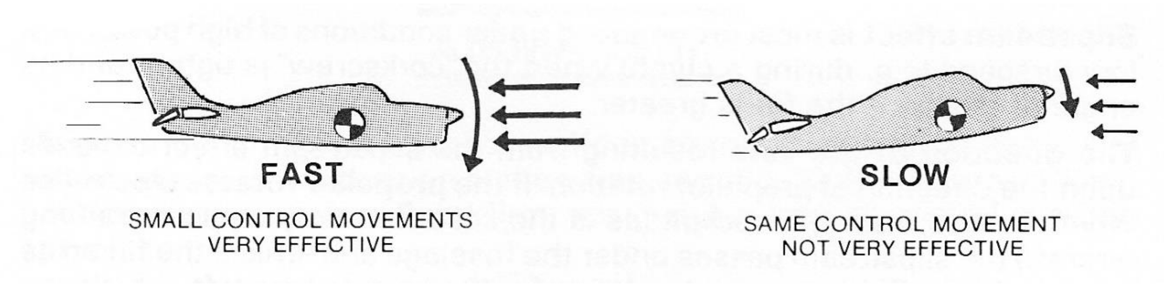


Fig 2-21: Effect of Airspeed

The elevator, ailerons and rudder will all experience an increased airflow at higher airspeeds. Each control will feel firmer – small movements required to produce effective response.

At low airspeeds the airflow over the control surfaces is reduced. Elevators, ailerons and rudder will all feel sloppy – large movement required to produce the desired effect.

At high airspeeds the wings produce more lift and therefore the angle of attack needs to be reduced to maintain straight and level flight compared to the angle of attack required at low airspeeds.

i) EFFECT OF SLIPSTREAM

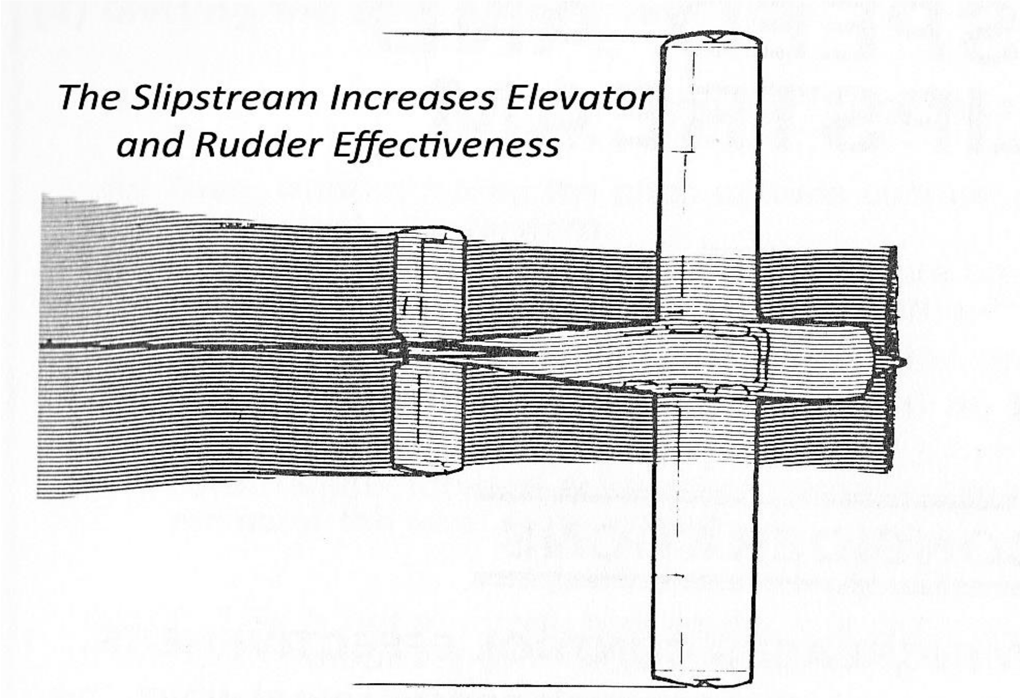


Fig 2-22: The Effect of Slipstream

The slipstream from the propeller flows rearward around the aeroplane in a corkscrew fashion, which increases the airflow over the tail section making the rudder and elevator more effective. The ailerons being outside of this slipstream are not affected by it and will remain sloppy at low airspeeds irrespective of power sittings.

The corkscrew fashion in which the slipstream flows along the fuselage results in the slipstream hitting the fin at an angle. This generates a sideways force which tends to yaw the nose of the aircraft – corrected with rudder.

Fig 2-23: Corkscrew Effect of Slipstream.

j) EFFECT OF POWER CHANGES

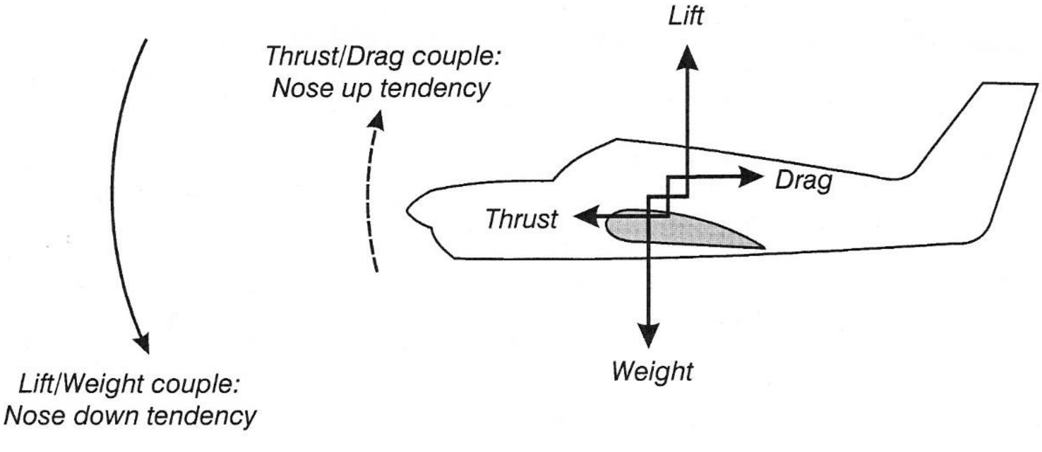


Fig 2-24: Couples Acting On an Aeroplane

i.) INCREASING POWER:

An increase in power results in a nose up pitching tendency. In addition the aircraft will roll and yaw in the opposite direction to the direction of rotation of the propeller. This is caused by the slipstream effect on the keel surface, and the changed angle of attack on the vertical fin.

ii.) DECREASING POWER:

A decrease in power results in a nose down pitching tendency. If the aircraft has been trimmed to account for the yawing effect of the increased power, it will roll and yaw in the direction of the applied trim.

k) EFFECT OF FLAPS

The flaps are attached to the inboard trailing edge of each wing. They are operated from the cockpit - in some aeroplanes electrically by a switch and, in others, mechanically by a lever. They operate symmetrically on each wing.

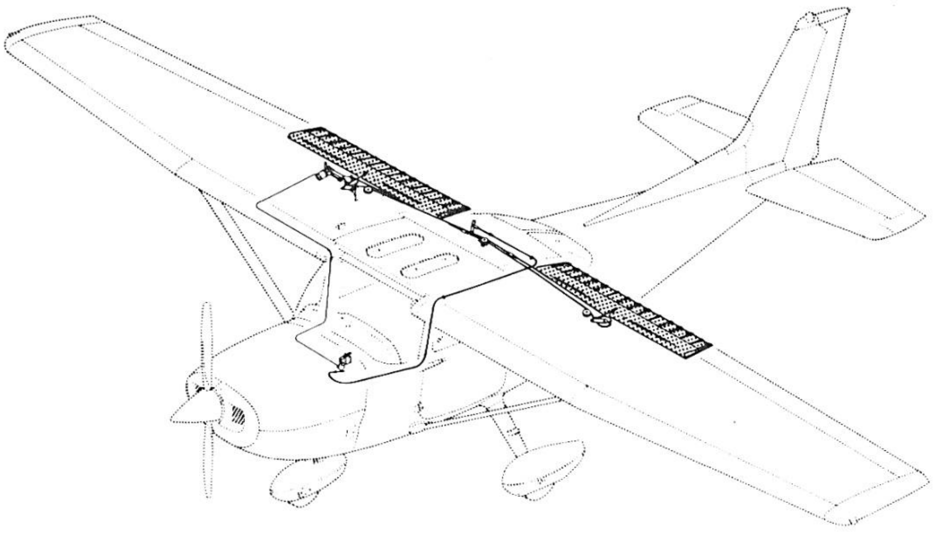


Fig 2-25: The Wing Flaps

Flaps alter the shape of the wings and the airflow around them. This changes the lifting ability of the wings, altering both the Lift and Drag generated. !n a sense, flaps create new wings. They are used to:

i.) Generate the required Lift at a lower speed (allowing safe flight at low airspeeds as well as reducing take-off and landing distances);

ii.) Increase Drag and steepen the descent path on approach to land;

iii.) Improve forward vision as a result of the lower nose attitude.

The flaps may be used to serve various purposes simultaneously; for example, to steepen the descent path while at the same time allowing better forward vision and safe flight at a lower airspeed. As the flaps are lowered the changes in lift and drag will cause a pitching tendency. This will result in the aeroplane 'ballooning' unless counteracted with pressure on the control column. Conversely, when flap is raised, there will be a pitching tendency in the opposite direction and a tendency to sink.

Once attitude and power changes are complete, and the airspeed has stabilised at the desired value, these pressures can be trimmed-off. In general, a lower pitch attitude is required to achieve the same airspeed when flaps are lowered compared to when the wings are 'clean'.

The initial stages of flap are sometimes called 'lift flaps', because the lifting ability of the wing is increased considerably even though there is the cost of a small amount of extra drag. Flaps allow the required lift to be generated at a lower speed.

The larger flap settings are sometimes called 'drag flaps', because they cause a marked increase in Drag for little improvement in lifting ability. If airspeed is to be maintained, the increased drag must be balanced by either:

i.) additional thrust; or

ii.) a greater component of the weight force acting along the flight path (achieved by steepening the descent).

"Lift Flaps" are normally in the range of up to 20^o of flaps, where increasing flaps beyond this falls into the range of "drag flaps".

Maximum flap speed (V_{fe}) is indicated by a white arc on the airspeed indicator. Imposed to avoid excessive stresses on the aircraft flap mechanisms.

l) EFFECT OF UNDERCARRIAGE

Not typically on training aircraft. In general the lowering of undercarriage results in a slight increase in stalling speed, a reduced airspeed (due to increase in drag) and a resultant pitching down moment.

m) THE TRIMMER

Trimming controls are designed to relieve the pilot of sustained loads on the flying controls. Correct method is to select the required attitude by use of primary flying controls, then adjust the appropriate trimmer until no pressure is required on the control column or rudder pedals, Change in trimmer position normally required after changes in power, speed, and flap setting, and also after variation in load.

Trimming controls are powerful and sensitive and should be used carefully. Trimming controls should not be used to relieve control loads of a transient nature (i.e. during turns).

The trimmer control commonly activates a "trim tab", which is a small flap type device, either hinged or fixed, located on the trailing edge of a primary control surface which moves in the opposite direction of the control to provide a balancing force.

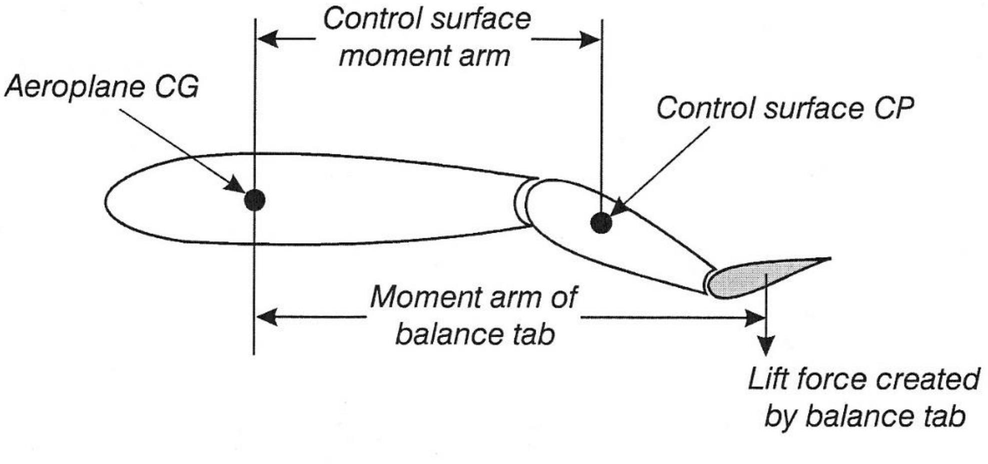


Fig 2-26: The Tab-Type Trimmer

A tab is a small flap type device, either hinged or fixed, located on the trailing edge of a primary control surface which moves in the opposite direction of the control to provide a balancing force.

For example, assume the pilot exerts a forward pressure on the control column to counteract a tail heavy situation. In other words, the trailing edge of the elevator is deflected downwards to maintain level flight.

The greater moment arm created by the balance tab is sufficient to resist the airflow pressure trying to force the control back to the neutral position.

These trim tabs can be of various types. Some are adjustable from the cockpit and some need to be adjusted on the ground. Typically on small aircraft the elevator trim will have a control in the cockpit and there will often be a ground-adjustable tab attached to the rudder and/or the ailerons. This normally takes the form of a bendable metal tab attached to the trailing edge of the control surface.

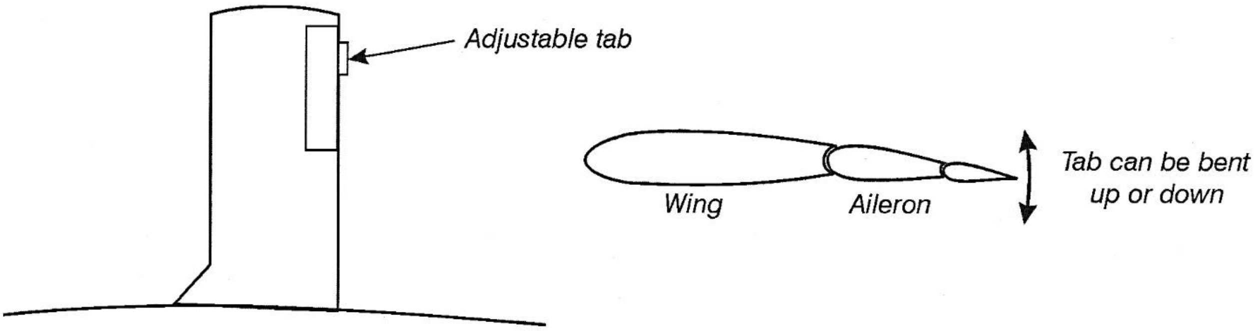


Fig 2-27: Adjustable Tab Trimmer

On some aircraft trimmer controls will adjust the trim by means of spring tension applied to the moving controls of the relevant control surface.

Another type of trim control is where the trim control is used to move the whole horisontal tail surface so that its *angle of incidence* will be altered.

n) ENGINE CONTROLS

i) THROTTLE: Used to control the engine RPM on aircraft with fixed pitch propellers, and manifold pressure on aircraft with variable pitch propellers. Normally, when pushed forward will produce increased power, and when pulled back will reduce power.

ii) PITCH: Used to control the engine RPM on aircraft equipped with variable pitch propellers. The control is most often situated on the centre console, generally to the right of the throttle, in the case where the throttle is situated on the centre console. The fully forward position corresponds with maximum RPM and minimum pitch. Pulling the pitch control back reduces engine RPM and increases the propeller pitch.

Fully fine (maximum RPM) is generally used for take-off and landing, with the RPM being reduced for cruise. As a rule of thumb, never let the manifold pressure (in inches Hg) exceed the RPM (in thousands), since this causes high pressures in the engine which can cause damage.

iii) MIXTURE:

Purpose – (i) Obtain maximum power and fuel economy,
(ii) To avoid damaging the engine.

The aim is to obtain optimum ratio of fuel/air mixture supplied to the engine in accordance with prevailing conditions. It is typically a simple push-pull knob or lever located adjacent to the throttle. Exhaust gas temperature gauge sometimes used for accurate setting.

USE OF MIXTURE CONTROL:

(i) *During Take Off:* Where airfield is located above 3000 feet MSL it is necessary to adjust the mixture to obtain maximum power.

(ii) *During Climb:* Mixture should be leaned periodically to obtain best performance as air density reduces.

(iii) *In the Cruise:* Provided the power settling is less than 75% the mixture may be leaned to provide best fuel economy. Depending on engine recommendations, lean mixture until RPM decreases then richen to regain full power.

DO NOT OVERLEAN. Lean mixture = hotter engine. An over lean mixture can overheat the engine. This thins the oil causing further overheating, reducing engine life or causing engine damage.

Also used to cut off fuel to the Carburettor to stop the engine.

d) CARBURETTOR HEAT: Vaporization of fuel in the carb reduced temperature possibly to below freezing. If air sufficiently moist, ice may form In the induction system, blocking air flow to the engine. Carb ice can occur at outside air temps of +25 degrees C or more.

Effect of carb ice:

- Drop in RPM
- Rough running
- Possible engine stoppage.

The Carb Heat control knob is usually situated near the throttle - directs hot air into the carburetor which melts or prevents ice. The hot air is less dense than cold air - reduces mass of fuel/air into engine, reducing power - RPM drops. If ice is present the RPM will rise as ice is melted.

It is normally used as a precaution at low rpm. FULL HOT is applied when rpm below the green zone. FULL COLD is returned when higher power required or when protection from carb ice is not required. *It is important to note that the hot air for carb heat is* ***unfiltered*** - taxy with carb heat FULL COLD to avoid reducing engine life due to dirt entering the intake manifold.

e) COWL FLAPS: Used on certain aircraft to maintain efficient cooling during all flight regimes. Typically the cowl flaps must be open for-high power setting (e.g. take off and climb), and partially or fully closed for cruise and descent. The optimum setting is obtained by monitoring the cylinder head temperature gauge. Care must be taken not to shock-cool the engine.

****

AIRMANSHIP:

- LOOK OUT - CLOCK-CODE METHOD.
- ATTITUDE FLYING.
- SMALL CONTROL MOVEMENTS.
- ORIENTATION IN GENERAL FLYING AREA.
- RECOVERY FROM SPIRAL DIVE.

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CHAPTER 3

EXERCISE 6

STRAIGHT & LEVEL

1. **DEFINITION:**

Maintaining a constant direction and a constant altitude whilst the aircraft is in balanced flight.

2. **OBJECTIVE:**

To acquire knowledge and understanding of the principles required to fly the aircraft straight and level at different attitudes, trim and power settings at various speeds and aircraft configurations.

Principles Involved:

1) FACTORS WHICH INFLUENCE STRAIGHT AND LEVEL FLIGHT:

a) Attitude in pitch and roll.
b) Power setting.
c) Speed.
d) Height.
e) Direction.

An alteration to one of these factors normally affects the others, i.e.:

If power is increased:

Speed increases or height increases or a combination of both.

If speed is increased:

A loss of height may result unless power is added.

2) FORCES ACTING ON AN AIRCRAFT:

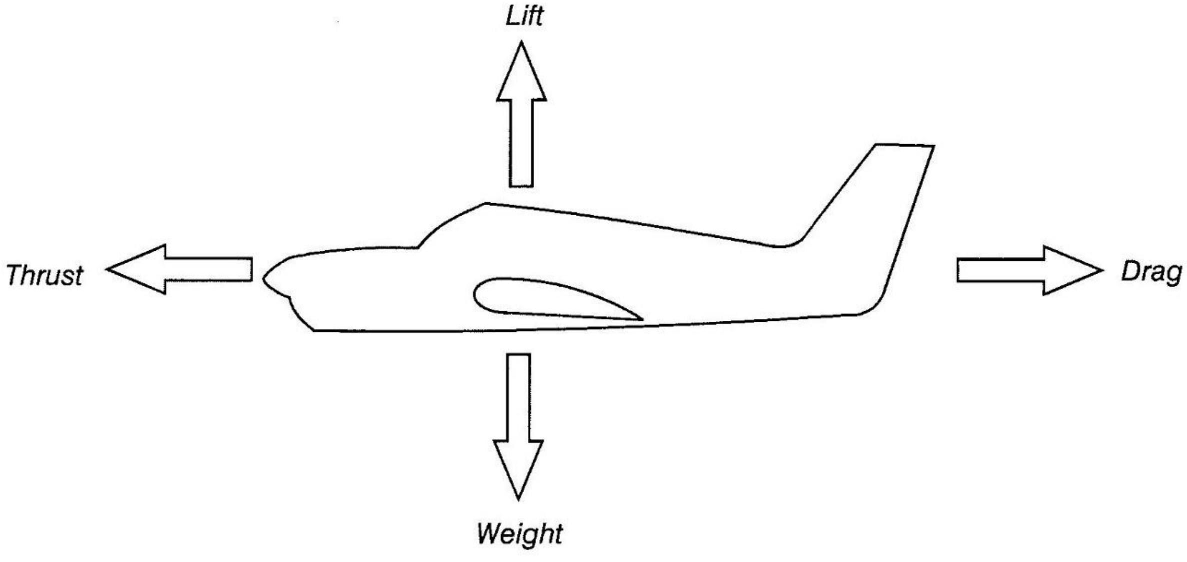


Fig. 3.1 Forces Acting In Straight and Level

For straight and level flight:

LIFT = WEIGHT

THRUST = DRAG.

The ratio of *Lift to Drag* (i.e. the LIFT/DRAG ratio is around 10 to 1 for a training aircraft. (This means there is ten times more lift than drag).

POINTS OF ACTION:

The four forces each have their own point of action:

- LIFT acts through the centre of pressure.
- WEIGHT acts through the centre of gravity.
- THRUST acts horizontally through the propeller shaft.
- DRAG acts horizontally backwards.

3) *THE STABILILY 0F AN AIRCRAFT:*

Stability is the natural or built-in ability of an aircraft to return to its original attitude following some disturbance (e.g. gust) without the pilot taking any action.

A. LONGITUDINAL STABILITY

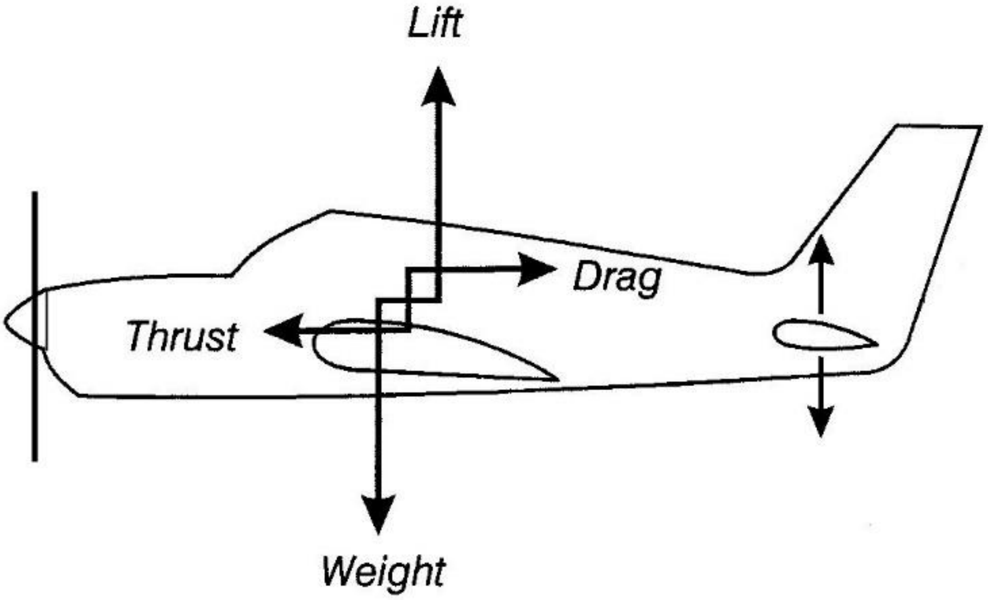


Fig. 3.2: Longitudinal Stability

The tail plane provides the final balancing force.

If a gust causes the nose to rise, then the tail plane is presented with a greater angle of attack. It will therefore generate a greater upward aerodynamic force that will raise the tail and lower the nose. (Same function as tail fins of a dart). A lower angle of incidence on the tail plane assists this effect. (Differential Angle of Incidence - DAoI)

Fig. 3.2.1: Differential Angle of Incidence

EXPLANATION OF THE EFFECT OF DAoI:

Consider a scenario where a gust of turbulence causes the nose to pitch up by say 2 degrees. As seen from fig. 3.2.1 this will cause the AoA of the main wing to increase by 2 degrees to 6 degrees – an increase of 50%. At the same time the angle of attack on the tail plane will also increase by 2 degrees to 4 degrees – an increase of 100%.

Thus, according to the lift formula, the lift on the main wings will increase by 50% whilst the lift on the tail plane will increase by 100%. The tail of the aircraft has much less mass and therefore much less inertia than the front portion of the fuselage where the main wing is affixed.

It is thus clear that the vertical acceleration of the tail section of the aircraft will accelerate upwards (or downwards in the case of an opposite disturbance) faster than the forward section, tending thereby to bring the aircraft back onto an even keel.

A forward Centre of Gravity makes the aircraft more stable because of the greater restoring moment from the tail plane.

If the aircraft is loaded so that the CG is too far forward;

- The excessive stability will require stronger controlling forces from the elevator;
- During the landing, the elevator is less effective due to the low airspeed and the nose heavy moment may make it impossible to round out.

If the aircraft is loaded with the CG too far rearward;

- The aircraft will be less stable and constant attention will have to be given to maintaining pitch attitude.
- The tail heavy moment may cause a stall at low speeds when the elevator is less effective.

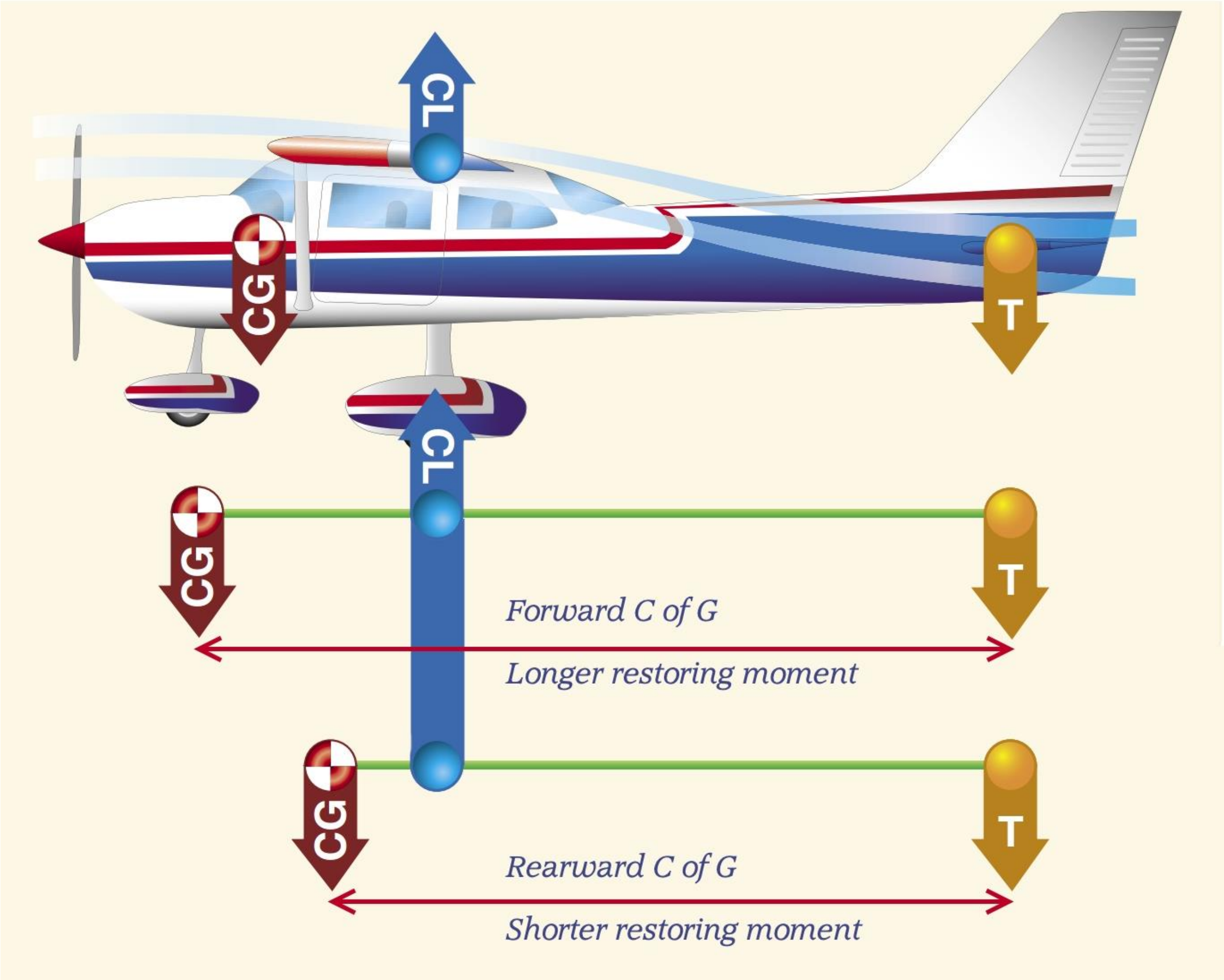


Fig 3.3: Loading Effects on Stability

The aircraft must always be flown within the CG limits stated in the Flight Manual.

B. LATERAL STABILITY

Involves **rolling** moments produced by a sideslip. A sideslip produces both a rolling and yawing motion. This is used to return the aircraft to a level attitude. A high-wing / CG relationship or geometric dihedral or combination of both.

The high wing results in the CG being positioned below the wing which acts as a pendulum. The high CL (Centre of Lift) acts as a type of pivot about which the CG acts.

Geometric dihedral is more effective than the high wing for enhancing lateral stability. The lower wing is presented to the airflow at a greater angle of attack in a sideslip, thereby generating a greater lift force which tends to restore a wings level condition.

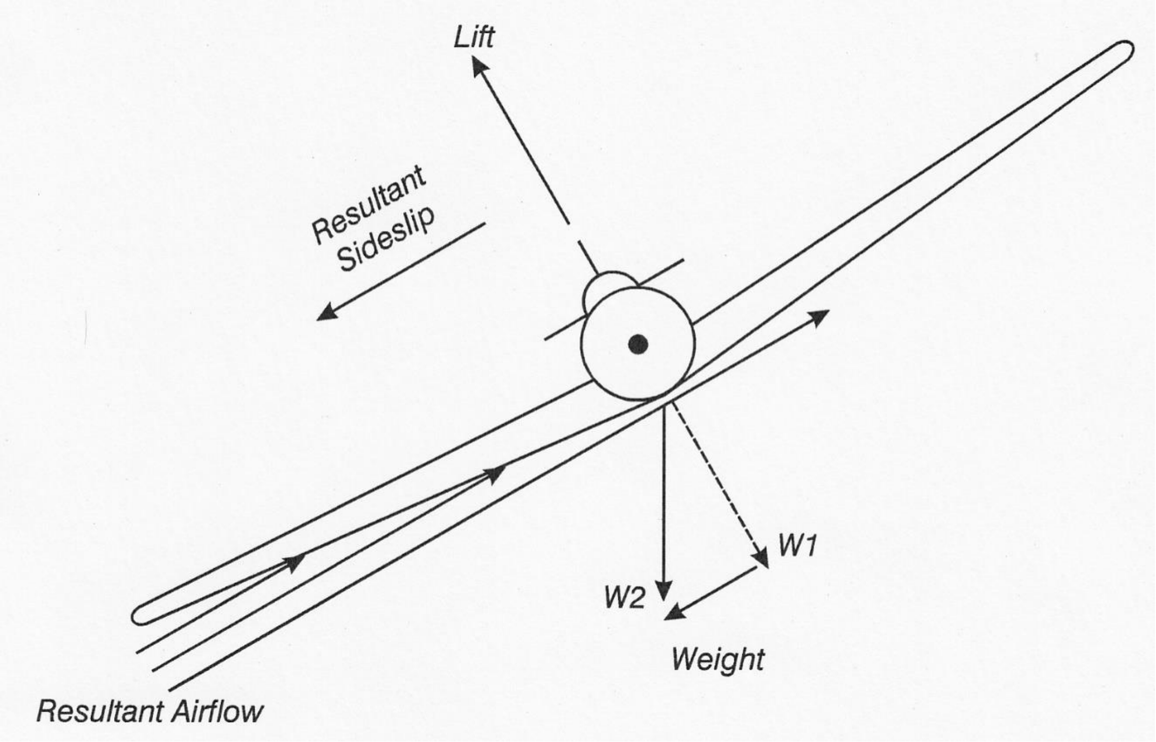


Fig 3.4: Dihedral Effect

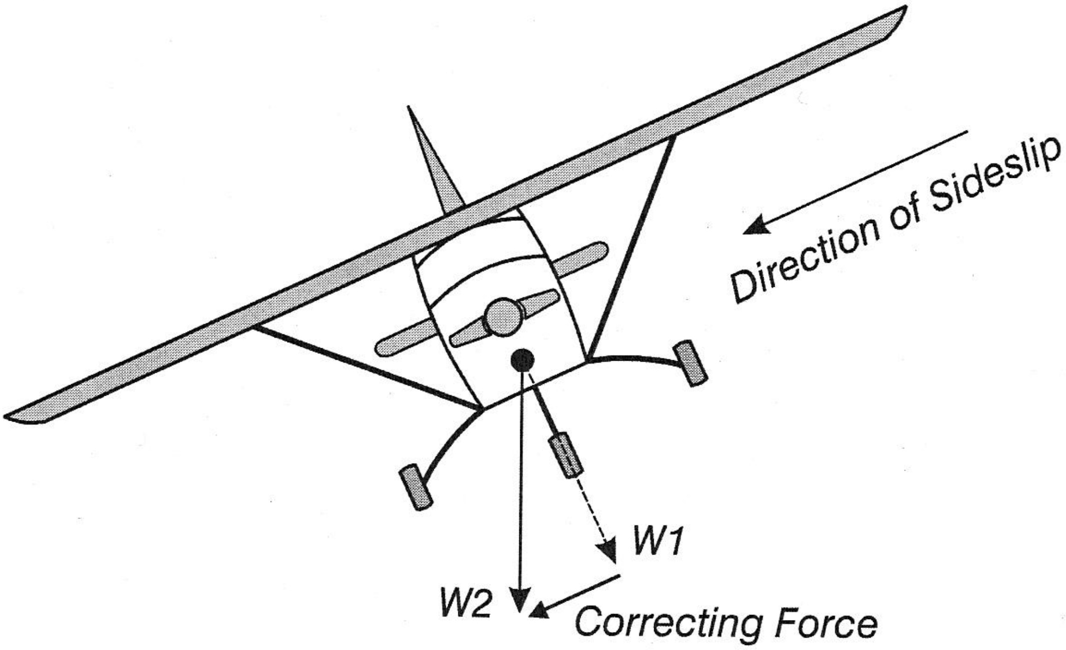


Fig 3.5: Pendulum Effect

C. DIRECTIONAL STABILITY

Provided by the vertical stabiliser (fin).

