



Federal Aviation Administration

[Home](#) / [Guide for Aviation Medical Examiners](#) / [Application Process](#) / [General Information](#)

IN THIS SECTION

[Overview](#)

[AMCS Login](#)

[Application Process](#) 

[Decision Considerations](#) 

[Pharmaceuticals \(Meds\)](#)

[Special Issuances](#) 

[Substances Dependencies/Abuse](#)

[Synopsis of Medical Standards](#)

Guide for Aviation Medical Examiners

Application Process for Medical Certification

General Information - Operations Not Requiring a Medical Certificate

The following do not require a medical certificate, however, applicants must certify that they do not know or have reason to know of any medical condition that would make them unable to operate any of the following in a safe manner.

1. **Glider pilots** are not required to hold a medical certificate of any class.
2. **Free Balloon Pilots** exercising private or student pilot privileges.
3. **Student Pilot.** [See Student Pilot Rule Change](#) Note: Student pilot will need a valid medical certificate prior to solo flight.
4. **“Sport” pilots** are required to hold either a valid pilot medical certificate or a current and valid U.S. driver’s license. When using a current and valid U.S. driver’s license to qualify, sport pilots must comply with each restriction and limitation on their U.S. driver’s license and any judicial or administrative order applying to the operation of a motor vehicle.

To exercise sport pilot privileges using a current and valid U.S. driver’s license as evidence of qualification, sport pilots must:

- Not have been denied the issuance of at least a third-class airman medical certificate (if they have applied for an airman medical certificate)
- Not have had their most recent airman medical certificate revoked or suspended (if they have held an airman medical certificate); and
- Not have had an [Authorization](#) withdrawn (if they have ever been granted an Authorization).

Sport pilots may not use a current and valid U.S. driver’s license in lieu of a valid airman medical certificate if they know or have reason to know of any medical condition that would make them unable to operate a light-sport aircraft in a safe manner.

Sport pilot medical provisions are found under 14 CFR §§ [61.3](#), [61.23](#), [61.53](#), and [61.303](#)).

[Provide Your Feedback](#)

For more information about the sport pilot final rule, see the 2/1/2010 [Certification of Aircraft and Airmen for the Operation of Light-Sport Aircraft; Final Rule](#).

Last updated: Wednesday, May 31, 2023

U.S. DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration
800 Independence Avenue, SW
Washington, DC 20591
866.835.5322 (866-TELL-FAA)
[Contact Us](#)

GET IMPORTANT INFO/DATA

- [Accident & Incident Data](#)
- [Airport Data & Information Portal \(ADIP\)](#)
- [Charting & Data](#)
- [Flight Delay Information](#)
- [Supplemental Type Certificates](#)
- [Type Certificate Data Sheets \(TCDS\)](#)

MOVING FAA FORWARD

- [Brand New Air Traffic Control System](#)
- [Advanced Air Mobility](#)
- [Air Traffic Controller Hiring](#)

REVIEW DOCUMENTS

- [Aircraft Handbooks & Manuals](#)
- [Airport Diagrams](#)
- [Aviation Handbooks & Manuals](#)
- [Examiner & Inspector](#)
- [FAA Guidance](#)
- [Performance Reports & Plans](#)

VISIT OTHER FAA SITES

- [Airmen Inquiry](#)
- [Airmen Online Services](#)
- [N-Number Lookup](#)
- [FAA Safety Team](#)
- [Frequently Asked Questions](#)



POLICIES, RIGHTS & LEGAL

- [About DOT](#)
- [Budget and Performance](#)
- [Civil Rights](#)
- [FOIA](#)
- [Information Quality](#)
- [No FEAR Act](#)
- [Office of Inspector General](#)

[Privacy Policy](#)

[USA.gov](#)

[Web Policies and Notices](#)

[Web Standards](#)



Federal Aviation Administration

[Home](#) / [Guide for Aviation Medical Examiners](#) / [Application Process](#) / [Exam Techniques](#)

IN THIS SECTION

[Overview](#)

[AMCS Login](#)

[Application Process](#) 

[Decision Considerations](#) 

[Pharmaceuticals \(Meds\)](#)

[Special Issuances](#) 

[Substances Dependencies/Abuse](#)

[Synopsis of Medical Standards](#)

Guide for Aviation Medical Examiners

Decision Considerations - Aerospace Medical Dispositions

Item 47. Psychiatric Conditions - Psychiatric Conditions Table of Medical Dispositions

Disease/Condition	Class	Evaluation Data	Disposition
Adjustment Disorders	All	Submit all pertinent medical information and clinical status report.	If stable, resolved, no associated disturbance of thought, no recurrent episodes, and psychotropic medication(s) used for less than 6 months and discontinued for at least 3 months - Issue Otherwise - Requires FAA Decision See Use of Antidepressant Medication Policy.
Attention-Deficit/Hyperactivity Disorder	All	See Attention-Deficit/Hyperactivity Disorder (ADHD) and/or Use of ADHD Medications (PDF)	See Disposition Table
Bipolar Disorder	All	Submit all pertinent medical information and clinical status report. A bipolar disorder may not...	Requires FAA Decision

Dysthymic	All	Submit all pertinent medical information and clinical status report	If stable, resolved, no associated disturbance of thought, no recurrent episodes, and; a). psychotropic medication(s) used for less than 6 months and discontinued for at least 3 months - Issue b). No use of psychotropic medication(s) - Issue Otherwise - Requires FAA Decision See Use of Antidepressant Medication Policy
Depression requiring the use of antidepressant medications	All	Submit all pertinent medical information and clinical status report. See Use of Antidepressant Medication Policy and Disease Protocols, Specifications for Neuropsychological Evaluations for Treatment with SSRI Medications (PDF)	Requires FAA Decision
Personality Disorders	All	Submit all pertinent medical information and clinical status report. The category of personality disorders...	Requires FAA Decision
Psychosis	All	Submit all pertinent medical information and clinical status report. The category of psychosis...	Requires FAA Decision
Psychotropic medications for Smoking Cessation	All	Document period of use, name and dosage of medication(s) and side-effects	If medication(s) discontinued for at least 30 days and w/o side-effects - Issue Otherwise - Requires FAA Decision
Substance Abuse	All	See Substances of Dependence/Abuse	Requires FAA Decision
Substance Dependence	All	See Substances of Dependence/Abuse	Requires FAA Decision
Suicide Attempt	All	Submit all pertinent medical information required.	Requires FAA Decision

Substance dependence and substance abuse are specified as disqualifying medical conditions.

