EGAST
Component of ESSI
European General Aviation Safety Team

STALL AND SPIN LOSS OF CONTROL

FOR GENERAL AVIATION PILOTS

SAFETY PROMOTION LEAFLET

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CONTENT

INTRODUCTION

Although some pilots think that stalling and spinning will only happen during training and skill tests, qualified pilots and their passengers continue to die after losing control at or near the stall. Loss of Control Inflight (LOCI) has been identified repeatedly in various EASA Annual Safety Reviews and other reference safety statistics as a major accident category in light (as well as in heavy) aeroplanes.

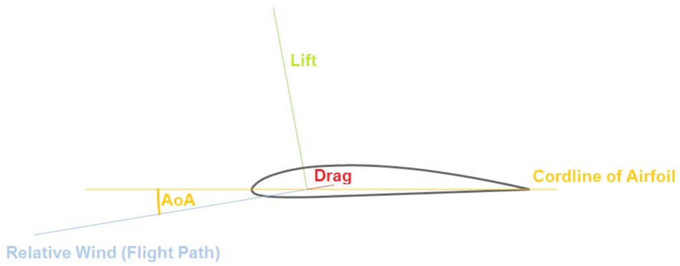
This leaflet has two objectives:

- It will help light aeroplane pilots recognise situations potentially leading to stall. The leaflet also provides generic principles for stall and spin prevention and recovery, but does not address the differences between aeroplane types. Keep in mind that Aircraft Flight Manuals should provide the procedures specific to each aeroplane.

- These generic principles will also be beneficial for leisure pilots seeking an airline pilot career. Acquiring the right 'reflexes' right from the beginning of a flying career is key.

BASIC INFORMATION

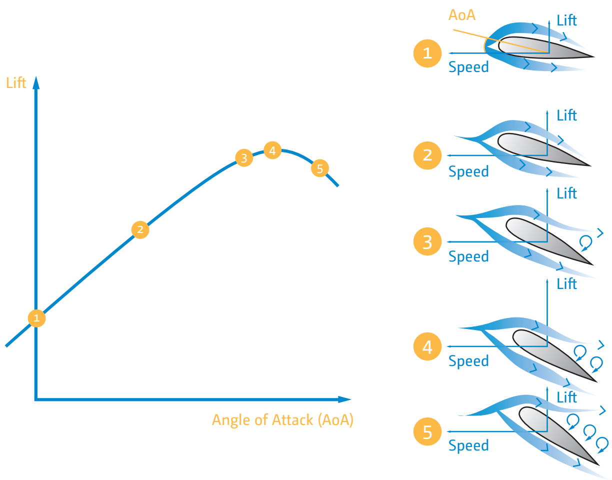
The Angle of Attack (AoA) is the angle between the aerofoil chord line and the free stream velocity vector.



The lift is the component of the aerodynamic force on the wing or on the aeroplane, perpendicular to the forward movement.

Stall occurs when the wing angle of attack has exceeded a critical value called *stall angle of attack* or *critical angle of attack*, and the airflow has detached from the aerofoil, thus ceasing to provide sufficient lift to balance the aeroplane weight.

Let's consider a wing having a constant profile on all its length, in a wind tunnel where the forward movement is constant and review various combinations of angle of attack and developed lift:



Point 1: The angle of attack and the lift are low.
Point 2: The angle of attack is higher and so is the lift.
Point 3: The airflow has separated from a large part of the upper surface. The curve gets flatter: the lift ceases to increase with the angle of attack in the same proportion.

Point 4: The critical angle of attack and the maximum lift are reached. This is the stall entry point.
Point 5: The flow is almost fully separated from the upper part of the aerofoil. The angle of attack is higher than the critical value and the lift is dropping.

The stall corresponds to point 4 where the lift reaches its maximum value.

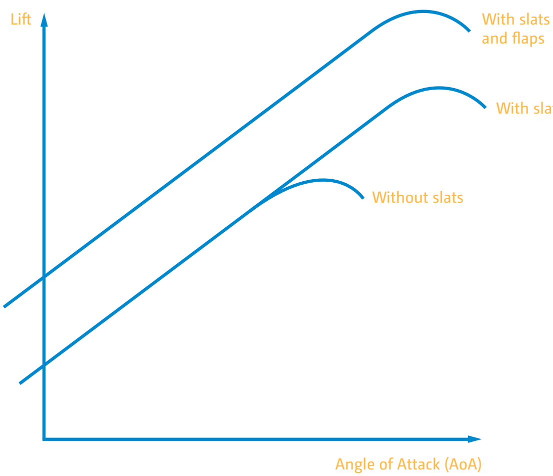
On an aeroplane, the stall is often more complex because the wing doesn't have a constant profile on the entire span, with sometimes minor manufacturing differences between the left and the right wing. In addition, in the case of propeller aircraft, the airflow from the propeller(s) creates a significant asymmetry on the wing. For all these reasons, even if the pilot manages to keep the aircraft in perfect balance, it may happen that one wing stalls slightly before the other one when increasing the angle of attack, leading to some wing drop or yaw motion.

