Translation of the French DGAC leaflet on stalls

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For drawings, refer to the original leaflet.

1 – The recovery procedure

This procedure is applicable on all aircraft types if in conformity with the AFM.

It is not applicable during the flare phase when the intent is to correct a landing.

Recovery procedure for stall

At the first indication of stall, for example aural or visual warning, uncontrolled lateral departure, pitch down, stick shaker, stick pusher, buffeting...

1 Disconnect the autopilot (if applicable)

Rationale: The disconnection of the autopilot allows taking manual control of the aircraft for the recovery. Be careful with a possible pitch variation at disconnection.

2a Apply nose down pitch control until there is no longer stall indications

Rationale: The priority is to reduce the angle of attack.

2b If necessary: nose down pitch trim

Rationale: If the authority of the elevator is not sufficient, it may be necessary to trim down.

3 Wings level

Rationale: Orientation of the lift vector vertically to ease the recovery.

4 Adjust thrust as necessary

Rationale: The stall may happen at any power between idle and maximum power. During the recovery, most of the time, the maximum power is not necessary. As a consequence, the thrust has to be adjusted as a function of the stall conditions. Insure as much as possible, the symmetry of the flight.

5 Retract the speedbrakes (if applicable)

Rationale: Improvement of the lift and of the margin with stall speed.

6 Return to the desired flight path

Rationale: Apply a smooth action, to avoid a secondary stall, and come back of an adapted trajectory. The priority must not be the minimum loss of altitude.

2 – Theoretical part

2.1 Definitions

Angle of attack: The angle of attack is the angle between the airfoil and the speed.

Lift: The lift is the component of the aerodynamic force on the wing or on the aircraft, perpendicular to the speed. (Refer to drawing)

2.2 The stall of a wing

Let's consider a wing having a constant profile on all its length, in a wind tunnel where the speed is constant, and review the lift that it can develop.

Point 1: The angle of attack and the lift are low.
Point 2: The angle of attack is higher as is the lift.
Point 3: The airflow starts to separate from the upper part of the airfoil. The lift does not increase regularly with the angle of attack.
Point 4: The maximum lift is reached.
Point 5: The flow is almost fully separated from the upper part of the airfoil.

By definition the stall corresponds to point 4 where the lift reaches its maximum value.
(Refer to drawing)

2.3 The stall of an aircraft

On an aircraft, the stall phenomenon is more complex because the wing has not a constant profile on the entire span, with sometimes minor manufacturing differences between the left and the right wing. In addition, in the case of propeller aircraft, the airflow from the propeller(s) creates a significant asymmetry on the wing. For all these reasons, it may happen that a wing stall slightly before the other one when increasing the angle of attack, leading to some wing drop or yaw motion.

The equilibrium in pitch is maintained up to the stall by adjusting the lift on the empennage thanks to the deflection of the elevator. When stalling, the lift is reduced on the wing, the equilibrium is no longer maintained and the aircraft pitches down. This pitch down motion is more or less significant according to aircraft type. For some of them, it may happen that a quasi equilibrium is reached due to the limited loss of lift on the wing when stalling.

All the parts of the wing are not stalling at the same time. Generally the aircraft are designed such as to get the stall first at the inner part of the wing in order to reduce the wing drop and ease the lateral control. However, the behaviour may be modified by the flight conditions and specifically on fast aircraft by the Mach effect. This can produce pitch effect, up or down. As an example, on a swept wing, if the outer parts of the wing are stalling first in some conditions, we may get some pitch up.

On business jets, in clean configuration, it is common that the pilot has difficulties to identify the stall, as the buffeting, which is increasing with the angle of attack, hides it. This buffeting is due to the small vortices on the upper part of the airfoil. This has to be considered as the approach to stall. This buffeting could become very strong if the pilot continues to increase the angle of attack.

Unless there is an obvious natural warning before reaching the stall (buffeting as an example), the installation of a specific warning is mandatory on the aircraft to alert the crew before reaching the angle of attack for stall. There are various types of warnings: audio, visual, stick shaker...

Finally, for various reasons, some aircraft may have unsafe stall characteristics, such as important wing drop. In order to avoid reaching these flight conditions, a stick pusher could be installed. It stronger pushes the stick forward before reaching a critical angle of attack when approaching stall.

2.4 The affecting parameters

2.4.1 The angle of attack

For a given configuration, an aircraft stalls always at the same angle of attack. The only exception is linked to the effect of the Mach.