Last updated: Wednesday, May 29, 2024

U.S. DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration
800 Independence Avenue, SW
Washington, DC 20591
866.835.5322 (866-TELL-FAA)
[Contact Us](#)

GET IMPORTANT INFO/DATA

[Accident & Incident Data](#)
[Airport Data & Information Portal \(ADIP\)](#)
[Charting & Data](#)
[Flight Delay Information](#)
[Supplemental Type Certificates](#)
[Type Certificate Data Sheets \(TCDS\)](#)

MOVING FAA FORWARD

[Brand New Air Traffic Control System](#)
[Advanced Air Mobility](#)
[Air Traffic Controller Hiring](#)

REVIEW DOCUMENTS

[Aircraft Handbooks & Manuals](#)
[Airport Diagrams](#)
[Aviation Handbooks & Manuals](#)
[Examiner & Inspector](#)
[FAA Guidance](#)
[Performance Reports & Plans](#)

VISIT OTHER FAA SITES

[Airmen Inquiry](#)
[Airmen Online Services](#)
[N-Number Lookup](#)
[FAA Safety Team](#)
[Frequently Asked Questions](#)



POLICIES, RIGHTS & LEGAL

[About DOT](#)
[Budget and Performance](#)
[Civil Rights](#)
[FOIA](#)
[Information Quality](#)
[No FEAR Act](#)
[Office of Inspector General](#)
[Privacy Policy](#)
[USA.gov](#)
[Web Policies and Notices](#)
[Web Standards](#)



**Federal Aviation
Administration**

[Home](#) / [Guide for Aviation Medical Examiners](#) / [Application Process](#) / [Exam Techniques](#)

IN THIS SECTION



Guide for Aviation Medical Examiners

Item 47. Psychiatric Conditions - Bipolar Disorder

Bipolar Disorders are considered on a continuum as part of a spectrum of disorders where there are significant alternations in mood. Generally, only one episode of manic or hypomanic behavior is necessary to make the diagnosis. Please note that cyclothymic disorder is part of this spectrum. Even if the bipolar disorder does not have accompanying symptoms that reach the level of psychosis, the disorder can be so disruptive of judgment and functioning (especially mania) as to pose a significant risk to aviation safety. Impaired judgment does occur even in the milder form of the disease.

All applicants with a diagnosis of Bipolar Disorder must be denied or deferred.

.

Last updated: Tuesday, November 9, 2021

U.S. DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration
800 Independence Avenue, SW
Washington, DC 20591
866.835.5322 (866-TELL-FAA)
[Contact Us](#)

GET IMPORTANT INFO/DATA

[Accident & Incident Data](#)
[Airport Data & Information Portal \(ADIP\)](#)
[Charting & Data](#)
[Flight Delay Information](#)
[Supplemental Type Certificates](#)
[Type Certificate Data Sheets \(TCDS\)](#)

REVIEW DOCUMENTS

[Aircraft Handbooks & Manuals](#)
[Airport Diagrams](#)
[Aviation Handbooks & Manuals](#)
[Examiner & Inspector](#)
[FAA Guidance](#)
[Performance Reports & Plans](#)

MOVING FAA FORWARD

[Brand New Air Traffic Control System](#)

[Advanced Air Mobility](#)

[Air Traffic Controller Hiring](#)

VISIT OTHER FAA SITES

[Airmen Inquiry](#)

[Airmen Online Services](#)

[N-Number Lookup](#)

[FAA Safety Team](#)

[Frequently Asked Questions](#)



POLICIES, RIGHTS & LEGAL

[About DOT](#)

[Budget and Performance](#)

[Civil Rights](#)

[FOIA](#)

[Information Quality](#)

[No FEAR Act](#)

[Office of Inspector General](#)

[Privacy Policy](#)

[USA.gov](#)

[Web Policies and Notices](#)

[Web Standards](#)

If airplane equipment includes an angle of attack indicator, the pilot should know how the particular device determines AOA, what the display indicates, and the appropriate response to any indication. Pilots are encouraged to conduct in-flight training to see the indications throughout various maneuvers, such as slow flight, stalls, takeoffs, and landings, and to practice the appropriate responses to those indications. It is also important to note that some items may limit the effectiveness of an AOA indicator (e.g., calibration techniques, wing contamination, unheated probes/vanes). Pilots flying an airplane equipped with an AOA indicator should refer to the pilot handbook information or contact the manufacturer for specific limitations applicable to that indicator type.

Ground and flight instructors should make every attempt to receive training from an instructor knowledgeable about AOA indicators prior to giving instruction pertaining to or in airplanes equipped with an AOA indicator. Pilot schools should incorporate training on AOA indicators in their syllabi whether their training aircraft are equipped with them or not.

Stall Characteristics

Different airplane designs can result in different stall characteristics. The pilot should know the stall characteristics of the airplane being flown and the manufacturer’s recommended recovery procedures. Factors that can affect the stall characteristics of an airplane include its geometry, CG, wing design, and high-lift devices. Engineering design variations make it impossible to specifically describe the stall characteristics for all airplanes; however, there are enough similarities in small general aviation training-type airplanes to offer broad guidelines.

Most training airplanes are designed so that the wings stall progressively outward from the wing roots (where the wing attaches to the fuselage) to the wingtips. Some wings are manufactured with a certain amount of twist, known as washout, resulting in the outboard portion of the wings having a slightly lower AOA than the wing roots. This design feature causes the wingtips to have a smaller AOA during flight than the wing roots. Thus, the wing roots of an airplane exceed the critical AOA before the wingtips, meaning the wing roots stall first. Therefore, when the airplane is in a stalled condition, the ailerons should still have a degree of control effectiveness until/unless stalled airflow migrates outward along the wings. Although airflow may still be attached at the wingtips, a pilot should exercise caution using the ailerons prior to the reduction of the AOA because it can exacerbate the stalled condition. For example, if the airplane rolls left at the stall (“rolls-off”), and the pilot applies right aileron to try to level the wing, the downward-deflected aileron on the left wing produces a greater AOA (and more induced drag), and a more complete stall at the tip as the critical AOA is exceeded. This can cause the wing to roll even more to the left, which is why it is important to first reduce the AOA before attempting to roll the airplane.

The pilot should also understand how the factors that affect stalls are interrelated. In a power-off stall, for instance, the cues (buffeting, shaking) are less noticeable than in the power-on stall. In the power-off, 1G stall, the predominant cue may be the elevator control position (full up elevator against the stops) and a high descent rate.

