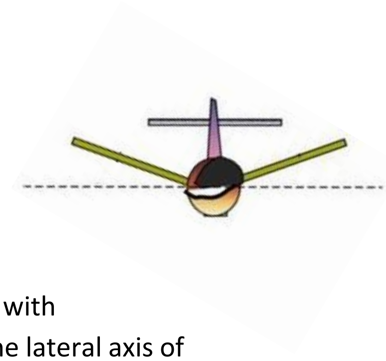
# Dihedral – A Brief Explanation

*Daniel Sullivan April 28, 2021*



General definition: The angle formed by the faces of two plane surfaces (the geometric kind of plane, not the airplane kind of plane)

Practical definition, aviation – The slight upward sloping of each wing that makes for a shallow 'V' shape when an aircraft is viewed straight on from the front.

Any pair of surfaces of an aircraft can have dihedral but in aviation dihedral is generally used with respect to the angle the wings form between themselves (or, alternatively, with respect to the lateral axis of the aircraft). Contrast this to the downward sloping *anhedral* wings of the Lockheed C-5 or Antonov AN-124.

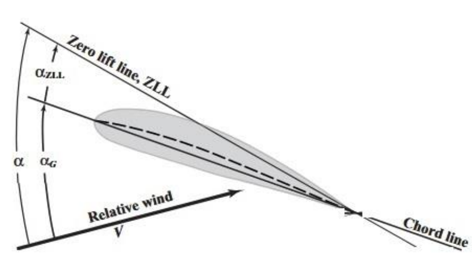
Most aircraft have a degree of dihedral (upward angle) of their wings to provide lateral stability (roll stability) about the longitudinal axis. Confusing enough, all this 'stability of this axis about that axis' stuff. But a good thing to get your head around so ask someone to help you if you don't think you have a good grasp on the concept of stability, aircraft axes and how aircraft move about their axes (and about the center of gravity).

Before explaining how dihedral 'fixes' the problem, let's describe the problem:

1. Some force (a wind gust, your knee on the yoke) causes one wing to go up, the other down.
2. Wings tilted (banked) due to roll cause a horizontal component of lift to be created (the same as occurs when you bank the aircraft intentionally to turn).
3. Initially (at least, and maybe to some degree for longer than the first few seconds depending on the design and inherent stability of the aircraft) the horizontal component of lift is unopposed, causing the aircraft to slip sideways.
4. So you have rolled, you are slipping sideways and if your coffee is not spilling on your leg one of your passengers may be puking down the back of your neck at which point you would clearly recognize this as 'a problem'.

Yes, you could fix the problem yourself but this would mean that you would constantly have to be doing something to get your aircraft to roll back to straight and level and at least some of the time you might want to have your attention on something else and not be constantly interrupted by having to straighten your airplane out. (OK, an autopilot would also fix the problem but it would not be as much fun to explain how that works).

If you did not know it already you have probably deduced that dihedral fixes the problem for you. So, back to … How does dihedral do that? Dihedral works for one reason and one reason only – because you are slipping. Most reasonably well designed aircraft will make a coordinated turn with a moderate bank angle without the need for aileron input and without rolling out of the bank by itself once the turn is established – because the turn is coordinated, there is no slip. Dihedral only comes into play when you are slipping. Here's why:

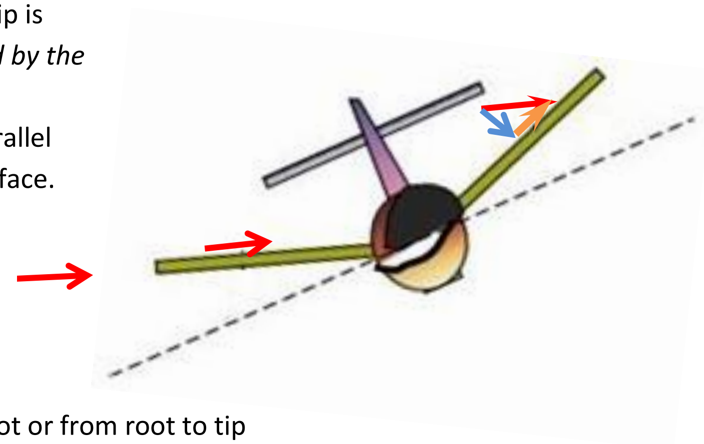



In straight and level flight the relative wind is equal in velocity to your true airspeed and in a direction opposite the direction of flight and at an angle to the wing equal to the angle of attack needed to hold the aircraft in straight and level flight. Your basic "usual angle of attack" for cruising along in smooth air at whatever weight and balance state you are currently at. Yes there are two ways to express angle of attack (and it does not matter which one you use).

