IX. STALL

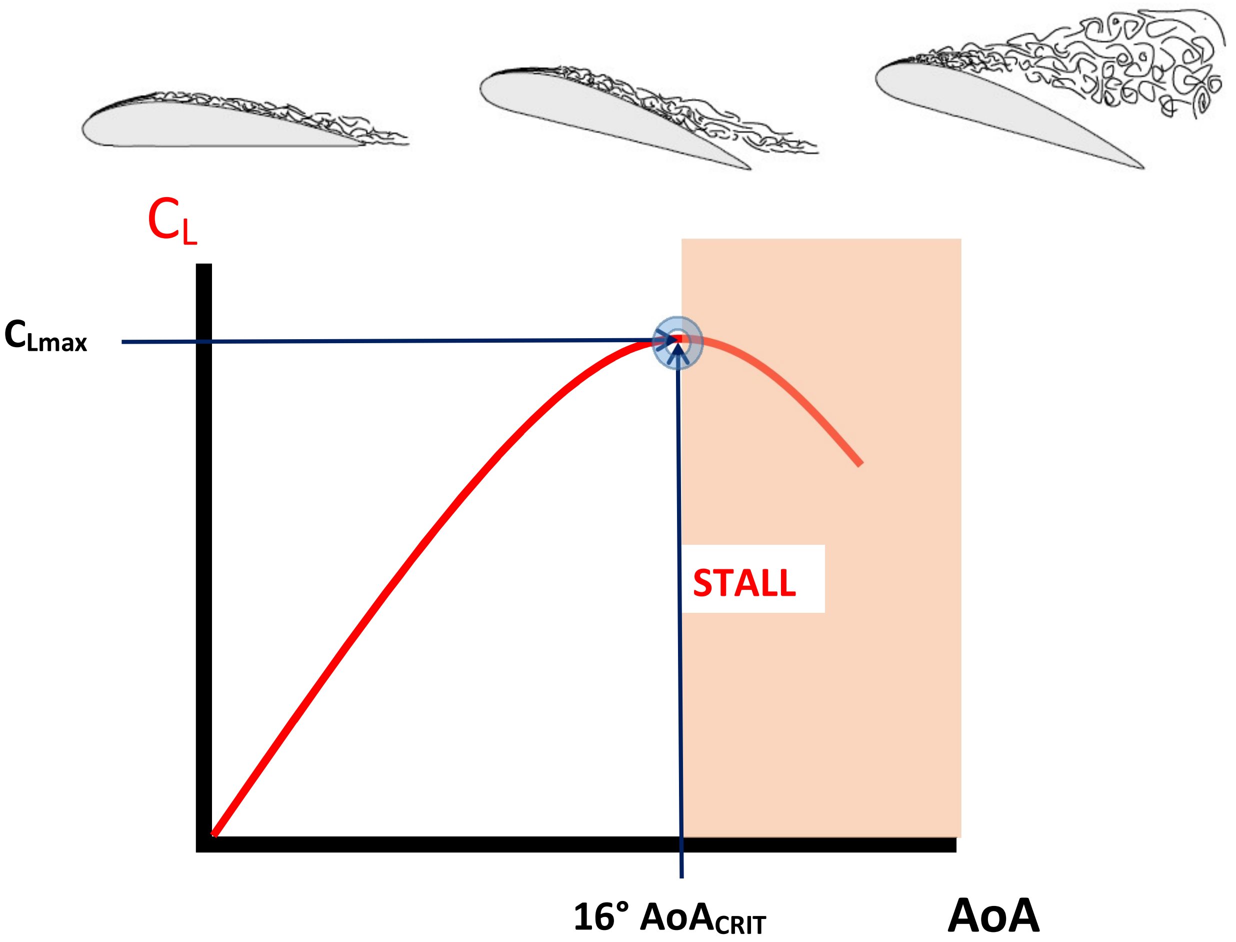
1) Definition & Demonstration

Stalling is a potentially hazardous manoeuvre involving loss of height and loss of control.

Stall is an increase in AoA causing a decrease in C_L

The C_L of an aerofoil increases with angle of attack up to a maximum ($C_{L\,MAX}$). Any further increase above this AoA called AoA_{CRIT}, will make it impossible for the airflow to smoothly follow the upper wing contour, the flow will separate from the surface, causing C_L to decrease and drag to increase rapidly. Since the $C_{L\,MAX}$ of an aerofoil corresponds to the minimum steady flight speed (the 1g stall speed), it is an important point of reference.

A stall is caused by airflow separation. Separation can occur when either the boundary layer has insufficient kinetic energy or the adverse pressure gradient becomes too great.



2) Stall Recovery

To recover from a stall or prevent a full stall, the angle of attack must be decreased to reduce the adverse pressure gradient. This may consist of merely releasing back pressure, or it may be necessary to smoothly move the pitch control forward, depending on the aircraft design and severity of the stall.

3) Aircraft behaviour close to the stall

The first indications of a stall may be provided by any or all of the following:-

- unresponsive flight controls,
- a stall warning or stall prevention device, or
- aerodynamic buffet.

4) Stall recognition

The aeroplane is considered stalled when the behaviour of the aeroplane gives the pilot a clear and distinctive indication of an acceptable nature that the aeroplane is stalled.
Acceptable indications of a stall, occurring either individually or in combination, are:

- A nose-down pitch that cannot be readily arrested
- Buffeting, of a magnitude and severity that is a strong and effective deterrent to further speed reduction; or
- The pitch control reaches the aft stop and no further increase in pitch attitude occurs when the control is held full aft for a short time before recovery is initiated.

5) Stall speed & Affecting factors

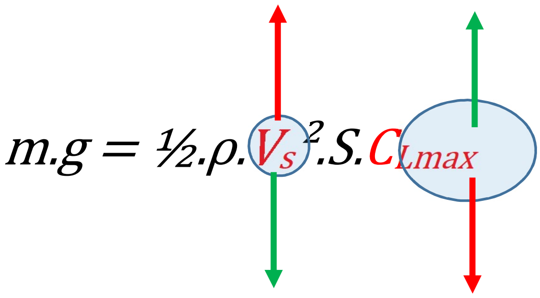
Remember, the stall occur when the AoA_{CRIT} is exceeded. At the AoA_{CRIT}, the aircraft is maintaining the minimum steady flight V_{MIN}, below that speed, increasing the AoA to increase C_L will lead to exceeding the AoA_{CRIT} and so the stall occur. That speed where the stall occurs, is called V_S.

It is very important to understand that the stall is because of AoA_{CRIT} is exceeded, and NOT because V_S is reached. To understand on what depends V_S, the equation between the LIFT and the WEIGHT must be studied:

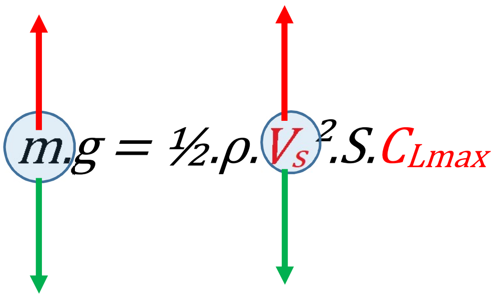
$$m.g = ½.\rho.V_S{}^2.S.C_{Lmax}$$

<u>**Affecting Factors**</u>

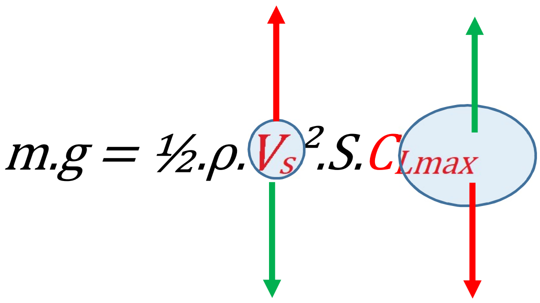
- **Aerofoil shape**: An aerofoil that has a better C_L, will be able to fly at a lower speed and so V_S decreases



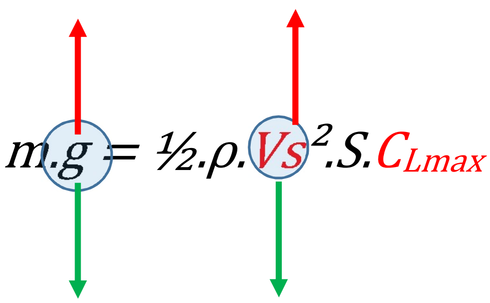
- **Aircraft mass**: When the aircraft mass increases, at $C_{L\ MAX}$, the increase in LIFT can be achieved by a higher minimum speed, meaning the V_S increases.