Fundamentals of Stall Recovery

Depending on the complexity of the airplane, stall recovery could consist of as many as six steps. Even so, the pilot should remember the most important action to an impending stall or a full stall is to reduce the AOA. There have been numerous situations where pilots did not first reduce AOA, and instead prioritized power and maintaining altitude, which resulted in a loss of control. This section provides a generic stall recovery procedure for light general aviation aircraft adapted from a template developed by major airplane manufacturers and can be adjusted appropriately for the aircraft used. [Figure 5-10] However, a pilot should always follow the aircraft-specific manufacturer’s recommended procedures if published and current.

Stall Recovery Template	
1. Wing leveler or autopilot	1. Disconnect
2. a) Pitch nose-down b) Trim nose-down pitch	2. a) Apply until impending stall indications are eliminated b) As needed
3. Bank	3. Wings Level
4. Thrust/Power	4. As needed
5. Speed brakes/spoilers	5. Retract
6. Return to the desired flight path	

Figure 5-10. Stall recovery template.

The recovery actions should be made in a procedural manner; they can be summarized in *Figure 5-10*. The following discussion explains each of the six steps:

1. Disconnect the wing leveler or autopilot (if equipped). Manual control is essential to recovery in all situations. Disconnecting this equipment should be done immediately and allow the pilot to move to the next crucial step quickly. Leaving the wing leveler or autopilot connected may result in inadvertent changes or adjustments to the flight controls or trim that may not be easily recognized or appropriate, especially during high workload situations.
2. a) Pitch nose-down control. Reducing the AOA is crucial for all stall recoveries. Push forward on the flight controls to reduce the AOA below the critical AOA until the impending stall indications are eliminated before proceeding to the next step.

b) Trim nose-down pitch. If the elevator does not provide the needed response, pitch trim may be necessary. However, excessive use of pitch trim may aggravate the condition, or may result in loss of control or high structural loads.
3. Roll wings level. This orients the lift vector properly for an effective recovery. It is important not to be tempted to control the bank angle prior to reducing AOA. Both roll stability and roll control will improve considerably after getting the wings flying again. It is also imperative to proactively cancel yaw with proper use of the rudder to prevent a stall from progressing into a spin.
4. Add thrust/power. Power should be added as needed, as stalls can occur at high power or low power settings or at high airspeeds or low airspeeds. Advance the throttle promptly, but smoothly, as needed while using rudder and elevator controls to stop any yawing motion and prevent any undesirable pitching motion. Adding power typically reduces the loss of altitude during a stall recovery, but it does not eliminate a stall. The reduction in AOA is imperative. For propeller-driven airplanes, power application increases the airflow around the wing, assisting in stall recovery.
5. Retract speedbrakes/spoilers (if equipped). This will improve lift and the stall margin.
6. Return to the desired flightpath. Apply smooth and coordinated flight control movements to return the airplane to the desired flightpath being careful to avoid a secondary stall. However, be situationally aware of the proximity to terrain during the recovery and take the necessary flight control action to avoid contact with it.

The above procedure can be adapted for the type of aircraft flown. For example, a single-engine training airplane without an autopilot would likely only use four of the six steps. The first step is not applicable. The actual first step is the reduction of the AOA until the stall warning is eliminated. Use of pitch trim is less of a concern in a training airplane because most pilots can overpower the trim in these airplanes. Any improper trim can be corrected when returning to the desired flightpath. The next step is rolling the wings level followed by the addition of power as needed all while maintaining coordinated flight. If the airplane is not equipped with speedbrakes or spoilers, this step is also skipped. Returning to the desired flightpath concludes the recovery.

Similarly, a glider pilot does not have an autopilot; therefore, the first step is the reduction of AOA until the stall warning is eliminated. The pilot would then roll wings level while maintaining coordinated flight. Since there is no power to add, this step would not apply. Retracting speedbrakes or spoilers would be the next step for a glider pilot followed by returning to the desired flightpath.

Stall Training

Practice in both power-on and power-off stalls is important because it simulates stall conditions that could occur during normal flight maneuvers. It is important for pilots to understand the possible flight scenarios in which a stall could occur. Stall accidents usually result from an inadvertent stall at a low altitude, with the recovery not completed prior to ground contact. For example, power-on stalls are practiced to develop the pilot's awareness of what could happen if the airplane is pitched to an excessively nose-high attitude immediately after takeoff, during a climbing turn, or when trying to clear an obstacle. Power-off turning stalls develop the pilot's awareness of what could happen if the controls are improperly used during a turn from the base leg to the final approach. The power-off straight-ahead stall simulates the stall that could occur when trying to stretch a glide after the engine has failed, or if low on the approach to landing.

As in all maneuvers that involve significant changes in altitude or direction, the pilot should ensure that the area is clear of other air traffic at and below their altitude and that sufficient altitude is available for a recovery before executing the maneuver. It is recommended that stalls be practiced at an altitude that allows recovery no lower than 1,500 feet AGL for single-engine airplanes, or higher if recommended by the AFM/POH. Losing altitude during recovery from a stall is to be expected.

point. If they had to mount the wings too far forward, and at right angles to the fuselage, the center of pressure would not be far enough to the rear to result in the desired amount of longitudinal stability. By building sweepback into the wings, however, the designers can move the center of pressure toward the rear. The amount of sweepback and the position of the wings then place the center of pressure in the correct location.

When turbulence or rudder application causes the aircraft to yaw to one side, the opposite wing presents a longer leading edge perpendicular to the relative airflow. The airspeed of the forward wing increases and it acquires more drag than the back wing. The additional drag on the forward wing pulls the wing back, turning the aircraft back to its original path.

The contribution of the wing to static directional stability is usually small. The swept wing provides a stable contribution depending on the amount of sweepback, but the contribution is relatively small when compared with other components.

Free Directional Oscillations (Dutch Roll)

Dutch roll is a coupled lateral/directional oscillation that is usually dynamically stable but is unsafe in an aircraft because of the oscillatory nature. The damping of the oscillatory mode may be weak or strong depending on the properties of the particular aircraft.

If the aircraft has a right wing pushed down, the positive sideslip angle corrects the wing laterally before the nose is realigned with the relative wind. As the wing corrects the position, a lateral directional oscillation can occur resulting in the nose of the aircraft making a figure eight on the horizon as a result of two oscillations (roll and yaw), which, although of about the same magnitude, are out of phase with each other.