If the aircraft is disturbed from a straight path, the fin is presented to the airflow at a greater angle of attack and generates a restoring aerodynamic force.

The stability in the rolling and yawing planes is not as great as the stability in the pitching plane. An uncorrected roll or yaw can lead to a spiral dive. The natural stability slows the rate at which this happens.

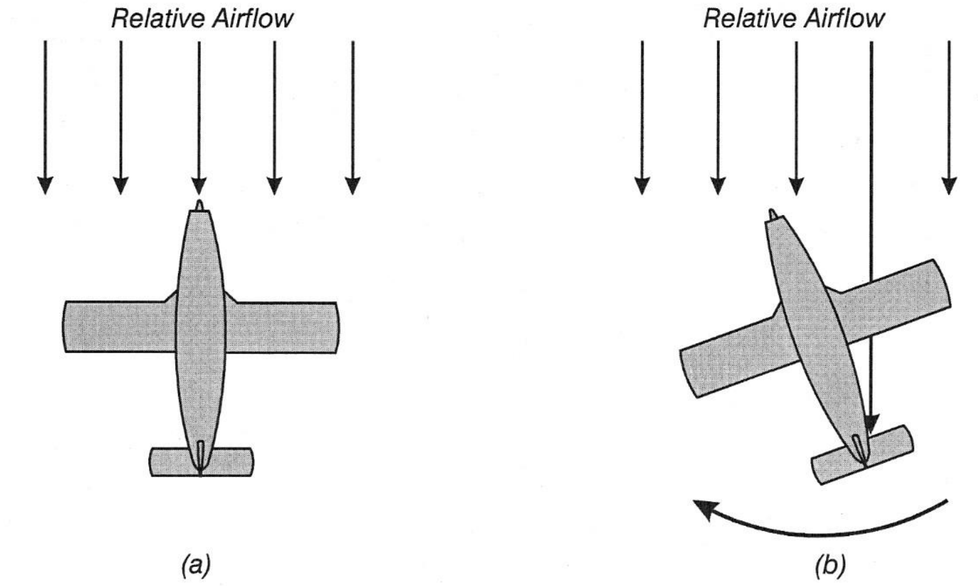


Fig 3.6: Weathercocking Effect

4) VARATION OF SPEED IN LEVEL FLIGHT:

For level flight, Lift = Weight. Also Lift = $C_L \frac{1}{2} \rho V^2 S$

The two variables are the lift co-efficient (varies with Angle of Attack), and the Velocity. To maintain the same lift, an increase in one results in a decrease in the other.

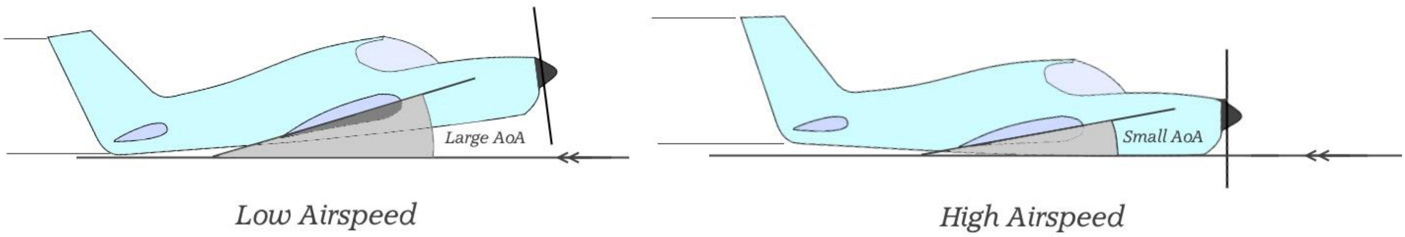


Fig 3.7: Effects of Airspeed

The graph indicates the increase in C_L with Angle of Attack:

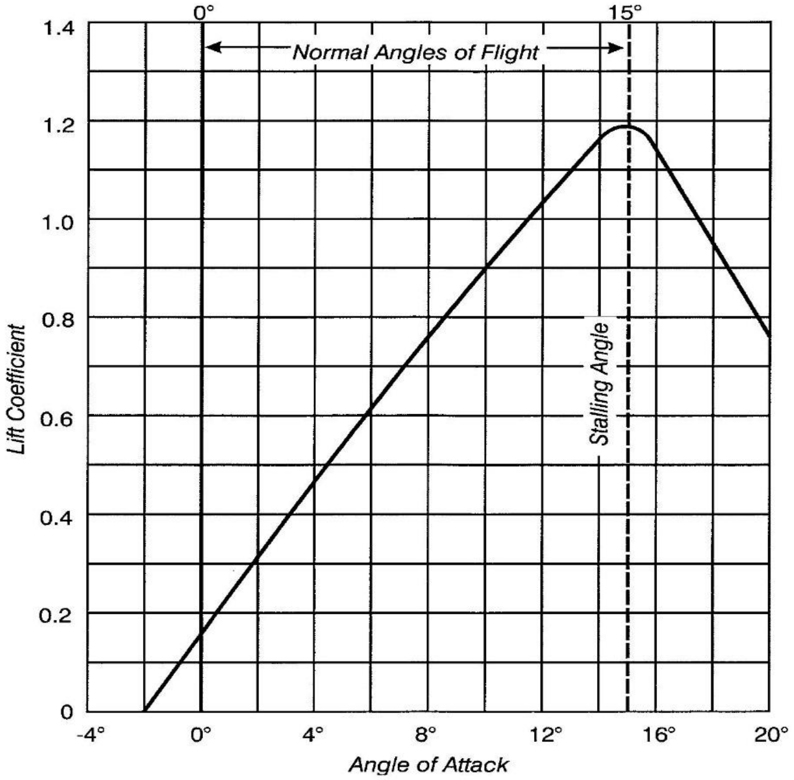


Fig 3.8: Lift Versus Angle of Attack

Level flight is possible while the aircraft accelerates providing balanced flight is maintained until the point is reached that thrust = drag and lift = weight.

The effect of inertia must be remembered. Attitude changes require a time lapse before equilibrium is reached.

5) DEVELOPMENT OF THE DRAG/POWER REQUIRED GRAPH:

The aircraft is subject to two kinds of drag: Profile Drag and Lift Induced Drag (LID).

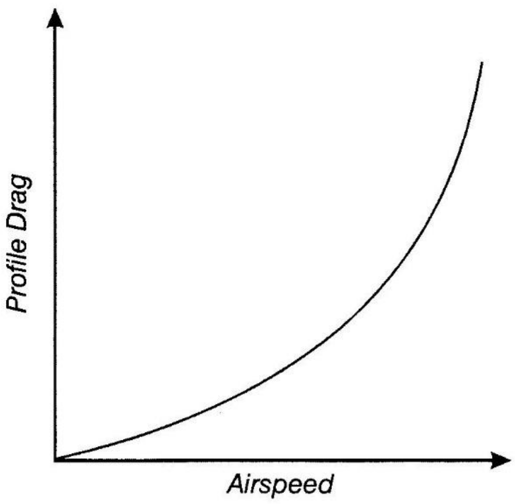


Fig 3.9: Profile Drag

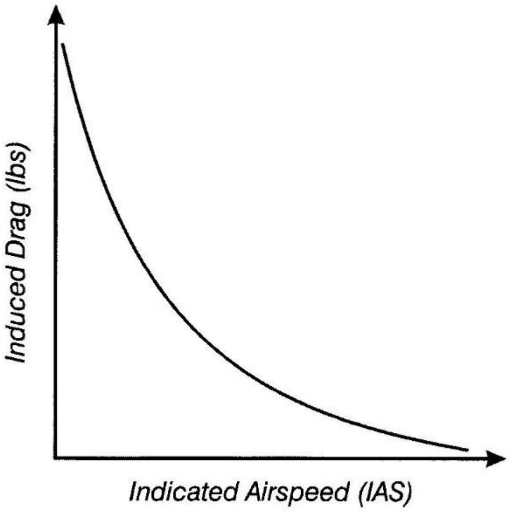


Fig 3.10: Lift Induced Drag

A) PROFILE DRAG: (Fig 3.9)

This is also referred to as *Zero Lift Drag* or *Parasite Drag* and may be subdivided into the following:

(a) FORM DRAG

This the drag a moving object experiences when moving through a fluid or gas and is dependent on a number of factors, of which the shape of the object is the major influence.

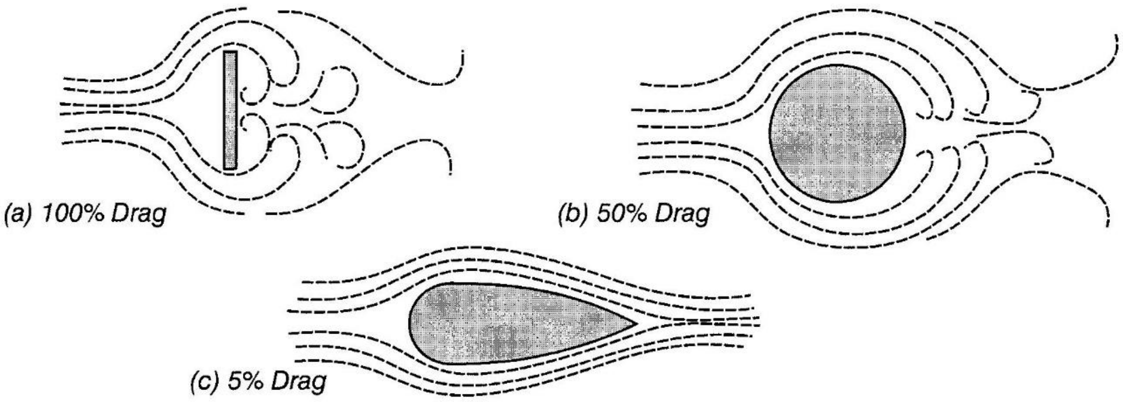


Fig 3.11: Effects of Streamlining

(b) SKIN FRICTION

Skin friction depends on the following:

- (i) Smoothness of the surface.
- (ii) Area of the surface (wetted area).
- (iii) Speed of the airflow.
- (iv) Viscosity of the air (stickiness)

(c) FACTORS AFFECTING PROFILE DRAG

- (i) Indicated airspeed - drag increases as the **square** of the speed.
- (ii) Shape (form) drag - already discussed.
- (iii) Interference drag - where aircraft components are attached to the fuselage, conflicting airflows cause interference in the form of eddies, vortices and burbles. This drag may be reduced by suitable fairings and fillets.
- (iv) Surface smoothness (skin friction) - already discussed.
- (v) Viscosity of the air - the colder the air, the greater the viscosity (stickiness) and, therefore, the greater dragging effect on the aircraft.

B) INDUCED DRAG (Fig 3.10)

Also referred to as Lift Dependent Drag.

CREATION OF INDUCED DRAG

Experiments have shown that the air flowing over the top surface of an aerofoil tends to flow inwards towards the fuselage. This is due to the decreased pressure over the top surface of the aerofoil which is less than the surrounding ambient pressures in the vicinity of the wing tip. Likewise, the air flowing below the aerofoil tends to move outwards. This is due to the increased pressure on the underside of the aerofoil which is higher than the surrounding ambient pressure in the vicinity of the wing tip. There is a continual "over-spillage" of air around the tip i.e. from high pressure to low pressure, and when these two airflows meet at the trailing edge of the wing, they are flowing at an angle to each other and create vortices. These vortices, when viewed from behind, rotate clockwise from the left wing and anticlockwise from the right wing. These trailing edge vortices link up and move upwards towards the tips and form one large wingtip vortex.

These vortices become more intense with each successive increase in angle of attack. This is due to larger pressure differentials experienced over the upper and lower surfaces of the aerofoil at higher angles of attack.

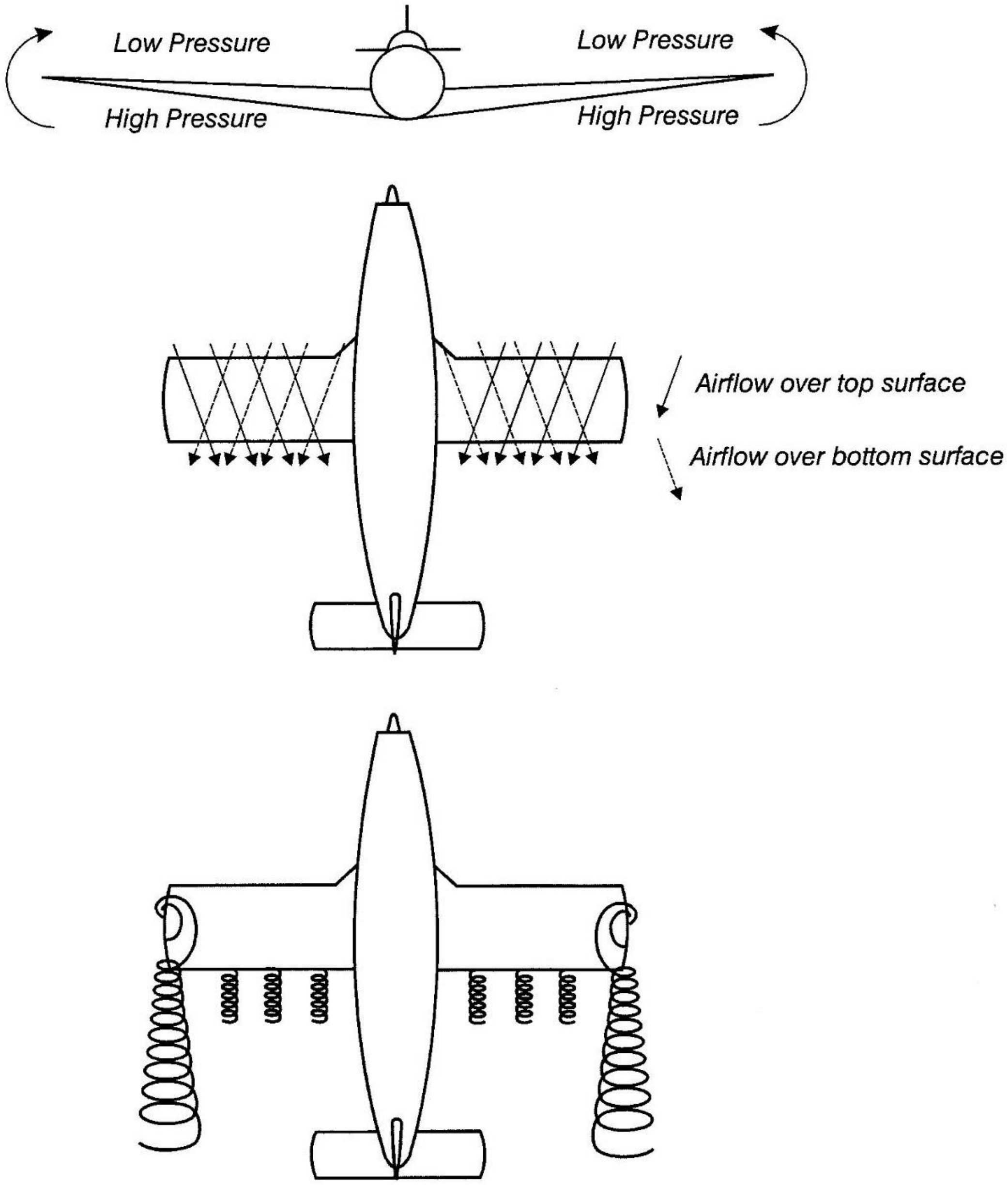


Fig 3.12: Creation of Induced Drag

Considering these rotating wing tip vortices, there is an upwards flow of air outside the wing tip and a downward flow of air behind the trailing edge of the wing. Thus the net direction of the airflow is altered. This downward flow of air is not the downwash already discussed, as downwash is always accompanied by a corresponding up wash in front of the wing and the net direction of the airflow remains unaltered.

This downward flow of air alters the net direction of the airflow in such a manner that the lift which is at right angles to the airflow - is inclined slightly aft. This inclination of the lift aft is a "part of drag" which is called ***induced*** drag. The greater the angle of attack, the greater the pressure differential and therefore the greater the induced drag so produced.

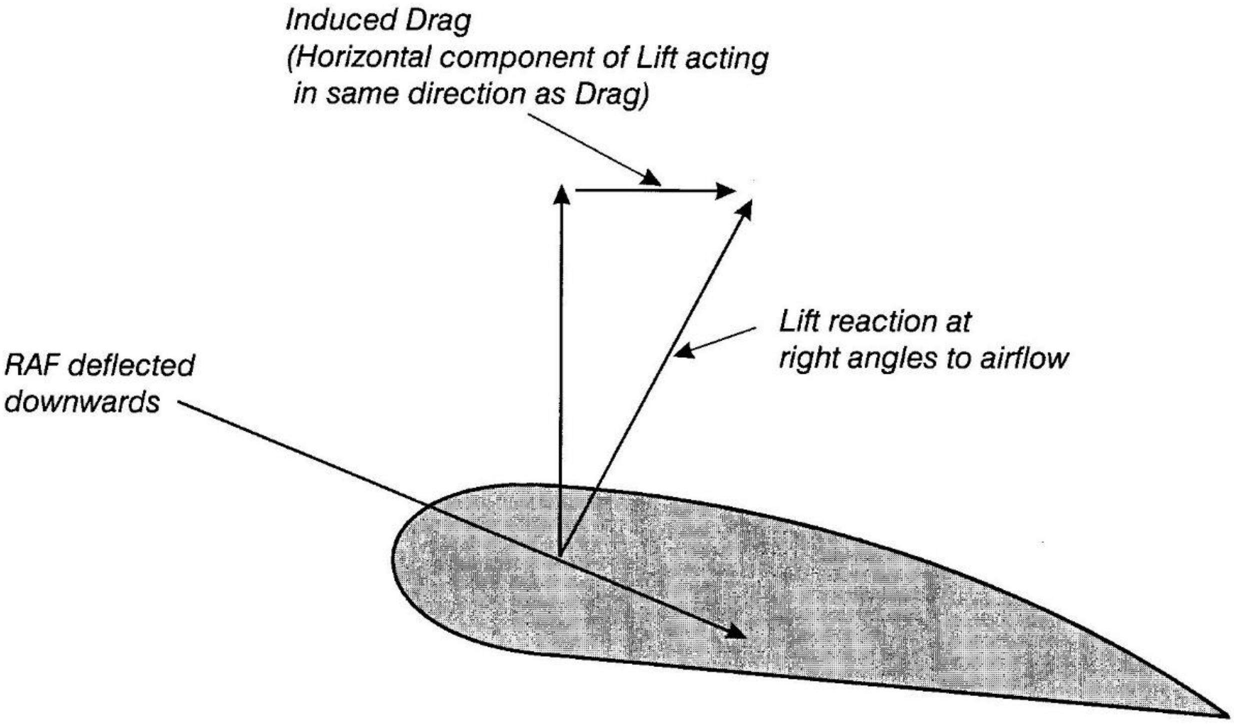


Fig 3.13: Induced Drag

C) TOTAL DRAG

The total drag on an aircraft of a given weight during flight is composed of:

PROFILE DRAG + INDUCED DRAG = TOTAL DRAG

Although the increments of drag go under different headings and sub-headings the total drag still remains the same.

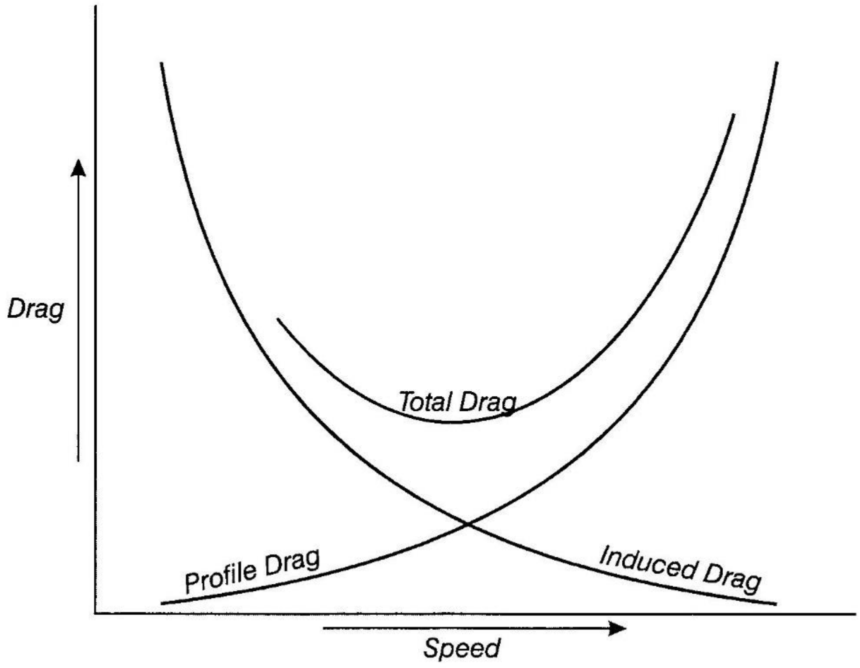


Fig 3.14: Total Drag

D) THE DRAG FORMULA

The total drag (resistance) of a body moving through the air depends on the following factors:

(a) The shape of the object
(b) Frontal area in the case of zero lift drag and surface area in the case of lift dependent drag. Frontal area = a, Surface area = S
(c) The square of the velocity
(d) The density of the air

From these factors the drag formula is derived, being:

$$DRAG = C_D \tfrac{1}{2}\rho V^2 S$$

Where:

C_D = the drag coefficient
ρ = the density of air
V = velocity
S = the surface area

E) POWER REQUIRED GRAPH

Fig 3.14 shows the Total Drag curve, indicating how the drag changes with airspeed. From the graph it is clear that a certain airspeed exists where that drag of the aircraft is minimum.

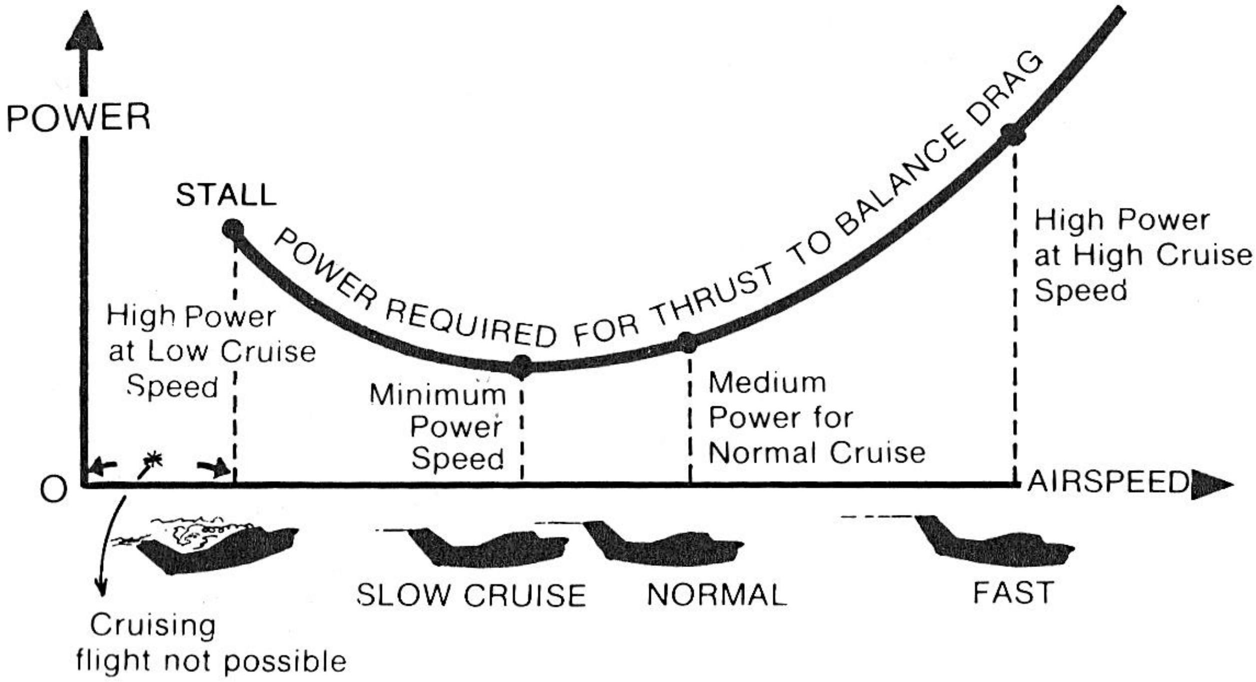


Fig 3.15: Power Required for Straight and Level Flight

6) *AIRCRAFT PERFORMANCE IN LEVEL FLIGHT:*

On the above graph the variation of power required to achieve equilibrium is illustrated.

Changing airspeed requires a change in angle of attack to maintain a constant lift.

Maximum level flight speed will be obtained where power or thrust required equals the maximum power or thrust available from the engine.

Note the minimum speed is not defined by power or thrust requirements since conditions of stall stability and control generally predominate.

7) *TWO AIRSPEEDS FOR ONE POWER SETTING:*

Often referred to as being on the wrong side of the Drag Curve.

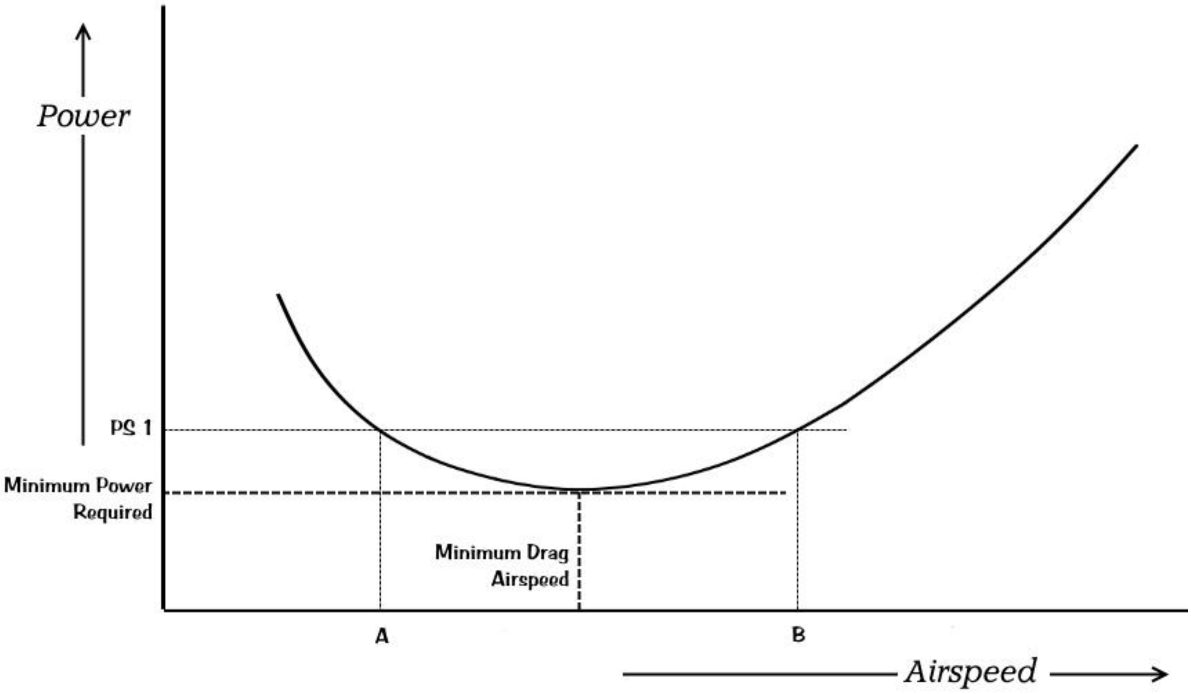


Fig 3.16: Two Speeds for One Power Setting

A represents low airspeed with a high induced drag.

B represents high airspeed with high profile drag. Therefore with one power setting, the aircraft can be flown at two airspeeds.

8) *BEST RANGE AND BEST ENDURANCE SPEEDS:*

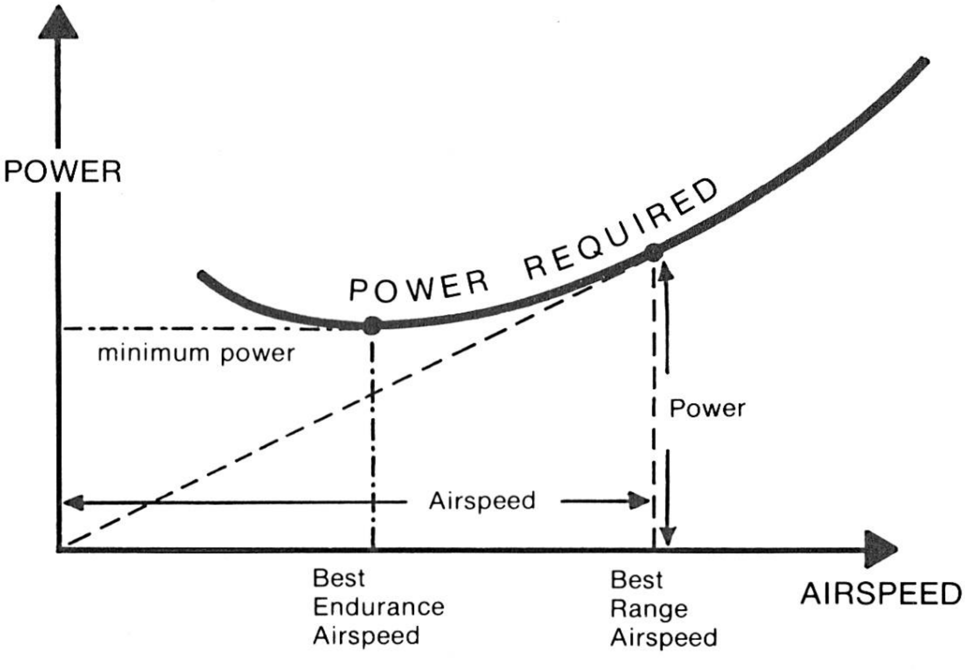


Fig 3.17: Best Range and Best Endurance Speeds

- FLYING FOR BEST ENDURANCE:

For minimum fuel consumption, fly at minimum power airspeed. This will achieve the maximum flight time for a given quantity of fuel. Flying at the airspeed for 'maximum endurance' provides minimum fuel burn for a given flight time.

This is achieved by flying at V_{MP} (Minimum Power Speed) at low altitude.

- FLYING FOR BEST RANGE:

A more common requirement, is to achieve the maximum distance for a given quantity of fuel. Since most flights are over a fixed distance, another way of expressing best range is minimum fuel burn to cover a given distance. This is $V_{MD.}$

Other factors which affect the endurance / range are altitude (low best), engine (properly leaned), and wind conditions.

<u>Example explanation:</u>

Using the following information:

- Aircraft Fuel Capacity: 80 Litres
- Fuel Consumption @ 60 mph (V_{MP}): 20 litres/hr = 4 hrs.
- Fuel Consumption @ 80 mph (V_{MD}): 24 litres/hr = 3.3 hrs.

When cruising at 60 mph, distance travelled is:

4 hrs. x 60 mph = 240 miles.

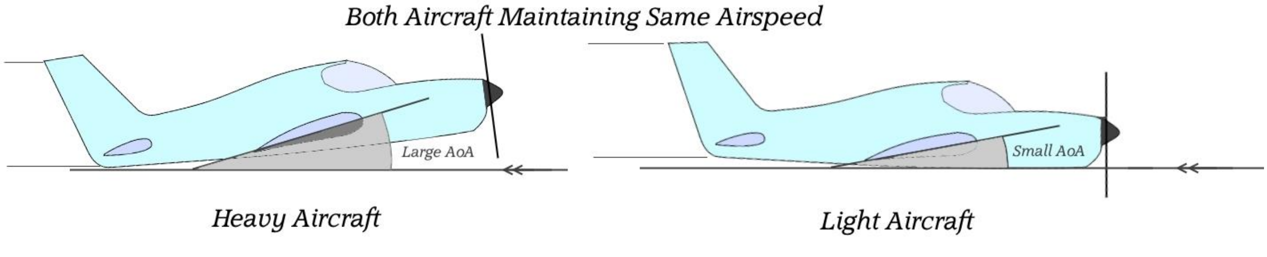
When cruising at 80 mph, distance travelled is:

3.3 hrs. x 80 mph = 267 miles.

9) EFFECT OF ALTITUDE:

Provided the Indicated Airspeed is the same, the attitude of the aircraft will be the same - at all heights. At higher altitudes the power available from the engine / propeller will be less than that available at sea-level. Because the air becomes less dense at higher altitudes, more speed is required to maintain lift, thus more power is required.

10) EFFECT OF WEIGHT:



The less the total weight, the less the Indicated Airspeed for a given angle attack, (speed is an element of the lift formula). The heavier the aircraft, the more power is required to maintain the same airspeed, thus the greater the fuel consumption.

11) EFFECT OF FLAP AND UNDERCARRIAGE:

The drag of the aircraft will be increased, requiring increased power for a given airspeed.

In addition, the lowering of flaps will also create a pitch change due to the associated movement in Centre of Pressure, the amount of drag, and the variation of the downwash angle. The amount of these forces will determine the direction and magnitude of the pitch changes.

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AIRMANSHIP

- LOOKOUT
- ATTITUDE FLYING
- TRIMMING - CORRECT METHOD
- SMOOTH CONTROL MOVEMENTS
- FUEL MANAGEMENT
- LOCATION – NAVIGATION

ENGINE CONSIDERATIONS

- METHOD OF REDUCING AND INCREASING POWER
- MIXTURE CONTROL
- TEMPERATURES & PRESSURES (Ts & Ps).

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CHAPTER 4

EXERCISE 7

CLIMBING

3. **Definition:**

A climb can be defined as any gain in height by an aircraft.

4. **Objective:**

To acquire knowledge and understanding of the principles required to climb the aircraft in the most efficient and safe way, in all configurations and conditions.

5. **How The Exercise Applies To Flying:**

Any time a gain in height is needed. (Take off, overshoot, general flying, GF work)

Principles Involved:

1) *NEWTON'S LAWS: Primarily 1st law (inertia) as applied to*

i) Initiating a climb
ii) Attitude changes during a climb
iii) Leveling off from a climb.

2) *FORCES IN A CLIMB:*

To maintain a climb, more power has to be provided than in level flight for the same airspeed.

Firstly, to overcome drag.

Secondly, due to the effect of weight being inclined backward along the flight path.