2.4.2 The configuration

The deflection of the slats, for aircraft equipped, allows increasing the stall angle of attack. There is no lift variation for a given angle of attack, but it is possible to fly safely at a higher angle of attack, therefore with a higher lift and with a reduction of the flying speed.

The flaps deflection increases the lift for a given angle of attack.
(Refer to drawing)

2.4.3 The load factor

There is no effect of the load factor on the stall angle of attack, in turn or in a pull up manoeuvre. For a given speed, to increase the load factor, the angle of attack and therefore the lift have to be increased. Therefore when tightening a turn or performing a pull up, the margin with the stall is reducing. This means also that the aircraft stalls at a higher speed in turn or in a pull up.

2.4.4 The engine power

For certification, the stall speeds are measured with the engine(s) at idle. A power increase on an aircraft with propeller(s) will create a flow on the wing and will limit the flow separation on the upper part of the airfoil. This allows increasing the lift and flying at a lower speed.

2.4.5 The position of the centre of gravity

The effect of the position of the centre of gravity is small, as the wing stall always at the same angle of attack. However, at forward CG, for a given angle of attack, for the longitudinal equilibrium of the aircraft, there is a need of more upward deflection of the elevator, and therefore the global lift is slightly reduced compared to aft CG. This explains a very small increase of the stall speed at forward CG.

2.4.6 The icing and the pollution of the wing

When the leading edge accumulates ice, for the same angle of attack, the lift decreases. On the other hand, the angle of attack for stalling is lower with an iced profile (refer to drawing). This phenomenon is more sensitive with thick airfoil and for wings without sweep. If intended to use an aircraft not de-iced in icing conditions, it would not be possible to maintain the usual approach speed, as the margin toward stall would be greatly reduced. Therefore, there is a need for a de-icing system to fly is such conditions. In case of failure of the system, the AFM generally recommends to increase the approach speed.

For some airfoils, the pollution on the wing or even water droplets can modify the flight characteristics with an increase of the stall speed. The AFM indicates the precautions to be taken when the aircraft is sensitive to this pollution.

2.5 The indicated airspeeds

On transport or business aircraft, the crew has generally displays where the minimum speeds are computed according to the weight and even to the load factor.

On general aviation aircraft, the stall speeds indicated on the anemometer (lower end of the arcs) correspond to the maximum weight for each configuration, forward CG and engine(s) at idle. When the weight is smaller, the stall speed that can be demonstrated in flight is smaller than the indicated one. Equally, for propeller aircraft, when stalling with some engine power (not at idle), the stall speeds will be well below the indicated ones.

2.6 The recovery from the stall

The stall is linked to a too high angle of attack and therefore, to recover, the angle of attack has to be reduced by pushing on the stick (refer to the procedure in paragraph 1).

2.7 The lateral control

During the recovery, the fact to push on the stick reduces immediately the angle of attack and therefore the aircraft can be flown normally. However, during the exercise itself, some precautions must be taken to fly on the lateral axis.

At stall, on almost all aircraft, the roll control is operating in a conventional manner. However, even if very few aircraft are concerned, it may happen that a large deflection of the ailerons lead to a stall of the wing at the opposite of the intended roll correction. Let's take an example on an aircraft with this flight characteristic. The pilot corrects a bank angle to the right with left stick, deflecting the right aileron downward. On the right wing, this new position of the aileron gives a local modification of the airflow and could lead to stall the right wing, banking on the right as a consequence. Therefore, even if this characteristic is not common at all, it is recommended to fly smoothly when approaching the stall with only small corrections in roll.

The launch of a spin needs the association of high angle of attack and large sideslip. When approaching stall, the angle of attack is high. A large deflection of the rudder can possibly create the sideslip leading to the spin. Therefore, it is wise to use the rudder pedals with some precautions when approaching the stall, trying just to limit the asymmetry. In other words, ball grossly in the middle, without need to be too precise.

2.8 Some comments on multi engines

The VMC (Minimum Control speed) can be below or above the stall speed. In case of stall with an engine failure, the power must be adjusted in order to minimize the asymmetry as much as possible. This means a reduction of the live engine in case of stall, and then, during the recovery, a progressive increase of the thrust in parallel with the speed increase.

2.9 The flight at high Mach and high altitude

The angle of attack for stall decreases progressively when the Mach increases. However, the lift increases quickly with the speed. The limits for manoeuvrability for each aircraft type are given in the AFM and are reviewed during the training course.

To be noted that the recovery from a stall at high altitude leads to a higher loss of altitude than at low altitude, because of the higher speeds (effect of Mach and altitude).