In most modern aircraft, except high-speed swept wing designs, these free directional oscillations usually die out automatically in very few cycles unless the air continues to be gusty or turbulent. Those aircraft with continuing Dutch roll tendencies are usually equipped with gyro-stabilized yaw dampers. Manufacturers try to reach a midpoint between too much and too little directional stability. Because it is more desirable for the aircraft to have “spiral instability” than Dutch roll tendencies, most aircraft are designed with that characteristic.

Spiral Instability

Spiral instability exists when the static directional stability of the aircraft is very strong as compared to the effect of its dihedral in maintaining lateral equilibrium. When the lateral equilibrium of the aircraft is disturbed by a gust of air and a sideslip is introduced, the strong directional stability tends to yaw the nose into the resultant relative wind while the

comparatively weak dihedral lags in restoring the lateral balance. Due to this yaw, the wing on the outside of the turning moment travels forward faster than the inside wing and, as a consequence, its lift becomes greater. This produces an overbanking tendency which, if not corrected by the pilot, results in the bank angle becoming steeper and steeper. At the same time, the strong directional stability that yaws the aircraft into the relative wind is actually forcing the nose to a lower pitch attitude. A slow downward spiral begins which, if not counteracted by the pilot, gradually increases into a steep spiral dive. Usually the rate of divergence in the spiral motion is so gradual the pilot can control the tendency without any difficulty.

Many aircraft are affected to some degree by this characteristic, although they may be inherently stable in all other normal parameters. This tendency explains why an aircraft cannot be flown “hands off” indefinitely.

Much research has gone into the development of control devices (wing leveler) to correct or eliminate this instability. The pilot must be careful in application of recovery controls during advanced stages of this spiral condition or excessive loads may be imposed on the structure. Improper recovery from spiral instability leading to inflight structural failures has probably contributed to more fatalities in general aviation aircraft than any other factor. Since the airspeed in the spiral condition builds up rapidly, the application of back elevator force to reduce this speed and to pull the nose up only “tightens the turn,” increasing the load factor. The results of the prolonged uncontrolled spiral are inflight structural failure, crashing into the ground, or both. Common recorded causes for pilots who get into this situation are loss of horizon reference, inability to control the aircraft by reference to instruments, or a combination of both.

Effect of Wing Planform

Understanding the effects of different wing planforms is important when learning about wing performance and airplane flight characteristics. A planform is the shape of the wing as viewed from directly above and deals with airflow in three dimensions. Aspect ratio, taper ratio, and sweepback are factors in planform design that are very important to the overall aerodynamic characteristic of a wing. *[Figure 5-33]*

Aspect ratio is the ratio of wing span to wing chord. Taper ratio can be either in planform or thickness, or both. In its simplest terms, it is a decrease from wing root to wingtip in wing chord or wing thickness. Sweepback is the rearward slant of a wing, horizontal tail, or other airfoil surface.

There are two general means by which the designer can change the planform of a wing and both will affect the

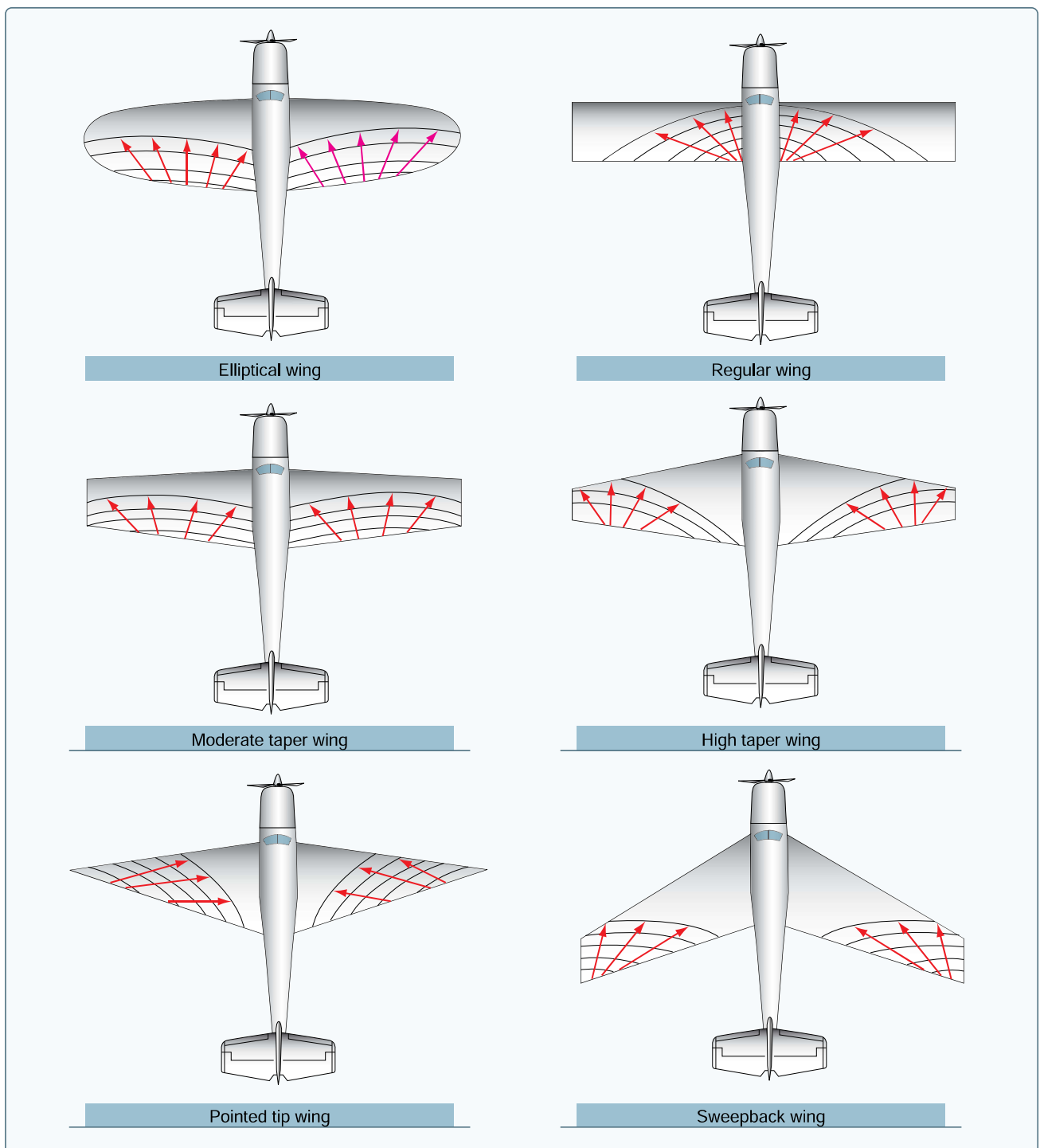


Figure 5-33. *Different types of wing planforms.*

aerodynamic characteristics of the wing. The first is to effect a change in the aspect ratio. Aspect ratio is the primary factor in determining the three dimensional characteristics of the ordinary wing and its lift/drag ratio. An increase in aspect ratio with constant velocity will decrease the drag, especially at high angles of attack, improving the performance of the wing when in a climbing attitude.