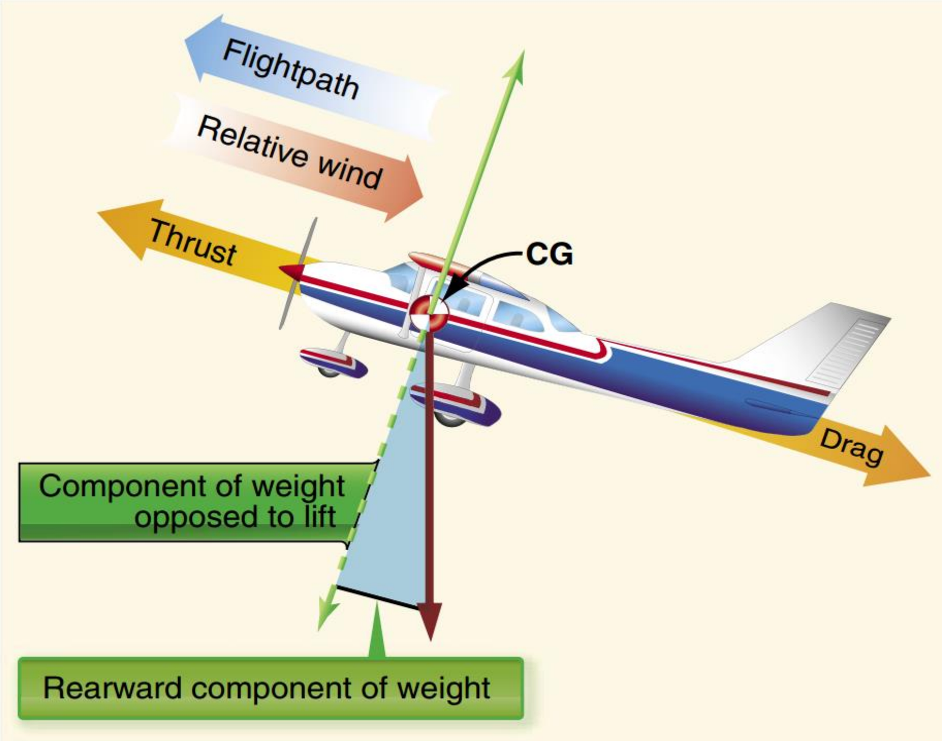

Fig 4.1: Forces on the aircraft in a climb

NOTE - in a steady climb, Lift is less than weight, Thrust is greater than Drag.

The angle of climb depends directly on the excess thrust and the weight. A heavy aircraft will not climb as well as a light one.

The lower the weight (W), the greater the angle of climb. A light aircraft can climb more steeply than a heavy one. Thrust is used to overcome Drag. If the engine/propeller can provide Thrust in excess of that needed to balance the Drag, then the aircraft is capable of climbing.

E.g. If excess power = zero, then rate of climb zero. This occurs if the aircraft flies at maximum speed in level flight. (An example is the aircraft's ceiling.)

The greater the Thrust (T), the greater the angle of climb. The lower the Drag (D), the greater the angle of climb.

3) RELATIONSHIP BETWEEN POWER - AIRSPEED AND RATE OF CLIMB

As mentioned, a rate of climb can be achieved if there is surplus power available after overcoming drag.

Furthermore at any airspeed the rate of climb depends on the excess power in hand. This is the difference between actual power available and that power to maintain the same speed in level flight.

4) MAXIMUM RATE OF CLIMB:

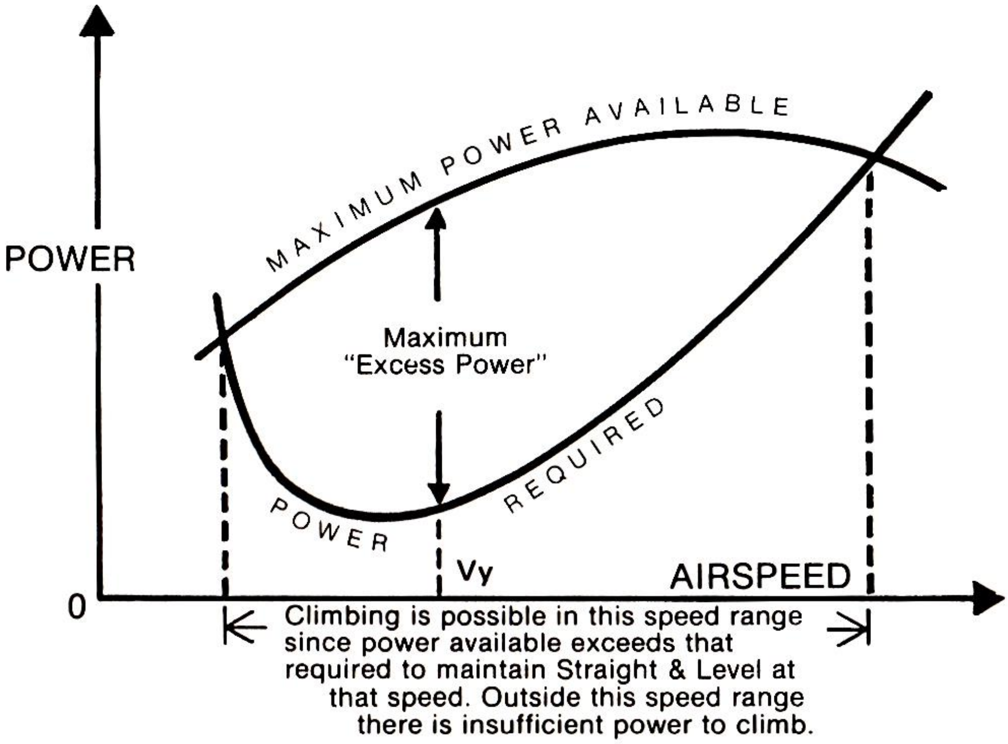

Fig 4.2: Excess Power

The speed at which Maximum Rate of Climb (MROC) is achieved is Vy, the point where Maximum Excess Power is available.

5) *MAXIMUM ANGLE OF CLIMB:*

Used when it is necessary to clear an obstacle, this occurs at an airspeed where there is maximum difference between the thrust available in a climb and thrust required.

For a given weight, the angle of climb depends on the difference between thrust and drag (T-D) or excess thrust. This can be defined in the formula:

$$\text{SIN (angle of climb)} = \frac{T - D}{W} = \frac{\text{EXCESS THRUST}}{\text{WEIGHT}}$$

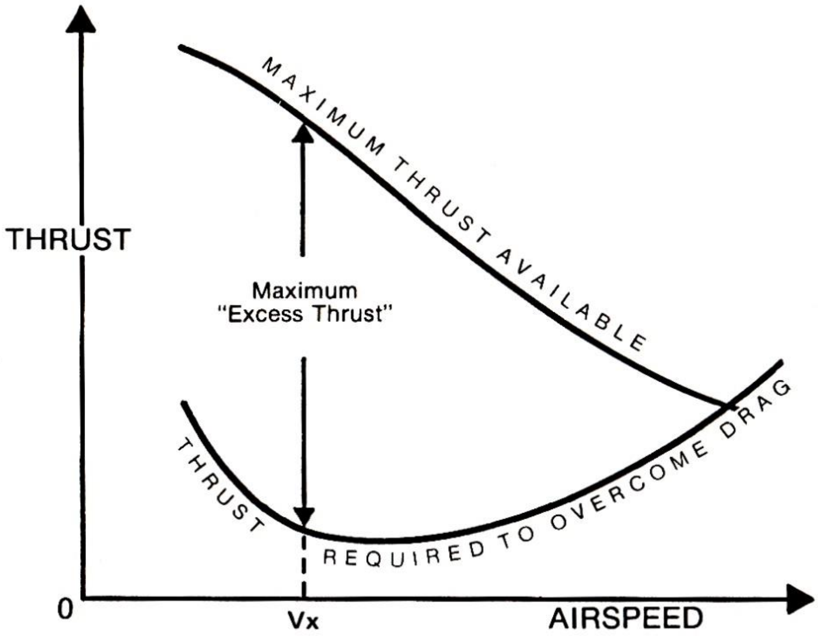

Fig: 4.3: Excess Thrust

The speed at which Maximum Angle of Climb (MAOC) is achieved is Vx, the point where Maximum Excess Thrust is available.

- Note the power available for a piston engine / propeller aircraft shows a variation of propulsive efficiency with variation of airspeed.
- If the propeller efficiency were constant over the whole speed range then the best rate of climb would coincide with the minimum power required airspeed.
- The actual propeller efficiency varies with the aircraft speed and produces a lower power available at lower speeds.
- The largest difference between power available and power required curves occur at a higher speed than that for minimum drag.
- It can be seen from the illustration that at Vy there is a fair amount of latitude either side without significantly reducing the rate of climb.

6) *THE CRUISE CLIMB*

The objective is to obtain a reasonable rate of climb as well as travel at a higher forward speed (cross country). Typically around 10 - 15 knots above max rate of climb speed, which would decrease rate of climb by about 7%, but increase forward speed by about 25%.

7) *EFFECT OF WEIGHT*

Increased weight affects both the angle and rate of climb. An increase' in weight will reduce the maximum rate of climb. The optimum rate of climb speed may be higher than when the aircraft is lighter.

8) *EFFECT OF FLAPS*

At a given speed, optimum flap selection will give added lift with only a small increase in drag.

- The original amount of lift can be obtained at a lower airspeed.
- The drag may be less and therefore the power required would be less for level flight at this lower airspeed.
- This means more thrust available to overcome the aircraft weight.
- Result is that the aircraft climbs at a higher angle.
- But!! Rate of climb is a function of both angle of climb and airspeed and because of lower airspeed with flaps the rate of climb is usually reduced.
- Therefore at normal cruise climb there is no advantage in climbing with flaps.
- However flying near ground or after take-off a steeper angle of climb may be important in clearing obstructions.

Raise flaps when a safe height is reached and adopt normal climb.

IMPORTANT - It is wrong to climb with a flap setting greater than optimum because a considerable increase in drag occurs, requiring more thrust. This detracts from the thrust to balance the weight and it becomes impossible to maintain the steep angle of climb.

When a climb is started with this amount of flaps (overshoot) - flaps should be raised to optimum as soon as a safe airspeed is maintained.

9) *EFFECT OF ALTITUDE:*

Typical light training aircraft have normally aspirated engines. The power available from this type of engine decreases from sea level upwards.

This causes the power available and power required curves to gradually close with increasing altitude until there is no excess power available for climbing. At this stage the aircraft has reached its absolute ceiling.

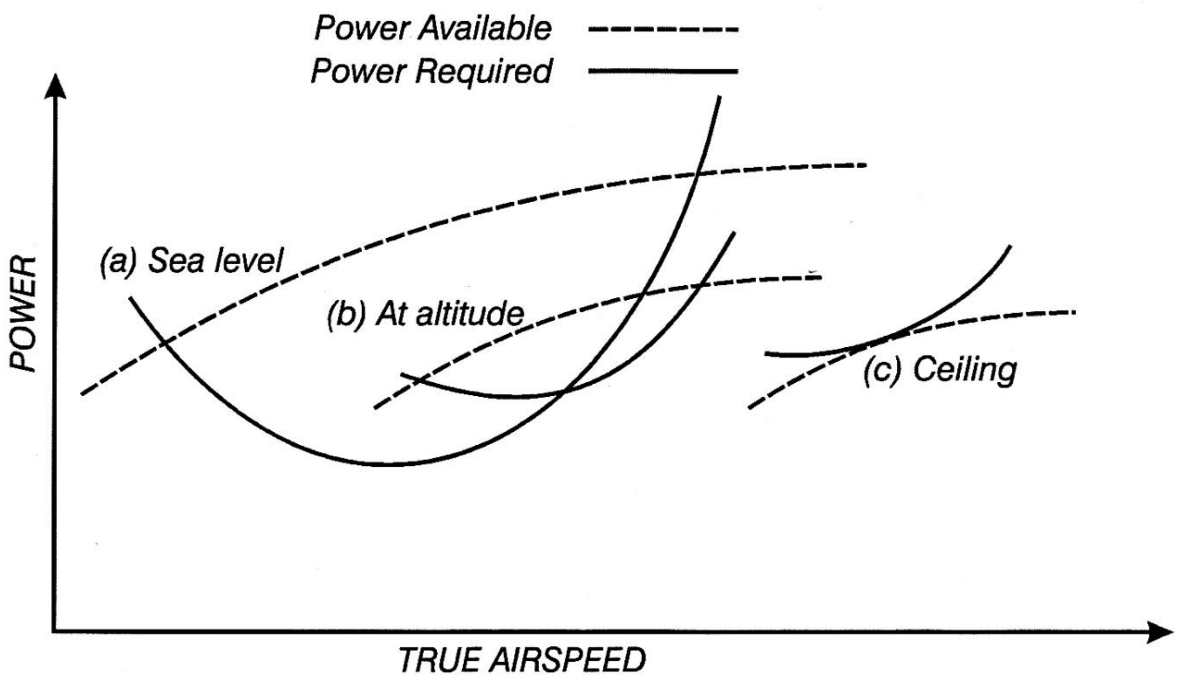

Fig 4.4: Effect of altitude

From the above figure it can be seen that the maximum rate of climb is highest at sea level. As altitude is increased, the excess power available reduces until an altitude is reached where no excess power is available at all. When **absolute ceiling** has been reached, the engine will be delivering full power and only one speed will be possible. This is defined as the point at which the rate of climb is zero.

SERVICE CEILING:

The service ceiling is defined as the altitude at which the maximum rate of climb achievable is 100 fpm (feet per minute).

10) TO RECAP:

Best RATE of climb speed (Vy) is maximum height gained in minimum time.

Best ANGLE of climb speed (Vx) is maximum height gained in minimum distance.

CRUISE climb is a compromise between rate of climb and groundspeed, to give a greater distance covered in the time taken to climb to cruise altitude.

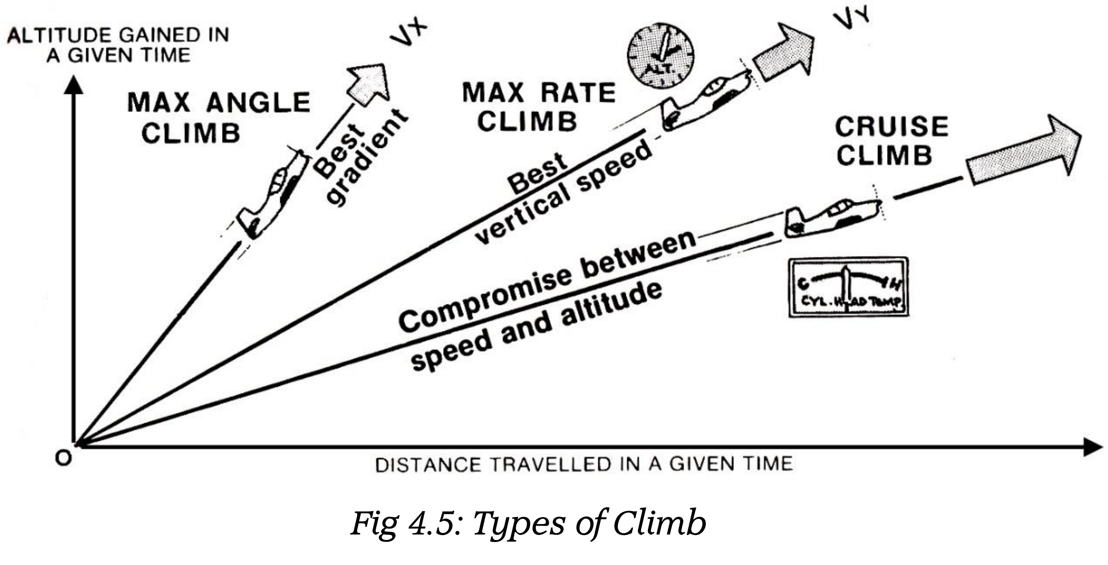

Fig 4.5: Types of Climb

11) ENTRY INTO A CLIMB:

LOOKOUT

The acronym **PAST** is used.

P	-	Power.	Select climb power; balance with rudder;
A	-	Attitude.	Raise nose to climb attitude;
S	-	Speed.	Allow airspeed to reduce and settle; Adjust attitude to achieve desired airspeed (check ASI);
T	-	Trim.	Trim off steady elevator pressure.

12) MAINTAINING A CLIMB:

LOOKOUT (nose down or S-turn every 500').

Maintain:

- Wings level with aileron;
- Balance with rudder;
- Airspeed with elevator.

Periodically check temps and pressures.

13) LEVELLING OFF FROM A CLIMB:

LOOKOUT

Acronym **APST** used:

A	-	Attitude.	Gradually lower nose to cruise attitude (monitor altimeter);
S	-	Speed.	Allow airspeed to increase to cruise speed (monitor ASI);
P	-	Power.	At cruise speed, reduce power to cruise power; Relax rudder pressure to balance;
T	-	Trim.	Trim off steady elevator pressure.

****

AIRMANSHIP

- LOOKOUT.
- LIMITS OF GFA.
- VISIBILITY – SUN AND CLOUD
- ATTITUDE FLYING.
- TRIMMING - CORRECT METHOD.
- SMOOTH CONTROL MOVEMENTS.
- FUEL MANAGEMENT.
- LOCATION – NAVIGATION.

ENGINE CONSIDERATIONS

- METHOD OF REDUCING AND INCREASING POWER.
- MIXTURE CONTROL DURING CLIMB.
- THROTTLE - POWER LIMITATIONS AND SETTINGS (A/C MANUAL).
- TEMPS AND PRESSURES - ENGINE IS WORKING HARD.

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CHAPTER 5

EXERCISE 8

DESCENDING

1. **Definition:**
   A descent can be defined as any reduction in height by an aircraft.

2. **Objective:**
   To acquire knowledge and understanding of the principles required to descend the aircraft in the most efficient and safe way, in all configurations and conditions.

3. **How The Exercise Applies To Flying**
   Any time a loss in height is needed. (Landings, changing altitudes, general flying, GF work)

Principles Involved:

1) GENERAL

There are two methods of descending:

- Close the throttle completely and glide.
- Partially close the throttle and carry out a power assisted descent.

When the throttle is completely closed and the appropriate gliding speed maintained, the pilot accepts whatever rate of descent this produces.

In the case of a power assisted descent the pilot can select an airspeed and rate of descent compatible with his requirements.

2) NEWTON'S LAWS.

i) Initiating a glide - Inertia.
ii) During a glide - Equilibrium.
iii) Levelling off from a glide – Inertia

3) FORCES IN DESCENT.

GLIDE:

If an aircraft is gliding with the engine producing no thrust, only three main forces will be acting on the aircraft - Weight, Lift & Drag. In a steady glide, these three main forces will be in equilibrium as the resultant force acting on the aircraft is zero.

Without thrust, the drag force would tend to decelerate the aircraft to stall speed. If a descent is initiated, a component of the weight force is angled in the direction of the flight path. This effect allows the aircraft to maintain airspeed by descending and converting potential energy due to altitude into kinetic energy (motion).

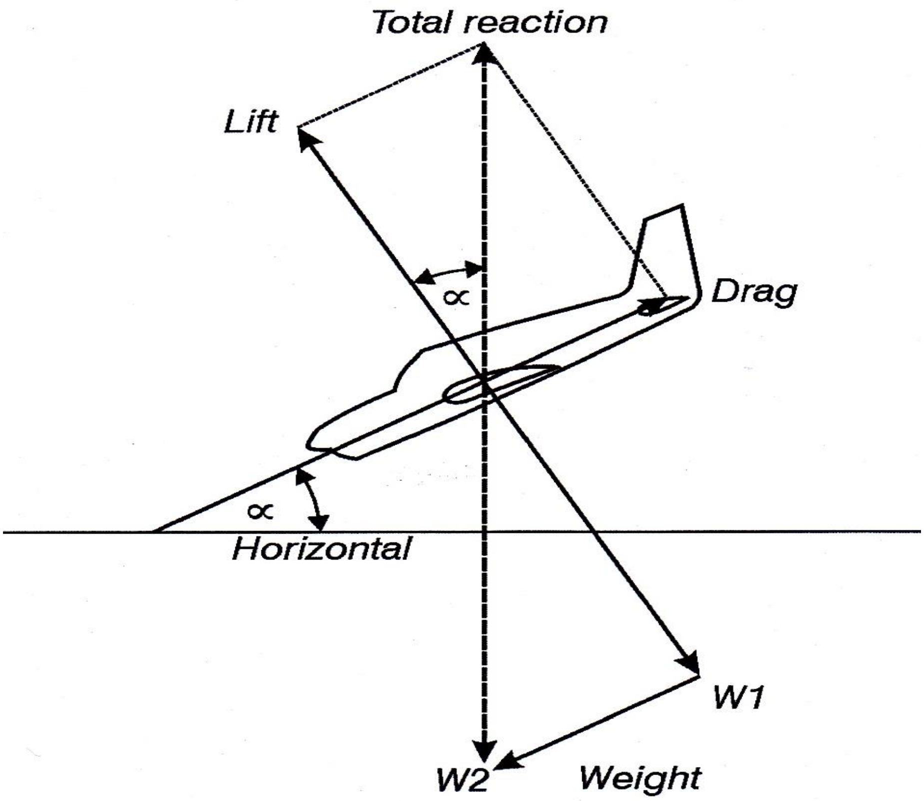


Fig 4.1: Forces in the Descent

The greater the drag force, the greater forward component of weight will be required. This equates to a steeper angle of descent

The shallowest glide is obtained when, for the required lift, the drag is least. Recap drag curve. This is shown in the formula for descent angle:

$$\text{SIN (DESCENT ANGLE)} = \frac{T - D}{W}$$

As no thrust is present, this simplifies to:

$$\text{SIN (GLIDE ANGLE)} = \frac{D}{W}$$

Remember the least drag occurs at the best Lift/Drag ratio. If the L/D ratio is high, the glide will be flat; if the L/D ratio is low, the glide will be steep and the aircraft will not glide very far.

An aircraft will glide the furthest through still air when it is flown at the angle of attack (and airspeed) that gives its best L/D ratio. This angle of attack is usually about 4 degrees.

By steepening the glide angle, a greater component of weight will act forwards, and speed will increase.

POWER ASSISTED DESCENT:

The forces are similar to those during a glide but the component of weight acting forward along the flight path is supplemented by the engine thrust applied.

The additional thrust would result in increased forward speed along the flight path. If elevators are used to maintain the airspeed to the original figure, the flight path will be shallower and the rate of descent less.

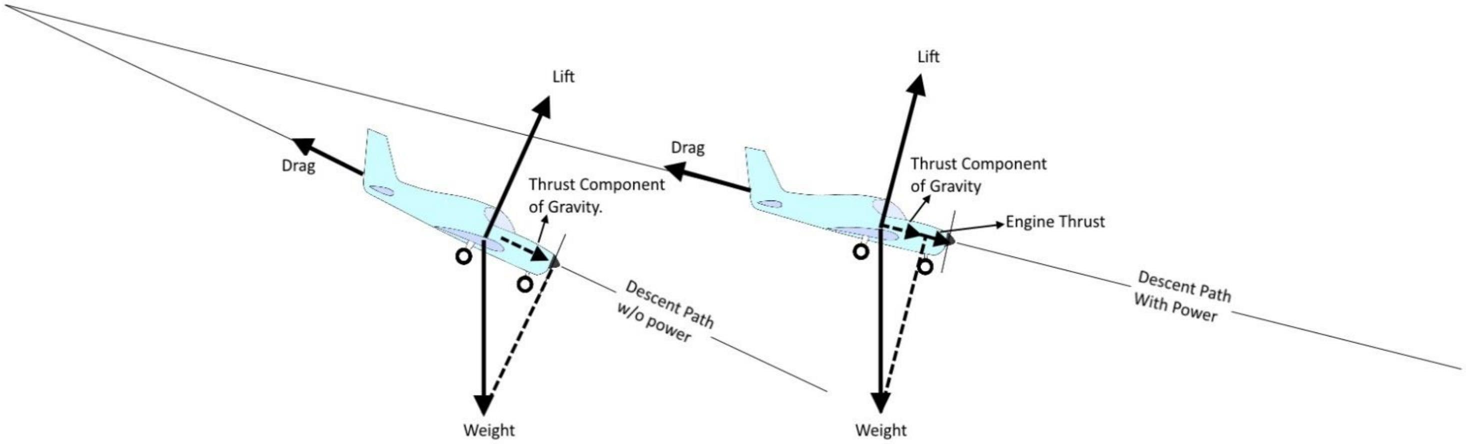


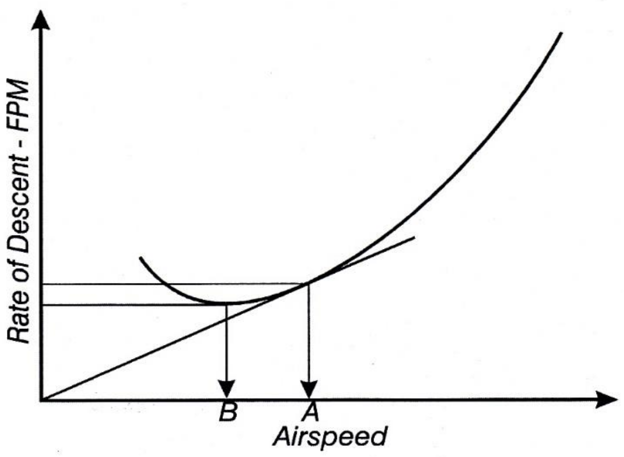
Fig 4.2: Power Assisted Descent

In a powered descent:

- Airspeed is controlled by elevators;
- Rate of descent is controlled by throttle.

4) *Minimum Glide Angle*

Refers to obtaining the greatest proportion of horizontal distance to height lost, giving maximum glide range.



The graph shows rate of descent verses airspeed. (Note similarity to total drag curve - why?). ***A*** represents the maximum proportion of speed to rate of descent. This is also the maximum Lift/Drag ratio.

The best gliding speed for range will not be the same as for level flight because:

Lack of slipstream causes a small loss of lift over inboard wings.

Fig 4.3: Gliding For Range

In the glide there is also added parasitic drag from the wind-milling propeller. If a VP propeller is fitted, the drag is greatly reduced if the pitch is turned fully course.

It can be seen that small deviations from the best L/D ratio speed will not significantly alter the glide. Speeds further distant from the optimum will result in a considerable drag increase, and thus shorter glide.

Attempts to increase the distance covered by raising the nose gives the appearance of stretching the glide due to the nose attitude, in actual fact decreases the glide distance.

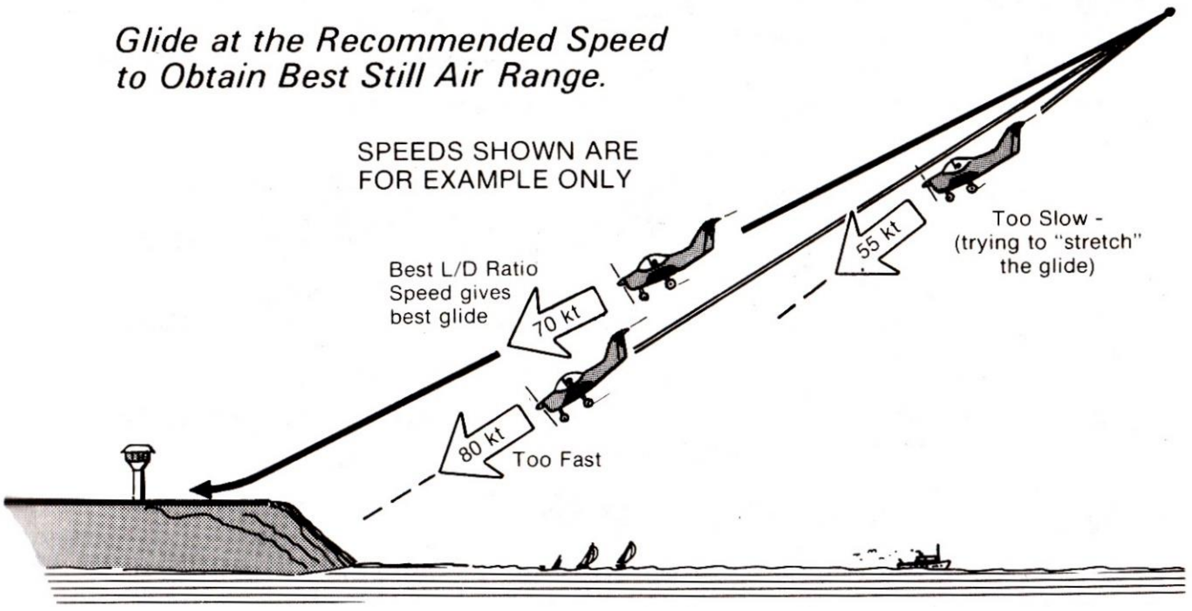
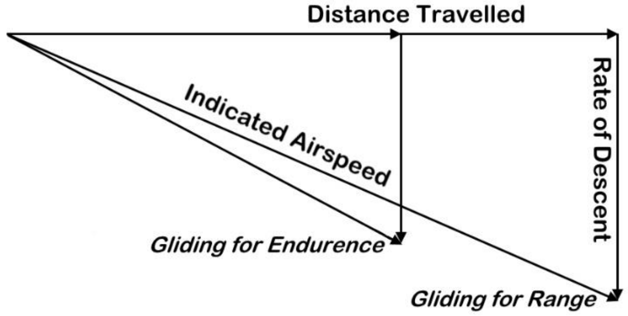


Fig 4.4: Glide Path cannot be extended.

5) MINIMUM RATE OF DESCENT:

This is used for attaining the greatest time airborne. The gliding distance will be shortened.



To recap during climbing, when the power available is greater than required for level flight, the excess will permit a rate of climb, and the climb rate will be dependent on the amount of excess power available.

Conversely when the power available is less than the power required for level flight, the deficiency of power available will produce a descent.

The minimum rate of descent without any power available occurs at the angle of attack and airspeed which together produce a condition of minimum power required.

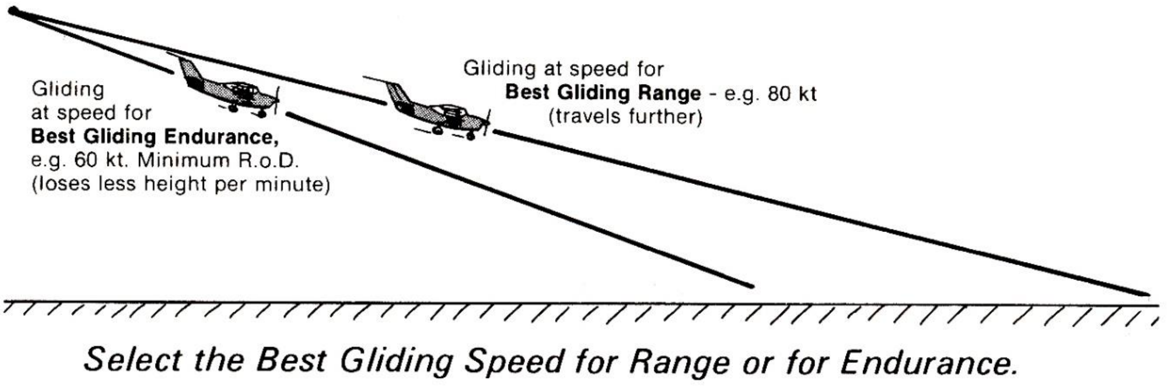


Fig 4.5: Gliding for Range or Endurance

<u>RULE OF THUMB</u>:

Speed for minimum rate of descent is 75% of best glide angle airspeed.

The minimum rate of descent has limited practical use. In circumstances where airborne time is more important than distance, minimum rate of descent is normally about 25% to 35% less than that for best angle of glide.

6) EFFECT OF FLAPS / UNDERCARRIAGE.

The best glide angle is achieved by flying at a speed which corresponds to the angle of attack which gives the best Lift/Drag ratio. But if additional parasite drag is caused as a result of lowering flaps or landing gear, the L/D ratio will reduce.

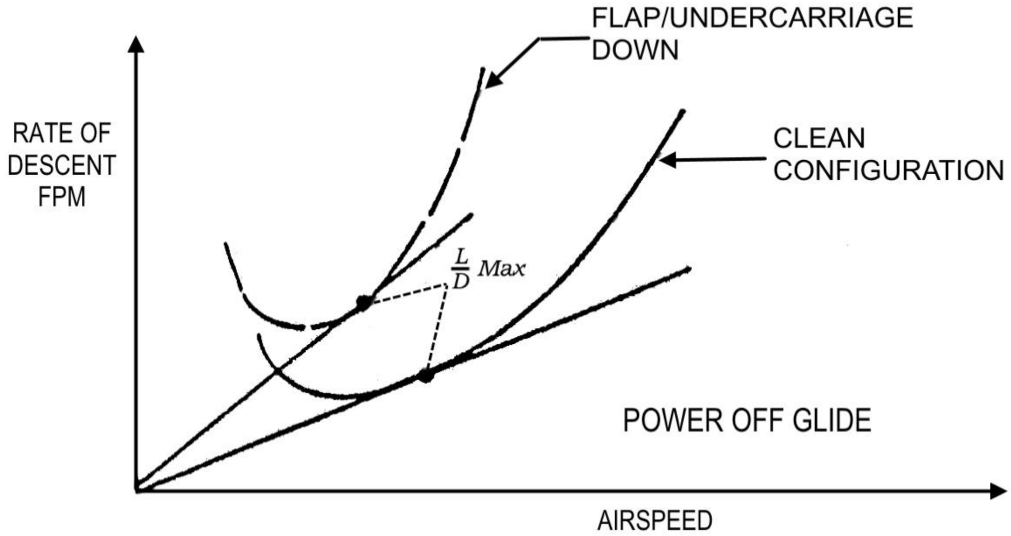


Fig 4.6: Effect of flaps / undercarriage

Maintain a clean aircraft if the best glide is required.

<u>Descending with flaps:</u>

- A change in pitch attitude will occur.
- Descent rate will be higher for a given airspeed.
- Maximum Lift/Drag ratio occurs at a lower airspeed than when flaps up.
- During approach to land use of flaps provides slightly lower airspeed and increased descent angle giving a better view.

7) *EFFECT OF WIND*

Headwind will reduce gliding range.

Tailwind will increase gliding range.

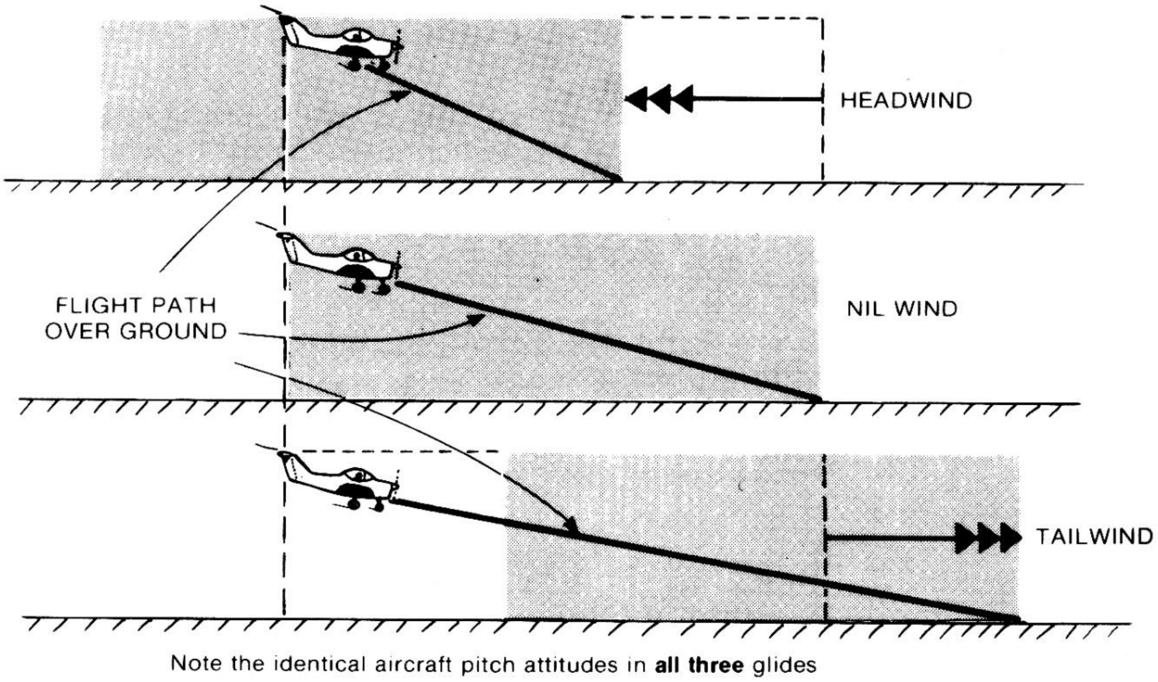


Fig 4.7: Effect of Wind

8) *Effect of weight*

Provided the aircraft is flown at the angle of attack giving the best Lift/Drag ratio, the actual weight will not affect its gliding range and the angle of glide will remain the same. To maintain the same angle of attack with an increase in weight, airspeed must be increased. Therefore the best glide speed for a heavy aircraft is higher than the glide speed for a light one.