The angle the relative wind makes with the chord line of the wing is the geometric angle of attack – the one that the FAA wants you to say is the answer when they ask you to define 'angle of attack'.  The other angle of attack is the absolute angle of attack (sometimes called the aerodynamic angle of attack) which is the angle the relative wind makes with the zero lift line of the airfoil.  Again, it does not matter which definition you use.  Dihedral works the same way.

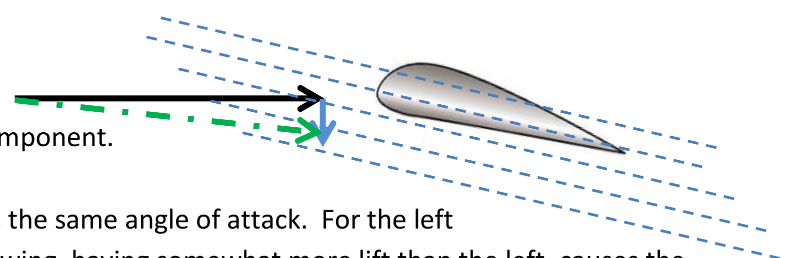
Here the aircraft has been rolled to the right and the right wing tip is now pointing in the direction of slip – so the relative wind *caused by the slip* is coming from the right, parallel to the *right* wing's surface. Because of dihedral you can see that the relative wind is NOT parallel to the left wing's surface; it is only parallel to the right wing's surface.

Red Arrow - Relative wind DUE TO SLIP



Recall that spanwise airflow (air moving from wing tip to wing root or from root to tip along the wing) creates no lift.  Only wind flowing from the leading edge of the wing to the trailing edge of the wing (parallel to the direction of the relative wind) creates lift, and the amount of lift that is created at a given speed is directly related to the angle of attack.  The greater the angle of attack the greater the lift created.  Reducing the angle of attack causes less lift to be created, and this is what slip + dihedral does, it reduces the angle of attack of the 'up' wing.

The 'up' wing (the left wing, in this example) has the relative wind due to slip hitting it at an angle.  So this wind can be resolved into two vector components.  One component (the orange arrow) is the spanwise flow component, so has not effect on lift.  The other component (the blue arrow) is the component perpendicular line of forward motion of the aircraft.  For straight and level flight the relative wind would be as shown by the black arrow, below.  The angle of attack in undisturbed flight is the angle between the black line and the dotted blue lines.  An inadvertent roll (with slip) would cause a component of airflow shown by the blue arrow.  Adding the blue arrow vector component to the forward velocity vector results in a relative wind that is shown by the dashed-line green arrow which you can see has a ***smaller*** angle of attack (a lesser angle between the dotted green line and the dotted blue lines) as a result of the added side slip component.



The right wing (with only spanwise flow due to slip) maintains the same angle of attack.  For the left wing the smaller angle of attack means less lift.  So, the right wing, having somewhat more lift than the left, causes the aircraft to roll the left wing down due to the net force upward on the right wing.  Once straight a level flight is re-established the slip goes away, so the component of wind due to slip goes away and the angle of attack again is equal for both the left and right wing.  Yes, the 'down' wing can and does develop an angle with the slip wind but always a lesser one than the 'up' wing so the net lifting force is always that which lifts the 'down' wing.

If you repeat the analysis assuming NO dihedral (the wings are aligned along the dotted lines on the illustration at the top of this page) then both wings would have a component of the relative wind due to slip and which would be equal for both the right and left wings.  The angle of attack would change as it did for the dotted green arrow for the case where there was dihedral but the change in the angle of attack would be *the same for both wings* so the change in lift would be the same for both wings.  There would be NO differential lift between one wing and the other, so no net force to roll the aircraft back to straight and level.  Dihedral causes a net lift which acts to lift the low wing up, so the aircraft re-establishes level flight without the need for pilot input.