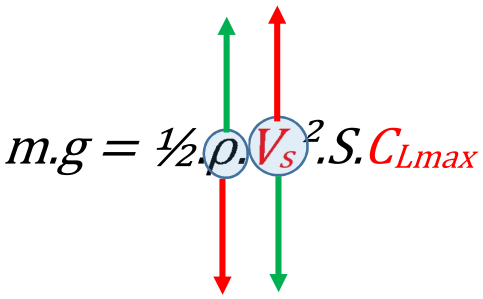
- **Aircraft configuration**: When the flaps are extended, $C_{L\ MAX}$ is increased so the same amount of LIFT can be achieved by at a lower minimum speed, meaning the V_S decreases.

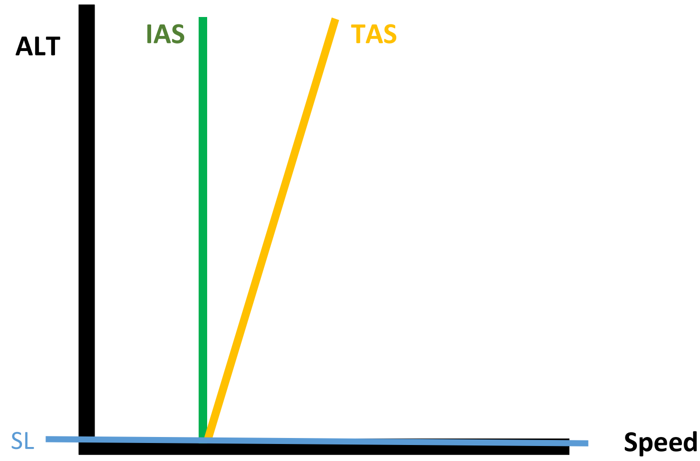


- **Load Factor**: When the load factor is increase (during manoeuvres), at C_{LMAX}, the increase in LIFT can be achieved by a higher minimum speed, meaning the V_S increases.



- **Density altitude**: At higher altitude, the decrease in pressure will decrease the density, or when the temperature is higher the density will also decrease. So at C_{LMAX}, the same amount of LIFT can be maintained by a higher minimum speed, meaning the V_S increases





NOTE: it is important to know that the aircraft will stall at higher TAS ah higher altitude, however since TAS increases with altitude with the same IAS, the aircraft stalls at the same IAS but at higher TAS when concerned by the density only.

CG position: When the CG is forward, it has been seen that aircraft will a have higher nose down moment that must be stabiliser by a higher downward force from the tailplane. This downward force will be added to the total weight of the aircraft and so the aircraft is effectively heavier, meaning that V_S increases

Airframe contamination: If the aircraft in contaminated, i.e. icing, the contamination on the airframe will increase the weight of the aircraft, so V_S increases. In addition, the contamination above the wing will modify the shape of the aerofoil and the surface roughness, leading in increase in the profile drag, decrease in C_{LMAX}, and so V_S increases even further

Affecting Factors	**V_S decreases**	**V_S increases**
Aerofoil shape	More positive camber Thicker	Less positive camber Thinner
Aircraft mass	Light	Heavy
Aircraft configuration	Flaps extended	Flaps retracted
Load Factor	Decreases	Increases
CG position	AFT	FWD
Airframe contamination	Clear, recent	Contaminated, old
Density altitude (TAS)	Decreases	Increases

6) Stall speed equation

Weight factor

$$m.g = \tfrac{1}{2}.\rho.V_S^2.S.C_{Lmax}$$

If the initial mass **(m_{init})** changes by ***n***, the new mass **(m_{new})** is:

$m_{new} = n \, . \, m_{old}$

At **m_{init}**, the stall speed was **$V_{S\,init}$**, and at **m_{new}**, the stall speed is **$V_{S\,new}$**

$$\begin{cases} m_{init}.g = \tfrac{1}{2}.\rho.V_{S\,init}^2.S.C_{Lmax} \\ m_{new}.g = \tfrac{1}{2}.\rho.V_{S\,new}^2.S.C_{Lmax} \end{cases}$$

We change the initial mass by a factor ***n*** to obtain the new mass

$$\begin{cases} n.m_{init}.g = n.\tfrac{1}{2}.\rho.V_{S\,init}^2.S.C_{Lmax} \\ m_{new}.g = n.\tfrac{1}{2}.\rho.V_{S\,new}^2.S.C_{Lmax} \end{cases}$$

$$\begin{cases} m_{new}.g = n.m_{init}.g \\ \tfrac{1}{2}.\rho.\ V_{S\,new}^2.S.C_{Lmax} = n.\tfrac{1}{2}.\rho.V_{S\,init}^2.S.C_{Lmax} \end{cases}$$

$$\cancel{\tfrac{1}{2}.\rho.}\ V_{S\,new}^2.\cancel{S.C_{Lmax}} = n.\cancel{\tfrac{1}{2}.\rho.}V_{S\,init}^2.\cancel{S.C_{Lmax}}$$

$$V_{S\,new}^2 = n.V_{S\,init}^2$$

$$V_{S\,new} = V_{S\,init} \, . \sqrt{n}$$

$$V_{S\,new} = V_{S\,init} \, . \sqrt{\frac{new\ mass}{old\ mass}}$$

Load factor

$$m.g = \frac{1}{2}.\rho.V_S^2.S.C_{Lmax}$$

If the initial Load Factor **(1g)** changes by ***n***, the Load Factor **(ng)** is:
ng = n.1g

At **1g**, the stall speed was $\mathbf{V_{S\,1g}}$, and at **ng**, the stall speed is $\mathbf{V_{S\,ng}}$

$$\begin{cases} m.1g = \frac{1}{2}.\rho.V_{S\,1g}^2.S.C_{Lmax} \\ m.ng = \frac{1}{2}.\rho.V_{S\,ng}^2.S.C_{Lmax} \end{cases}$$

We change the initial load factor by a factor ***n*** to obtain the new load factor

$$\begin{cases} n.\ m.1g = n.\frac{1}{2}.\rho.\ V_{S\,1g}^2.S.C_{Lmax} \\ m.ng = n.\frac{1}{2}.\rho.\ V_{S\,ng}^2.S.C_{Lmax} \end{cases}$$

$$\begin{cases} m.ng = n.\ m.1g \\ \frac{1}{2}.\rho.\ V_{S\,ng}^2.S.C_{Lmax} = n.\frac{1}{2}.\rho.\ V_{S\,1g}^2.S.C_{Lmax} \end{cases}$$

$$\cancel{\frac{1}{2}.\rho.}\ V_{S\,ng}^2.\cancel{S.C_{Lmax}} = n.\cancel{\frac{1}{2}.\rho.}\ V_{S\,1g}^2.\cancel{S.C_{Lmax}}$$