Parameters affecting Stall

Angle of attack

For a given configuration, an aircraft stalls always at the same angle of attack. The only exception is linked to the Mach effect which occurs at very high speeds and/or altitudes.

Configuration



The deflection of slats (for aircraft equipped) allows an increase in 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 the same lift at a lower flying speed. The deflection of the flaps increases the lift for a given angle of attack.

Load factor

Load factor does not affect the angle of attack at which an aeroplane stalls but does affect its stall speed. In a turn or a pull up manoeuvre, at a given speed, to increase the load factor, the angle of attack or the speed must be increased. Therefore when tightening a turn or performing a pull up, at a constant speed, 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.

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 over part of the wing. This limits the flow separation on the upper part of the aerofoil, increasing the lift available at a given angle of attack and allowing to fly at a lower speed.

SIGNS OF STALL AND SPIN

The stall angle of attack can be reached in any attitude, at any speed and with any control force.

Speeds: Most light aeroplanes provide no direct indication of the angle of attack. The main available parameter is Indicated Airspeed. The indicated speeds for the stall in level flight may be available in the Aircraft Flight Manual in the Performance / Stall Chapter. Always think angle of attack when reading your speed: if you are in a turn, the same speed does not provide the same margin from the stall as in level flight!

Stall warning devices, linked to the angle of attack, are fitted to many (but not all) aeroplanes. Pilots must be able to recognise the stall warnings and to react, reducing the angle of attack by moving the control column forward. Know the sound of the stall warning to discriminate it from with other warnings, for example a gear warning which may sound continuously.

Stall warning devices should be used as the principal, but not as sole, indicator of an approach to stall. They are not guaranteed to work correctly at all times. So check it on the ground if you can.

Several stall consequences will occur and be noticeable simultaneously or separately:

1. Buffet – sometimes strong, depending on the aircraft's aerodynamic characteristics;

2. The aeroplane does not respond as expected to inputs in pitch and/or roll;

3. The nose of the aeroplane can drop and unusual lateral motions can appear;

4. The vertical speed increases drastically, sometimes even with a nose up attitude.

5. The pilot cannot raise the nose with the pitch control.

If a stalled aircraft rolls or yaws, perhaps as a result of a pilot's control inputs, it will start the incipient stage of a spin.

Be prepared to react to the unexpected; if the aeroplane does not respond correctly to the control inputs, moving the control column forward will almost certainly be the most appropriate action to save the situation.

> The only option to recover from a stall is to make the airflow readhere to the aerofoil by decreasing the angle of attack below the critical value. This can best be achieved by moving the stick or wheel centrally forward.

What signs can help avoid a stall and a spin? Several signs warn of an approaching stall in straight and level flight: the nose attitude becomes increasingly high, the airspeed is low and continues to reduce, and some buffet may be felt through the elevator control.

If a pilot is climbing, descending, turning, manoeuvring hard or just holding large out of trim forces, these signs may not be obvious. However, the stall warning device will trigger when approaching the critical value. Stall warning devices are important safety tools.

If you fail to react to the stall warning, or if your aeroplane is not equipped with such a device, symptoms of a fully developed stall can develop. At least one of these symptoms will appear before the aeroplane can spin: if you cannot maintain level flight, if you feel buffeting through the elevator control, or if the aeroplane starts rolling, take recovery action immediately.

RISKY SITUATIONS

Many loss of control accidents occur just after takeoff or when going around from an approach to land. These phases of flight are particularly critical. If you climb too steeply to avoid an obstacle, there might not be enough power to maintain speed and to climb. This is particularly true when the aeroplane is heavilyloaded or in hot weather. The angle of attack will increase and can reach the stall value. A stall at full power is often more violent than at idle, due to engine torque inducing roll and yaw, often causing the incipient stage of a spin.

If an engine fails in the climb at low level and at relatively low speed with a high nose attitude, the aeroplane will rapidly decelerate and the angle of attack will quickly increase. To prevent a stall or spin, the pilot must promptly select a lower nose attitude to achieve and maintain a safe gliding speed (or best single engine climb speed in twin-engined aeroplanes). If the aeroplane is already below that speed, the pilot may initially have to select a pitch attitude considerably lower than normal. The nose should not be raised to the normal attitude for the glide (or for the single engine climb) until a safe speed has been restored.