A decrease in aspect ratio will give a corresponding increase in drag. It should be noted, however, that with an increase in aspect ratio there is an increase in the length of span, with a corresponding increase in the weight of the wing structure, which means the wing must be heavier to carry the same load. For this reason, part of the gain (due to a decrease in drag) is lost because of the increased weight, and a compromise in

design is necessary to obtain the best results from these two conflicting conditions.

The second means of changing the planform is by tapering (decreasing the length of chord from the root to the tip of the wing). In general, tapering causes a decrease in drag (most effective at high speeds) and an increase in lift. There is also a structural benefit due to a saving in weight of the wing.

Most training and general aviation type airplanes are operated at high coefficients of lift, and therefore require comparatively high aspect ratios. Airplanes that are developed to operate at very high speeds demand greater aerodynamic cleanliness and greater strength, which require low aspect ratios. Very low aspect ratios result in high wing loadings and high stall speeds. When sweepback is combined with low aspect ratio, it results in flying qualities very different from a more conventional high aspect ratio airplane configuration. Such airplanes require very precise and professional flying techniques, especially at slow speeds, while airplanes with a high aspect ratio are usually more forgiving of improper pilot techniques.

The elliptical wing is the ideal subsonic planform since it provides for a minimum of induced drag for a given aspect ratio, though as we shall see, its stall characteristics in some respects are inferior to the rectangular wing. It is also comparatively difficult to construct. The tapered airfoil is desirable from the standpoint of weight and stiffness, but again is not as efficient aerodynamically as the elliptical wing. In order to preserve the aerodynamic efficiency of the elliptical wing, rectangular and tapered wings are sometimes tailored through use of wing twist and variation in airfoil sections until they provide as nearly as possible the elliptical wing's lift distribution. While it is true that the elliptical wing provides the best coefficients of lift before reaching an incipient stall, it gives little advance warning of a complete stall, and lateral control may be difficult because of poor aileron effectiveness.

In comparison, the rectangular wing has a tendency to stall first at the wing root and provides adequate stall warning, adequate aileron effectiveness, and is usually quite stable. It is, therefore, favored in the design of low cost, low speed airplanes.

Aerodynamic Forces in Flight Maneuvers

Forces in Turns

If an aircraft were viewed in straight-and-level flight from the front [Figure 5-34], and if the forces acting on the aircraft could be seen, lift and weight would be apparent: two forces. If the aircraft were in a bank it would be apparent that lift did not act directly opposite to the weight, rather it now acts in the direction of the bank. A basic truth about turns is that when the aircraft banks, lift acts inward toward the center of the turn, perpendicular to the lateral axis as well as upward.

Newton's First Law of Motion, the Law of Inertia, states that an object at rest or moving in a straight line remains at rest or continues to move in a straight line until acted on by some other force. An aircraft, like any moving object, requires a sideward force to make it turn. In a normal turn, this force is supplied by banking the aircraft so that lift is exerted inward, as well as upward. The force of lift during a turn is separated into two components at right angles to each other. One component, which acts vertically and opposite to the weight (gravity), is called the "vertical component of lift." The other, which acts horizontally toward the center of the turn, is called the "horizontal component of lift" or centripetal force. The horizontal component of lift is the force that pulls the aircraft from a straight flight path to make it turn. Centrifugal force is the "equal and opposite reaction" of the aircraft to the change in direction and acts equal and opposite to the horizontal component of lift. This explains why, in a correctly executed turn, the force that turns the aircraft is not supplied by the rudder. The rudder is used to correct any deviation between the straight track of the nose and tail of the aircraft into the relative wind. A good turn is one in which the

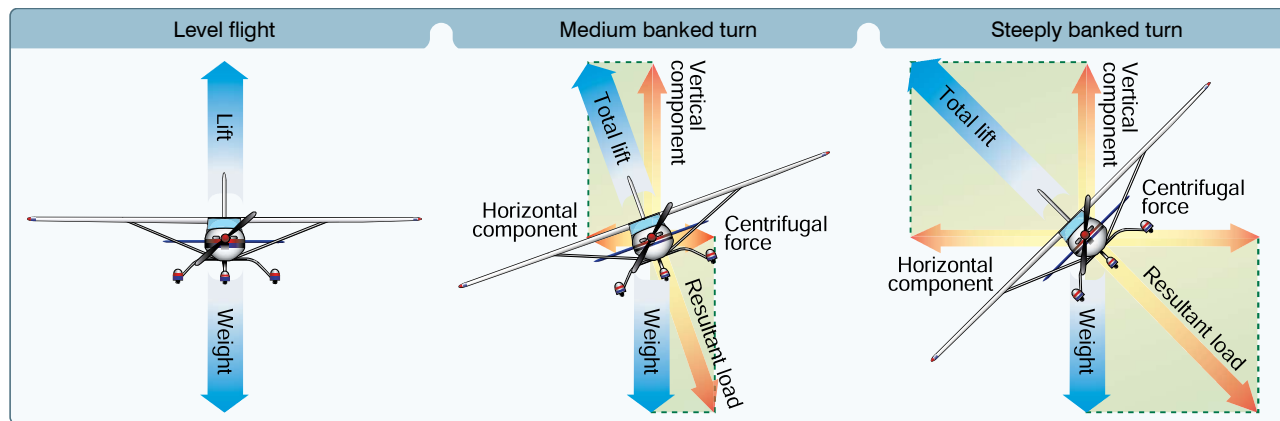


Figure 5-34. Forces during normal, coordinated turn at constant altitude.

nose and tail of the aircraft track along the same path. If no rudder is used in a turn, the nose of the aircraft yaws to the outside of the turn. The rudder is used rolling into the turn to bring the nose back in line with the relative wind. Once in the turn, the rudder should not be needed.