$$V_{S\,ng}^2 = n.\ V_{S\,1g}^2$$

$$\boxed{V_{S\,ng} = V_{S\,1g}.\sqrt{n}}$$

$$\boxed{V_{S\,ng} = V_{S\,1g}.\sqrt{load\ factor}}$$

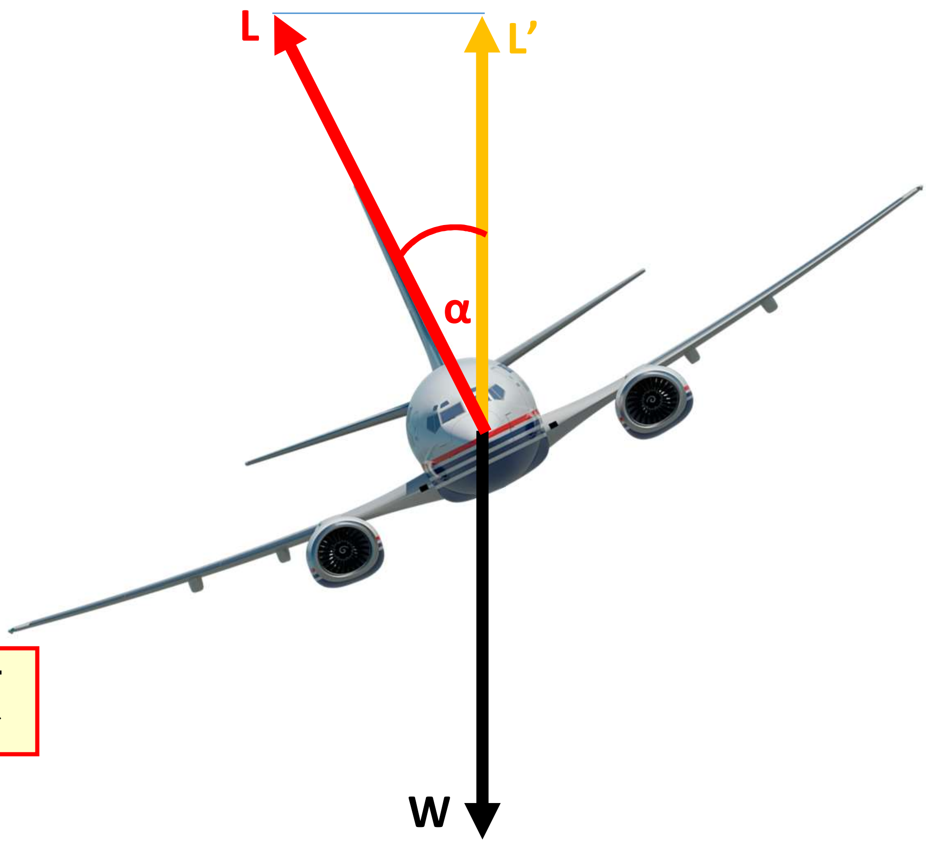
In turn

$$W = L' \Leftrightarrow \begin{cases} W = 1 \\ L' = 1 \end{cases}$$

$L = L'/\cos\alpha$
$L = W/\cos\alpha$
$L = 1/\cos\alpha$

Load factor "n" = L/W
In turn,
$\text{"n"} = (1/\cos\alpha)/W$
$\text{"n"} = 1/\cos\alpha$

$$V_{S\,new} = V_{S\,init} \cdot \sqrt{1/\cos\alpha}$$



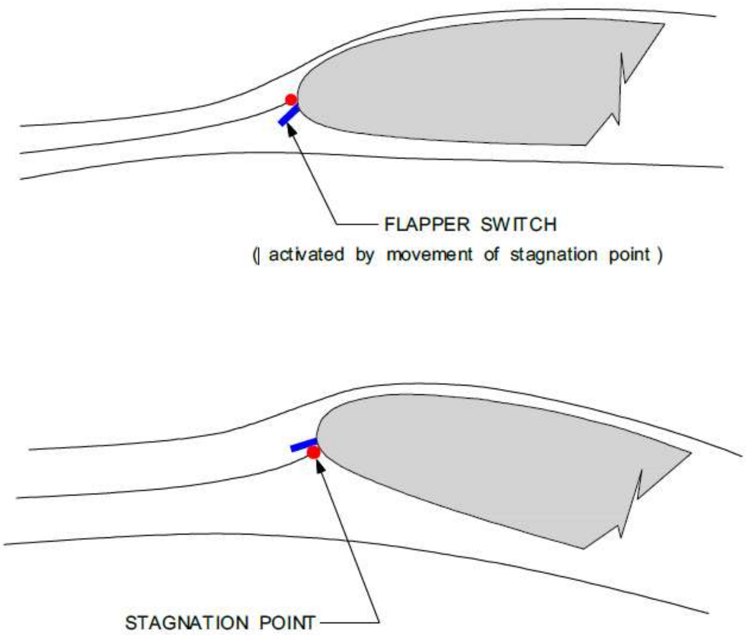
7) Stall warning

The stall warning must be earlier than the stall and the margin must be sufficient to allow the pilot to prevent stalling

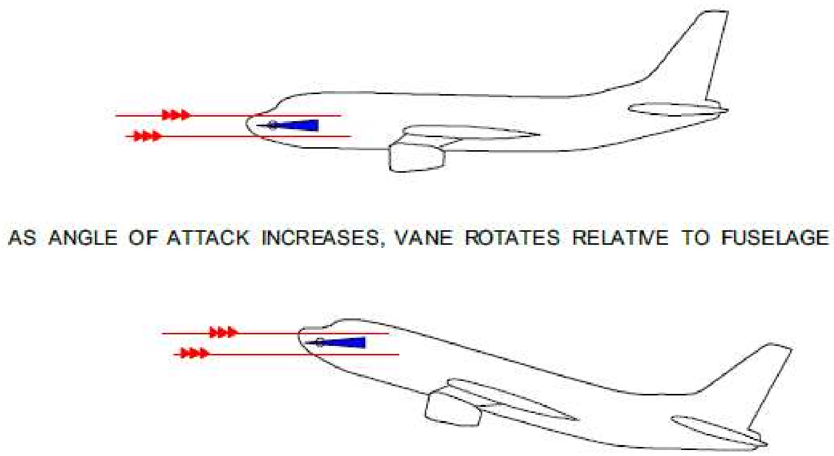
Artificial stall warning on small aircraft is usually given by a buzzer or horn. The artificial stall warning device used on modern large aircraft is a stick shaker, in conjunction with lights and a noise-maker.

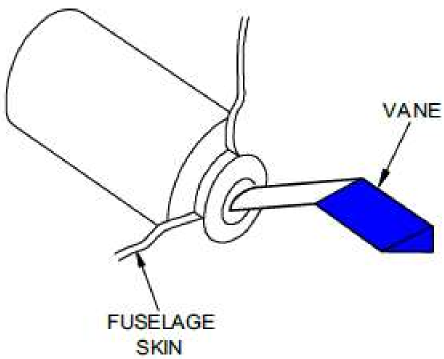
Stick shaker: A stick shaker represents what it is replacing; it shakes the stick and is a tactile warning. If the stick shaker activates when the pilot's hands are not on the controls: when the aircraft is on autopilot, for example, a very quiet stick shaker could not function as a stall warning so a noise maker is added in parallel.

An artificial stall warning device can receive its signal from a number of different types of detector switch, all activated by changes in angle of attack,



Flapper switch (leading edge stall warning vane): As angle of attack increases, the stagnation point moves downwards and backwards around the leading edge. The flapper switch is so located, that at the appropriate angle of attack, the stagnation point moves to its underside, and the increased pressure lifts and closes the switch.





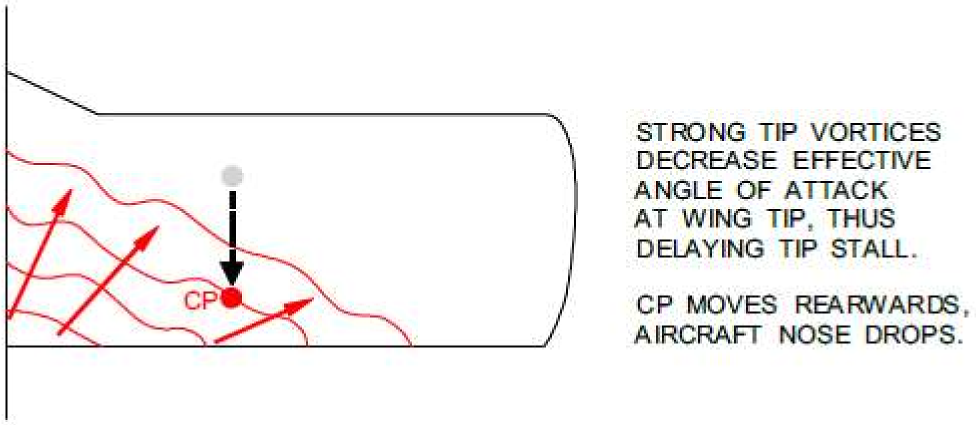
Angle of attack vane: Mounted on the side of the fuselage, the vane streamlines with the relative airflow and the fuselage rotates around it. The stick shaker is activated at the appropriate angle of attack.