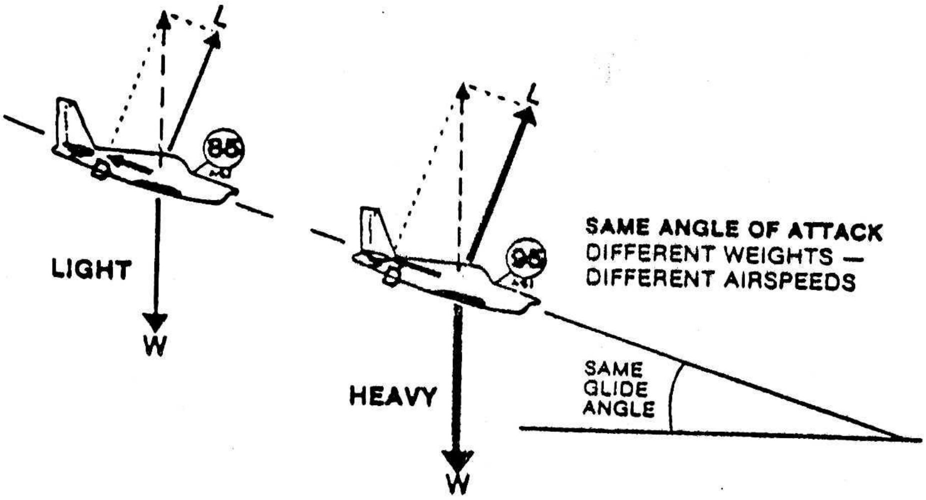


Fig 4.8: Effect of weight

9) ENTRY INTO THE DESCENT

LOOKOUT

The acronym **PSAT** is used.

P - Power. Reduce to idle power **-** carb heat on;
S - Speed. Allow speed to reduce to descent speed;
A - Attitude. Lower the nose to maintain descent speed;
T - Trim. Trim to remove column forces.

10) LEVELLING OUT FROM THE DESCENT

LOOKOUT

The acronym **PAST** is used.

P - Power. Select full power;
A - Attitude. Increase nose attitude to stop descent;
S - Speed. Allow speed to increase to cruise speed;
T - Trim. Trim to maintain straight & level.

****

AIRMANSHIP

1. LOOKOUT.
2. DON'T NEGLECT THE TRIM.
3. NOSE ATTITUDE SPEED RELATIONSHIP (ATTITUDE FLYING).
4. RATE OF DESCENT CONTROLLED BY POWER.
5. SMOOTH CONTROL MOVEMENTS.
6. FUEL MANAGEMENT.

ENGINE CONSIDERATIONS

1. MIXTURE RICHENED FOR THE DESCENT.
2. TEMPERATURES & PRESSURES (Ts & Ps).
3. USE OF CARB HEAT.
4. WARM ENGINE EVERY 1000 ft.

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CHAPTER 6

EXERCISE 9

TURNING

NB: Due to the similarity in basic principles, this section has medium, climbing/descending, and steep turns combined.

1. **Definition:**

A turn can be described as any change in direction by an aircraft.

2. **Objective:**

To teach the student to carry out a controlled and coordinated manoeuvre to effect a change in heading whilst holding a constant height (where applicable) and maintaining the aircraft in balanced flight.

3. **How The Exercise Applies To Flying:**

All flying involves turning or changes in heading in heading.

Introduction:

For an aircraft to turn, centripetal force is required to deflect it towards the centre of the turn. By banking the aircraft and using the horizontal component of the now inclined lift force, the necessary force is produced to enable a change in direction.

RECAP: i) Further effects of ailerons,
ii) Adverse aileron yaw,
iii) Use of rudder for balance.

1) Principles Involved:

1.1) NEWTON'S LAWS:

A moving body tends to continue moving in a straight line at a constant speed (Newton 1). To change this state (either to change the speed or to change the direction, i.e. to accelerate the body) a force must be exerted on the body (Newton 2).

This is applicable in

a) Commencing a turn,
b) Maintaining a turn, and
c) Rolling out of a turn.

1.2) FORCES IN A TURN:

Weight always acts straight down relative to the Horizontal. However the direction of the forces produced by Lift, Thrust and Drag will be controlled by the direction of the aircraft's flight path.

A sideways force is required to make the aircraft turn in flight. This is produced by bank which tilts the Lift force. This produces two components of lift at right angles to each other. One acts in the direction of the turn and is called CENTRIPETAL FORCE, whilst the other acts upwards and against weight.

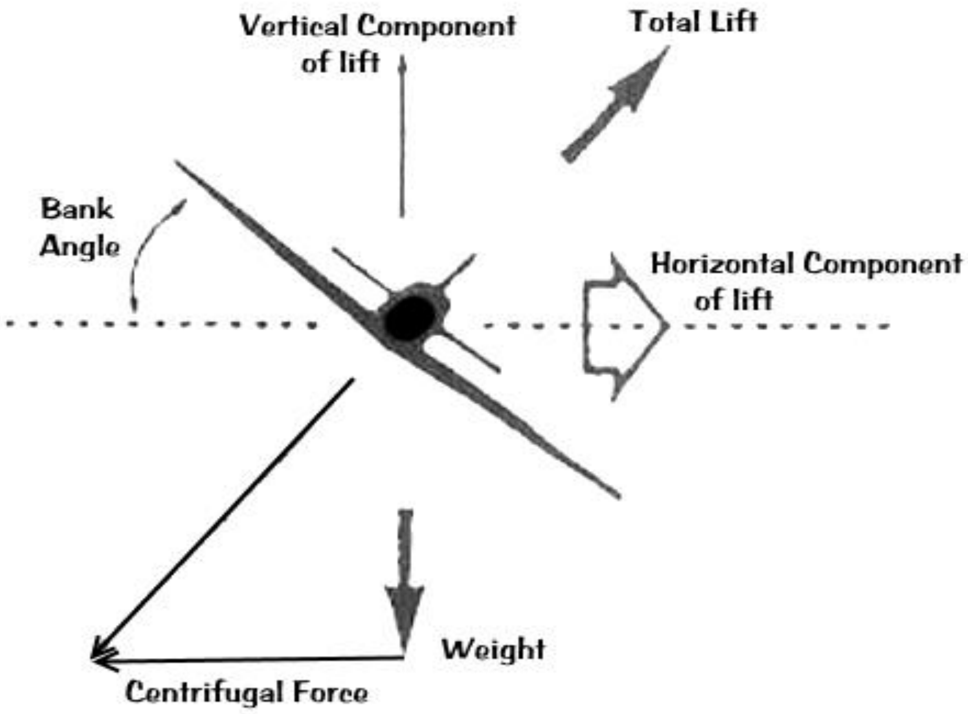

Fig 6.1: Forces in a turn

In turning flight the aircraft is not in a state of static equilibrium due to a condition of acceleration into the turn.

In a steady coordinated turn during level flight the vertical component of lift must be equal to weight so there is no acceleration in a vertical direction. (Climbing or descending).

1.3) LOAD FACTOR:

Straight and level, the wing produces a Lift force equal to the weight, i.e. L = W. The load factor is said to be 1. The pilot experiences a force from the seat equal to his normal weight. He feels it as '1g '.

In a banked turn of 60 degrees, the wings produce a force equal to double the weight, i.e. L = 2W. This means the loading on the wings is doubled when compared to straight and level flight, i.e. each square metre of the wing has to produce twice as much lift in a 60 degree bank as it does in straight and level flight. The pilot experiences a force from the seat equal to twice his weight, i.e. 2g. The load factor is said to be 2. The load factor is the ratio of the Lift force produced by the wings compared to the Weight force of the Aeroplane.

LOAD FACTOR = Lift/Weight
= Wing Loading in Manoeuvre/Wing Loading S&L

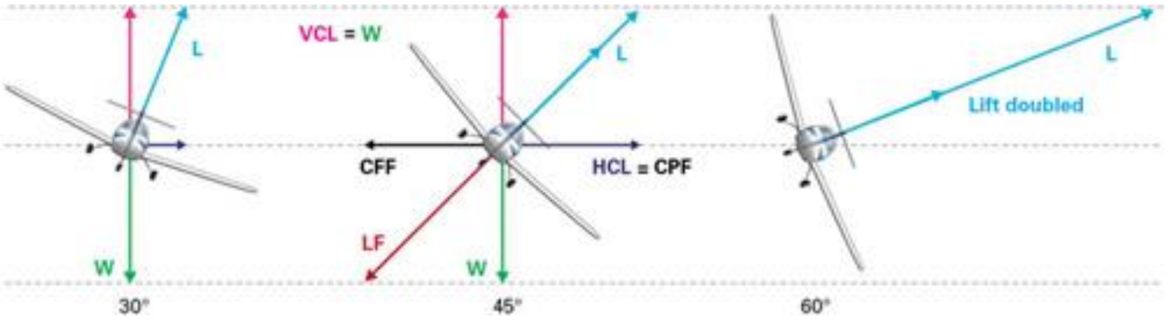

Fig 6.2: Load Increase with Angle of Bank

At angles of bank beyond 60 degrees, the lift force generated by the wings must increase greatly so that its vertical component can balance the weight - otherwise height will be Lost. The graph of ‘Load factor' vs 'bank angle’ follows:

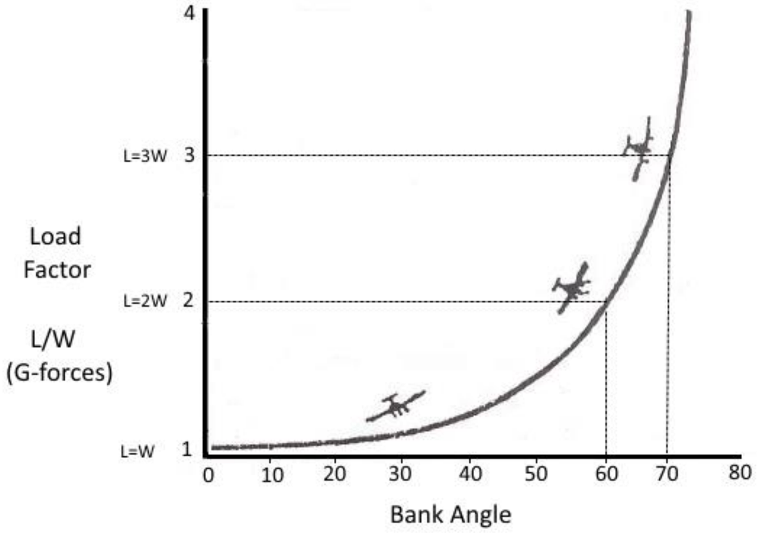

Fig 6.3: Load Factor versus Bank Angle.

To achieve the additional lift in a turn, the AIRSPEED or the ANGLE OF ATTACK must be increased. In a turn the angle of attack has to be greater than at the same speed in straight and level flight. This means that the stalling angle of attack will be reached at a higher speed in a turn - the sleeper the angle of bank, the higher the airspeed at which the stalling angle of attack is reached.

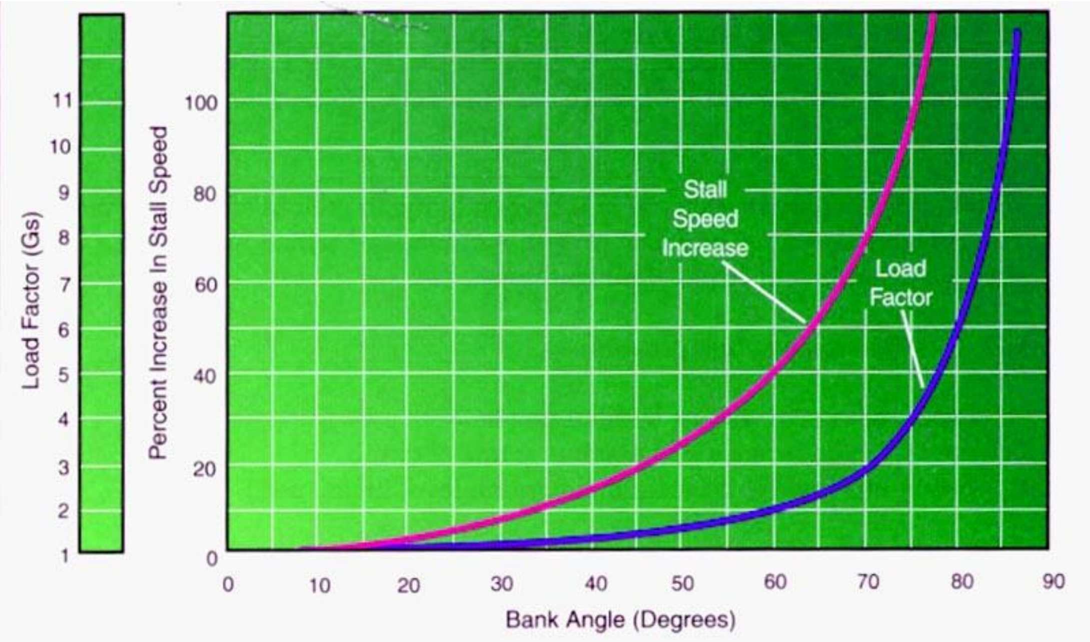

Fig 6.4: Stall Speed Increase Due to Bank Angle

If an aircraft stalls at 50 knots in straight and level, then in a 60 degree banked turn it will stall at (141% of 50kt =) 71kt - a significant increase.

1.4) *TURNING PERFORMANCE:*

The performance of an aircraft in a steady turn is measured in terms of **rate** and **radius**

This can be seen from the following equations based upon the horizontal component of lift being equal to the centrifugal force during the turn.

Turn Rate:-

$$\text{Rate of Turn (Rot)} = \frac{1.091 \tan (\text{Bank Angle in degrees})}{V\ (\text{Velocity in kts TAS})}$$

Turn Radius:-

$$\text{Turn radius (in feet)} = \frac{V}{11.26 \tan (\text{Bank Angle})}$$

The two variables in the above relationship being:

- Bank angle
- True airspeed (V)

So if an aircraft is in a correctly balanced tum at a constant angle of bank and airspeed, the turn rate and turn radius are fixed and are not dependent upon the aircraft type or its weight.

1.5) *RATE OF TURN*

The rate of turn at any given airspeed depends amount of sideways force causing the turn, and at a given airspeed, increases with angle of bank.

A rate of turn of 3 degrees per second is known as a **standard rate** or **rate one** turn. A simple rule of thumb for estimating the correct angle of bank in a standard turn is to use 10% of the indicated airspeed and add 7 for knots or 5 for mph. (i.e. 100kts = 10 + 7 = 17 deg. or 100mph = 10 + 5 = 15 deg.)

1.6) *RADIUS OF TURN:*

Radius of a turn at any given angle of bank depends on the airspeed. The radius of turn will be least at the lowest airspeed fear which the aircraft can be flown for a given angle of bank. Remember increase in stall speed in a turn

2) Medium Turn:

2.1) *DEFINITION:*

A medium turn is a turn:

- at a constant height
- a 30 degree angle of bank
- at constant bank
- in balance.

2.2) *FLYING THE MANOEUVRE:-*

- Apply bank by using ailerons to roll to 30 degrees bank. (Remember simultaneous rudder to prevent adverse aileron yaw).
- Roll rate depends on amount of aileron deflection.
- Steepness of bank depends on the length of time ailerons are deflected.
- When bank angle reached ailerons neutralised and used to monitor bank angle.

- Prevent the tendency of side slip and nose drop by slight back pressure on the control column which will increase the angle of attack and produce more lift.
- Use the rudder to keep ball in the centre.
- To return to straight and level we use the ailerons to roll the wings level. Rudder is used to prevent yaw and release back pressure on the control column to prevent height variation.
- Extra power is not needed for a medium turn.

3) The Climbing Turn:

3.1) FORCES IN A CLIMBING TURN:

Similar to those in a straight climb except that, because the Lift is tilted to turn the Aeroplane, its contribution to supporting the weight is reduced. The result is a decreased climb performance if airspeed is maintained.

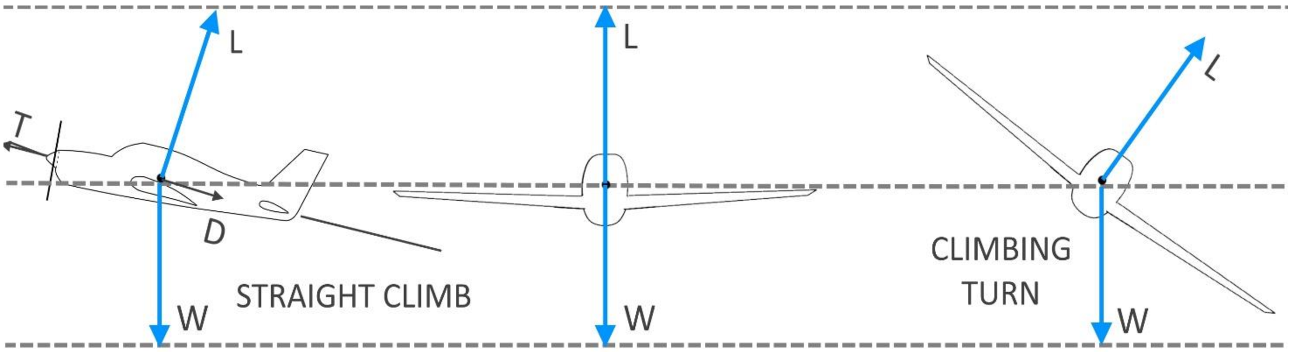

Fig 6.5: A Straight Climb and Climbing Turn

The rate of climb depends on excess power (refer climbing). Tilting of the Lift and .the increased Drag in a climbing turn reduces the excess power available for climb performance. The result is a deceased rate of climb in a turn. The steeper the bank angle in a climbing turn, the poorer the rate of climb. To retain a reasonable rate of climb, the bank angle in climbing turns should be limited to 15 degrees.

-

3.2) *THERE IS A TENDENCY TO OVERBANK IN A CLIMBING TURN:*

The higher speed and greater angle of attack of the outer wing in a climbing turn creates a tendency for the bank angle to increase. Bank may have to be held off in a climbing turn.

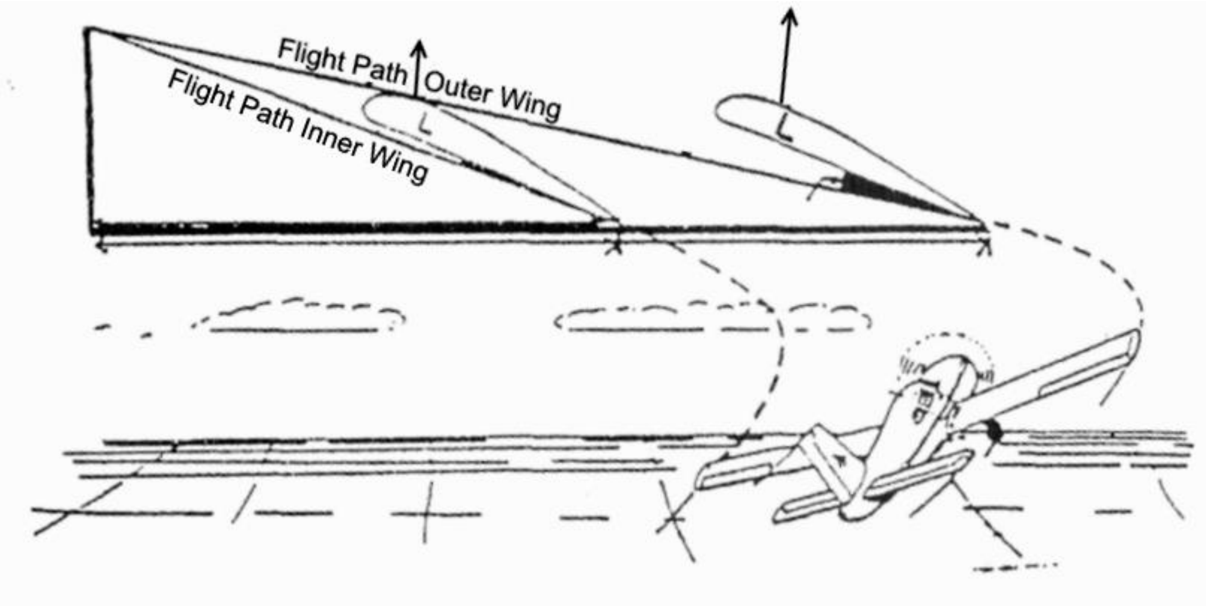

Fig 6.6: Overbanking Tendency

4) The Gliding Turn

4.1) *THE FORCES IN A GLIDING TURN*

Forces similar to straight glide, except lift is tilted.

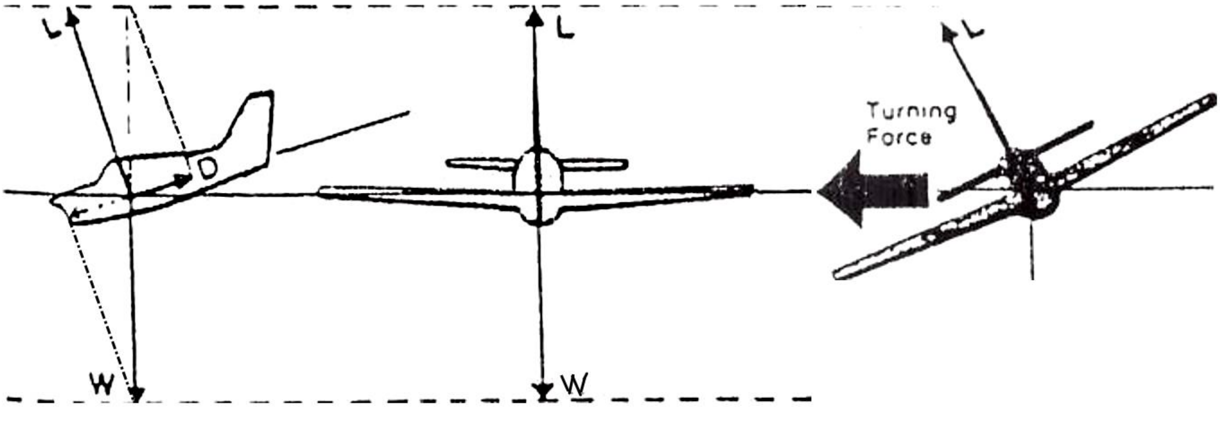

Fig 6.7: Forces in the Gliding Turn

Banking the aircraft to turn:

- reduces the amount of Lift available to oppose the weight force - results in an increased rate of descent and a steeper glide; and
- Increases the Drag resulting in a tendency to decrease the airspeed. (Watch for increased stall speed in a turn).

Nose position in a gliding turn will be lower than normal descending to maintain airspeed. Rate of descent will increase.

4.2) *UNDERBANK/OVERBANK IN A DESCENDING TURN.*

In a descending turn, the outer wing travels faster and wants to produce more lift than the inner wing, but, due to the descent, the inner wing travels a smaller horizontal distance for the same height loss when compared to the outer wing.

Therefore the outer wing and has a larger angle of attack. Thus the inner wing tends to produce more Lift - and the two effects may be cancelled out.

In a descending tum the pilot may have to hold on (or off) bank, depending on the aircraft.

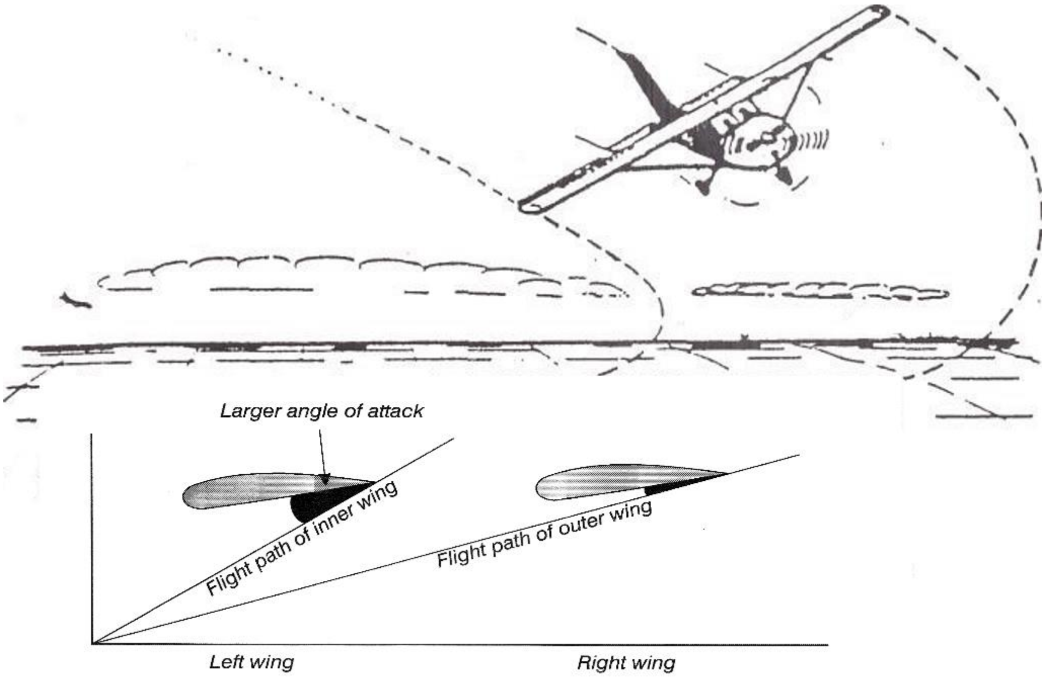

Fig 6.8: Over-/Under-banking Tendency

5) The Steep Turn: (> 45 Degrees)

As previously mentioned, a significant increase in lift is required. This is generated by back pressure on the control column which increases the angle of attack. The back pressure can be quite significant. With this increase in angle of attack, there is an increase in induced drag. This must be balanced by increasing the engine power if the aircraft is not to slow down. It is very important not to lose speed in a steep turn due to the increase in stall speed (refer load factor above). At any hint of stalling in a steep turn some of the back pressure on the control column should be released.

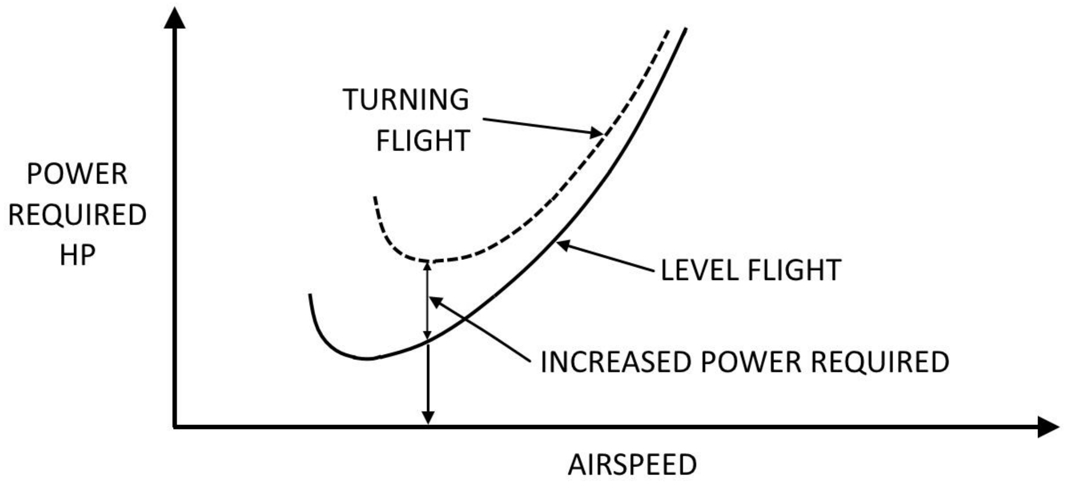

Fig 6.9: Increase in Power Required During Turning

5.1) ENTRY INTO A STEEP TURN

Look Out ! ! ! !

Roll into a bank as for a medium turn, except that as the bank angle exceeds 30 degrees:

- smoothly add power;
- progressively increase back pressure on control column;
- adjust the bank angle and back pressure to place the nose in the correct position relative to the horizon ; and
- Balance with rudder.

Remember that application of rudder will cause the aircraft to climb or dive, so coordinated rudder/elevator will be required.

5.2) *MAINTAINING A STEEP LEVEL TURN*

The primary action is to hold the nose in the correct position relative to the horizon, ensuring airspeed is maintained (power).

Keep a good look out to monitor the nose position and the approach of the roll-out reference pointe as well as look for other aircraft.

An occasional glance at the instruments will confirm the progress of the turn. Do not sacrifice your outside reference by concentrating on instruments. In a second or two check:

- *HEIGHT* on the Altimeter and Vertical Speed Indicator;
- *AIRSPEED* on the .Airspeed Indicator;
- *BANK ANGLE* on the Attitude Indicator;
- *BALANCE* using the ball (in the centre).

Adjusting the bank angle and nose position is a continuous requirement throughout the steep turn and keeps the pilot quite busy. The sooner corrections are made, the smaller they can be and the better the steep turn.

If height is being gained in a steep turn, it means that the vertical component of the lift is too great and so either:

- *Steepen* the bank angle; and/or
- *Relax* some of the back pressure.

If height is being lost then the vertical component of the lift force is insufficient. To regain height;

- *Reduce the bank angle slightly;*
- *Raise the nose with back pressure; and*
- *Once back on height, reapply the desired bank angle and back pressure.*

If the nose drops below the horizon during a steep turn, trying to raise the nose with back pressure will only tighten the turn rather than raise the nose. Should the height loss rapidly increase, roll out to straight and level, climb back to desired height and start again.

5.3) *ROLLING OUT OF A STEEP TURN*

Same as rolling out of a medium turn except:

- *Greater anticipation is required to roll out on reference point;*
- *There is a great deal more back pressure to be released, otherwise height will be gained; and*
- *Power must be reduced to cruise power.*

Remember to balance with rudder.

-

6) Balancing the Turn:

6.1) THE BALANCED TURN:

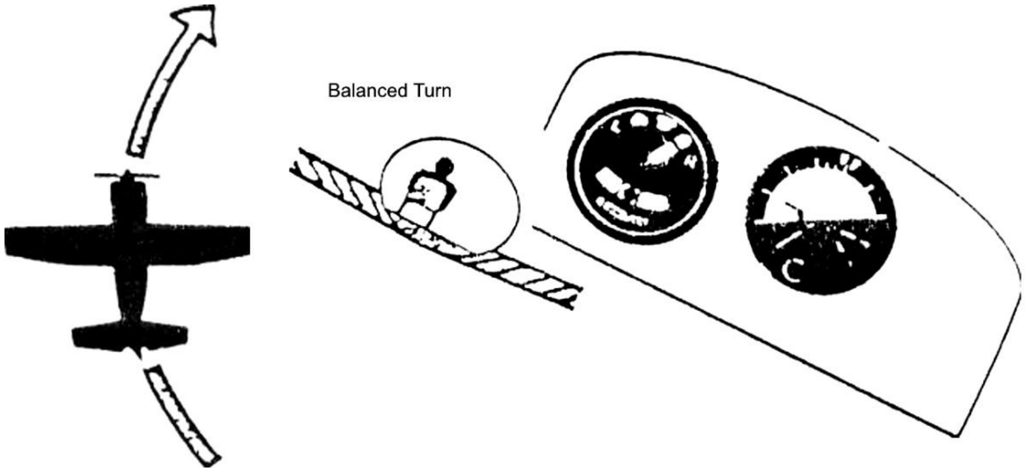

Fig 6.10 The pilot will feel comfortable in the turn

6.2) THE SLIPPING TURN

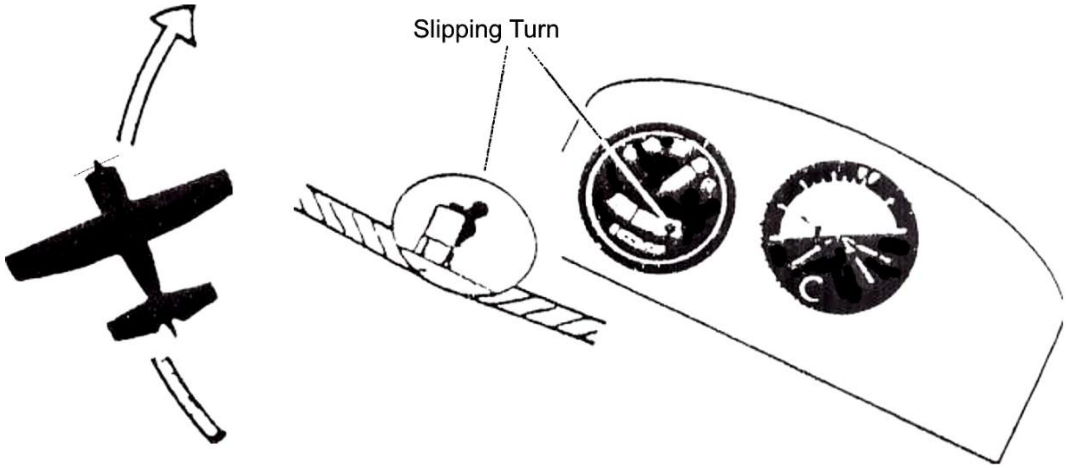

Fig 6.11 More right rudder is required.

6.3) THE SKIDDING TURN

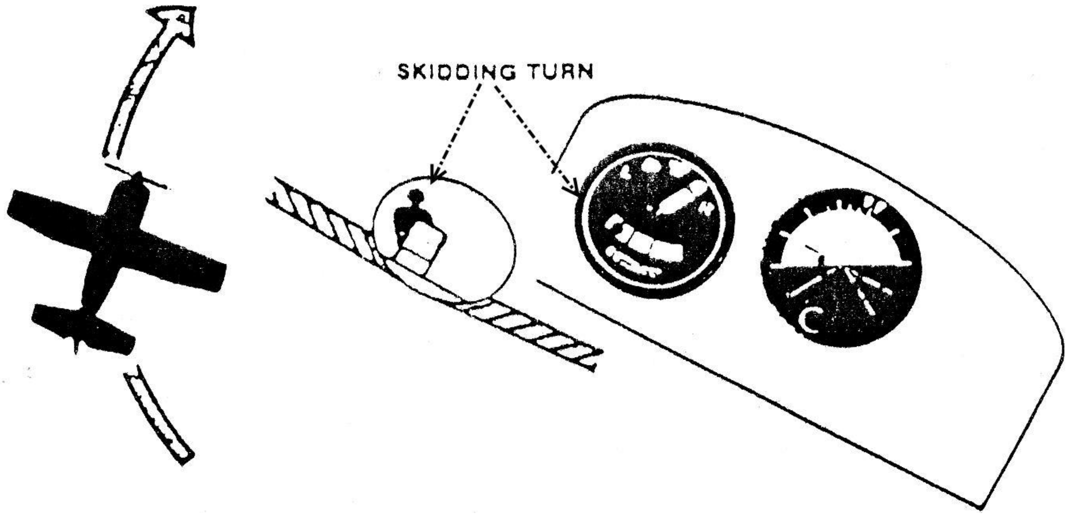

Fig 6.12 Left rudder pressure is required to balance the turn

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AIRMANSHIP

1. LOOKOUT PRIOR TO ENTRY AND DURING TURN.
2. ORIENTATION PRIOR TO ENTRY AND ON RECOVERY.
3. CONCENTRATE ON ATTITUDES IN RELATION TO HORIZON FOR JUDGING ANGLES OF BANK.
4. DEVELOP SMOOTH FLYING TECHNIQUES, ESPECIALLY CO-ORDINATION OF CONTROL COLUMN AND RUDDER.
5. COCKPIT INSPECTIONS FOR TURNS IN EXCESS OF NORMAL (45 / 60DEG).
6. TRIM AND STABILISE AIRCRAFT BEFORE ROLLING INTO TURN.