An aircraft is not steered like a boat or an automobile. In order for an aircraft to turn, it must be banked. If it is not banked, there is no force available to cause it to deviate from a straight flight path. Conversely, when an aircraft is banked, it turns provided it is not slipping to the inside of the turn. Good directional control is based on the fact that the aircraft attempts to turn whenever it is banked. Pilots should keep this fact in mind when attempting to hold the aircraft in straight-and-level flight.

Merely banking the aircraft into a turn produces no change in the total amount of lift developed. Since the lift during the bank is divided into vertical and horizontal components, the amount of lift opposing gravity and supporting the aircraft's weight is reduced. Consequently, the aircraft loses altitude unless additional lift is created. This is done by increasing the AOA until the vertical component of lift is again equal to the weight. Since the vertical component of lift decreases as the bank angle increases, the AOA must be progressively increased to produce sufficient vertical lift to support the aircraft's weight. An important fact for pilots to remember when making constant altitude turns is that the vertical component of lift must be equal to the weight to maintain altitude.

At a given airspeed, the rate at which an aircraft turns depends upon the magnitude of the horizontal component of lift. It is found that the horizontal component of lift is proportional to the angle of bank—that is, it increases or decreases respectively as the angle of bank increases or decreases. As the angle of bank is increased, the horizontal component of lift increases, thereby increasing the rate of turn (ROT). Consequently, at any given airspeed, the ROT can be controlled by adjusting the angle of bank.

To provide a vertical component of lift sufficient to hold altitude in a level turn, an increase in the AOA is required. Since the drag of the airfoil is directly proportional to its AOA, induced drag increases as the lift is increased. This, in turn, causes a loss of airspeed in proportion to the angle of bank. A small angle of bank results in a small reduction in airspeed while a large angle of bank results in a large reduction in airspeed. Additional thrust (power) must be applied to prevent a reduction in airspeed in level turns. The required amount of additional thrust is proportional to the angle of bank.

To compensate for added lift, which would result if the airspeed were increased during a turn, the AOA must be

decreased, or the angle of bank increased, if a constant altitude is to be maintained. If the angle of bank is held constant and the AOA decreased, the ROT decreases. In order to maintain a constant ROT as the airspeed is increased, the AOA must remain constant and the angle of bank increased.

An increase in airspeed results in an increase of the turn radius, and centrifugal force is directly proportional to the radius of the turn. In a correctly executed turn, the horizontal component of lift must be exactly equal and opposite to the centrifugal force. As the airspeed is increased in a constant-rate level turn, the radius of the turn increases. This increase in the radius of turn causes an increase in the centrifugal force, which must be balanced by an increase in the horizontal component of lift, which can only be increased by increasing the angle of bank.

In a slipping turn, the aircraft is not turning at the rate appropriate to the bank being used, since the aircraft is yawed toward the outside of the turning flight path. The aircraft is banked too much for the ROT, so the horizontal lift component is greater than the centrifugal force. *[Figure 5-35]* Equilibrium between the horizontal lift component and centrifugal force is reestablished by either decreasing the bank, increasing the ROT, or a combination of the two changes.

A skidding turn results from an excess of centrifugal force over the horizontal lift component, pulling the aircraft toward the outside of the turn. The ROT is too great for the angle of bank. Correction of a skidding turn thus involves a reduction in the ROT, an increase in bank, or a combination of the two changes.

To maintain a given ROT, the angle of bank must be varied with the airspeed. This becomes particularly important in high-speed aircraft. For instance, at 400 miles per hour (mph), an aircraft must be banked approximately 44° to execute a standard-rate turn (3° per second). At this angle of bank, only about 79 percent of the lift of the aircraft comprises the vertical component of the lift. This causes a loss of altitude unless the AOA is increased sufficiently to compensate for the loss of vertical lift.

Forces in Climbs

For all practical purposes, the wing's lift in a steady state normal climb is the same as it is in a steady level flight at the same airspeed. Although the aircraft's flight path changed when the climb was established, the AOA of the wing with respect to the inclined flight path reverts to practically the same values, as does the lift. There is an initial momentary change as shown in *Figure 5-36*. During the transition from straight-and-level flight to a climb, a change in lift occurs when back elevator pressure is first applied. Raising the aircraft's nose increases the AOA and momentarily increases

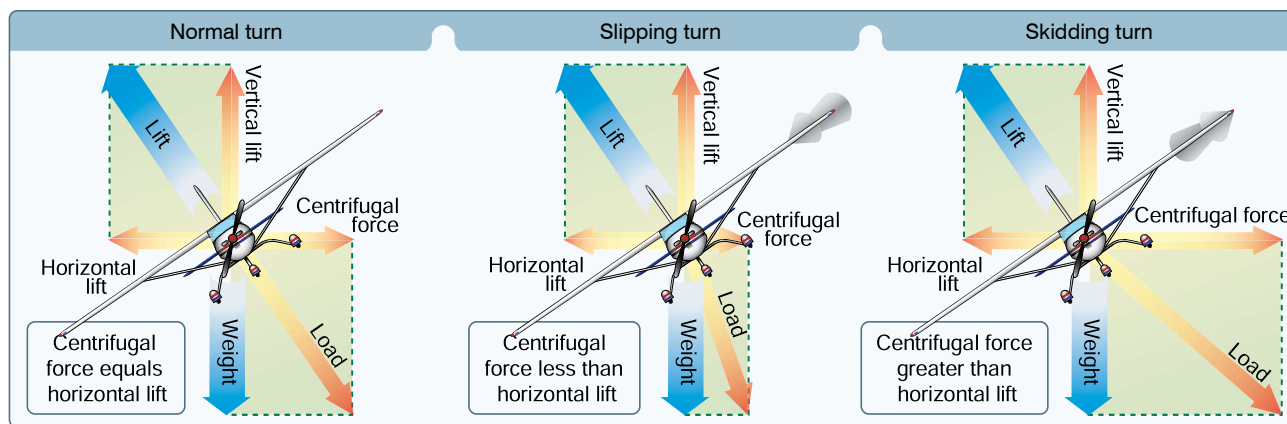


Figure 5-35. Normal, slipping, and skidding turns at a constant altitude.

the lift. Lift at this moment is now greater than weight and starts the aircraft climbing. After the flight path is stabilized on the upward incline, the AOA and lift again revert to about the level flight values.