Angle of attack probe: Also mounted on the side of the fuselage; consists of slots in a probe, which are sensitive to changes in angle of relative airflow.

All of these sense angle of attack and, therefore, automatically take care of changes in aircraft mass; the majority also compute the rate of change of angle of attack and give earlier warning in the case of faster rates of approach to the stall. The detectors are usually datum compensated for configuration changes and are always heated or anti-iced. There are usually sensors on both sides to counteract any sideslip effect.

8) Effect of the aerofoil section & Correcting devices

A) <u>Rectangular wings</u>



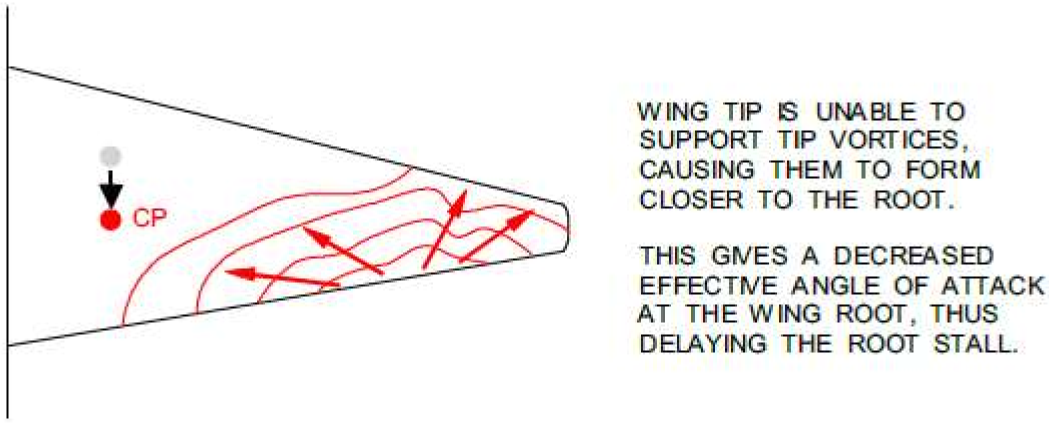
On a rectangular wing, separation tends to begin at the root, and spreads out towards the tip. Reduction in lift initially occurs inboard near the aircraft CG, and if it occurs on one wing before the other, there is **little tendency for the aircraft to roll**.

The aircraft loses height, but in doing so remains more or less wings level. **Loss of lift is felt ahead of the centre of gravity of the aircraft and the CP moves rearwards, so the nose drops and angle of attack is reduced.** Thus, there is a natural tendency for the aircraft to move away from the high angle of attack which gave rise to the stall. The separated airflow from the root immerses the rear fuselage and tail area, and aerodynamic buffet can provide a warning of the approaching stall. Being located outside of the area of separated airflow, the ailerons tend to remain effective when the stalling process starts. All of these factors give the most desirable kind of response to a stall:

- Aileron effectiveness
- Nose drop
- Aerodynamic buffet, and
- Absence of violent wing drop

Unfortunately, a rectangular wing has unacceptable wing bending characteristics and is not very aerodynamically efficient, so most modern aircraft have a tapered and/or swept planform.

B) <u>Tapered wings</u>

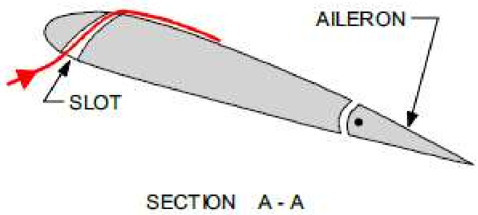


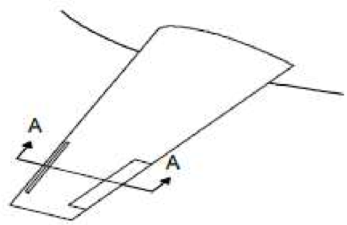
Separation tends to occur first in the region of the wing tips, reducing lift in those areas. If an actual wing were allowed to stall in this way, stalling would give aileron buffet, and perhaps violent wing drop. (Wing drop at the stall gives an increased tendency for an aircraft to enter a spin). There would be no buffet on the tail, no strong nose down pitching moment, and very little, if any, aileron effectiveness. To give favourable stall characteristics, a tapered wing must be modified using one or more of the following:

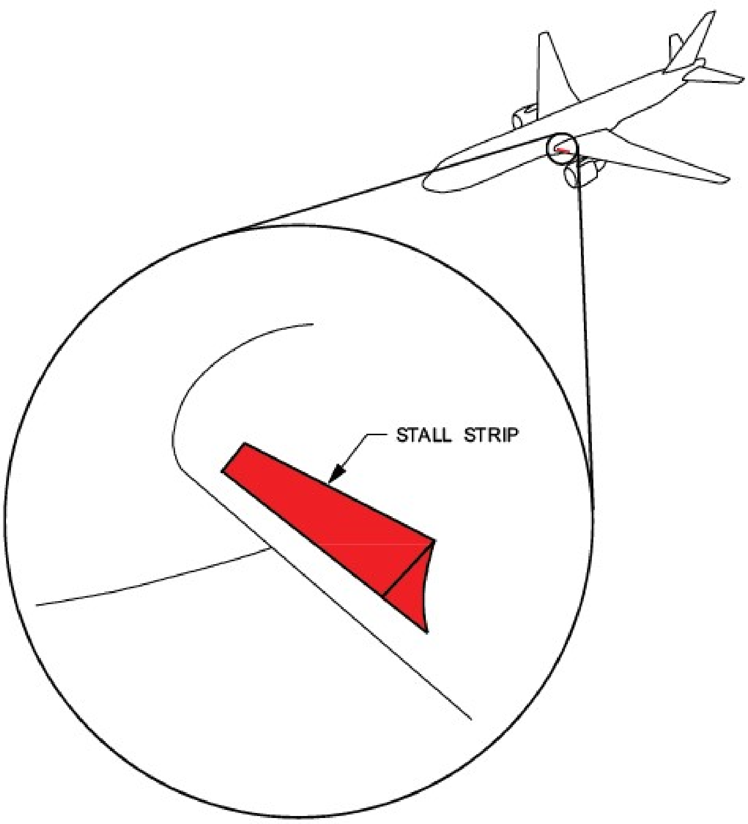
- **Geometric twist (washout),** a decrease in incidence from root to tip. This decreases the angle of attack at the tip, and the root will tend to stall first.

- The aerofoil section may be varied throughout the span such that sections with greater thickness and camber are located near the tip. The higher C_{LMAX} of such sections delays stall so that the root will tend to stall first.