ENGINE CONSIDERATIONS

1. POWER SETTING FOR STEEP TURNS:
2. MIXTURE AS REQUIRED - RICHEN IF NECESSARY;
3. PITCH - RPM AS FOR CLIMB;
4. THROTTLE - CLIMB POWER OR FULL POWER FOR STEEP TURN
5. TEMPERATURES AND PRESSURES

- Asdfdfgh

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CHAPTER 7

EXERCISE 10A

SLOW FLIGHT

1. AIM

To enable the student to fly the aircraft at the lower speed range safely and accurately, and to control the aircraft in balance while returning to normal airspeeds.

DEFINITION

Any speed below the normal operating range of the aircraft.

WHY IT IS BEING TAUGHT

To give the student a good understanding and thorough knowledge of the principles required to fly at the lower speed range of the aircraft at different attitude, trim and power settings at various speeds and configurations.

2. LONG BRIEFING

i. OBJECTIVES:

a. Aeroplane Handling Characteristics during Slow Flight at –
   Vs1 & Vs0 + 10 knots;
   Vs1 & Vs0 + 5 Knots.
b. Slow Flight during Instructor Induced distractions.
c. Effect of going around from an approach or landing in configurations where application of engine power causes a strong ‘nose-up’ movement requiring a large trim change.

ii. CONSIDERATIONS:

a. The effect of controls during Slow Flight

The ailerons can be very ineffective at slow airspeeds. Furthermore, in a slow airspeed/high angle-of-attack situation, adverse yaw (described in exercise 9) is far more pronounced, especially with large aileron deflections, i.e. when rolling into or out of a turn.

The rudder is also less effective at slow airspeed and coarser use of the rudder pedals may be necessary. The elevator/stabilator is the most powerful of the three primary flying controls. As well as controlling the attitude, the tail plane or stabilator provides stability in pitch. The elevator or stabilator is, of course, less effective at slow airspeeds. In addition the high angle of attack of the wing can produce a considerable ‘downwash’ over the tail, altering its angle of attack and therefore the lift force produced by the tail plane. The effect of downwash is generally more noticeable on a high-wing aircraft than a low wing aircraft.

The slipstream will alter the feel and effectiveness for the rudder and the elevator/stabilator (except on a ‘T’-tail aircraft where the elevator is outside the slipstream). At slow airspeeds the helix of the slipstream is much tighter around the fuselage and its effect more pronounced. Changes in power setting at slow airspeeds will have a more noticeable yawing effect, which the pilot will have to anticipate and correct.

Raising and lowering of flap is another factor to consider more carefully during slow flight. The change in drag (and therefore change in airspeed) is more critical at these slower airspeeds. Do not raise the flaps if the airspeed is below Vs1 – the flaps-up stalling airspeed (i.e. the bottom of the green arc on the ASI).

All control movements should be smooth and coordinated. Harsh and excessive control movements must be avoided.

b. Maneuvering in Slow Flight

During the flight at slow airspeed, maintaining the selected airspeed and balanced flight are all-important. Any change in power setting will have a pronounced yawing effect, which the pilot must anticipate and correct. Similarly, when turning the increased adverse yaw needs to be compensated for by the pilot.

We return to the maxim that Power + Attitude = Performance. To fly level, the required power is set and the attitude adjusted to attain the target airspeed. It may be necessary to make small adjustments to the power and attitude to stay level at the selected airspeed. An excess of power will cause the aircraft to climb, while too little power will cause the aircraft to descend. Attitude is controlling airspeed; power is controlling height/altitude.

During a turn, the small loss of airspeed normally acceptable is no longer safe so, the aircraft is pitched nose-down to maintain airspeed and power is added (during a level turn) to stop the aircraft descending. During slow flight, turns are normally made at no more than 30º angle of bank due to the increase in stalling speed as angle of bank increases emphasize awareness and caution.

It is worth repeating that during all these maneuvers, keeping the aircraft in balance using the rudder and maintenance of the selected airspeed through attitude is all important.

c. Distractions during Slow Flight

The danger of flying too slowly often manifests itself when the pilot is distracted from the primary task of flying the aircraft by some secondary factor (i.e. radio calls, talking to passengers, map reading, positioning in the circuit etc.) The instructor is to simulate a number of distractions to demonstrate the importance of making the actual flying of the aircraft the Number One priority at all times.

4. SIMILARITY TO PREVIOUS EXERCISES

a. Effect of controls.

b. Straight climbs and descents.

c. Medium turns.

d. Climbing and descending turns

****

AIRMANSHIP

1. LOOKOUT – CLEAR OF OTHER AIRCRAFT AND CLOUD.
2. MAINTAIN AIRCRAFT IN-TRIM AT ALL TIMES.
3. USE VISUAL HORIZON FOR OBTAINING NOSE ATTITUDE AND BANK ANGLES IN TURNS AND CONFIRM WITH INSTRUMENT INDICATION.
4. CO-ORDINATION OF CONTROLS THROUGHOUT EXERCISE:
5. BALANCE – SLIP AND SKID.
6. SPEED CONTROL DURING FLAP EXTENSION AND RETRACTION.

ENGINE CONSIDERATIONS

1. SAME AS STRAIGHT CLIMBS AND DESCENTS.

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EXERCISE 10B

STALLING

1. **Definition:**

A breakdown of the airflow over a wing, when lift no longer rises with an increased angle of attack. A loss of lift, a loss of altitude and a pitching moment results.

2. **Objective:**

To ensure a good understanding and thorough knowledge of the principles required to:

(i) Recognise the symptoms of an impending stall.
(ii) Know the characteristics of the stall.
(iii) The recovery procedure (minimum height loss)

3. **How The Exercise Applies To Flying:**

This is an abnormal condition of flight which can occur at any airspeed, any attitude, any power setting and any configuration and at any weight or g loading.

4. **Objective:**

To explain and demonstrate the occurrence of the stall with respect to:

a. Effects of controls.
b. Straight and level flight.
c. Turning

****

1) Principles Involved:

1.1) *RECAP ON WHAT MAKES AN AEROPLANE FLY:*

Bernoulli's Principle - refer effects of controls. Remember energy of motion (kinetic) + potential energy remains constant. If one component is increased, the other must decrease.

The Venturi tube illustrates this principle.

This principle when applied to the airflow over an airfoil produces an increased velocity on the upper airfoil surface, which is greater; than the increase on the lower surface.

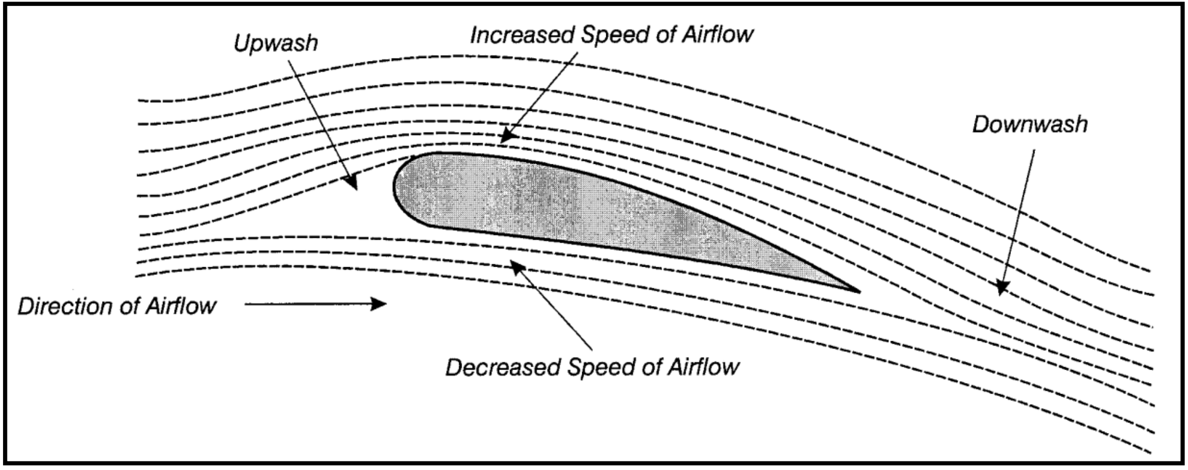


Fig 7.1: Venturi Effect on an Aerofoil

Both upper and lower surface contribute to lift, but it is the decreased pressure on the upper surface which has the most effect.

Remember, Lift is the vertical component or upwards force which in flight is supplied mostly by the wings. It always acts at right angles to the wing.

Lift Formula:

LIFT = $C_L.1/2.\rho.V^2.S$

C_L = Coefficient of lift
P = Density of the air
V = Velocity
S = Surface area of the wings.

1.2) RECAP ON DEFINITIONS

ANGLE OF ATTACK: Angle between chord line and the relative air flow.

CHORD LINE: A straight line joining the leading edge and the trailing edge of an airfoil.

RELATIVE AIRFLOW: Air in a region where pressure, temperature and relative velocity are unaffected by the passage of the aircraft through it.

INERTIA: The natural tendency for the motion of objects to continue with what they are already doing, (Newton's first law).

NEWTON'S LAWS:

1. Air which is still will tend to remain still, while air which is moving will tend to remain moving and will resist any change of speed or direction.
2. To change the direction of the airflow a force must be applied.
3. The application of the force upon the air will cause an equal and opposite reaction upon the surface which produces the force.

BOUNDARY LAYER: The layer of air between the surface and the full velocity of the airflow. It can be either laminar or turbulent, usually laminar near the leading edge then becoming turbulent at the transition point.

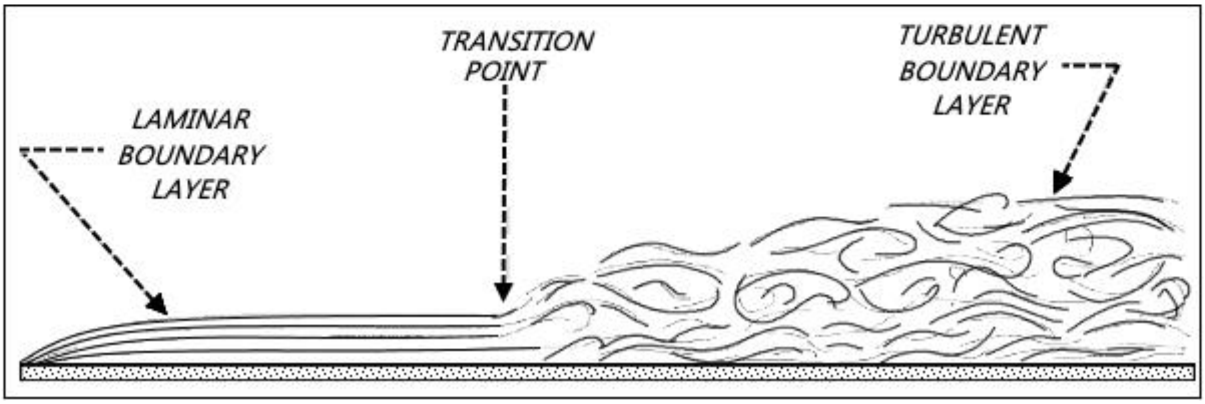


Fig 7.2 Boundary Layer

CENTRE OF PRESSURE: A single resultant force representing the lift produced by the wing.

FORCES AND COUPLES ACTING ON AN AIRCRAFT – REVISE:

Remember: Lift acts through centre of pressure.
Weight acts through centre of gravity.

Thrust acts horizontally through the prop shaft.

Drag acts horizontally backwards.

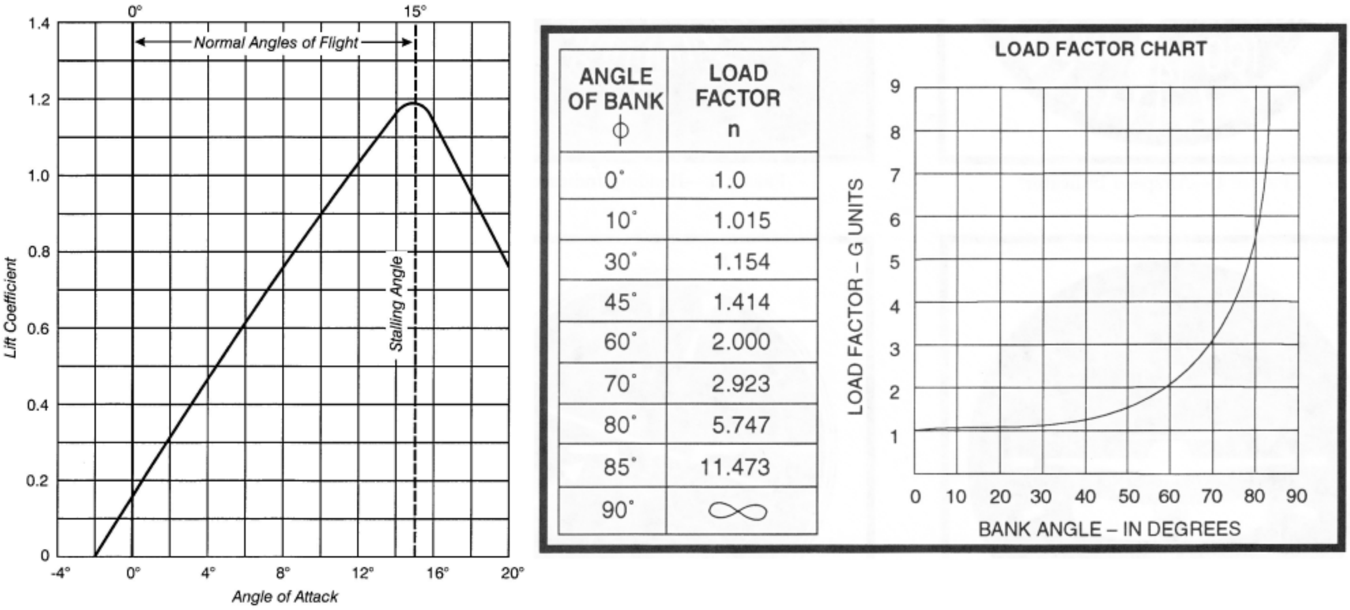
The positions of the centre of pressure and the centre of gravity are variable and for most conditions of level flight are not coincident:

- The centre of pressure changes with variations in angle of attack.
- The centre of gravity changes with reduction in fuel, when stores are expended, or variations in loading between flights.

1.3) CHARACTERISTICS OF THE AIRCRAFT IN SLOW FLIGHT:

- Slow flight can be defined as flight in the speed range from below the endurance speed to just above the stalling speed.
- The amount of lift and the control of the aircraft in flight depends on maintaining the minimum airspeed.
- It is important to remember that the minimum speed is not defined by power or thrust requirements since the conditions of stall, stability and control generally predominate.
- This minimum speed varies with the all up weight imposition of loads due to manoeuvres and density altitude.
- The closer the actual speed to this minimum speed the greater the angle of attack and the less effective are the flying controls.
- We know that in level flight the weight of the aircraft is balanced by the lift and from the lift formula (LIFT = $C_L.1/2.\rho.V^2.S$) it can be seen that lift is reduced whenever any of the other factors in the formula are reduced. For all practical purposes density and wing area can be considered as constants (for a particular altitude and configuration). So if the engine is throttled back the drag will reduce the speed from the formula, lift will be reduced - to keep lift constant and so maintain level flight the only factor the only factor that is readily variable is the lift coefficient (C_L).

  The coefficient of lift can be made larger by increasing the angle of attack and by so doing the lift can be restored to its original value and level flight can be maintained at a lower airspeed.



ANGLE OF BANK ϕ	LOAD FACTOR n
0°	1.0
10°	1.015
30°	1.154
45°	1.414
60°	2.000
70°	2.923
80°	5.747
85°	11.473
90°	∞

Fig 7.3 Effect of Load Factor

However, eventually at a certain indicated airspeed the wing reaches its stalling angle, beyond which point any further increase in angle of attack, in an attempt to maintain lift will precipitate a stall.

Thus the minimum speed below which it is impossible to maintain controlled flight~ is the stalling speed.

1.4) *MOVEMENT OF CENTRE OF PRESSURE WITH ANGLE OF ATTACK:*

As the angle of attack is increased so the centre of pressure moves forward.

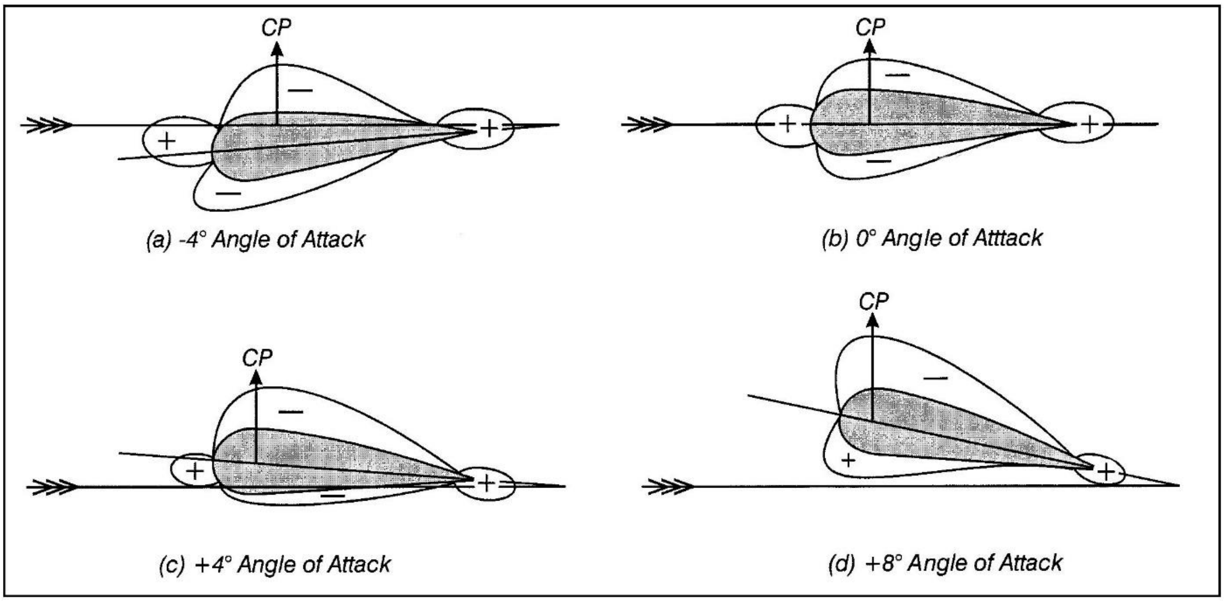


Fig 7.4: Movement of Centre of Pressure

This movement brings the Centre of Gravity and the Centre of Pressure closer together and weakens the lift over weight couple (nose down tendency).

- Elevators become less responsive with airspeed reduction as angle of attack increases.
- Ailerons and rudders become less effective as airspeed decreases and larger control movement deflection becomes necessary to control the aircraft in 3 axes.
- Increases in power make elevators and rudders more effective due to slipstream effect.
- But yaw due to slipstream is much more pronounced at slow flight and requires use of rudder to maintain balanced flight.
- Now the further effect generated necessitates the use of aileron to hold the wings level. This is a cross controlled condition and makes the aircraft vulnerable to an emphatic wing drop and possible spin entry and should be AVOIDED.

1.5) *AIRFLOW AT CRITICAL ANGLE OF ATTACK:*

- As previously mentioned lift from the wing among other factors depends on the smoothness of the airflow around it. Furthermore an increase in angle of attack = increase in lift. Eventually a certain angle of attack is reached and the boundary layer separates, the smooth airflow breaks down and becomes turbulent, resulting in a large loss of lift and increased drag.
- This marked reduction in the lift coefficient which accompanies the breakdown of airflow over the wing occurs at the CRITICAL ANGLE of attack for a particular wing.

- Apart from the use of flap, the aircraft will always stall at the same critical angle of attack.
- Now the Boundary Layer separation is produced as a result of the adverse pressure gradient which develops causing the airflow close to the surface to flow in the opposite direction to the free stream flow. Where the flow close to the surface has reversed, it is said to have separated and the point where it occurs is defined as being the separation point.

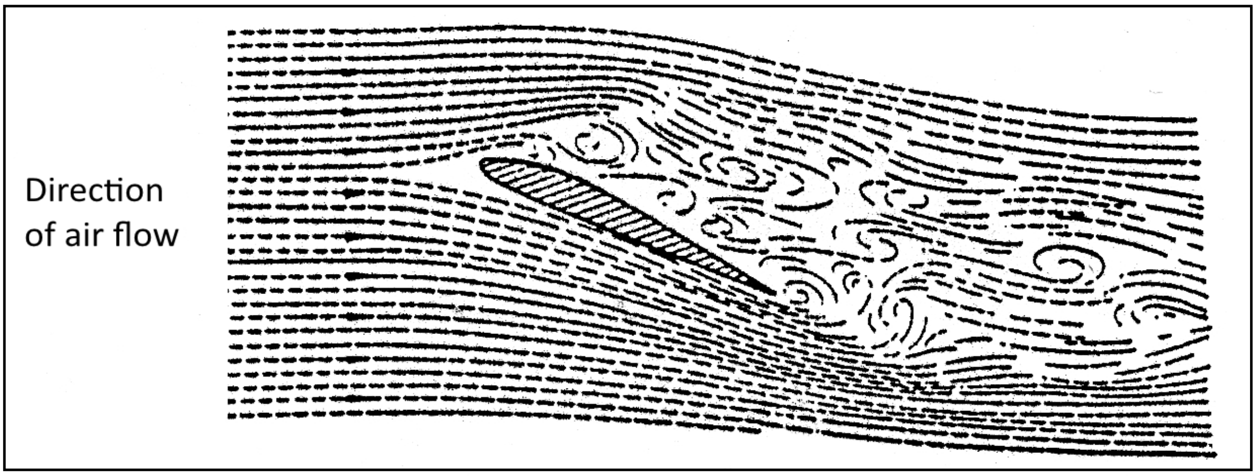


Fig 7.5: Airflow at Critical Angle of Attack

The separation point moves forward with increased angle of attack and eventually the critical angle of attack is reached.

The flow over the upper surface is then completely broken down and the lift produced by the wing decreases and the wing is said to STALL.

1.6) BASIC STALLING SPEED:

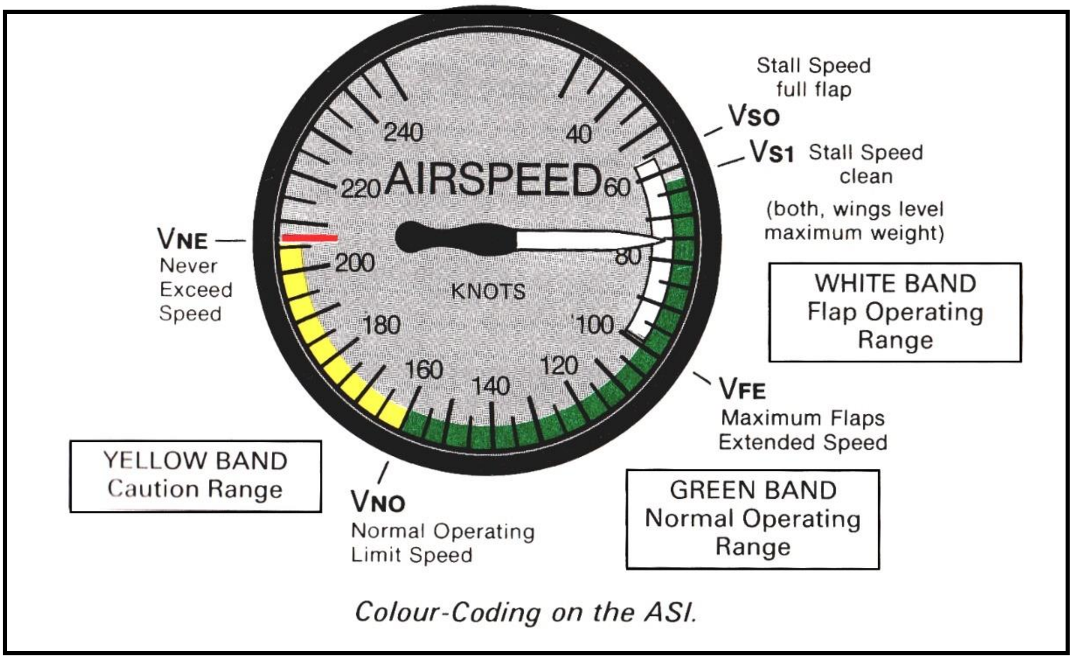
The most useful STALLING SPEED to remember is the stalling speed corresponding to the Critical Angle of Attack in straight and level flight.

Definition

The speed below which an aircraft with clean configuration and of stated weight with engine throttled back can no longer maintain straight and level flight. This speed is listed in the aircraft manual.

2) Execution of the Stall

2.1) *SYMPTOMS APPROACHING THE STALL:*



Colour-Coding on the ASI.

- A lowering of airspeed as the throttle is closed and the aircraft held in approximately level attitude.
- A reduced response from all three controls as airspeed becomes lower.
- Stall warning will commence 5 to 10 knots before the stall is reached.
- A buffet can be felt over the elevators as the smooth
- Airflow breaks away and becomes turbulent

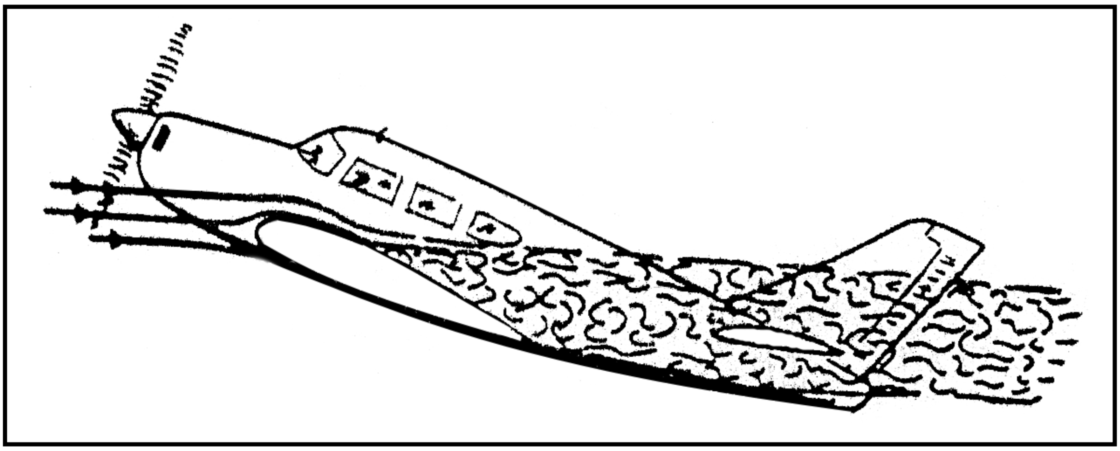


Fig 7.6: Turbulent Air Flow

2.2) *SYMPTOMS AT THE STALL:*

- This is a condition where height is lost and the nose drops, even though the control column is held well back or even full back.

Remember the attitude of the aircraft to the horizon bears no relationship to the stalling angle of attack, it is the direction of the relative airflow which determines the angle of attack.

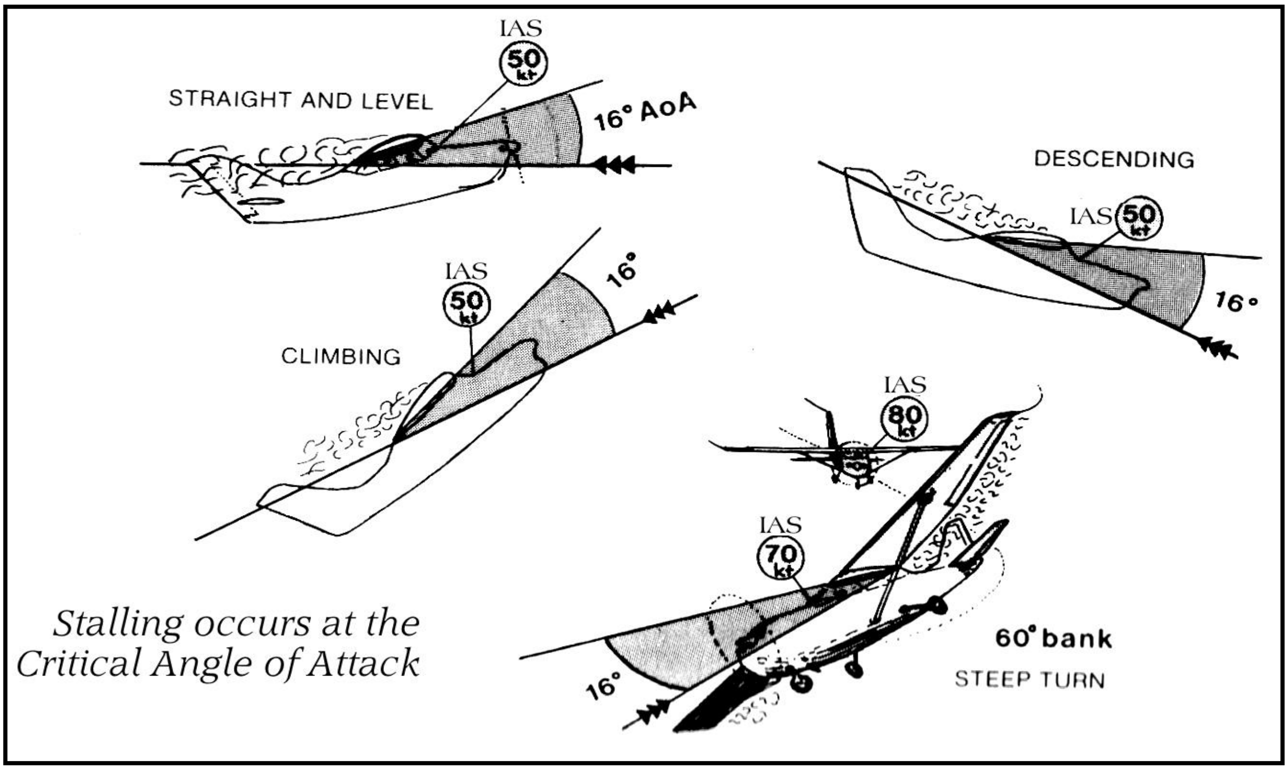


Fig 7.7 Stalls occur at any Attitude

2.3) RECOVERY PROCEDURE:

To recover from a stall it is necessary to reduce the angle of attack until it is below the angle at which the stall occurred. This reduction in angle of attack can be made by moving the control column forward and applying power.

It is important to understand that these actions will change the flight path of the aircraft and therefore the relative airflow which will now meet the aircraft at an angle less than the stalling angle of attack.

2.4) FACTORS AFFECTING THE STALL:

Weight: Extra weight requires extra lift. For all angles of attack more airspeed is needed to provide greater lift. So the stalling speed will be higher.

Power: With power on the stalling speed will be lower, because thrust inclined upwards contributes to lift. Slipstream prevents turbulent airflow over the wings, the increased velocity provides more lift and decreases the angle of attack of the centre section of the wing.

Flaps: Lowered flaps increase the lift co-efficient of the wing. Speed required to maintain lift is less therefore stalling speed is also less.

Load factor: In a turn lift must be increased to maintain level flight. Load factor and stalling speed will be higher. Sudden increase in pitch will increase the load factor. A sudden pullout of a dive momentarily increases the angle of attack and raises the stalling speed.

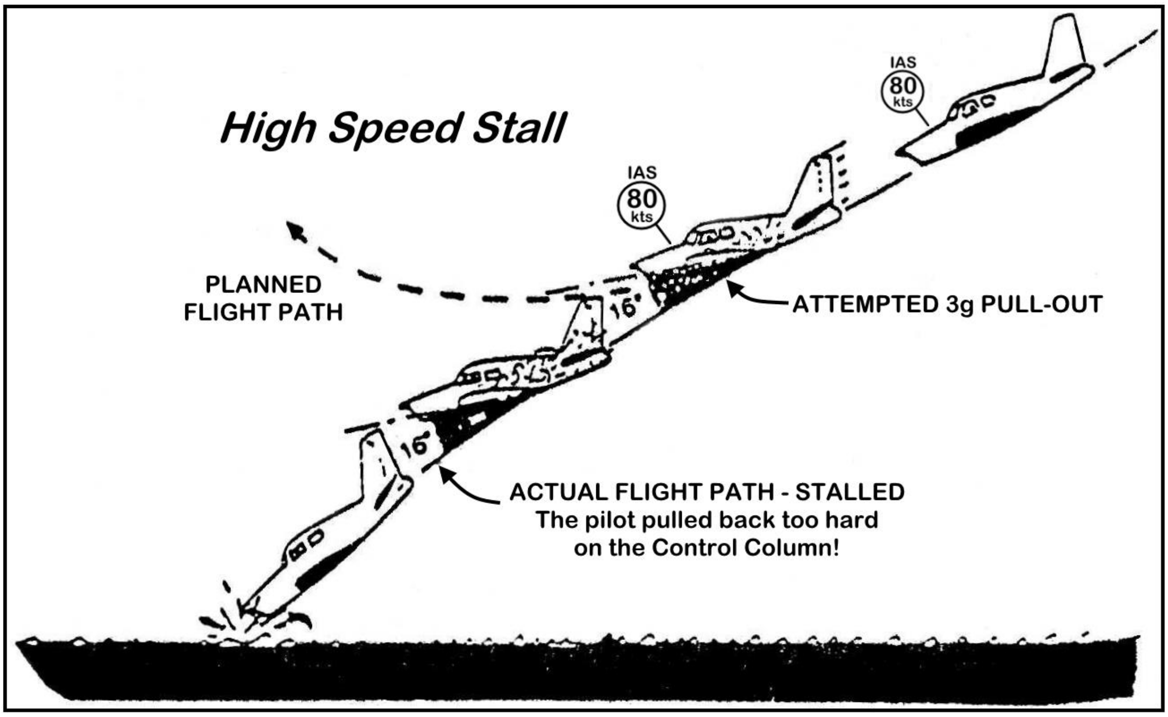


Fig 7.8 Stalls occur at any Speed

Aerofoil Section: Icing, shape and damage can frequently alter the lift characteristics and increase the stalling speed.

Formula: $\text{STALLING SPEED (TAS)} = \frac{2W}{P\,C_L\,\text{max}\,S}$

3) Wing Tip Stalling

The wing of an aircraft is designed to stall progressively from the root to the tip.