If the climb is entered with no change in power setting, the airspeed gradually diminishes because the thrust required to maintain a given airspeed in level flight is insufficient to maintain the same airspeed in a climb. When the flight path is inclined upward, a component of the aircraft's weight acts in the same direction as, and parallel to, the total drag of the aircraft, thereby increasing the total effective drag. Consequently, the total effective drag is greater than the power, and the airspeed decreases. The reduction in airspeed gradually results in a corresponding decrease in drag until the total drag (including the component of weight acting in the same direction) equals the thrust. [Figure 5-37] Due to momentum, the change in airspeed is gradual, varying considerably with differences in aircraft size, weight, total drag, and other factors. Consequently, the total effective drag is greater than the thrust, and the airspeed decreases.

Generally, the forces of thrust and drag, and lift and weight, again become balanced when the airspeed stabilizes but at

a value lower than in straight-and-level flight at the same power setting. Since the aircraft's weight is acting not only downward but rearward with drag while in a climb, additional power is required to maintain the same airspeed as in level flight. The amount of power depends on the angle of climb. When the climb is established steep enough that there is insufficient power available, a slower speed results.

The thrust required for a stabilized climb equals drag plus a percentage of weight dependent on the angle of climb. For example, a 10° climb would require thrust to equal drag plus 17 percent of weight. To climb straight up would require thrust to equal all of weight and drag. Therefore, the angle of climb for climb performance is dependent on the amount of excess thrust available to overcome a portion of weight. Note that aircraft are able to sustain a climb due to excess thrust. When the excess thrust is gone, the aircraft is no longer able to climb. At this point, the aircraft has reached its "absolute ceiling."

Forces in Descents

As in climbs, the forces that act on the aircraft go through definite changes when a descent is entered from straight-and-level flight. For the following example, the aircraft

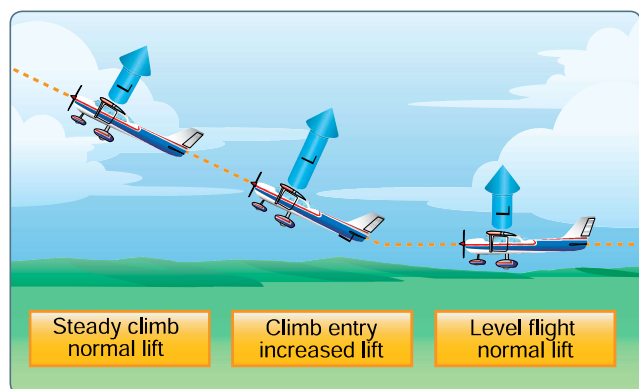


Figure 5-36. Changes in lift during climb entry.

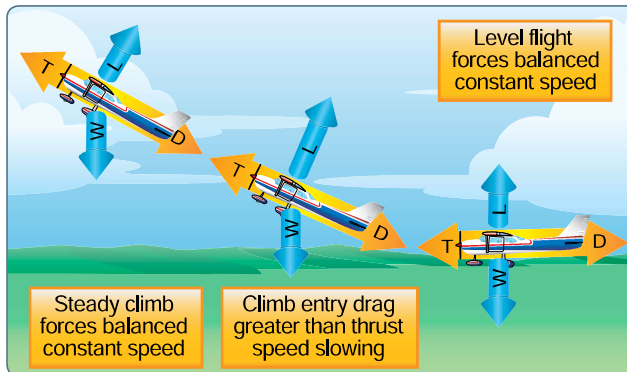


Figure 5-37. Changes in speed during climb entry.

is descending at the same power as used in straight-and-level flight.

As forward pressure is applied to the control yoke to initiate the descent, the AOA is decreased momentarily. Initially, the momentum of the aircraft causes the aircraft to briefly continue along the same flight path. For this instant, the AOA decreases causing the total lift to decrease. With weight now being greater than lift, the aircraft begins to descend. At the same time, the flight path goes from level to a descending flight path. Do not confuse a reduction in lift with the inability to generate sufficient lift to maintain level flight. The flight path is being manipulated with available thrust in reserve and with the elevator.

To descend at the same airspeed as used in straight-and-level flight, the power must be reduced as the descent is entered. Entering the descent, the component of weight acting forward along the flight path increases as the angle of descent increases and, conversely, when leveling off, the component of weight acting along the flight path decreases as the angle of descent decreases.

Stalls

An aircraft stall results from a rapid decrease in lift caused by the separation of airflow from the wing's surface brought on by exceeding the critical AOA. A stall can occur at any pitch attitude or airspeed. Stalls are one of the most misunderstood areas of aerodynamics because pilots often believe an airfoil stops producing lift when it stalls. In a stall, the wing does not totally stop producing lift. Rather, it cannot generate adequate lift to sustain level flight.

Since the C_L increases with an increase in AOA, at some point the C_L peaks and then begins to drop off. This peak is called the C_{L-MAX} . The amount of lift the wing produces drops dramatically after exceeding the C_{L-MAX} or critical AOA, but as stated above, it does not completely stop producing lift.

In most straight-wing aircraft, the wing is designed to stall the wing root first. The wing root reaches its critical AOA first making the stall progress outward toward the wingtip. By having the wing root stall first, aileron effectiveness is maintained at the wingtips, maintaining controllability of the aircraft. Various design methods are used to achieve the stalling of the wing root first. In one design, the wing is "twisted" to a higher AOA at the wing root. Installing stall strips on the first 20–25 percent of the wing's leading edge is another method to introduce a stall prematurely.

The wing never completely stops producing lift in a stalled condition. If it did, the aircraft would fall to the Earth. Most training aircraft are designed for the nose of the aircraft to

drop during a stall, reducing the AOA and "unstalling" the wing. The nose-down tendency is due to the CL being aft of the CG. The CG range is very important when it comes to stall recovery characteristics. If an aircraft is allowed to be operated outside of the CG range, the pilot may have difficulty recovering from a stall. The most critical CG violation would occur when operating with a CG that exceeds the rear limit. In this situation, a pilot may not be able to generate sufficient force with the elevator to counteract the excess weight aft of the CG. Without the ability to decrease the AOA, the aircraft continues in a stalled condition until it contacts the ground.

The stalling speed of a particular aircraft is not a fixed value for all flight situations, but a given aircraft always stalls at the same AOA regardless of airspeed, weight, load factor, or density altitude. Each aircraft has a particular AOA where the airflow separates from the upper surface of the wing and the stall occurs. This critical AOA varies from approximately 16° to 20° depending on the aircraft's design. But each aircraft has only one specific AOA where the stall occurs.