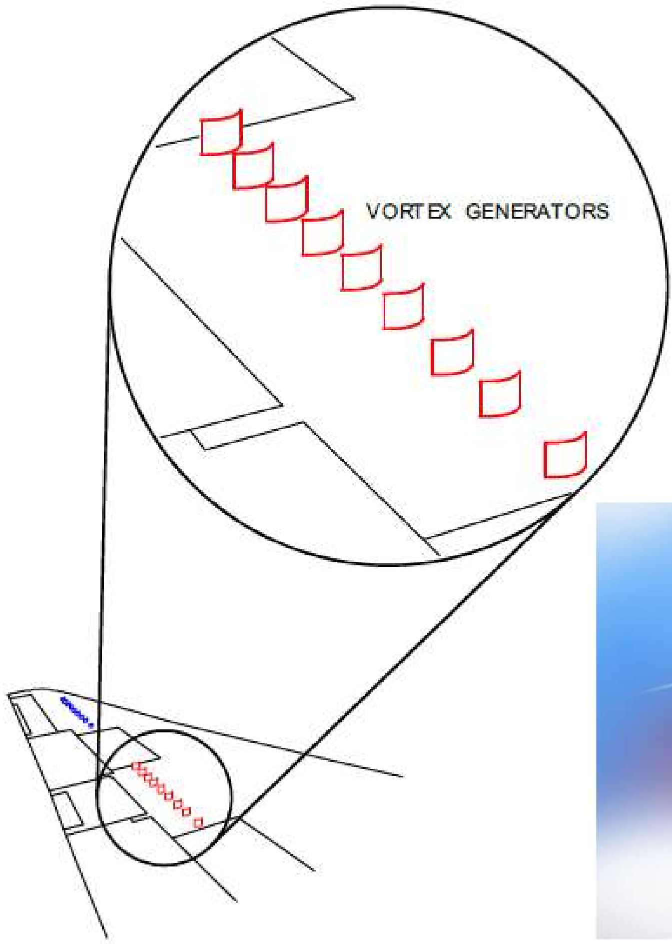
- **Leading edge slots**, towards the tip re-energise (increase the kinetic energy of) the boundary layer. They increase local CL MAX and are useful, both for delaying separation at the tip, and retaining aileron effectiveness.



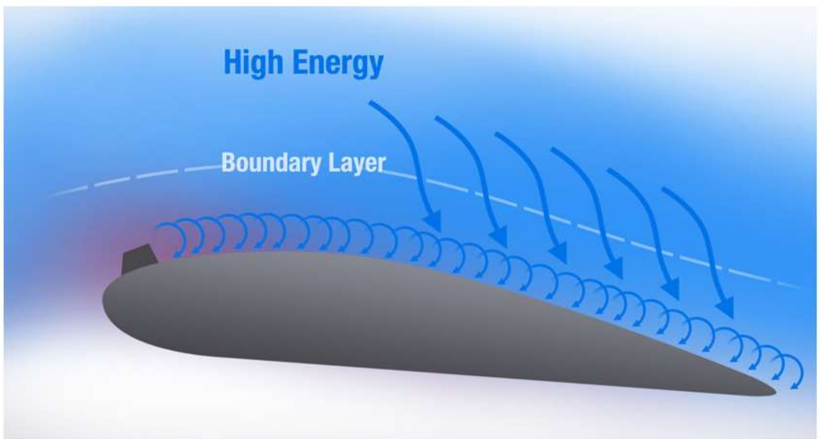




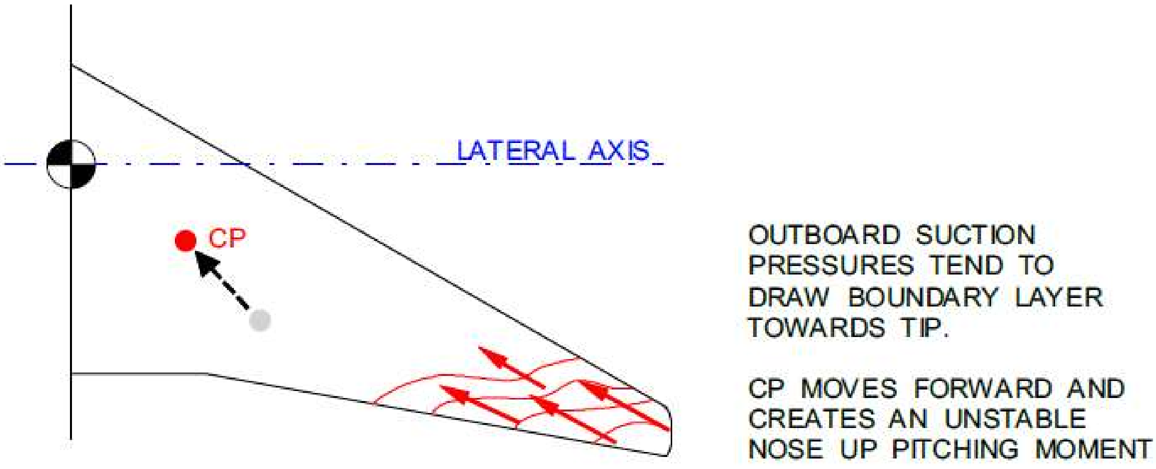
Stall strips:
Another method for improving the stall pattern is by forcing a stall to occur from the root. An aerofoil section with a smaller leading edge radius at the root would promote airflow separation at a lower angle of attack but decrease overall wing efficiency. The same result can be accomplished by attaching **stall strips** (small triangular strips), to the wing leading edge.
At higher angles of attack stall strips promote separation, but will not affect the efficiency of the wing in the cruise.



Vortex generators, are rows of small, thin aerofoil shaped blades which project vertically (about 2.5cm) into the airstream. They each generate a small vortex which causes the free stream flow of high energy air to mix with and add kinetic energy to the boundary layer. This re-energises the boundary layer and tends to delay separation.

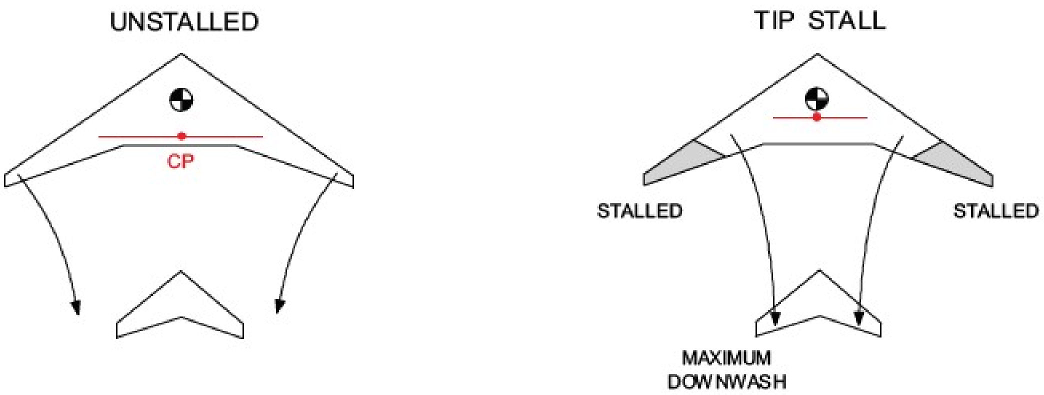


C) Sweptback

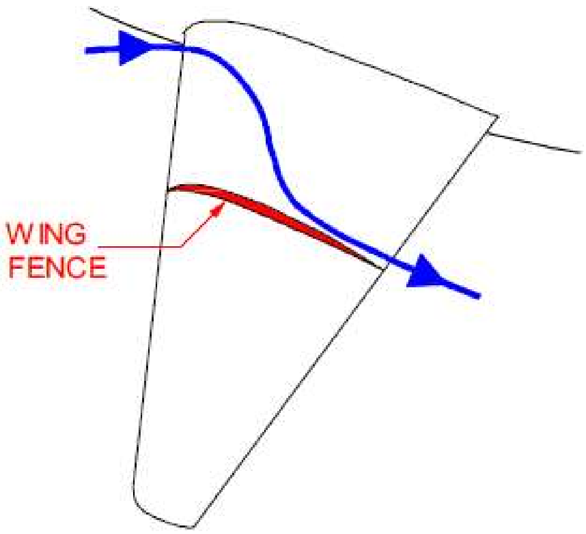


A swept wing is fitted to allow a higher maximum speed, but it has an increased tendency to stall first near the tips. Loss of lift at the tips moves the CP forward, giving a nose up pitching moment.
Effective lift production is concentrated inboard and the maximum downwash now impacts the tailplane, adding to the nose up pitching moment.