Reasons why:

- To produce early buffet symptoms over the tail surfaces
- To retain aileron effectiveness up to critical angle of attack.
- To avoid a large rolling moment which would arise if the tip of one wing stalled before the other wing (wing drop).

11) FEATURES TO PREVENT WING TIP STALLING

Washout Reduction of incidence at the tips will result in the wing root reaching critical angle before the wing tips.

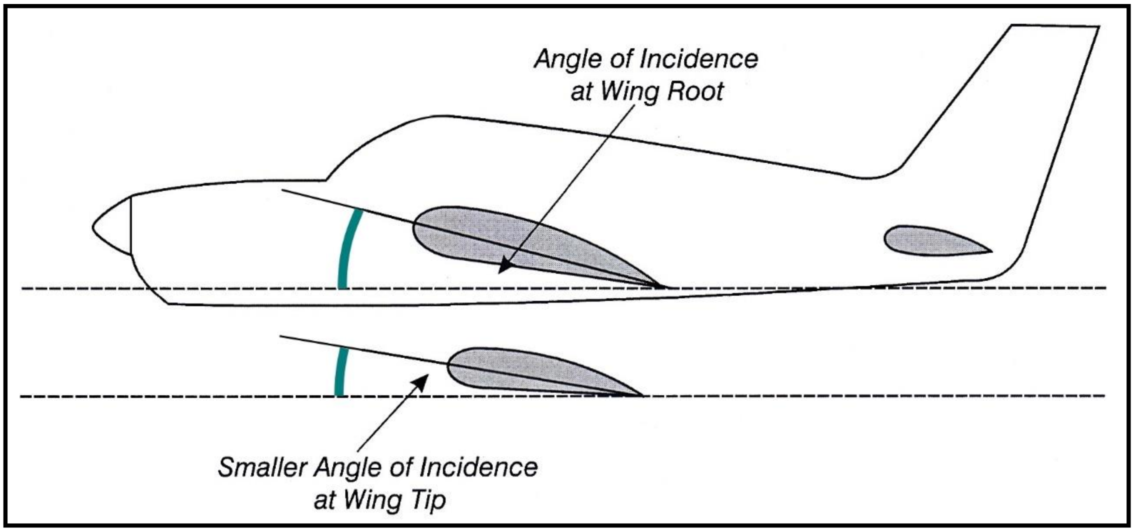


Fig 7.9 Washout

Root Spoilers By making the leading edge of the root sharper, the airflow has difficulty following the contour of the leading edge and an early stall is induced.

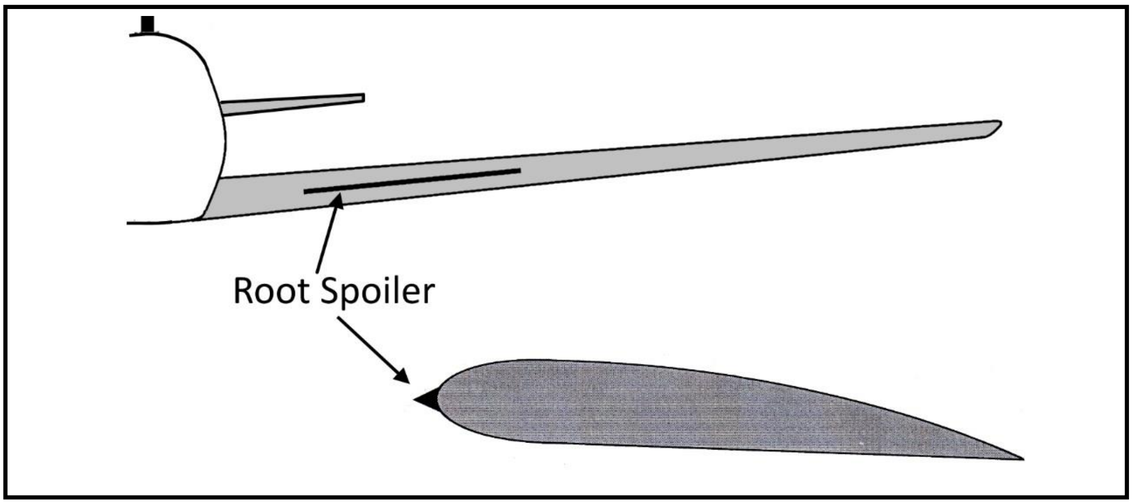


Fig 7.10: Position of Root Spoilers

Slats and Slots on the outer portion of the wing increases the stalling angle on that part of the wing.

12) REASONS FOR WING TIP STALLING

Power/Slipstream: The effective angle of attack within the slipstream is reduced, therefore the outboard wing sections will stall first. This condition is more severe if flaps are down.

Ailerons, being outside the influence of the slipstream, will be less effective at lower speed and control in roll may not be possible. If used under stall conditions they may produce an adverse aileron yaw leading to an emphatic wing drop and autorotation.

4) Autorotation

Covered more fully in spinning briefing. At this stage it is sufficient to mention that it is a condition of flight during which the aircraft has a tendency to continually rotate about the longitudinal axis due to a marked variation of lift between the left and right wings.

It is however possible that we may inadvertently cause a wing to drop while practicing stalling and therefore recovery will be briefly covered.

4.1) DROPPING A WING

- When an aircraft stalls and a wing drops, (assume left wing), the left wing moves in the direction of the undercarriage, and the relative airflow comes from beneath the left wing. This increases the angle of attack.
- This stalls the wing further and any attempts to pick the wing up with aileron will increase the angle of attack even further, aggravating the situation.

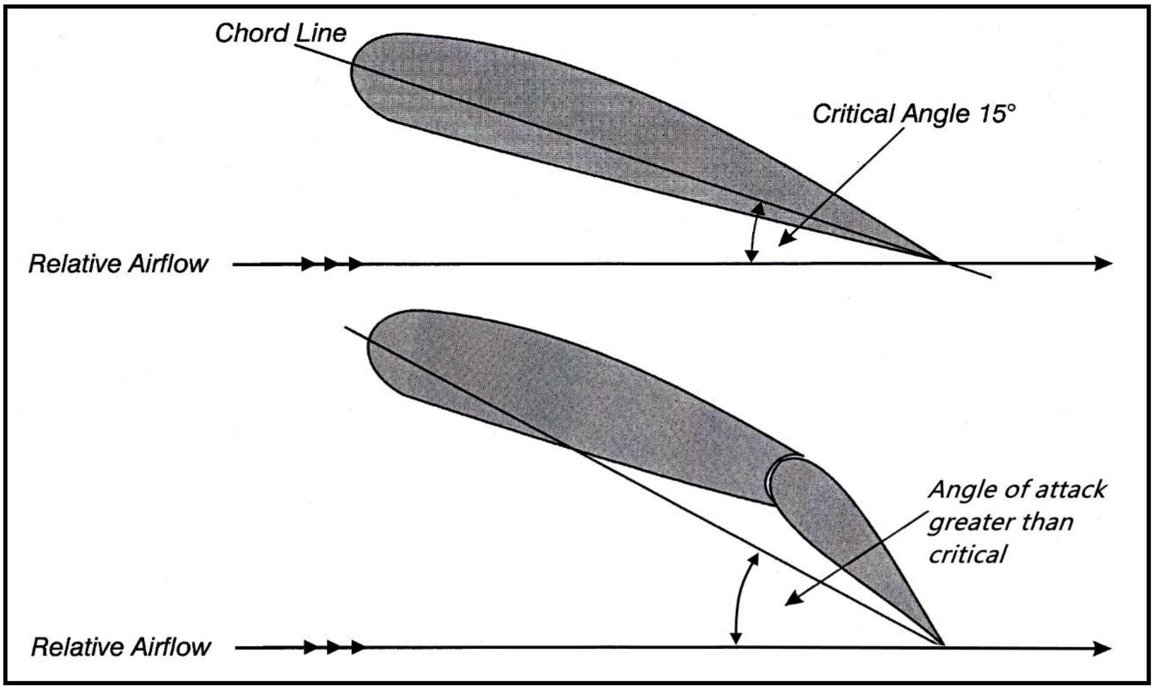


Fig 7.11: Use of Aileron at Critical AoA

- To pick up the wing rudder is applied. By yawing the nose towards the right wing, this causes the left wing to speed up and as per lift formula, more lift is obtained.
- The yawing action of the stalled wing changes the direction of the relative airflow, reducing the angle of attack of the wing below the stall angle. Lift is increased.
- The right wing which is not stalled is retarded. This decreases the speed - less lift is produced and the wing moves in the direction of the undercarriage.

5) Conclusion

Remember when flying at a slow airspeed the aircraft will be flying at the lower end of the power curves. The rate of climb will deteriorate markedly. Attempts to regain height by raising the nose will increase the induced drag and without an increase in power the airspeed will lower even further. No height will be gained and by continuing to raise the nose will result in more height being lost and eventually the aircraft will stall.

So to regain height when operating at a very low speed demands an increase of power as the nose is raised.

****

AIRMANSHIP

HASELL checks prior to stalling practice.

H Height - Recovery complete at min 2000' AGL.

A Airframe - U/C and flap position.

S Security - Harness tight, seats locked, gyros caged, loose articles stowed.

E Engine - Temperatures and pressures. Pitch and mixture set for climb power.

L Location

L Lookout - as below.

INSPECTION TURN: Minimum of 30 degree bank angle for 270 degrees, then steepen turn to stay in inspected area.

Check for: Other aircraft
Sufficient separation from cloud.
Good position relative to the sun.

LOOKOUT/LOCATION: In relation to ground position to ensure you are:

- In the General Flying Area.
- Not over a built-up area.
- Not over high ground.
- Not over rough terrain.
- Not over large expanses of water.
- Not over airfield or in an air corridor.
- Have chosen a possible forced landing field.
- That you remain in the area inspected.

ENGINE CONSIDERATIONS

1. THROTTLE-USE SMALL SLOW MOVEMENTS INITIALLY.
2. OVER BOOST / OVER-REV TAKE CARE.
3. USE OF CARB HEAT.
4. USE OF MIXTURE.

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CHAPTER 8

EXERCISE 11

SPINNING

1. **DEFINITION:**

A condition of stalled flight in which the aircraft describes a spiral descent. The aircraft will be rolling, yawing, pitching, side slipping and rapidly losing height.

2. **OBJECTIVE:**

Primarily safety. If the controls of an aircraft are mishandled during any phase of flight, other than structural failure, a spin is the worst situation that may result. It is desirable to recognise the development of a spin at the incipient stage, and carry out an early recovery. However a fully developed spin is a possibility, therefore necessitating the knowledge of a full spin entry and recovery.

An additional reason for teaching spinning is to build confidence and co-ordination.

3. **HOW THE EXERCISE APPLIES TO FLYING:**

This is an abnormal condition of flight which can occur at any airspeed, any attitude, any power setting and any configuration and at any weight or g loading.

4. **INTRODUCTION:**

You are probably very apprehensive about this lesson, and that is natural. This apprehension will disappear with practice. You have already experienced the aspects of the initial entry into a spin when you did stalling and incipient spins. It is also worth recapping on the characteristics of the spiral dive, in order that you may be able to differentiate between a spiral dive and a spin. More on this later. It must be emphasised that not all aircraft are cleared for deliberate spins.

****

1) Principles Involved:

1.1) *PRIMARY CAUSE:*

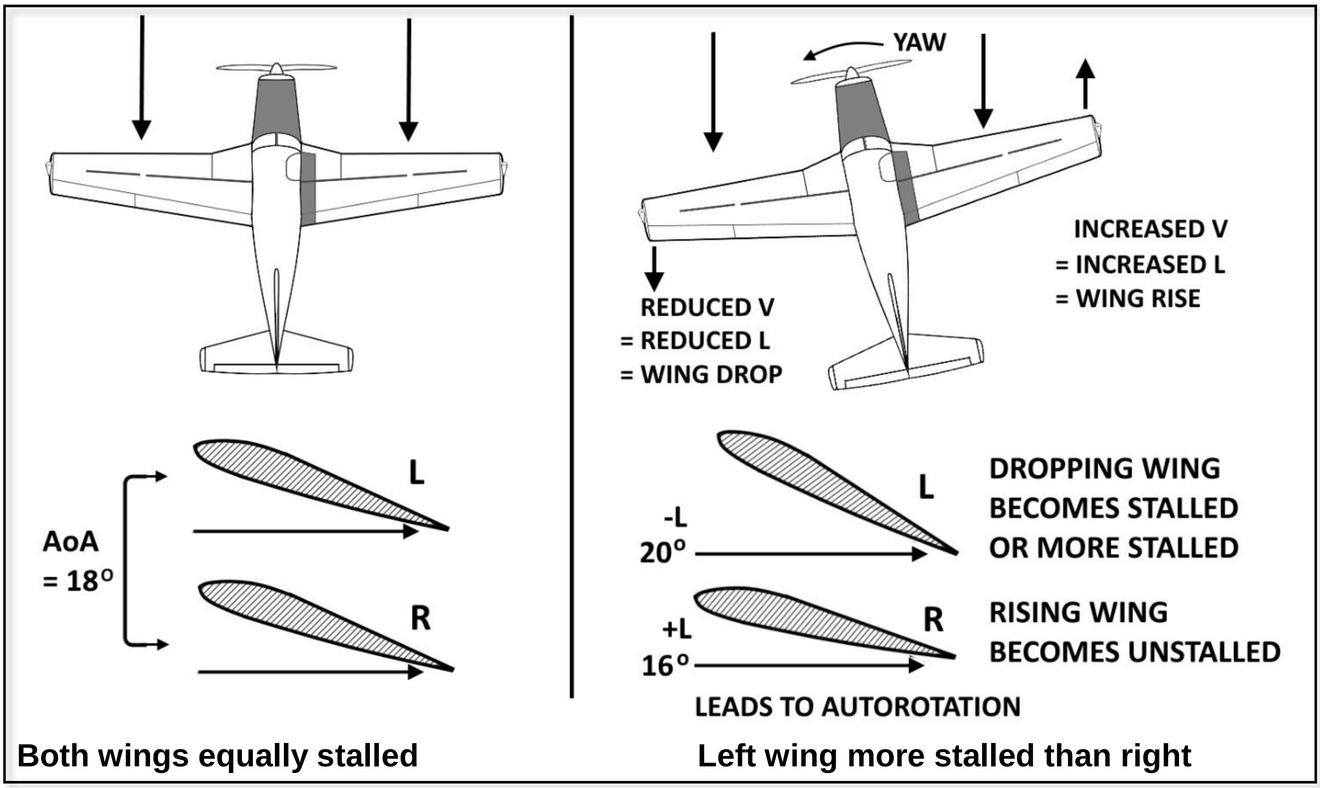
A spin may develop from many flight attitudes, level climbing or descending, and may be deliberate or inadvertent. Typically the reason is the development of a yaw when the aircraft is close to the stalling angle of attack. A spin does not occur without a yaw.

During the development of a spin the aircraft is rotating around all three the axes. Some aircraft will have better anti-spin properties than other. The reasons for this will be discussed here.

In order to demonstrate the spin, deliberate action will have to be taken. Your instructor will take you through the process and show you how to recover.

Spins are to be practiced in a properly certificated airplane. Before getting a demonstration, you should have a good idea of what to expect. The spin is an aggravated stall resulting in autorotation. In short, it is a condition where one wing stalls first and the plane "falls off" in that direction. One wing has more lift left and it is chasing the other stalled wing like a dog after its tail.

1.2) STAGES OF A SPIN ENTRY:



Both wings equally stalled **Left wing more stalled than right**

Fig 8.1 Development of a Spin

The above diagram assumes a stalling Angle of attack of 20 degrees

1.3) AUTOROTATION:

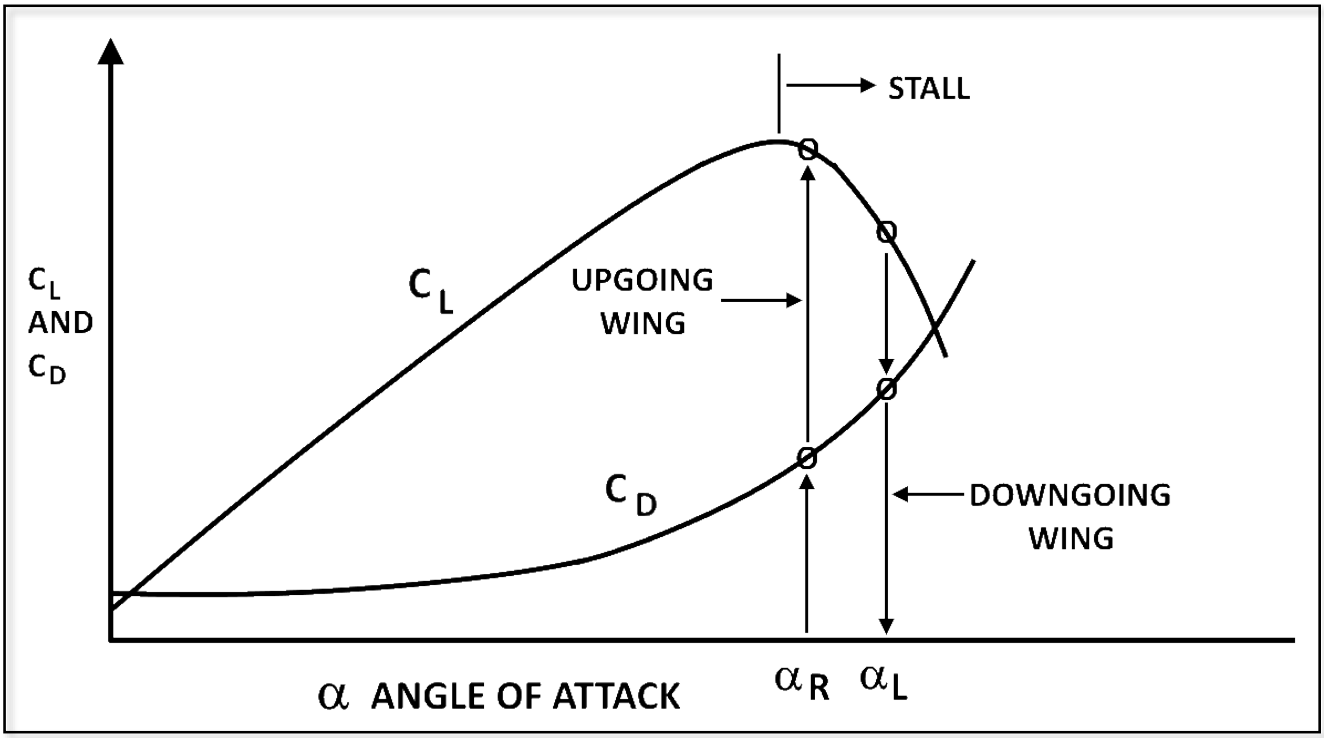


Fig 8.2 Difference in Lift of the Wings

The down going wing is more stalled and will thus produce more drag and less lift. The drag difference results in a yaw, and the lift difference results in a roll. Both the yaw and the roll will be in the direction of the down going wing. This action about the aircraft's longitudinal axis is known as AUTOROTATION.

The auto-rotational rolling and yawing moments of an aircraft at high angles of attack are the major pro-spin moments, and tend to accelerate the aircraft into the spin until other equal and opposite moments provided by aerodynamic damping and inertial forces limit the rate of rotation and yaw.

1.4) *INTENTIONAL SPIN ENTRY:*

- Reduce power, raise nose.
- Maintain aircraft in balance, wings level until near the stall.
- Hold wings level, apply full rudder towards spin direction and move control column fully back.
- Aircraft will yaw and roll in the direction of applied rudder.
- Maintain controls in this position until recovery is to be initiated.

1.5) *CHARACTERISTICS OF A SPIN:*

The aircraft is simultaneously rolling, yawing, pitching and side slipping. It will be losing height rapidly and descending along a vertical path about the spin axis. The main tendency is to continue the autorotation, thus maintaining the spin. If the aircraft has good directional stability, this will minimise the yaw, and allow an easier recovery.

On spin entry, aircraft will usually rotate several times before it settles down into a state of steady spin. Once settled in a spin the forces and moments acting upon it will be in equilibrium and the balance of forces will determine the values of angle of attack, sideslip, turn radius and rate of descent. The rate of yaw, roll and descent will be constant values.

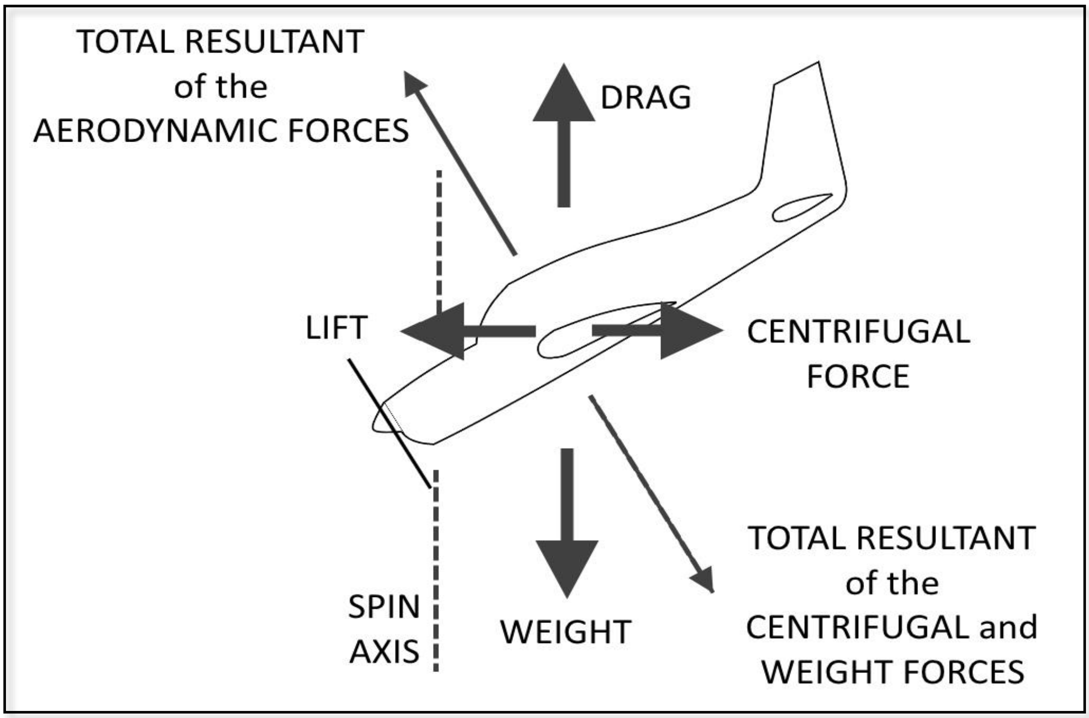


Fig. 8.3 Forces in a Spin

1.6) *B:A RATIO:*

This is a useful parameter in predicting the spin characteristics of an aircraft.

It compares the moment of inertia about the lateral axis with the moment of inertia about the longitudinal axis.

B is the inertial yawing moment of the fuselage.

A is the inertial rolling moment of the wings.

The size of the moments will be dependent on the distribution of the mass of the fuselage and wings.

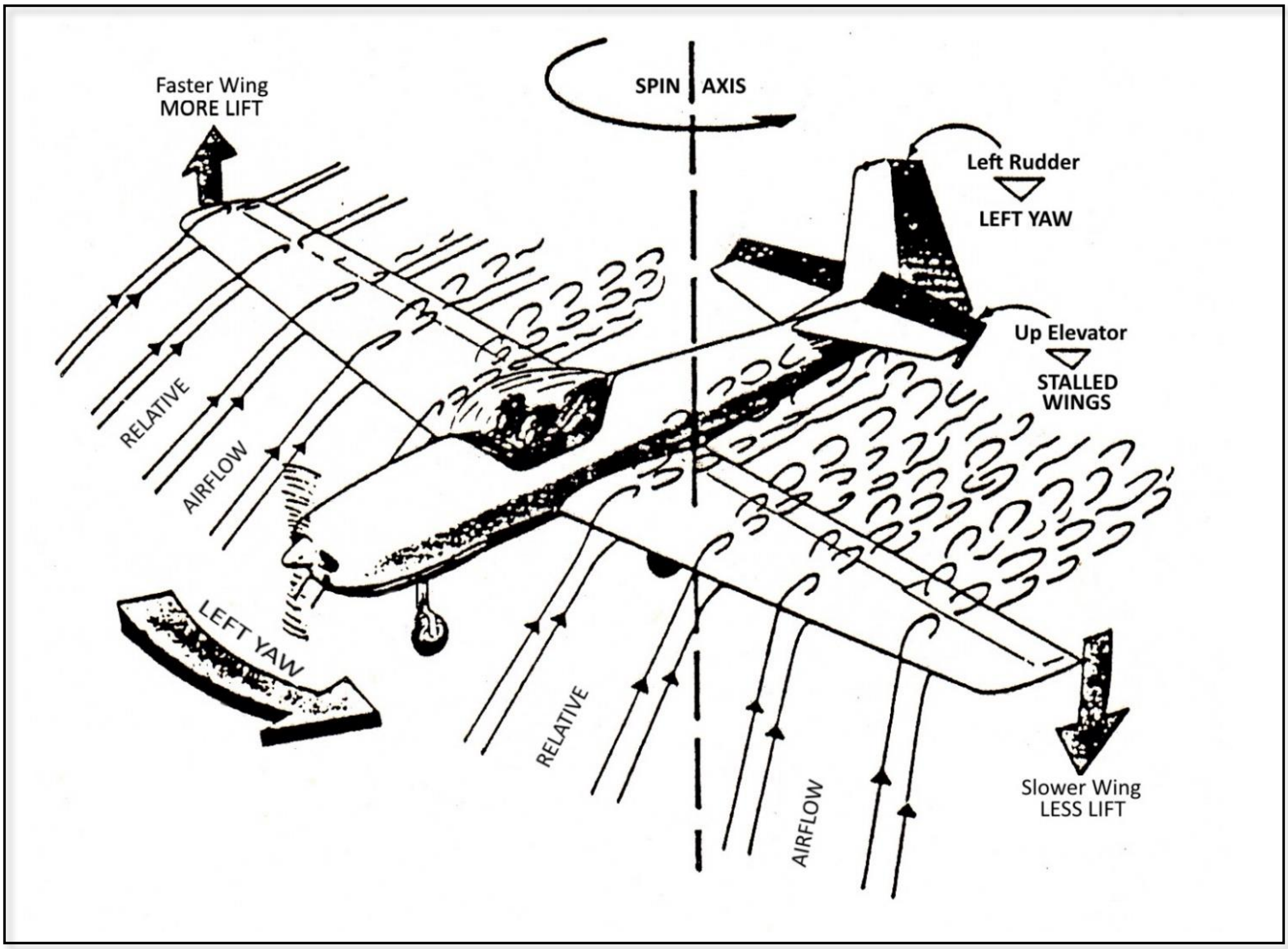


Fig. 8.4 Yawing Moments of Inertia in a Spin

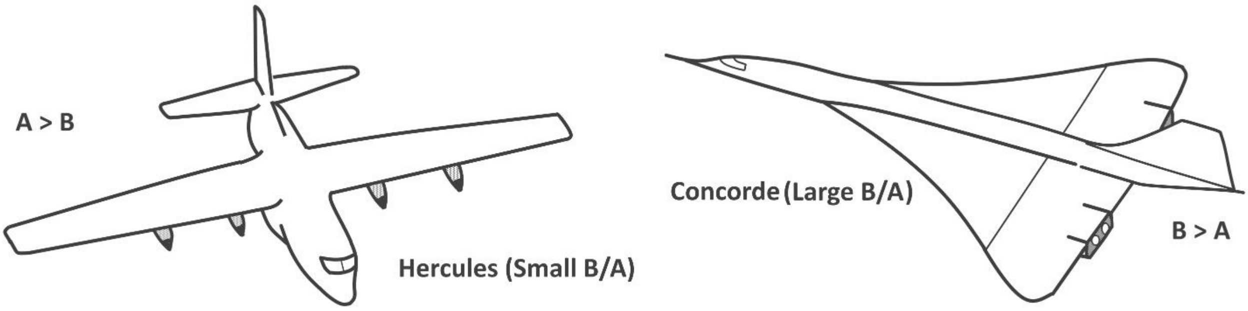


Fig. 8.4: B / A Ratio

1.7) RECOGNITION AND IDENTIFICATION OF SPIN AND SPIN DIRECTION

Most air-driven instruments will topple in a spin, but the turn indicator and pressure instruments will remain operative.

Instrument	**Indication**
Airspeed Indicator (ASI)	LOW AIRSPEED
Altimeter	LOSING HEIGHT RAPIDLY
Vertical Speed Indicator (VSI)	HIGH RATE OF DESCENT
Turn Indicator	IN DIRECTION OF SPIN
Slip Indicator (Ball)	EITHER DIRECTION

1.8) SPIN RECOVERY

The rudder is the primary yaw control and therefore it will be the most effective anti-spin control during recovery.

The standard recovery action which must be applied sequentially in a firm and positive manner follows;

- THROTTLE CLOSED
- AILERONS HOLD NEUTRAL
- FULL RUDDER OPPOSITE TO SPIN DIRECTION
- PAUSE MOMENTARILY
- EASE CONTROL COLUMN FORWARD UNTIL SPINNING STOPS.
- WHEN SPIN STOPS, IMMEDIATELY CENTRALISE RUDDER AND LEVEL WINGS WITH AILERONS
- WHEN WINGS LEVEL EASE OUT OF DIVE

1.9) EFFECT OF POWER IN A SPIN:

Power has a destabilising tendency. This is caused by asymmetric lift about the wings created by the slipstream path being mal-aligned with the horizontal axis during a yaw. This causes more lift on the outer wing resulting in more roll into the spin. Power should be fully closed in a spin.

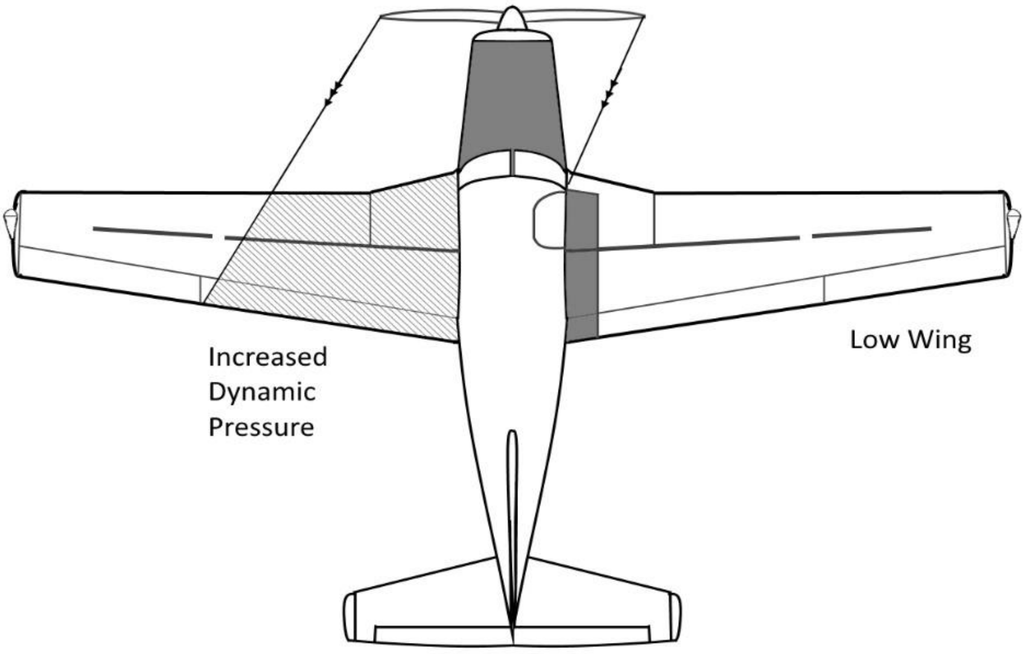


Fig 8.5: De-Stabilising Effect of Slip-Stream

1.10) EFFECT OF FLAPS IN A SPIN:

Intentional spinning with flaps is prohibited in most aircraft. The reason for this is the adverse effect on control responsiveness and the possibility of exceeding the flap limiting speed during recovery. With flap down, the airflow over the tail is disturbed and deflected, reducing the effectiveness of the rudder and elevators. During spin recovery, effectiveness of controls is vitally important.

If an inadvertent spin occurs when the flaps are deployed, the flaps must be retracted immediately.

1.11) EFFECT OF CENTRE OF GRAVITY:

The Center of Gravity changes the spin characteristics of an aircraft, even within the CG limits.

Forward CG - steeper spin, faster rate of descent, recovery easier as spin less stable. Extreme forward CG may prevent spin.

Aft CG - flatter spin, less rate of descent, spin more stable, recovery more difficult. If center of gravity is aft of limits, aircraft recovery may be impossible (flat spin).

****

AIRMANSHIP

- As applicable to stalling, but as greater loss of height involved, entry should be at a higher altitude.
- HASELL checks.
- Aircraft cleared for spinning.
- Weight and balance within limits.
- Correct use of throttle.
- Controls should always be applied smoothly.

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CHAPTER 8

EXERCISE 12

THE TAKE-OFF AND CLIMB TO THE DOWNWIND POSITION

1. AIM

DEFINITION

The take-off is considered to start when the aircraft is accelerated under its own take-off power on the ground until flying speed is reached, whereupon the aircraft is rotated and leaves the ground. The speed is now allowed to increase up to the safety speed, at which speed the aircraft is rotated into the climbing attitude.

WHAT THE INSTRUCTOR IS TO TEACH

i. Discuss the principles involved.
ii The air exercise briefing:
  a. Applicable procedures and checklists.
  b. Aircraft handling techniques: Demonstration and Observation.
  c. Considerations of airmanship and engine handling.
  d. Similarity to previous exercises.
  e. De-briefing after flight.

WHY IT IS BEING TAUGHT

To give the student a good understanding and thorough knowledge of the principles required to:

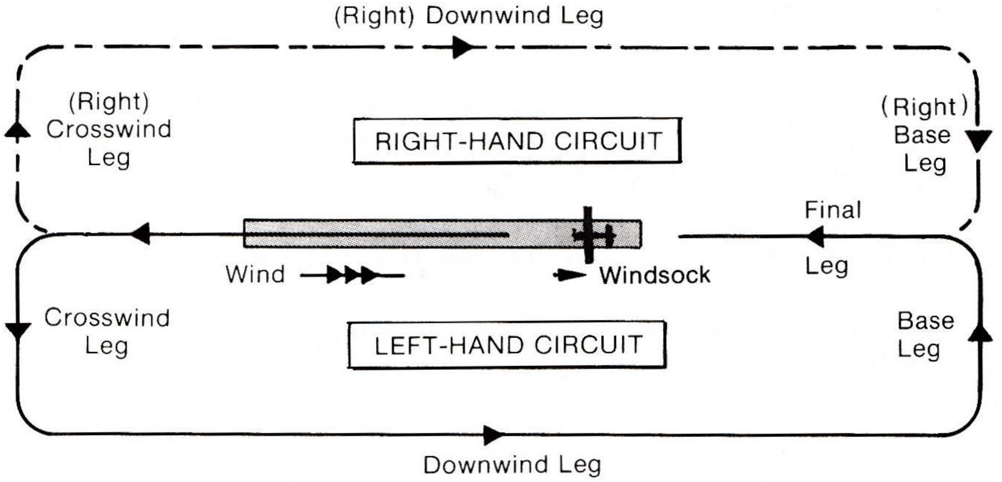
i. Control the aircraft on the ground before becoming airborne.
ii. Take account of the different considerations applicable to take-offs under varying weather conditions.