There are three flight situations in which the critical AOA is most frequently exceeded: low speed, high speed, and turning.

One way the aircraft can be stalled in straight-and-level flight by flying too slowly. As the airspeed decreases, the AOA must be increased to retain the lift required for maintaining altitude. The lower the airspeed becomes, the more the AOA must be increased. Eventually, an AOA is reached that results in the wing not producing enough lift to support the aircraft, which then starts settling. If the airspeed is reduced further, the aircraft stalls because the AOA has exceeded the critical angle and the airflow over the wing is disrupted.

Low speed is not necessary to produce a stall. The wing can be brought into an excessive AOA at any speed. For example, an aircraft is in a dive with an airspeed of 100 knots when the pilot pulls back sharply on the elevator control. [Figure 5-38] Gravity and centrifugal force prevent an immediate alteration of the flight path, but the aircraft's AOA changes abruptly from quite low to very high. Since the flight path of the aircraft in relation to the oncoming air determines the direction of the relative wind, the AOA is suddenly increased, and the aircraft would reach the stalling angle at a speed much greater than the normal stall speed.

The stalling speed of an aircraft is also higher in a level turn than in straight-and-level flight. [Figure 5-39] Centrifugal force is added to the aircraft's weight and the wing must produce sufficient additional lift to counterbalance the load imposed by the combination of centrifugal force and weight. In a turn, the necessary additional lift is acquired by applying back pressure to the elevator control. This increases the wing's

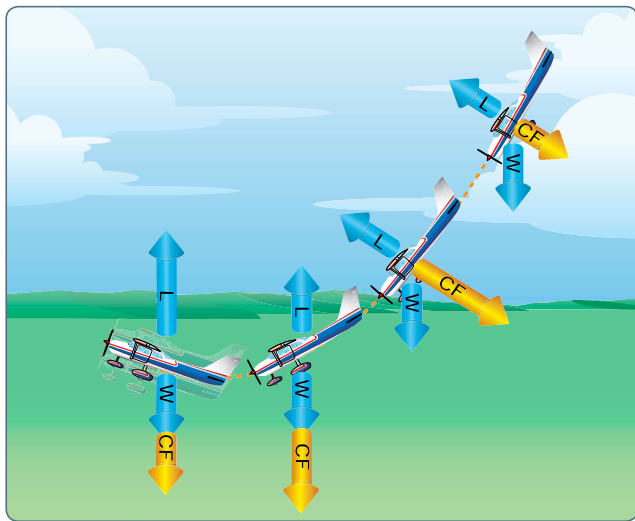


Figure 5-38. Forces exerted when pulling out of a dive.

AOA and results in increased lift. The AOA must increase as the bank angle increases to counteract the increasing load caused by centrifugal force. If at any time during a turn the AOA becomes excessive, the aircraft stalls.

At this point, the action of the aircraft during a stall should be examined. To balance the aircraft aerodynamically, the CL is normally located aft of the CG. Although this makes the aircraft inherently nose-heavy, downwash on the horizontal stabilizer counteracts this condition. At the point of stall, when the upward force of the wing's lift diminishes below that required for sustained flight and the downward tail force decreases to a point of ineffectiveness, or causes it to have an upward force, an unbalanced condition exists. This causes the aircraft to pitch down abruptly, rotating about its CG. During this nose-down attitude, the AOA decreases and the airspeed again increases. The smooth flow of air over the wing begins again, lift returns, and the aircraft begins to fly again. Considerable altitude may be lost before this cycle is complete.

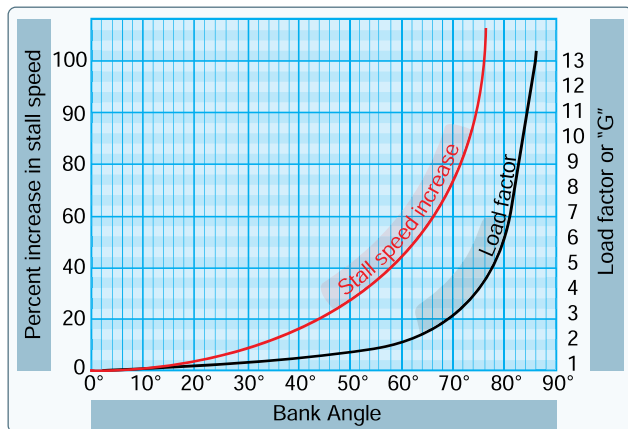


Figure 5-39. Increase in stall speed and load factor.

Airfoil shape and degradation of that shape must also be considered in a discussion of stalls. For example, if ice, snow, and frost are allowed to accumulate on the surface of an aircraft, the smooth airflow over the wing is disrupted. This causes the boundary layer to separate at an AOA lower than that of the critical angle. Lift is greatly reduced, altering expected aircraft performance. If ice is allowed to accumulate on the aircraft during flight, the weight of the aircraft is increased while the ability to generate lift is decreased. [Figure 5-40] As little as 0.8 millimeter of ice on the upper wing surface increases drag and reduces aircraft lift by 25 percent.

Pilots can encounter icing in any season, anywhere in the country, at altitudes of up to 18,000 feet and sometimes higher. Small aircraft, including commuter planes, are most vulnerable because they fly at lower altitudes where ice is more prevalent. They also lack mechanisms common on jet aircraft that prevent ice buildup by heating the front edges of wings.

Icing can occur in clouds any time the temperature drops below freezing and super-cooled droplets build up on an aircraft and freeze. (Super-cooled droplets are still liquid even though the temperature is below 32 °Fahrenheit (F), or 0 °Celsius (C).

Angle of Attack Indicators

The FAA along with the General Aviation Joint Steering Committee (GAJSC) is promoting AOA indicators as one of the many safety initiatives aimed at reducing the general aviation accident rate. AOA indicators will specifically target Loss of Control (LOC) accidents. Loss of control is the number one root cause of fatalities in both general aviation and commercial aviation. More than 25 percent of general aviation fatal accidents occur during the maneuvering phase of flight. Of those accidents, half involve stall/spin scenarios. Technology such as AOA indicators can have a tremendous impact on reversing this trend and are increasingly affordable for general aviation airplanes. [Figure 5-41]

The purpose of an AOA indicator is to give the pilot better situation awareness pertaining to the aerodynamic health



Figure 5-40. Inflight ice formation.