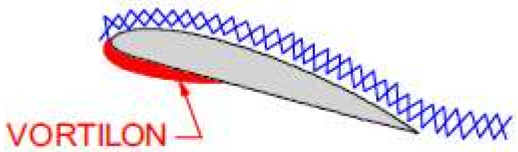
Pitch-up: As soon as a swept wing begins to stall, both forward CP movement and increased downwash at the tailplane cause the aircraft nose to rise rapidly, further increasing the angle of attack. This is a very undesirable and unacceptable response at the stall and can result in complete loss of control in pitch from which it may be very difficult, or even impossible, to recover. This phenomenon is known as pitch-up, and is a very dangerous characteristic of many high speed, swept wing aircraft.

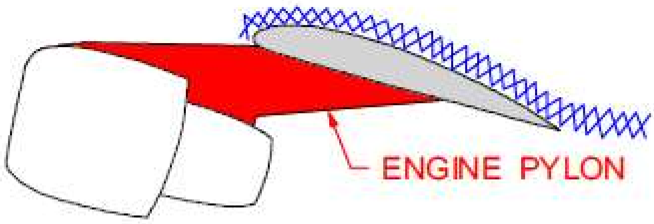


The tendency of a swept back wing to tip stall is due to the induced spanwise flow of the boundary layer from root to tip. The following design features can be incorporated to minimise this effect and give a swept wing aircraft more acceptable stall characteristics:



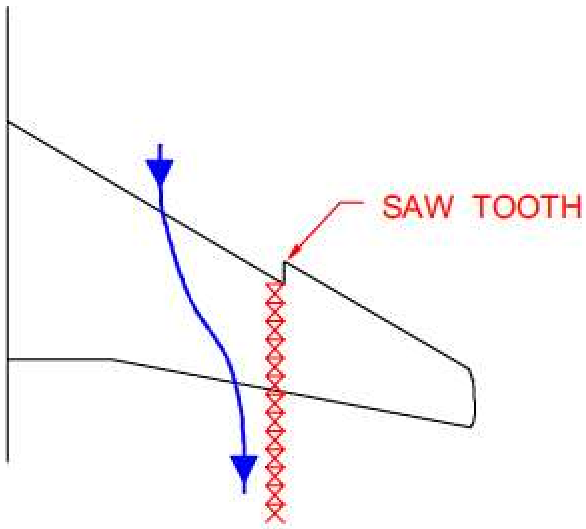
Wing fences (boundary layer fences), are thin metal fences which generally extend from the leading edge to the trailing edge on the top surface and are intended to prevent outward drift of the boundary layer.





Vortilons are also thin metal fences, but are smaller than a full chordwise fence. They are situated on the underside of the wing leading edge.

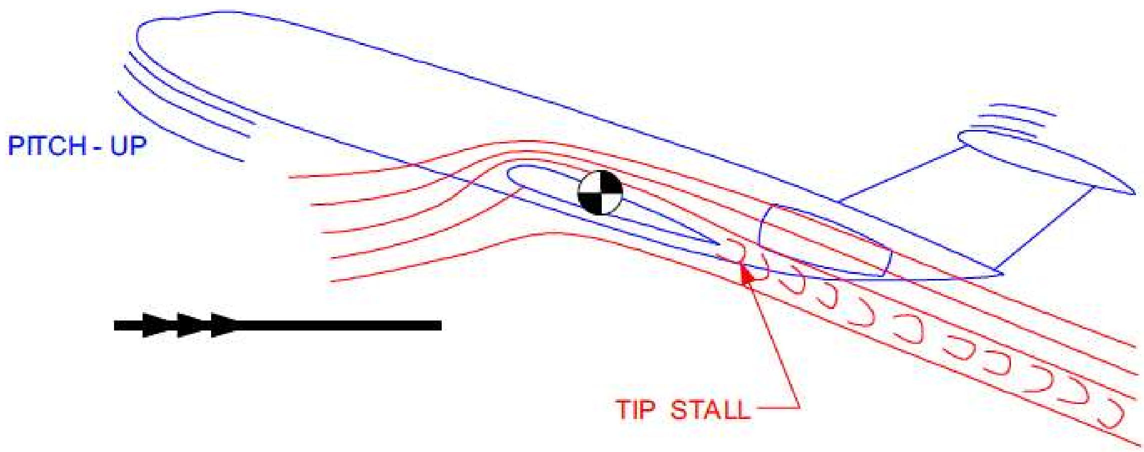
The support pylons of pod mounted engines on the wing also act in the same way. At high angles of attack a small but intense vortex is shed over the wing top surface which acts as an aerodynamic wing fence.



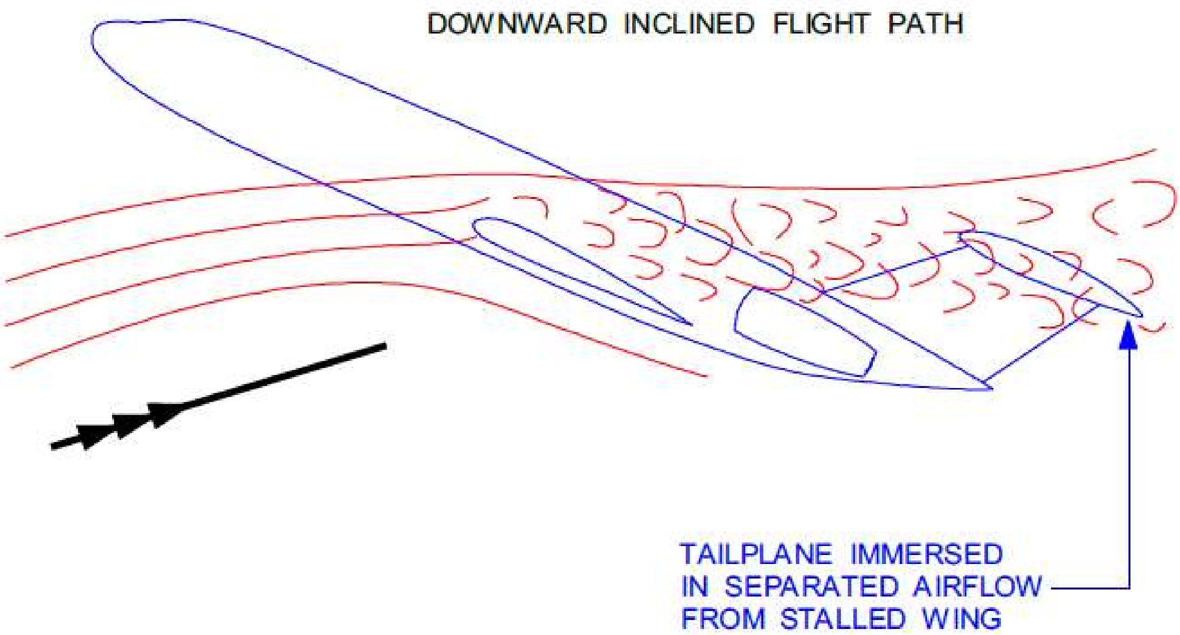
Saw tooth leading edge, will also generate a strong vortex over the wing upper surface at high angles of attack, minimising spanwise flow of the boundary layer. (Rarely used on modern high speed jet transport aircraft).

9) Super Stall / Deep Stall

A swept-back wing tends to stall first near the tips. Since the tips are situated well aft of the CG, the loss of lift at the tips causes the pitch attitude to increase rapidly and further increase the angle of attack.



This "automatic" increase in angle of attack, caused by pitch-up, stalls more of the wing. Drag will increase rapidly, lift will reduce, and the aeroplane will start to sink at a constant, nose high, pitch attitude. This results in a rapid additional increase in angle of attack



Separated airflow from the stalled wing will immerse a high-set tailplane in low energy turbulent air. Elevator effectiveness is greatly reduced making it impossible for the pilot to decrease the angle of attack. The aeroplane will become stabilized in what is known as the "super-stall" or "deep-stall" condition.