HOW THE EXERCISE APPLIES TO FLYING

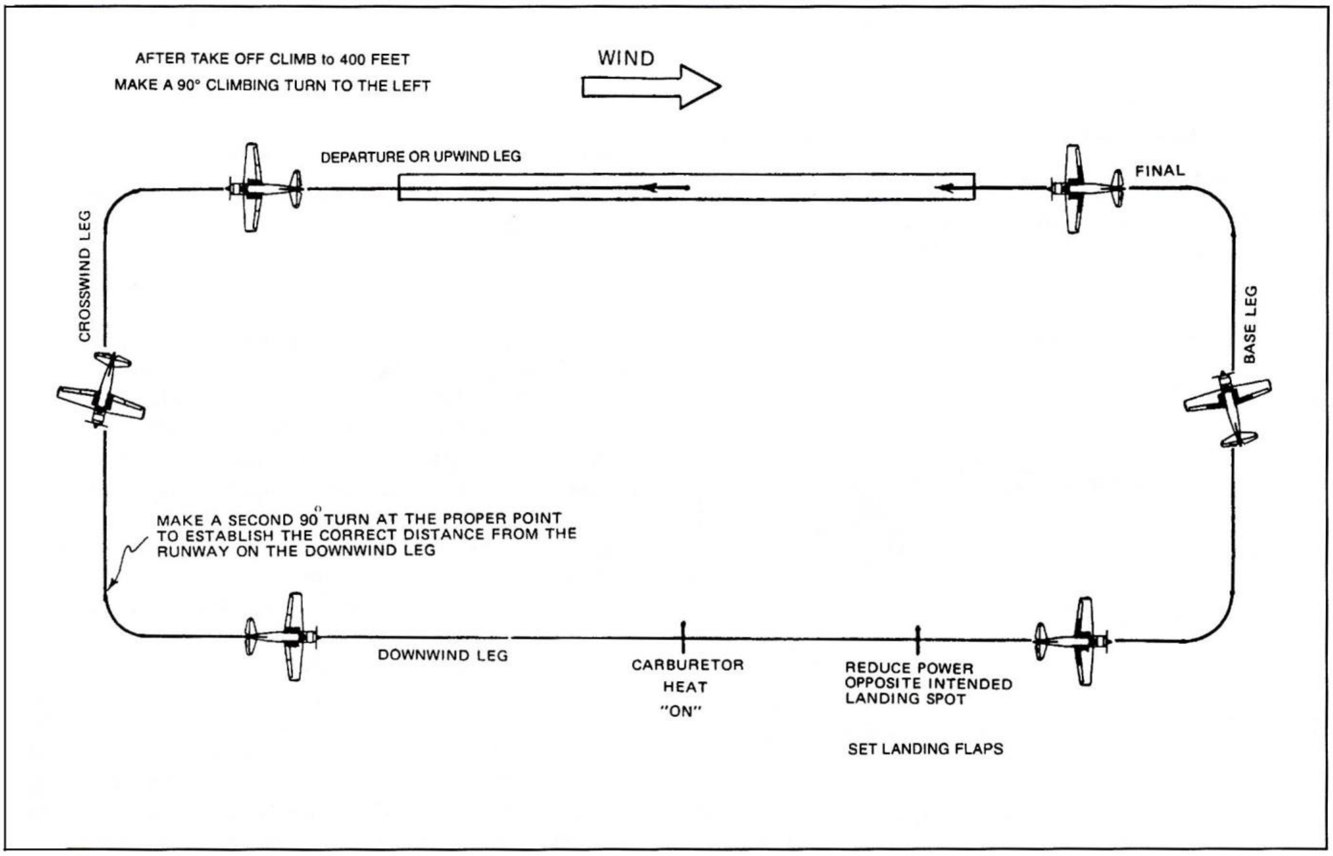
i. Normal take-off.
ii. Short take-off.
iii. First solo.

2. PRINCIPLES INVOLVED

The traffic Pattern:

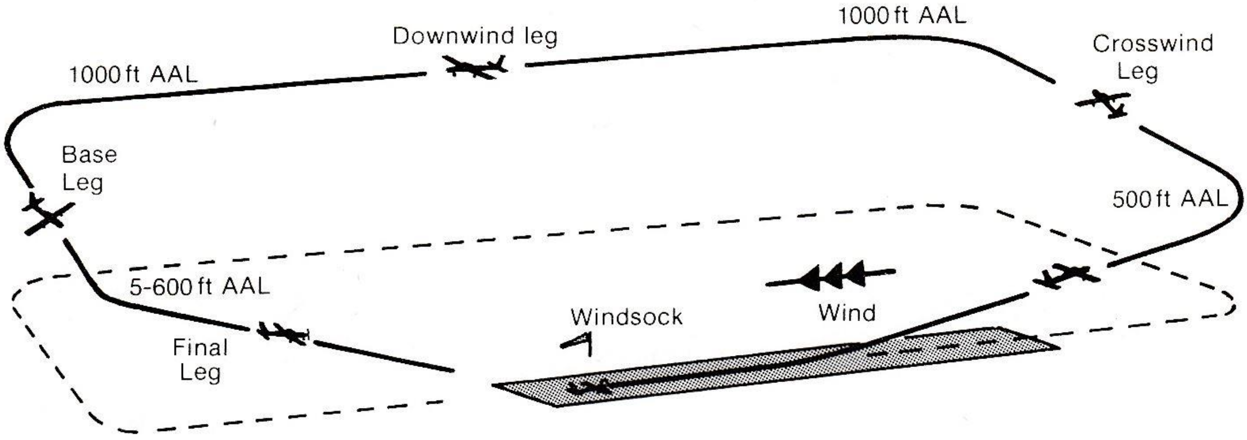


The Circuit Pattern is Rectangular.



An example traffic pattern. Shown is a "Closed Patten"as used in shooting take-offs and landings. Your instructor will demonstrate and you will practise. the pattern. You will also be shown how to depart and enter the pattern. The leg after take-off, as you climb out tracking the centre line, is the 'departure leg' or the 'upwind leg'. When making a go-around or aborted landing, fly to the right of the runway as you climb out so you can see the runway and any moving aircraft.

Fig 12.1. The Standard Touch-and-Go Procedure

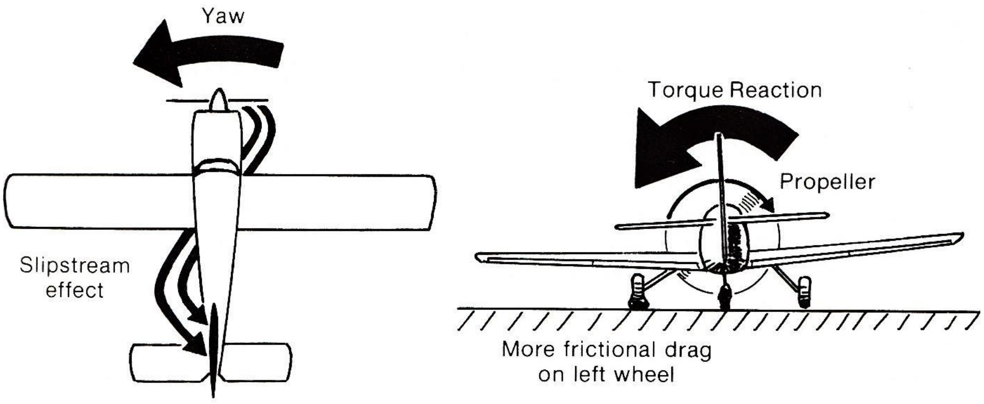


The Normal Circuit Pattern is Flown at 1000 ft AAL.

Fig 12.2 Circuit Height

A. GROUND RUN

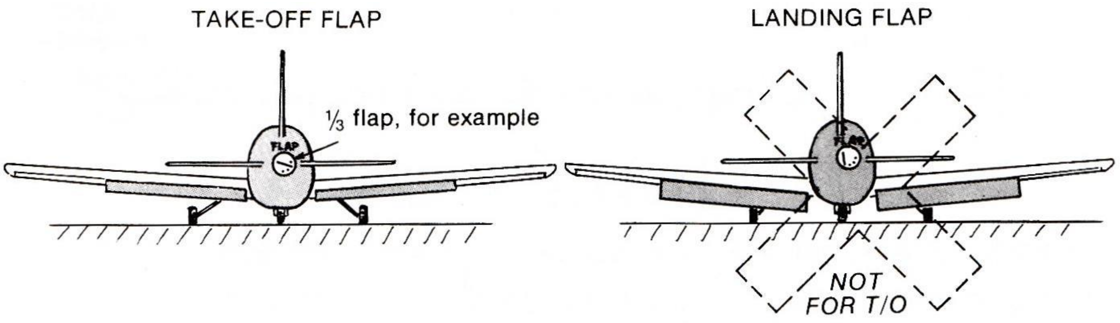
i. Re-cap on Newton's Law 1 and 2.
ii. Forces whilst on the ground – Thrust, Drag and Weight.
iii. Thrust – at maximum power available.
iv. Effect of power:
  a. Slipstream.
  b. Torque.
  c. Gyroscopic.
  d. Asymmetric Blade Thrust.



There is a Tendency to Yaw on the Take-Off Run.

Fig. 12.3 Slipstream Effect

v. Drag:
  a. Elevator stabiliser position.
  b. Tail up movement – applicable to tail wheel aircraft.
  c. Surface friction between tyres and runway.

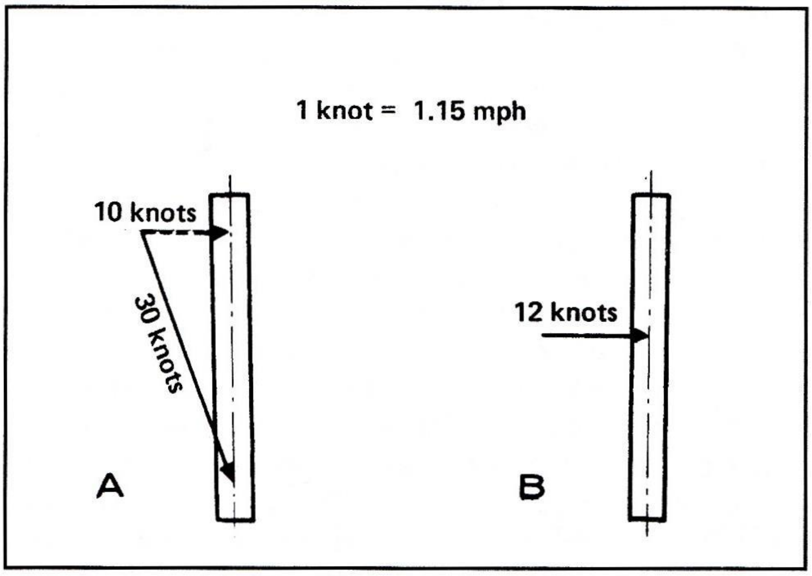


Flap for Take-Off is Less Than That Used for Landing.

Fig 12.4 Use of Flaps

vi. Flaps – discuss the various flap settings which may be used for take-off

vii. Wind:
  a. Headwind.
  b. Crosswind.



(A) Although the wind has a velocity of 30 Kts, It has a crosswind component of only 10 Kts.
(B) The wind velocity is 12 Kts, all of which is crosswind component.

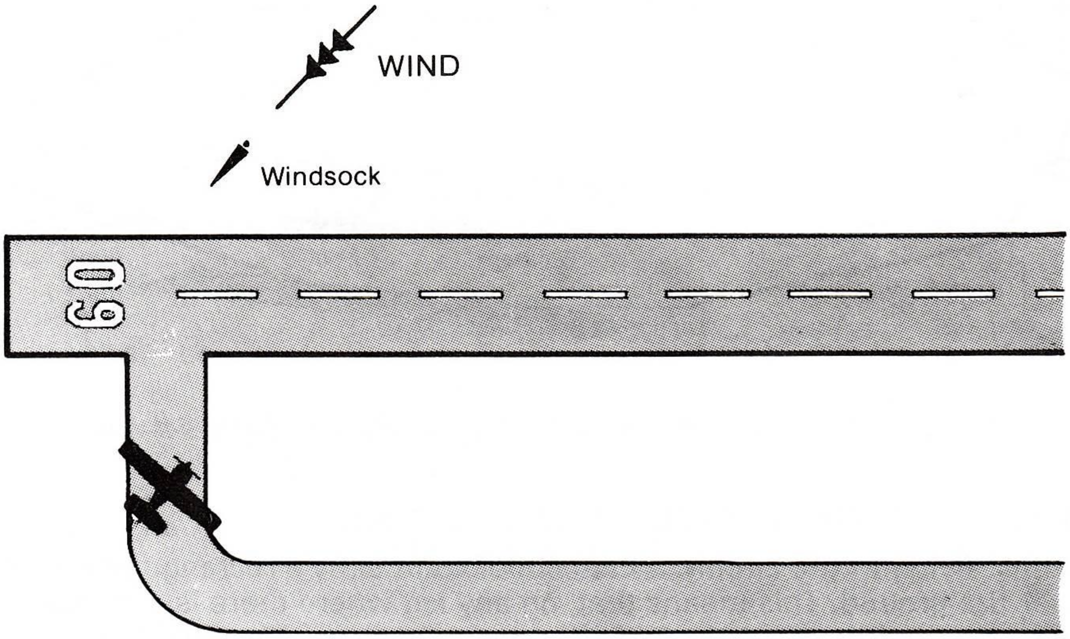
Fig 12.5 Crosswind Component

   c. Tailwind.

viii. Aircraft take-off graphs:

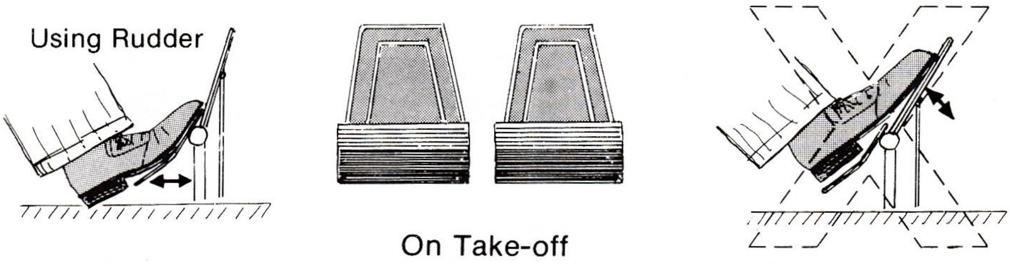
   a. Density altitude considerations.
   b. Aircraft weight.
   c. Runway surface and gradient (upslope / downslope).
   d. Runway length and obstacle clearance considerations.

Line-up and Take-off:



Position Aircraft for Pre Take-Off Check, Preferably Into-Wind.

Fig 12.6: The Holding Point



CORRECT

INCORRECT

Fig.12-7. Heels on the Floor (and No Pressure on Brakes).

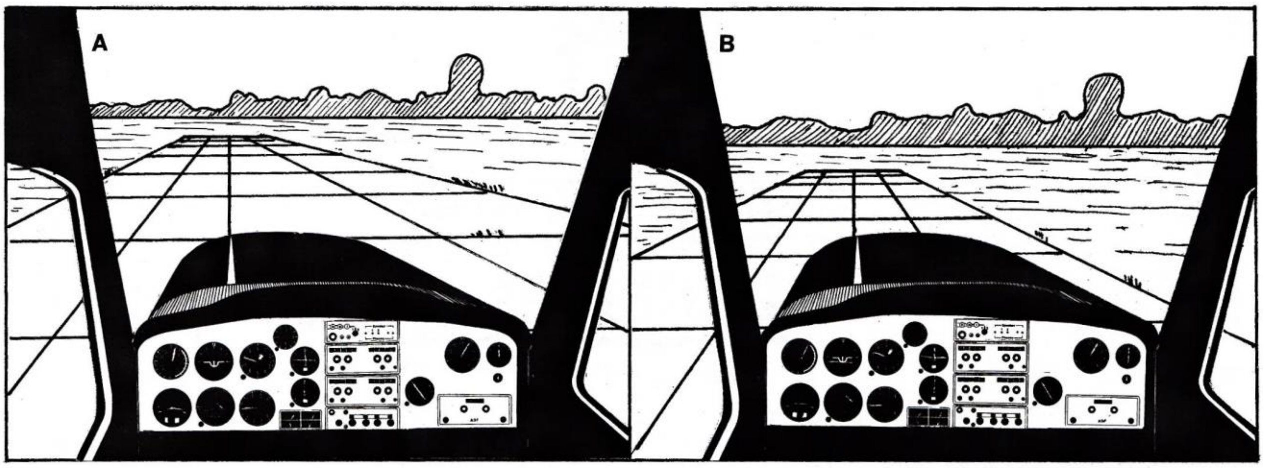


Fig 12.7: (A) Line up with the centre line and apply power to start rolling, then smoothly go to full power for take-off, keeping the airplane straight by smooth application of right rudder. (B) As the controls firm, start applying back pressure to ease the nose to up take-off attitude.

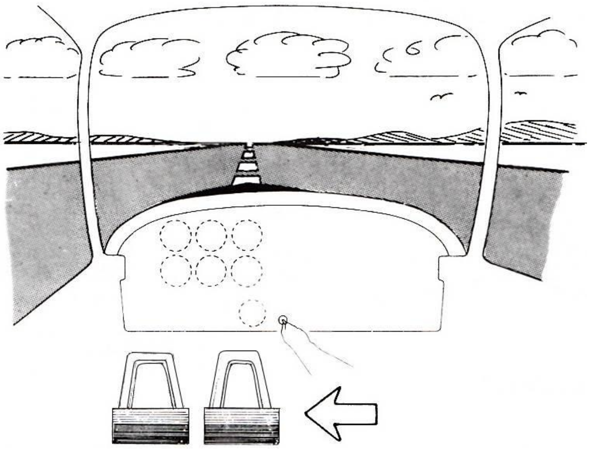


Fig 12.8
Keep Straight Using Your Feet.

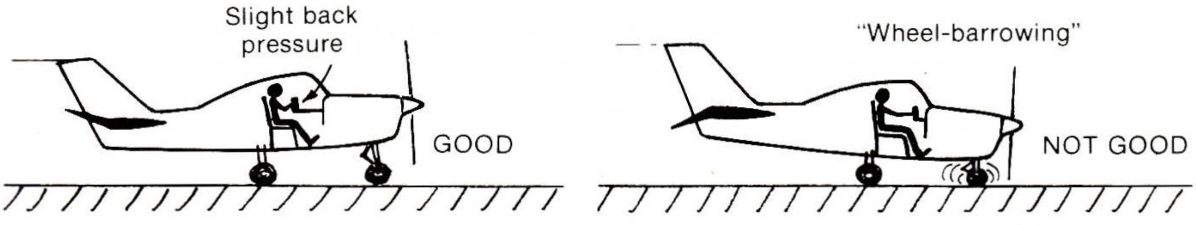


Fig 12.9: Protect the Nose Wheel

B. BECOMING AIRBORNE

   i. Speed – depending on flap used.
   ii. Attitude – flight path.
   iii. Undercarriage – where applicable.

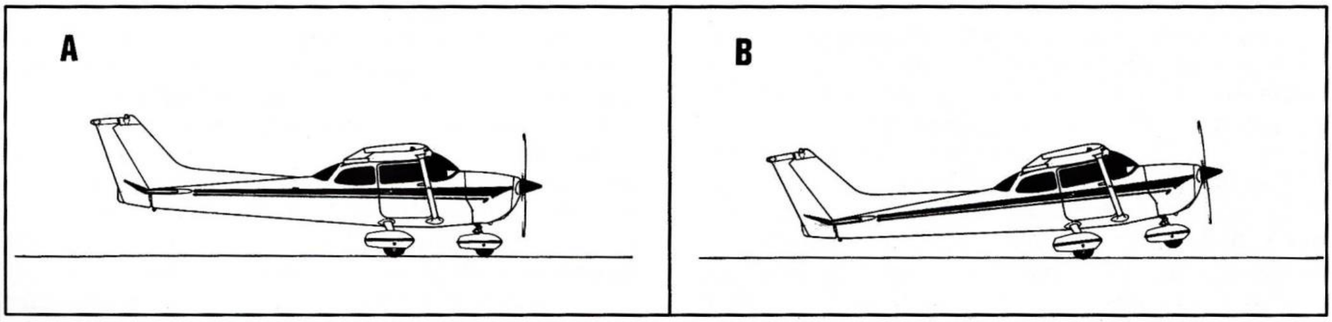


Fig 12.10 A side view of the initial roll (A) and the lift-off (B) attitudes for a tricycle-gear aeroplane

C. TRANSITION TO CLIMB AND CLIMBING AWAY

   i. Speed – depending on flap used.
   ii. Power – per aircraft manual.
   iii. Attitude – flight path.
   iv. After take-off checks

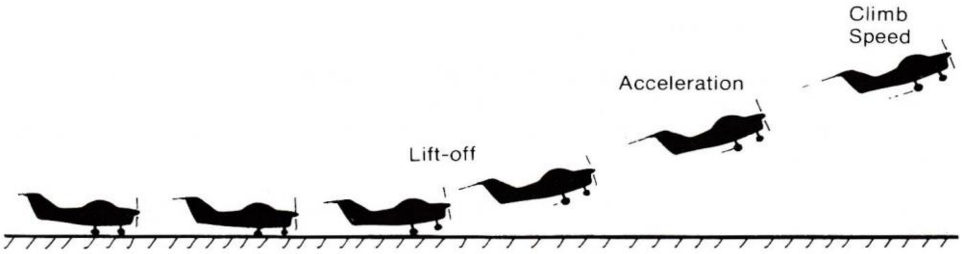


Fig.12-11. When Flying Speed is Reached, Lift-Off Gently with Elevator.

3. CONSIDERATIONS OF AIRMANSHIP AND ENGINE HANDLING

AIRMANSHIP

A. HOLDING POINT OF RUNWAY

   i. Holding position, visibility, safety and surface wind considerations.
   ii. Before take-off checks.
   iii. Lookout.
   iv. Radio procedures.

B. LINING UP ON RUNWAY

   i. Use maximum runway length available.
   ii. Aligning aircraft with centreline.
   iii. Reference point to keep straight.
   iv. Windsock check.

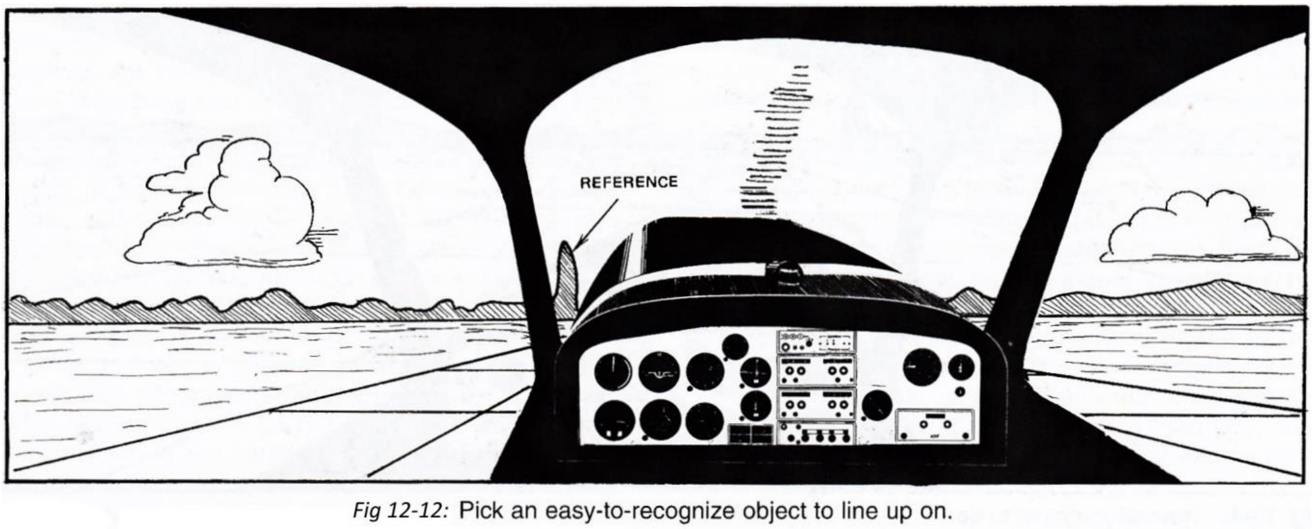


Fig 12-12: Pick an easy-to-recognize object to line up on.

C. TAKE-OFF RUN
  - i. Use of controls:
    - a. Throttle – smooth application.
    - b. Rudder – increasing effectiveness during take-off run.
    - c. Elevators.
    - d. Ailerons.
  - ii. Confirm build-up of airspeed on ASI.

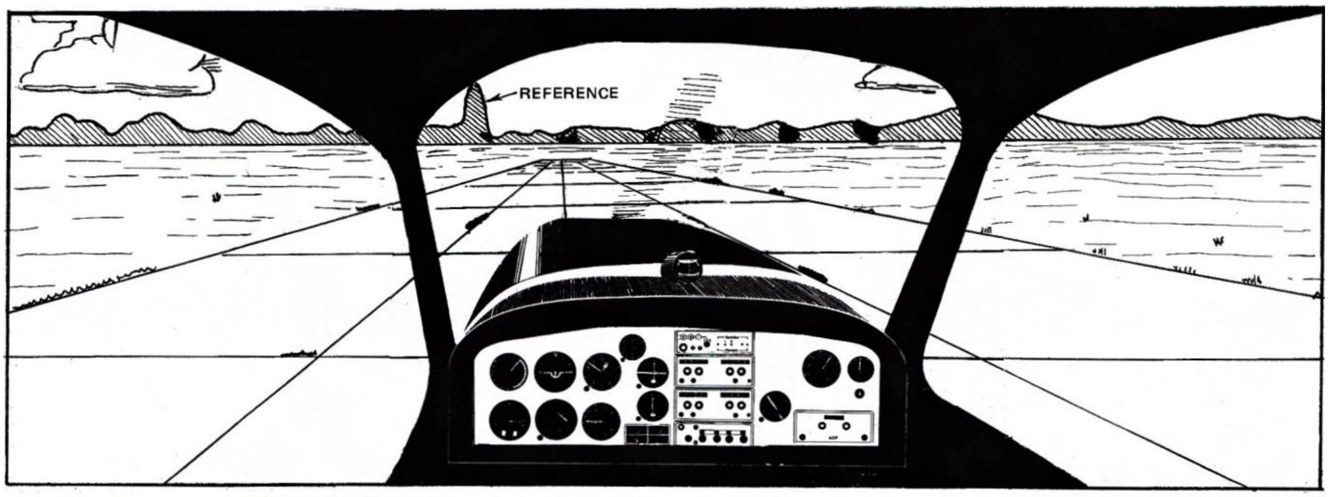


Fig 12-13: Now all you have to do is keep it straight and wait.

D. BECOMING AIRBORNE
  - i. Nose attitude after rotation.
  - ii. Safety speed.
  - iii. Rudder at low speed.
  - iv. Undercarriage – if applicable.
  - v. Transition to climb.
  - vi. 300 ft agl after take-off checks.
  - vii. 500 ft agl. – commence climbing turn onto crosswind leg.

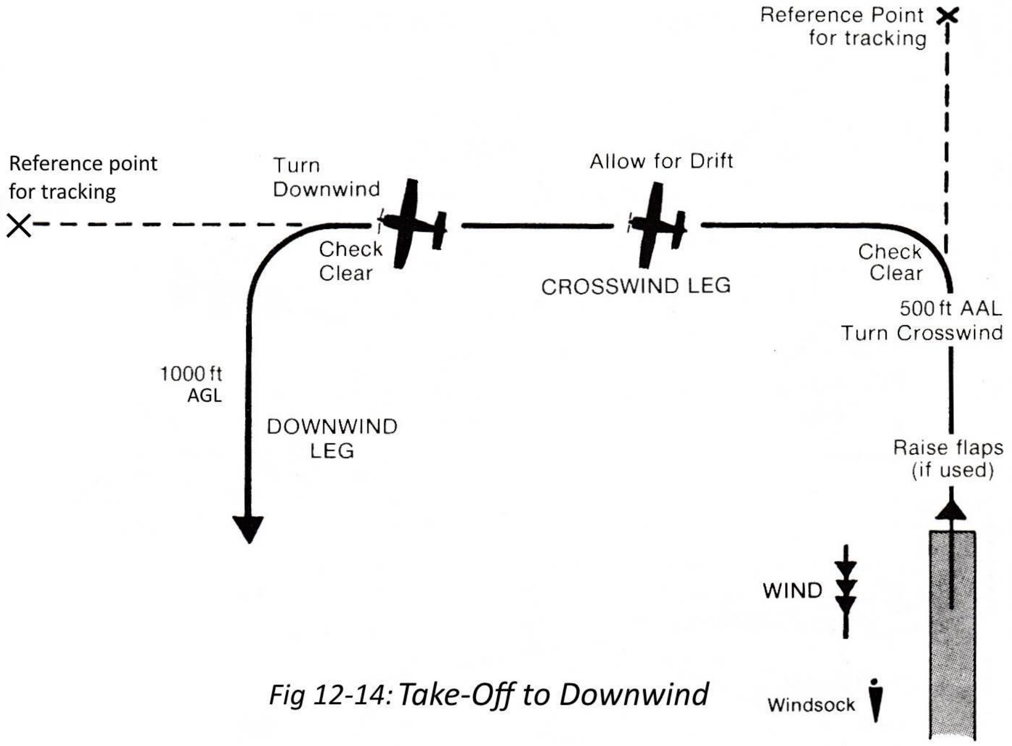


Fig 12-14: Take-Off to Downwind

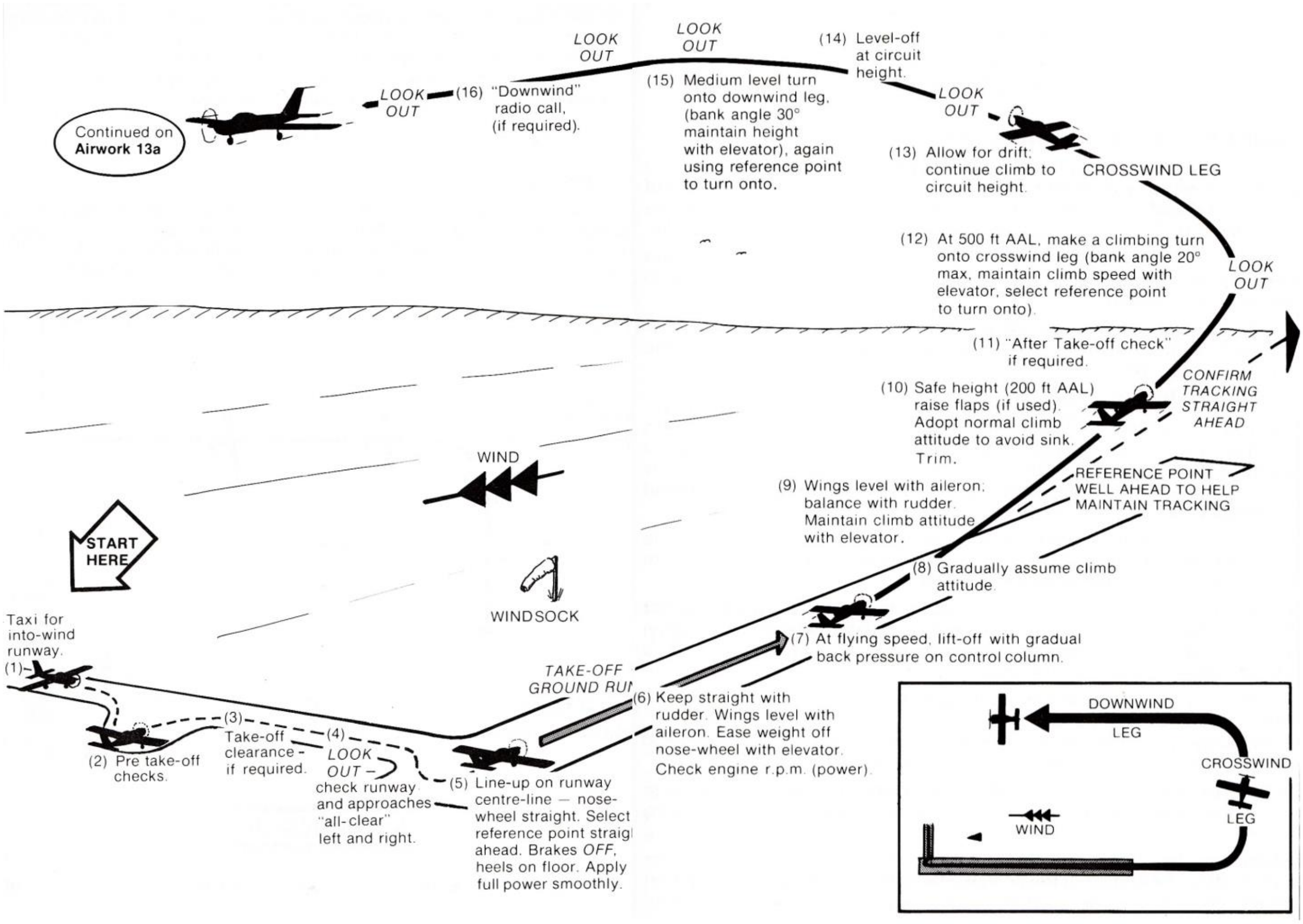


Fig 12-14b: Take-off to Downwind Profile

E. CROSSWIND LEG

  i. Allowance for drift.
  ii. Turn onto downwind leg.

F. CROSSWIND TAKE-OFF

  i. Higher take-off speed required to ensure positive lift-off.
  ii. Use of controls – ailerons.
  iii. Allowance for drift after take-off.

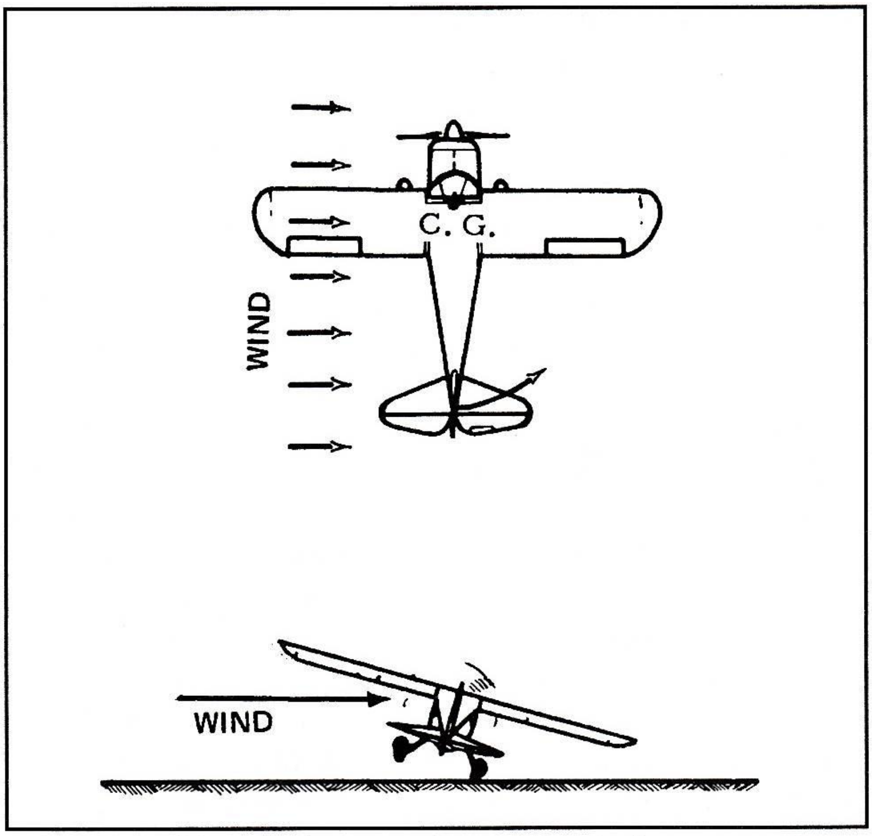


Fig 12-15: The airplane tends not only to lean away from the wind but also to turn into it (weathercock).