Pilots have lost control while turning to take avoiding action from another aircraft in the circuit. Others have become distracted when under stress and entered a spin during the turn onto final approach. This has caused many fatalities during attempted forced landings. It is vital that you fly coordinated and that

the first signs of an approaching stall be recognised and the correct action, moving the control column forward, taken.
Be aware that when taking avoiding action, the load factor increases and so does the stall speed, which means that stall will occur sooner. When manoeuvring, keep a safe margin from stall: keep the speed up!

If a pilot loses visual references and has no suitable instruments and qualifications, or has not been trained to use the ones he has, the pilot is unlikely to be able to stay within the flight envelope, which may result in stalling or spinning. Beware of clouds, fog, snow, or heavy rain showers! Turn around and divert while you are still able to keep visual references.

Ice, and in some aeroplanes, even raindrops, on the wings will affect the aerodynamics: stall speeds will increase and the stall symptoms may change. The Aircraft Flight Manual indicates the precautions to take when the airplane is sensitive to this pollution. Note that even small amounts of ice can seriously affect lift and drag. Check for ice before deciding to make the flight and keep your wings and airframe clear of ice! If there is a risk to encounter icing conditions, don't make the flight.

If the aeroplane has an autopilot with height lock engaged, an engine failure will cause the autopilot to increase the AoA, to reduce the speed and the aeroplane may stall. The autopilot is likely to have trimmed the aeroplane to a high AoA resulting in low speed, which may cause problems during the recovery. Even if the engine continues to give normal power, autopilot systems may fail. They require constant monitoring, and pilots must disconnect them at the first sign of a problem. In doubt, disconnect the autopilot, fly the aeroplane, keep the angle of attack low and the speed high.

AVOIDING STALL AND LOSS OF CONTROL

It is important to make every effort to avoid stalling. To reduce the risk of stalling, always select appropriate visual attitudes and trim the aeroplane. Incorrect trim can increase the risk by generating unexpected pitch movements.

Pilots who cannot fly solely by reference to instruments must constantly look ahead for signs that they might be about to fly into conditions of very poor visibility, and remain well clear. It is safer to make a precautionary landing if the conditions deteriorate than to risk losing control in cloud.

Aircraft Flight Manuals and Pilots Operating Handbooks recommend speeds to fly in most situations. Although training in stall recognition, avoidance and recovery should prevent a stall from occurring, pilots must take care to maintain the correct airspeed, especially when flying close to the ground. As stated before, speed is your primary indicator but always think angle of attack when reading your speed. If you are in a turn or in a level flight the same speed does not provide the same margin from the critical angle of attack.

RECOVERING FROM A STALL

Pilots should take recovery action as soon as they recognise the signs of an approaching stall, either from a warning system or from other indications. Relax any back pressure on the control column or move it forward centrally (ailerons neutral) to reduce the angle of attack on both wings together. In a turn, release the pull but avoid inducing roll by replacing the control in the centre. If prompt action is taken while approaching the stall - just when the stall warning device sounds for instance, the attitude change required is usually small and the loss of altitude, if any, will be minimal.

If the aeroplane stalls, move the stick or wheel forward to decrease the angle and regain lift.

Once you have recovered from the stall, level the wings. Do not roll the aeroplane until all symptoms of the stall have disappeared to avoid asymmetrical inputs at high angle of attack. Then adjust speed with power appropriately for the remainder of your flight.

Be gentle on the controls!
Recovery actions should be smooth because:

- Secondary stall may occur if the load factor used for recovery is too high, due for instance due to brisk inputs on the stick or wheel;
- Brisk roll/yaw or power inputs can also induce asymmetry, which can result in a spin.

Timely and appropriate control and power settings are required, especially at low heights! The priority is to get out of the stall and to be able to fly the aircraft and not to minimize the altitude loss.

Know and practice the procedure adapted your aeroplane!
Do you know, and have you practised, the stall recovery procedure specific to your aeroplane? Refer to the Aeroplane Flight Manual and Pilot Operating Handbook and practise the procedure regularly at a safe height -best with an instructor.

PREVENTING A DEVELOPED SPIN

Spinning an aeroplane can result in considerable height loss - during the spin itself and even more during the recovery. Pilots therefore should not allow the aircraft to enter a spin.

If the aeroplane remains stalled, the aircraft can start to roll and/or to yaw to an extreme attitude, which may result in a spin.

This may happen if the pilot uses ailerons and/or rudder when the aeroplane is close to, or at, stall or when applying asymmetric power in a multiengined aeroplane.