Clearly, the combination of a swept-back wing and a high mounted tailplane (‘T’ - Tail) are the factors involved in the “super or deep-stall”. Of the two:

THE SWEPT-BACK WING IS THE MAJOR CONTRIBUTORY FACTOR

It has been shown that the tendency for a swept-back wing to pitch-up can be reduced by design modifications (wing fences, vortilons and saw tooth leading edge) which minimise the root-to-tip spanwise flow of the boundary layer. These devices **delay** tip stall. Vortex generators are also frequently used on a swept wing to delay tip stall and improve the stall characteristics.
The wing root can also be encouraged to stall first. This can be done by modifying the aerofoil section at the root, fitting stall strips and by fitting less efficient leading edge flaps (Kruger flaps) to the inboard section of the wing.

Aircraft such as the DC-9, MD-80, Boeing 727, Fokker 28 and others, have swept-back wings and high mounted tailplanes (‘T’ - Tail). They also have rear, fuselage mounted engines. The only contribution rear mounted engines make is that they are the reason the designer placed the tailplane on top of the fin in the first place. In-and-of-itself, mounting the engines on the rear fuselage does not contribute to super stall.

SUPER STALL PREVENTION - STICK PUSHER

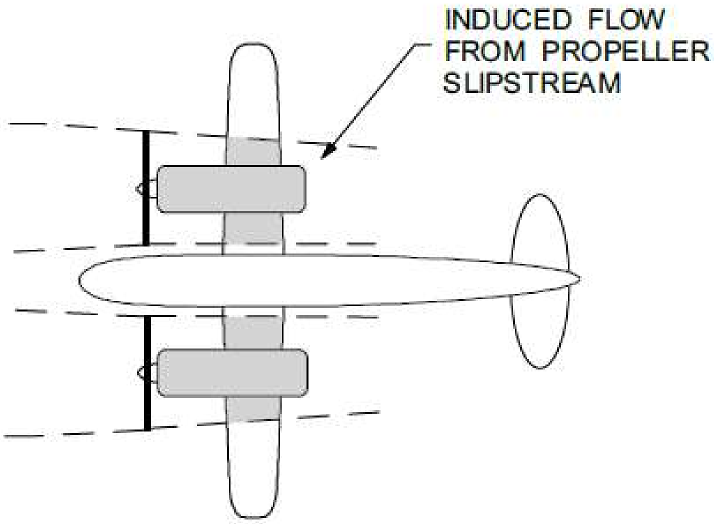
An aircraft design which exhibits super-stall characteristics must be fitted with **a device to prevent it from ever stalling.** This device is a stick pusher. Once such an aircraft begins to stall it is too late; the progression to super stall is too fast for a human to respond, and the aircraft cannot then be un-stalled.
A stick pusher is a device attached to the elevator control system, which physically pushes the control column forward, reducing the angle of attack before super-stall can occur. The force of the push is typically about **80 lbs**. This is regarded as being high enough to be effective, but not too high to hold in a runaway situation.
Provision is made to “dump” the stick pusher system in the event of a malfunction. Once dumped, the pusher cannot normally be reset in flight.
Once actuated, the stick pusher will automatically disengage once the angle of attack reduces below a suitable value.

The sequence of event is, from high speed to the V_S or from low AoA to AoA_{CRIT}:

Stick shaker activates initially, then stick pusher activate, and lastly the stall.

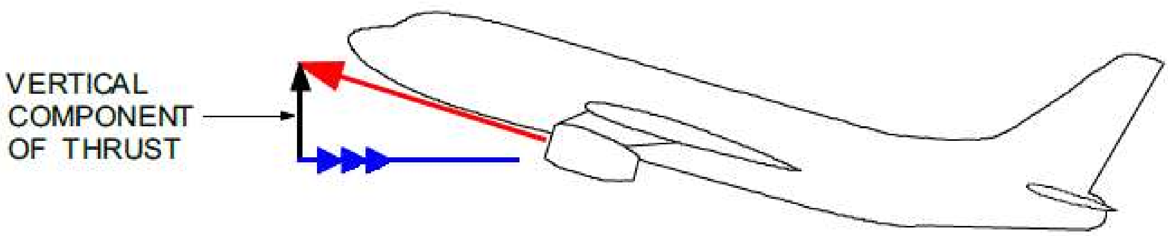
10) Engine effect

Propeller: The slipstream velocity behind the propeller is greater than the free stream flow, depending on the thrust developed. Thus, when the propeller aeroplane is at low airspeeds and high power, the dynamic pressure within the propeller slipstream is much greater than that outside and this generates much more lift than at zero thrust. The lift of the aeroplane at a given angle of attack and airspeed will be greatly affected. If the aircraft is in the landing flare, reducing power suddenly will cause a significant reduction in lift and a heavy landing could result. On the other hand, a potentially heavy landing can be avoided by a judicious 'blast' from the engines.



Jet: The typical jet aircraft does not experience the induced flow velocities encountered in propeller driven aeroplanes, thus the only significant factor is the vertical component of thrust.

Since this vertical component contributes to supporting the weight of the aircraft, less aerodynamic lift is required to hold the aeroplane in flight. If the thrust is large and is given a large inclination at maximum lift angle, the effect on stall speed can be very large. Since there is very little induced flow from the jet, the angle of attack at stall is essentially the same power-on as power-off.



11) Stall & Recovery characteristics of CANARDS

With the conventional rear tailplane configuration the wing stalls before the tailplane, and longitudinal control and stability are maintained at the stall. On a canard layout if the wing stalls first, stability is lost, but if the foreplane stalls first then control is lost and the maximum value of C_L is reduced.

12) Spin

A **spin** is an uncoordinated stall resulting in autorotation.

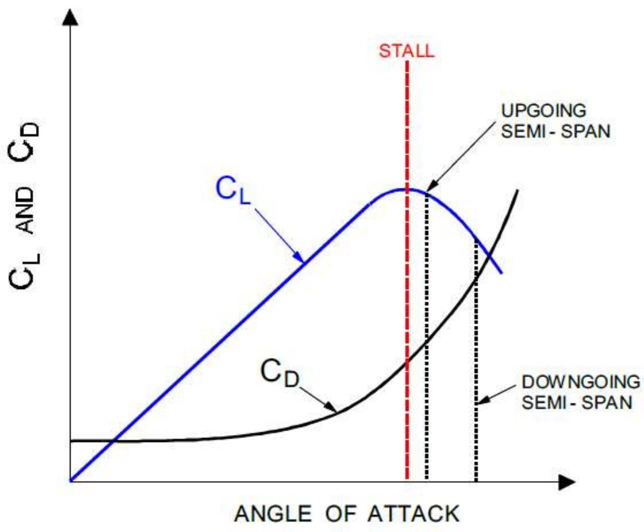
When an aircraft is accidentally or deliberately stalled, the motion of the aircraft may in some cases develop into a spin. The important characteristics of a spin are:

a) the aircraft is descending along a steep helical path about a vertical spin axis
b) the angle of attack of both wings is well above the stall angle,
c) the aircraft has a high rate of rotation about the vertical spin axis,
d) viewed from above, the aircraft executes a circular path about the spin axis, and the radius of the helix is usually less than the semi-span of the wing
e) the aircraft may be in the “erect” or “inverted” position in the spin.

The spin is one of the most complex of all flight manoeuvres. A spin may be defined as an aggravated stall resulting in autorotation, which means the rotation is stable and will continue due to aerodynamic forces if nothing intervenes. During the spin the wings remain unequally stalled.

CAUSE OF SPIN

Many types of airplane will spin only if the pilot simultaneously yaws and stalls the airplane (intentionally or unintentionally). Under these circumstances, one wing will stall, or stall more deeply than the other. The wing that stalls first will drop, increasing its angle of attack and deepening the stall. At least one wing must be stalled for a spin to occur. The other wing will rise, decreasing its angle of attack, and the aircraft will yaw towards the more deeply stalled wing. The difference in lift between the two wings causes the aircraft to roll, and the difference in drag causes the aircraft to continue yawing.