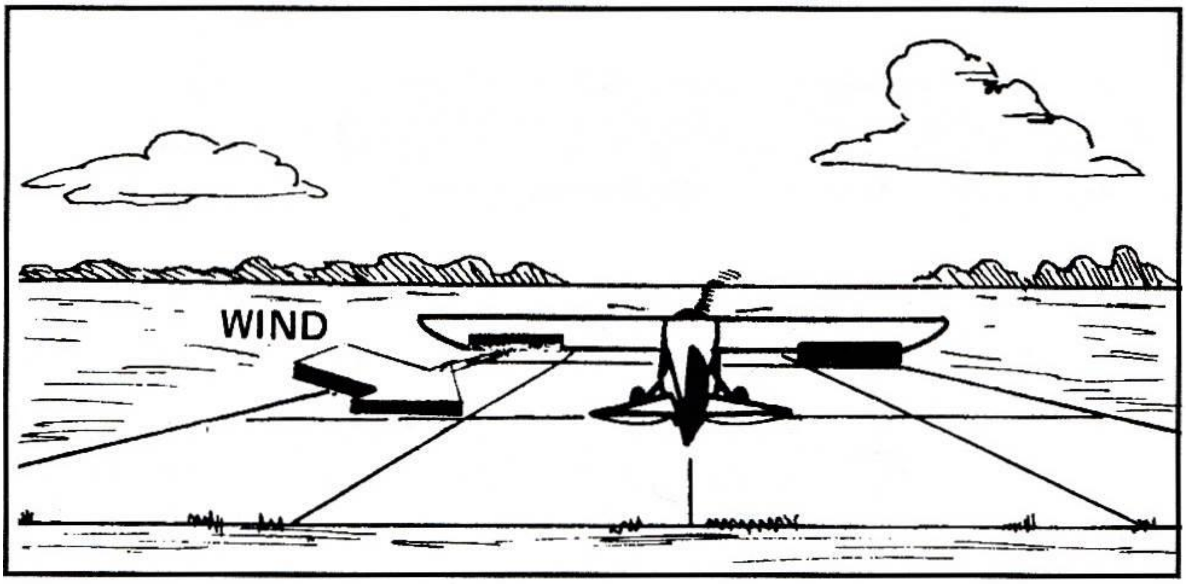


Fig 12-16: Starting the crosswind takeoff roll.

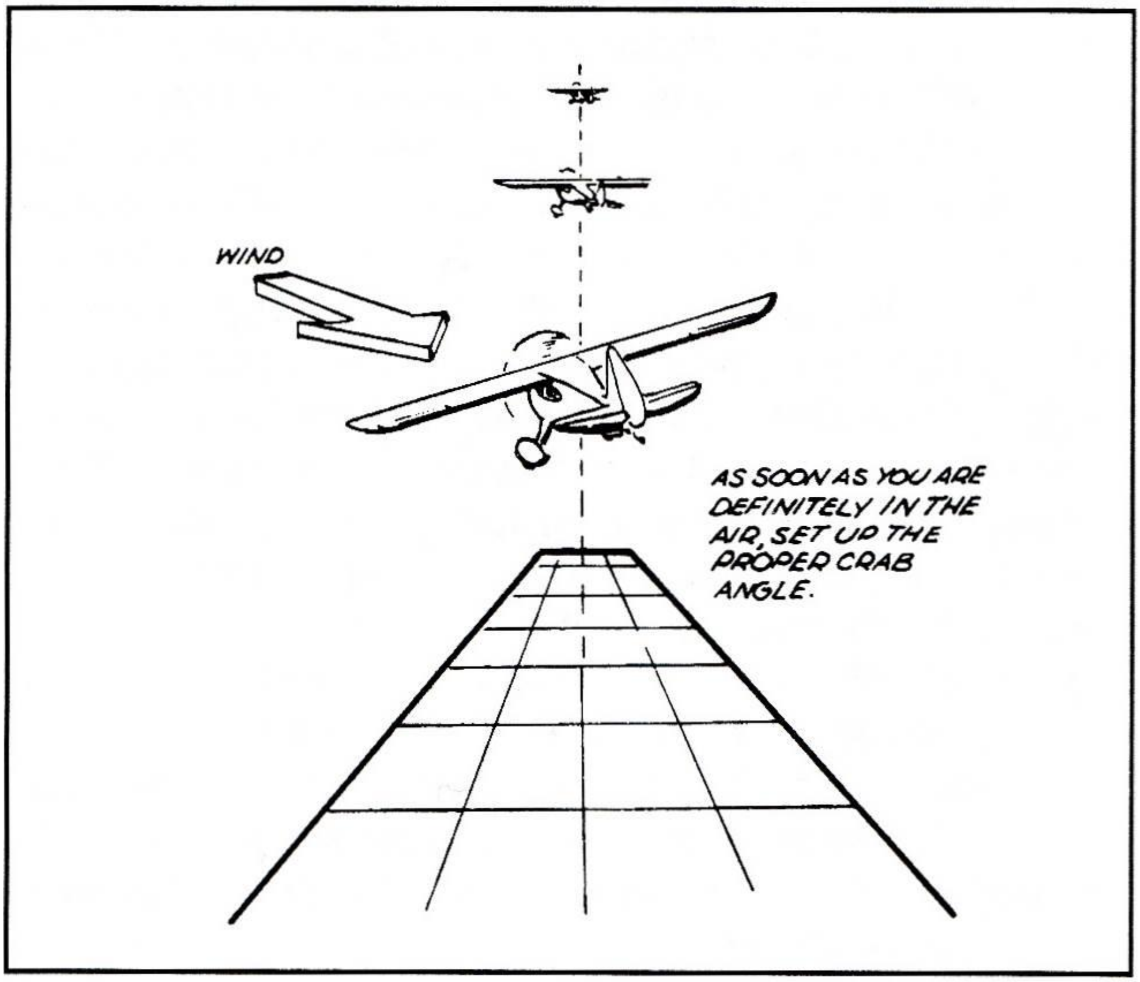


Fig12-17: Allowance for Crosswind on the Take-off

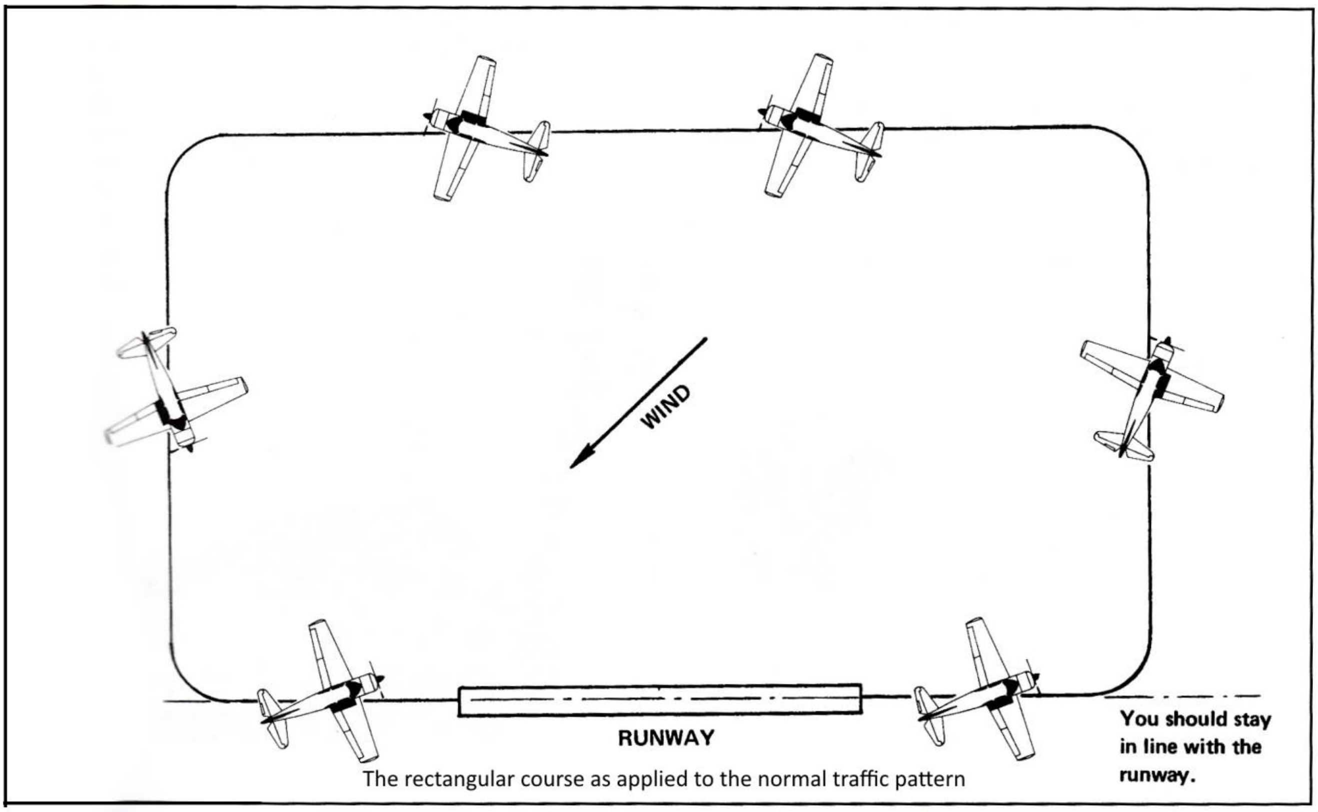


Fig 12-18: Crosswind Traffic Pattern.

G. ENGINE FAILURE AFTER TAKE-OFF

i. Selection of landing area.
ii. Checks and procedures.
iii. Climbing away (after simulated exercise).
Iv. ATC notification.

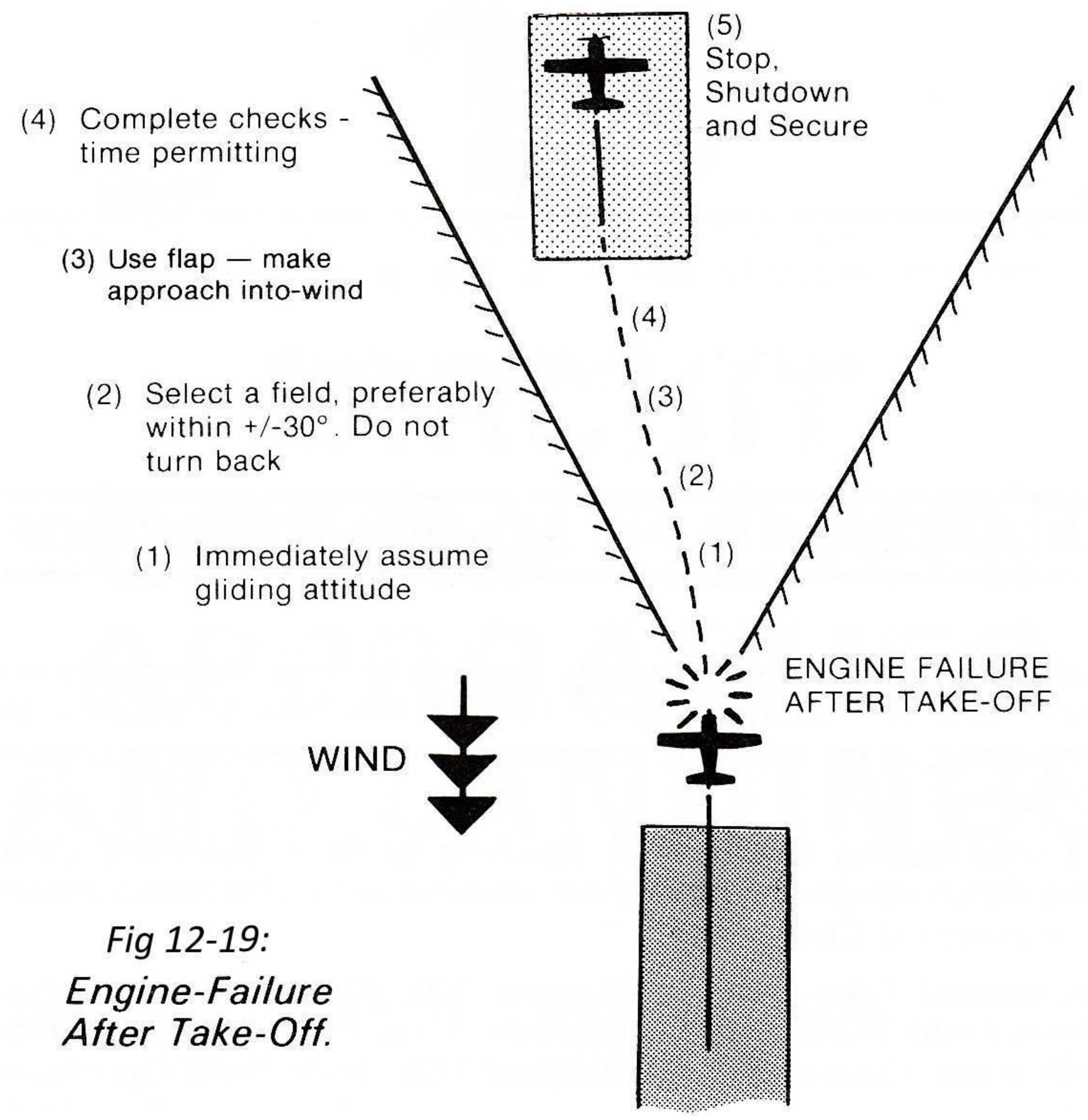


Fig 12-19:

Engine-Failure After Take-Off.

ENGINE CONSIDERATIONS

- i. Engine control positions.
- ii. Power check before take-off:
  - a. RPM settings.
  - b. Temperatures and pressures.
  - c. Reducing power after take-off – where applicable.

4. DE-BRIEFING AFTER FLIGHT

1. Briefly recap on the exercise and emphasise the important aspects applicable to:

   Taking-off into wind:

   - i. Lining up and the take-off run.
   - ii. Becoming airborne and climbing away.
   - iii. Crosswind leg.
   - iv. Engine failure after take-of from the circuit.
   - v. Vital actions and circuit and R/T procedure.
   - vi. Effect of wind.

2. Discuss the common faults students usually make.

   - i. Insufficient knowledge of checklists and procedures.
   - ii. Forgetting to check the approaches clear before lining up on the runway.
   - iii. Not using maximum available runway or aligning DI with runway.
   - iv. Rotating too rapidly into the climb attitude instead of rotating to just below the climb attitude, allowing the speed to build up to the required climb speed and rotating further into the climb attitude.
   - v. Reciting the after take-off checks without actually going through the required actions.
   - vi. Spending too much attention in the cockpit to complete the after takeoff checks without sufficient attention to visual references outside for attitude and heading.
   - vii. A tendency to over bank during the climbing turns onto crosswind for left hand circuits. This results in a decrease in the rate of climb and a lengthening of the crosswind leg causing excessive large circuits being flown. NB – opposite occurs in R/H circuit.
   - viii. Insufficient correction for drift on the cross wind leg.
   - ix. The high degree of concentration required from the student during his initial attempts at take-offs may cause tenseness on the controls and resulting in over-controlling and lack of co-ordination.

3. Discuss student’s actual faults

   For each fault the instructor must indicate:

   - i. The symptoms of the fault.
   - ii. The cause of the fault.
   - iii. The result the fault could have led to.
   - iv. The corrective action required.

EXERCISE 13

CIRCUIT, APPROACH AND LANDING

1. AIM

DEFINITION

The approach and landing phase may be considered to commence from after the turn onto the downwind leg to the touch down point on the runway and the completion of the landing roll.

i. The Approach may be defined as that part of the circuit from after the turn onto the downwind leg, to the touch down.
ii. The Final Approach is considered to start from a point where the aircraft is some distance downwind of the runway, in line with it, and approaching on a descending flight path.
iii. The Round-Out is the change of attitude made from the descent part of the approach to a path level with and slightly above the ground.
iv. The Hold-off or Float describes a subsequent period in which the aircraft is flown parallel to the ground, with increasing angle of attack and decreasing airspeed, until the aircraft touches the ground.
v. The Landing – (Touch-Down) is the ultimate development of the hold-off, where the aircraft gradually approaches the stall in the landing attitude, followed by the touch-down just before the stall.
vi. The Wheel Landing is a type of landing done in tail wheel aircraft where the main wheels are placed on the ground before the tail wheel.

WHAT THE INSTRUCTOR IS TO TEACH

i. Discuss the principles involved.
ii. The air exercise briefing:
    a. Applicable procedures and checklists.
    b. Aircraft handling techniques: - Demonstration and Observation.
    c. Considerations of airmanship and engine handling.
    d. Similarity to previous exercises.
    e. De-briefing after flight.

WHY IT IS BEING TAUGHT

To give the student a good understanding and thorough knowledge of the principles required to:

i. Fly the aircraft in the circuit in an accurate manner.
ii. Complete the before landing checks in the approved manner
iii. Fly the approach and execute the landing in varying wind conditions, thus enabling the student to carry out short landings, flapless landings and crosswind landings.

HOW THE EXERCISE APPLIES TO FLYING

i. First solo flight.
ii. Landing the aircraft safely after each flight.
iii. Landings with various flap settings.
iv. Short landing technique.
v. Forced landing with power – precautionary landing.
vi. Force landing without power – after an actual engine failure.

2. PRINCIPLES INVOLVED

2.1. DEFINITIONS, PROCEDURES AND CHECKLISTS

2.2. DOWNWIND LEG

- i. Undercarriage extension – if applicable to type.
- ii. Flaps:
  - a. Flap extension speed.
  - b. Attitude.
  - c. Power required.
- iii. Downwind checks.

2.3. TURN ONTO BASE LEG

- i. Position relative to runway – wind effect.
- ii. Nose position.
- iii. Power setting.
- iv. Angle of bank - 30° medium level turn.

2.4. ON BASE LEG

- i. Drift considerations.
- ii. Base leg checks.
- iii. Power reduction to commence descent with/without power.
- iv. Flap setting.
- v. Speed on descent plus control of speed.
- vi. Attitude plus control of attitude.
- vii. Speed/attitude relationship.

2.5. TURNING FINAL

- i. Descending turn – angle of bank required.
- ii. Speed control.
- iii. Drift considerations.
- iv. Aligning aircraft with runway.

2.6. FINAL APPROACH

- i. Forces in descent with/without power.
- ii. Final flap setting – effect of flap.
- iii. Approach path – speed and height control.
- iv. Use of trimmer.
- v. What to do if –
  - a. Overshooting.
  - b. Undershooting.
- vi. Discuss use of Vref speeds (Vref = 1.3 x Vs0 or Vs1 depending upon configuration)

2.7. THE ROUND-OUT

- i. Lift formula and ground effect – coefficient of lift V^2 relationship.
- ii. Throttle control technique
- iii. Speed dissipation.

2.8. THE HOLD-OFF AND NORMAL LANDING

- i. Flight parallel to surface.

ii. Speed and angle of attack.
iii. Prevention of stalling onto runway.
iv. Normal landing.
v. Advantages of normal landing.

2.9. AFTER LANDING RUN

i. Throttle closed.
ii. Keeping straight – high speed taxying.
iii. Causes of swing.

2.10. EFFECT OF WIND ON THE APPROACH AND LANDING

i. Head winds (i.e. wind down the runway):
    a. Downwind leg.
    b. Base leg.
    c. Final approach.
    d. Landing phase.

ii. Crosswind (i.e. wind at an angle to the runway) or Strong, Gusty Wind:
    a. Downwind leg.
    b. Base leg.
    c. Final approach.
    d. Landing phase.
    e. Discuss the need for less or no flap and use of power till touchdown:
        (1). Ailerons less effective at low speeds – the need to increase approach and Vref speeds.
        (2). Higher speeds results in lower nose attitude for landing therefore the need to use less flap or no flap – gives higher nose attitude at landing (touchdown on main wheels first) and faster response to power changes in gusty and wind shear conditions.
        (3). Use of power till touchdown ensures good elevator and rudder responsiveness.
    f. Discuss the need to close power immediately on touchdown:
        (1). Possibility of coming airborne again.
        (2). Effect on landing run.

iii. Tail wind (i.e. wind down the runway):
    a. Downwind leg.
    b. Base leg.
    c. Final approach.
    d. Landing phase.
    e. Discuss effect of higher ground speed on landing run.

iv. Discuss allowances to be made to approach (Vapp and Vref speeds) in strong and gusty wind. Various calculation methods exist and the following are two examples of allowance to be made:

Allowance A:

a. Approaches in calm conditions are normally made at Vref+5 knots but with reported wind speeds in excess of 10 knots the recommendation is a correction of ½ the steady wind above 10 knots + 100% of the gust value, with a total maximum correction of 15 knots.

b. For example; with a Vref of 63 knots and a headwind of 20 gusting 25 knots the Vapp would become 63+5+5 knots = 73 knots

c. The steady wind correction should be bled off approaching the threshold but the gust factor carried into the landing round out.

d. Note that only the wind and gust factors are added to the Vref for the Vapp.

Allowance B:

a. Adjust approach (Vapp) and Vref airspeed by adding a wind additive of the greater of the following (not to exceed 10 knots): 5 knots; ½ the steady wind in excess of 15 knots; or the gust factor.

b. Practical example:

Wind 20kts gusting 30kts.

Aircraft is a Cherokee 140.

Normal approach speed with two notches of flap is 75kts.

Vs1 is 48kts.

Vref (1.3 x Vs1) = 63kts.

Wind additive the greater of the following but not more than 10kts:

5kts; or

½ the steady wind in excess of 15 knots = 2.5kts (5÷2 = 2.5); or the gust factor which is 10kts.

Thus wind additive = 10kts.

New approach speed + wind additive = 85kts.

New Vref = 73kts.

v. Wind gradient.
vi. Wind gust effect (see par iv. above).

2.11. WHEEL LANDINGS (Applicable to tail wheel aircraft):

i. Technique.
ii. Advantages.

2.12. OVERSHOOT PROCEDURE

i. Go-around procedure.
ii. Missed approach procedure.

GO-AROUND PROCEDURE

i. Apply go-around power – engine considerations.
ii. Rotate into climb attitude – best angle of climb/rate of climb speed.
iii. Flaps – select optimum climb setting.
iv. Check altimeter for positive rate of climb.
v. Undercarriage – Up (if applicable to aircraft type).
vi. Accelerate to best angle of climb/rate of climb speed.
vii. Trim aircraft.
viii. 300 ft agl after take-off checks.
ix. Accelerate to best rate of climb speed.

2.13. TOUCH AND GO LANDINGS

- i. Keep straight on centreline of runway after touchdown.
- ii. Select; Flaps as required – confirm position. Trim as required.

Engine considerations – Carb. Heat etc.

- iii. Throttle – open smoothly to maximum power – temperatures and pressures.
- iv. Continue with normal takeoff and after take-off procedure

3. SIMILARITY TO PREVIOUS EXERCISES

- i. Effects of Controls.
  - a. Changing power.
  - b. Undercarriage and flaps.
  - c. Technique of raising flaps during go-around procedure.
  - d. Engine handling.
- ii. Taxying
  - a. The after landing run – high speed taxying.
  - b. Use of brakes.
- iii. Straight and level flight.
  - a. Maintaining straight and level flight.
  - b. Turning.
  - c. Descending.
  - d. Descending turns.

4. DE-BRIEFING AFTER FLIGHT

1. BRIEFLY RECAP ON THE EXERCISE.

Emphasise the important aspects applicable to each type of landing under the following headings:

- i. The approach.
- ii. The final approach.
- iii. The Round-out.
- iv. The hold-off or landing.
- v. The touch down or landing.
- vi. The after-landing roll.
- vii. The touch and go landing.
- viii. The go-around procedure.
- ix. Effect of crosswind, wind gradient and gusty conditions.
- x. Lookout.

2. DISCUSS THE COMMON FAULTS STUDENT USUALLY MAKE:

- i. To fly a proper circuit requires an ability to be able to complete exercises 4 to 10A with a certain degree of skill. The instructor must not attempt exercises 12 and 13 until he is satisfied that the student can cope with these requirements. Most problems in the circuit can be related to insufficient skills in the basic flight manoeuvres.
- ii. Insufficient knowledge of the checks and procedures.
- iii. Spending too much attention in the cockpit to complete the before landing checks without sufficient attention to the visual references outside for attitude and heading.
- iv. Insufficient lookout in the circuit.

v. If too much time is taken in setting up the descent on the base leg the approach usually ends up being too high.

vi. Speed/attitude relationship on final approach. Do not “chase” the speed. Fly attitude and allow the speed to stabilize before correcting according to the ASI. Hold the threshold on a constant imaginary horizontal line on the windscreen and adjust power to maintain a constant IAS (this is a shortcut to “*Power controls height/rate of descent and attitude controls airspeed*” because, as for instance, attitude is lowered to increase airspeed, power needs to be increased to reduce rate of descent. Therefore increasing power to increase the airspeed would in turn result in the lowering of the attitude to maintain the threshold on the imaginary horizontal line on the windscreen).

vii. After turning onto final approach select the required landing flap and trim the aircraft. From this point on the power controls the rate of descent.

viii. A good approach makes a good landing. From a good approach the transition to the round-out requires only a small attitude change. Do not close the throttle until the round-out phase is complete.

3. DISCUSS THE STUDENT’S ACTUAL FAULTS

For each fault the instructor must indicate:

i. The symptoms of the fault.

ii. The cause of the fault.

iii. The result the fault could have led to.

iv. The corrective action required

EXERCISE 12 E & 13 E

EMERGENCIES

a. Abandoned take off: Causes: Surging engine.
Inadequate Power.
Rough running engine.
Direction control loss.
Zero airspeed indication.
Loss of air pressure.
Door opens during T/off Roll.
Pedestrian crossing.
Animal/ Bird strike.
Aircraft not vacated runway ahead.

Procedure: Throttle closed.
Brakes as required.
Vacate runway.
Advise ATC.

b. Engine failure after take-off: Lower nose.
Trim for best glide speed.
Select field within 30° Left or Right of nose. (Never turn around!)
Flap as required.
Fuel pump on.
Change tanks.
Try power.
Shut down if unsuccessful.
Door open.
Passenger brace.
Sideslip if required to loose height.
May Day call if time permits.
Land at slowest safe airspeed.

c. Aborted Landing/Go-Around:
Causes: X-wind out of A/C limits.
X-wind out of pilot ability.
Runway incursion.
Approach;
- Too high.
- Too fast.
- Too low.
- Off centreline.

A/C undercarriage malfunction.
Decision height not been 100’ AGL.
Full power – Level out – Move to right of runway.
Safe airspeed attained.
Retract flap to optimum for climb.
Climb straight ahead.
Carry out vital actions
Advise ATC.
Request assistance if required.
Rejoin circuit.

d. Missed Approach: Conform to published missed approach procedure for airfield and aircraft MOP

CROSSWIND TAKE-OFF AND LANDING

1. AIM

DEFINITION

The CROSSWIND TAKE-OFF is considered to start when the aircraft is accelerated under its own take-off power on the ground whilst using rudder, ailerons and brakes to counteract the effect of the crosswind until a slightly higher than normal lift-off speed is reached, hereupon the aircraft is positively rotated to leave the ground, and whilst the speed is increasing to the climb speed, the appropriate drift correction is applied.

Upon reaching the recommended climb speed the aircraft is further rotated into the climb attitude during which time corrections are again made for the effect of drift to ensure the track is a continuation of the take-off path.

THE CROSSWIND APPROACH may be considered to commence from after the turn onto the downwind leg to the touchdown point on the runway. On the approach, drift effect is counteracted by using the sideslip or crab method.

THE CROSSWIND LANDING progressed through the same stages of development, namely the round-out, hold-off or float and the actual touchdown, as in the case of a normal landing, except that a combination of rudder and ailerons is used to counteract the effect of the crosswind during the landing process.

WHAT THE INSTRUCTOR IS TO TEACH

i. Discuss the aerodynamic principles involved,

ii. The air exercise briefing:
  a. Applicable Procedures and Check lists.
  b. Aircraft handling techniques: - Demonstration and Observation.
  c. Considerations of Airmanship and engine handling.
  d. Similarity to various exercises.
  e. De-briefing after flight.

WHY IT IS BEING TAUGHT

To ensure that the student fully understands the techniques applicable to safely handle the aircraft in crosswind conditions.

i. Use of rudder, ailerons and brakes.
ii. Selection of correct flap setting (if applicable).
iii. Allowing for crosswind effect while descending on base leg.
iv. Effect of crosswind during ground run.
v. Drift effect during climb out and approach.

HOW THE EXERCISE APPLIES TO FLYING

i. Taking off and landing in a crosswind.
ii. Correcting for drift while maintaining a desired track.

2. PRINCIPLES INVOLVED

A. NEWTON'S LAWS

B. AERODYNAMIC AND MECHANICAL CONSIDERATIONS APPLICABLE TO AIRCRAFT TYPE

- i. Torque effect.
- ii. Slipstream.
- iii. Gyroscopic tendencies.
- vi. Weather cocking effect.
- v. Control limitations.
- vi. Effect on undercarriage.

C. TAKE-OFF

- i. Control (aileron) input required.
- ii. Use of rudder and brake.
- iii. Considerations in addition to those required for taking off into wind – Exercise 12.

D. LANDING

- i. Control – use of aileron and rudder.
- ii. Use of controls and brakes after landing.
- iii. Considerations in additions to those required for landing into wind – Exercise 13.

3. CONSIDERATIONS OF AIRMANSHIP AND ENGINE HANDLING

AIRMANSHIP

- i. Refer to same section of exercises 12 and 13 for details.
- ii. Emphasise the effect of the crosswind on the above.

ENGINE CONSIDERATIONS

- i. As per aircraft manual.
- ii. Refer to aircraft manual for undercarriage and flap limitations in crosswind conditions.

4. SIMILARITY TO PREVIOUS EXERCISES

- i. Taking off into wind.
- ii. The normal circuit.
- iii. The approach and landing.
- iv. Side slipping.
- v. Taxying – high speed and the effects of weather cocking.

5. DE-BRIEFING AFTER FLIGHT

1. Briefly Recap On The Exercise And Emphasise The Important Aspects Applicable To:

- i. The take-off.
- ii. The climb-out.
- iii. The downwind leg.
- iv. The base leg.
- v. The final approach.
- vi. The round out.
- vii. The hold-off or float.
- viii. The touch down or landing.
- ix. The after-landing roll.
- x. The touch and go landing.

    xi. The go-around procedure.

2. <u>Discuss the Common Faults Students Usually Make:</u>

    i. Insufficient allowance for drift.
    ii. Student either under turns or hammerheads on turning finals.
    iii. On landing he holds the aircraft too long off before touching down.
    iv. Direction control loss after touch down (tail wheel A/C).

3. <u>Discuss the Student’s Actual Faults:</u>

    For each fault the instructor must indicate;
    i. The symptoms of the fault.
    ii. The cause of the fault.
    iii. The result the fault could have led to.
    v. The corrective action required.

EXERCISE 14

FIRST SOLO

1. AIM

The student pilot only becomes really confident in his own ability to fly when he knows that he can do it without the aid of an instructor. There are, therefore, obvious advantages in allowing him to go solo as soon as he is fit to do so.

The student's instructor must exercise very careful judgement in this matter and should arrange the pre- solo test with another experienced instructor only when the student has complied with all the statutory and practical flight requirements.

i. Principles involved.

ii. The air exercise briefing:

  a. Applicable procedures and checklists.

  b. Aircraft handling techniques.

  c. Considerations of airmanship and engine handling.

  d. Similarity to previous exercises.

  e. De-briefing after flight.

2. PRINCIPLES INVOLVED

Statutory requirements:

i. Valid Student Pilot's Licence.

This ensures that the student has met the following requirements:-

  a. Passed within the last 30 days the written Student Pilot Licence Air Law examination for the issue of the above licence.

  b. Passed a written technical examination on the aircraft type.

  c. Is able to use the aircraft radio with reasonable confidence.

  d. Is medically fit to hold a Student Pilot's Licence.

ii. Flight instruction.

  a. The student must have satisfactorily completed training on sequences 1 to 13 of the flight instruction syllabus prescribed in Appendix 1.1 to the CATS-FCL 61.

  b. The student pilot must have written authority from the instructor to undertake the solo flight and this authority must be made in writing in the student's presence, (i.e. Authorization Sheet).

NOTE: The student's first solo flight will normally come at the end of a period of dual circuits and landings and he should, therefore, only be given a short briefing on what to expect during his first solo flight.

Do not confuse him with a lot of detail which he already knows about, because he should not be undertaking his first solo flight if the instructor is not confident about sending him solo. Remember that the standard required for the first solo is safety before precision.

3. CONSIDERATIONS OF AIRMANSHIP AND ENGINE HANDLING

AIRMANSHIP

- i. Ensure that loose harnesses ate secure and that seats are properly locked.
- ii. Emphasise the need to keep a good lookout and radio listening watch as he will be alone in the aircraft.
- iii. Authorise him to do one circuit and landing, but should he feel the necessity to do a go-around on his final approach, he must not hesitate to do so.
- iv. Remind him to do all checks and procedures methodically.
- v. Point out that the aircraft should climb faster without the weight of the instructor.
- vi. Prior to leaving the aircraft the instructor should, at controlled airfields, advise ATC of the impending solo flight.
- vii. The instructor should observe the student's first solo flight and at a controlled airfield the instructor's whereabouts should be known to the controller.

ENGINE CONSIDERATIONS

- i. Engine control positions.
    - a. RPM settings.
    - b. Temperature and pressures.
    - c. Magneto check.
- ii. Power check before take-off.
- iii. Reducing power after take-off – where applicable.

4. DE-BRIEFING AFTER FLIGHT

- i. Briefly recap on the exercise and emphasise the important aspects applicable to:
    - a. Encourage the student to be critical of his flying.
    - b. Show the student how to make the necessary entry in his logbook.
    - c. Enter in the student's logbook the authority for him to fly solo in the circuit.
- ii. Discuss the common faults students usually make
    - a. Panicking if something goes wrong in the aircraft.
    - b. Not sticking to recognized procedures.
    - c. Student is so keen to land the aircraft that he touches down at too high a speed.
- iii. Discuss the student actual faults.
  For each fault the instructor must indicate:
    - a. The symptoms of the fault.
    - b. The cause of the fault.
    - c. The result the fault could have led to.
    - d. The corrective action required.