Do not attempt to 'pick up' a dropped wing when the aeroplane is stalled. Reduce the angle of attack and then fly the aeroplane when you have resumed actual control.

Even in case of asymmetrical stall it is still possible to avoid a fully developed spin. At any time, if the aeroplane changes its attitude in a direction or at a rate which the pilot has not demanded by use of the controls, the pilot should immediately centralise all the flying controls.

The aeroplane's natural stability should return it to an AoA which allows it to recover proper airflow on the wings, reduce the angle of attack and accelerate to a safe speed.

During recovery, the nose is likely to be low, so pilots must take care not to exceed their airframe or engine speed limits! The pull up has to be gentle enough not to induce a secondary stall while pulling up!

Once the aircraft has recovered from the incipient spin, the pilot should use the controls as normal, and power as required, to regain a safe flight path, and then analyse what happened. A considerable amount of height may be lost during recovery, but exiting the stall and/or spin is the priority. Altitude aspects will be dealt with after fully recovering from the stall.

As different aeroplanes may have different spin behaviours and recovery procedures, know the spin recovery procedure mentioned in your Aeroplane Flight Manual.

TRAINING

After their initial training, pilots should ensure that they maintain their competencies to prevent, recognise, and recover from a stall in the aeroplane(s) they fly by practising regularly at a safe altitude - best with an instructor.

Stall and spin training should of course take place at safe altitudes, and in clear weather. However, an aeroplane is more likely to depart from controlled flight in other conditions described in this leaflet in the Risky Situations Section.

Pilots must know and understand how their aircraft is likely to respond to control movements close to the edges of the flight envelope.

SUMMARY

A stall occurs when the angle of attack is above the stall or critical angle of attack.

To safely avoid and recover from stall and spin:

›› Be alert and prepared at all times to face the unexpected.

›› Keep your wings and airframe clean and clear of ice, anticipate bad weather and stay in Visual Meteorological Conditions (VMC).

›› Keep a safe margin from the stall angle of attack by keeping always a safe speed. When manoeuvring, the load factor and the stall speed increase, so keep the speed up!

›› Apply immediate recovery action whenever the stall warning rings or if the aeroplane does not normally react to your control inputs. Relax any back pressure on the control column or move it forward centrally to reduce the angle of attack. In a turn, beware not to induce yaw by roll while moving the column to the centre.

›› Be gentle on the stick or wheel to avoid secondary stall or spin.

›› Apply power with care so that resultant forces do not make the situation worse.

- Read, understand and remember the contents of the Aircraft Flight Manual and Pilot Operating Handbook for your aeroplane: remember the stall indicated airspeeds for the different flaps configurations.
- Recognise the stall warning indications for YOUR aeroplane and practise your airplane specific stall avoidance and recovery procedures regularly at safe altitudes to maintain your handling skills – best with an instructor.
- Seek advice from an instructor if you are unsure of any technique.
- Know the behaviour and feel of the aircraft at high AoA, so that you can use this behaviour and feel to detect that you are close to stall.

APPENDIX

Use the stall recovery procedure as provided in your Aeroplane Flight Manual.

In case your Aeroplane Flight Manual doesn't include such a procedure, this Appendix provides an internationally recognised comprehensive stall recovery procedure which covers all aeroplanes including modern airliners.

This procedure is not applicable during the flare phase or when the intent is to correct a landing.

Seek advice from an instructor if you are unsure of how this technique applies to your aircraft.

COMPREHENSIVE STALL RECOVERY PROCEDURE

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

1. Disconnect the autopilot (if applicable)
Rationale: Autopilot disconnection allows taking manual control of the airplane for the recovery. Beware of possible pitch variation at disconnection.

2a. Apply nose down pitch control until the stall indications have disappeared
Rationale: The priority is to reduce the angle of attack to recreate lift.

2b. If necessary: apply nose down pitch trim
Rationale: If the authority of the elevator is not sufficient, it may be necessary to trim down.

3. Level the wings
Rationale: Direct 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, it might not be necessary to apply maximum power. Thrust has to be adjusted as a function of the stall conditions and of the power of the engine(s) mounted on the airplane. Insure as much as possible the symmetry of the flight.

5. Retract the airbrakes (or speedbrakes) (if applicable)
Rationale: will improve acceleration and may also increase lift available.

6. Return to the desired flight path
Rationale: Apply a smooth action to avoid secondary stall and come back to a suitable trajectory. The first priority is to recover from the stall, not to minimise loss of altitude: altitude aspects will be dealt with after full stall recovery.

IMPRINT

References

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