One common scenario that can lead to an unintentional spin is a skidding uncoordinated turn toward the runway during the landing sequence. A pilot who is overshooting the turn to final approach may be tempted to apply more rudder to increase the rate of turn. The result is twofold: the nose of the airplane drops below the horizon and the bank angle increases due to rudder roll. Reacting to these unintended changes, the pilot then begins to pull the elevator control aft (thus increasing the angle of attack and load factor) while applying opposite aileron to decrease bank angle. Taken to its extreme, this can result in an uncoordinated turn with sufficient angle of attack to cause the aircraft to stall. This is called a cross-control stall, and is very dangerous if it happens at low altitude where the pilot has little time to recover. In order to avoid this scenario, pilots are taught the importance of always making coordinated turns. They may simply choose to make the final turn earlier and shallower to prevent an overshoot of the runway centerline and provide a larger margin of safety. Certificated, light, single-engine airplanes must meet specific criteria regarding stall and spin behavior. Spins are often entered intentionally for training, flight testing, or aerobatics.

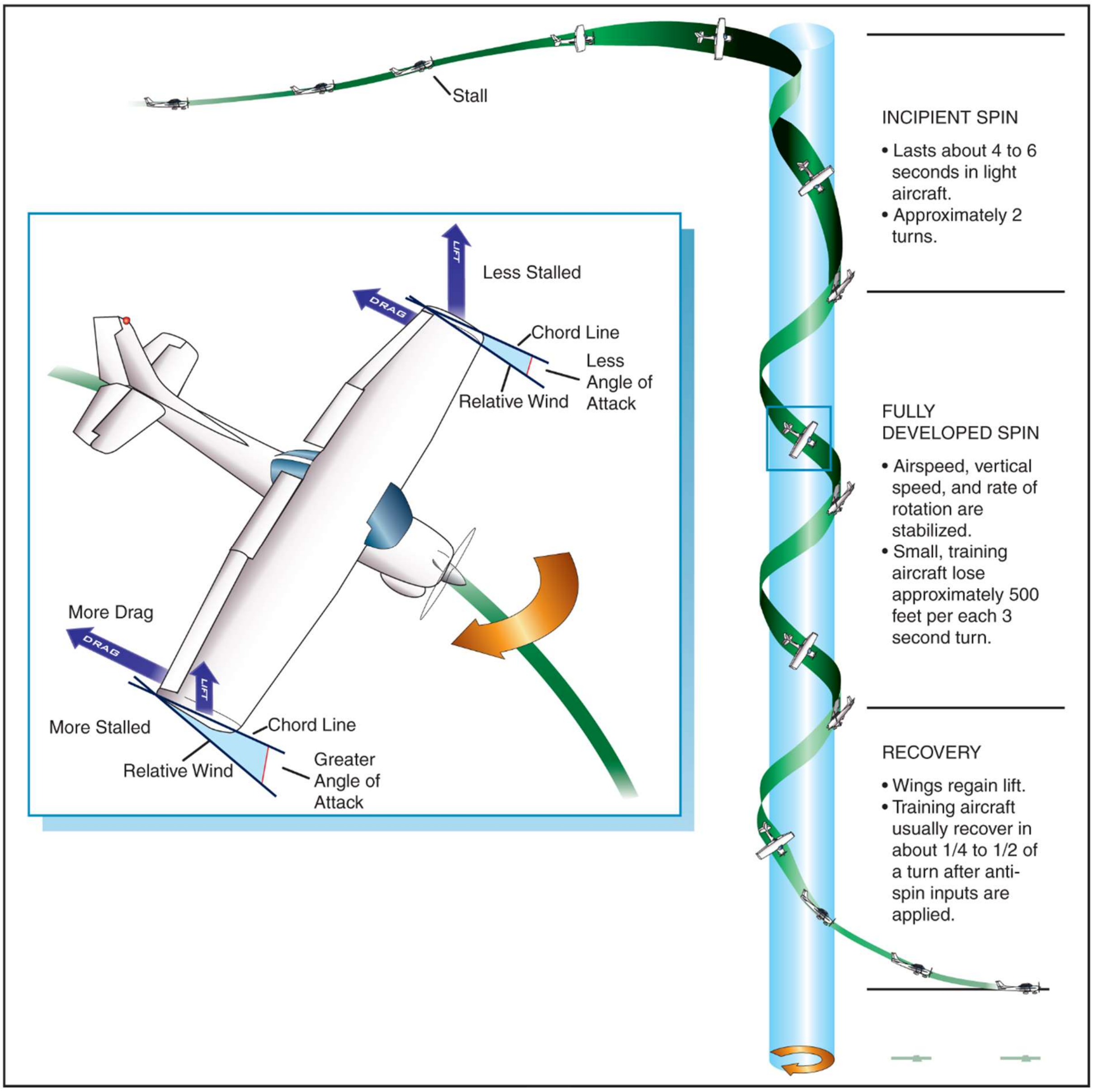
PHASES OF SPIN

There are three phases of a spin.

1) The **incipient spin** is the first phase, and exists from the time the aeroplane stalls and rotation starts until the spin is fully developed.

2) A **fully developed** spin exists from the time the angular rotation rates, airspeed, and vertical descent rate are stabilized from one turn to the next.

3) The **third phase**, spin recovery, begins when the anti-spin forces overcome the pro-spin forces.



If an aircraft is near the critical angle of attack, and more lift is lost from one wing than the other, that wing will drop. Its relative airflow will be inclined upwards, increasing its effective angle of attack. As the aeroplane rolls around its CG, the rising wing has a reduced effective angle of attack and remains less stalled than the other. This situation of unbalanced lift tends to increase as the aeroplane yaws towards the low wing, accelerating the high, outside wing and slowing the inner, lower wing. As with any stall, the nose drops, and as inertia forces begin to take effect, the spin usually stabilizes at a steady rate of rotation and descent.

It is vitally important that recovery from an unintentional spin is begun as soon as possible, since many aeroplanes will not easily recover from a fully developed spin, and others continue for several turns before recovery inputs become effective. Recovery from an incipient spin normally requires less altitude and time than the recovery from a fully developed spin. Every aeroplane spins differently, and an individual aeroplane's spin characteristics vary depending on configuration, loading, and other factors.

RECOVERY FROM A SPIN

Recovery from a simple stall is achieved by reducing the angle of attack which restores the airflow over the wing; spin recovery additionally involves stopping the rotation. The extremely complex aerodynamics of a spin may dictate vastly different recovery procedures for different aeroplanes, so no universal spin recovery procedure can exist for all aeroplanes.

The recommended recovery procedure for some aeroplanes is simply to reduce power to idle and release pressure on the controls. At the other extreme, the design of some aircraft is such that recovery from a developed spin requires definite control movements, precisely timed to coincide with certain points in the rotation, for several turns.

The following is a general recovery procedure for erect spins. Always refer to the Flight Manual for the particular aircraft being flown and follow the manufacturer's recommendations.

1- Move the throttle or throttles to idle. This minimises altitude loss and reduces the possibility of a flat spin developing. It also eliminates possible asymmetric thrust in multi-engine aeroplanes. Engine torque and gyroscopic propeller effect can increase the angle of attack or the rate of rotation in single-engine aeroplanes, aggravating the spin.

2- **Neutralise the ailerons**. Aileron position is often a contributory factor to flat spins, or to higher rotation rates in normal spins.

3- Apply full rudder against the spin. Spin direction is most reliably determined from the turn co-ordinator. Do not use the ball in the slip indicator, its indications are not reliable and may be affected by its location within the flight deck.

4- Move the elevator control briskly to approximately the neutral position. Some aircraft merely require a relaxation of back pressure, while others require full forward pitch control travel.

The above four items can be accomplished simultaneously.

5- Hold the recommended control positions until rotation stops.

6- As rotation stops, neutralise the rudder. If rudder deflection is maintained after rotation stops, the aircraft may enter a spin in the other direction.

7- Recover from the resulting dive with gradual back pressure on the pitch control.

a- Pulling too hard could trigger a secondary stall, or exceed the limit load factor and damage the aircraft structure.

b- Recovering too slowly from the dive could allow the aeroplane to exceed its airspeed limits, particularly in aerodynamically clean aeroplanes. Avoiding excessive speed build-up during recovery is another reason for closing the throttles during spin recovery

c- Add power as you resume normal flight, being careful to observe power and RPM limitations.