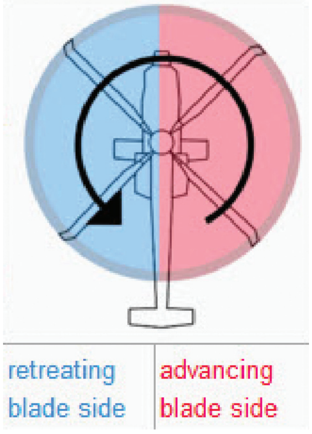
Helicopter Control:

What is Retreating Blade Stall?

By Johan de Villiers

In order to understand retreating blade stall, it is important to understand that the amount of lift generated by a helicopter's rotor is proportionate to its relative airflow. In a normal hover, without any forward airspeed, the rotor blades, regardless of their position in rotation, have equal relative airflow and therefore generate equal lift. A rotor blade that is moving in the same direction as the helicopter is called the advancing blade and the blade moving in the opposite direction is called the retreating blade.



In forward flight the advancing blade has a higher relative airflow than the retreating blade owing to the machine moving forward thus creating unequal lift across the rotor disc. This effectively means that the aerodynamic lift on opposite sides of the helicopters rotor disc is uneven and is commonly referred to a dissymmetry of lift. Unless countered, dissymmetry causes the helicopter to roll to the retreating side. More about that later on.

A normal airplane's fixed wing has a certain pitch or angle of attack that generates lift. All airfoils or wings have a critical angle of attack (also called a stall angle of attack) which is the angle of attack that produces most lift. If this is exceeded, the wing will stop generating lift and the entire aircraft will experience a flight condition known as a stall. The stall of the wing thus limits the low speed limits of the airplane. In addition to that, a stall will result in a steep nose down dive and resultant drop in altitude, but is normally a recoverable event for a fixed wing aircraft.

For a helicopter, only a portion of the retreating blade or airfoil experiences a stall. The advancing blade continues to generate lift, which explains the body of the helicopter rolling towards the retreating blade experiencing the stall. The retreating blade must, however, produce an amount of lift equal to that of the advancing blade. Therefore, as the airspeed of the retreating blade decreases with forward aircraft speed, the blade angle of attack must be increased to equalize lift throughout the rotor disk area. As this angle increase is continued, the blade will stall at some high forward speed.

This is the major factor that limits the maximum forward speed of helicopters today. This upper speed limit is known as Vne, the never-exceed speed. This speed limit becomes lower with an increase in altitude, owing to the fact that the angle of attack of the blades needs to increase to compensate for the lower air density and resultant lift being created. All helicopter manufacturers publish charts and/or graphs with the pilot operating handbook illustrating the Vne decrease with altitude.

How helicopters compensate

In modern day helicopters, dissymmetry of lift between the advancing and retreating rotor blades is countered by "blade flapping". The advancing blade flaps up with a resultant smaller angle of attack, thereby creating less lift. Conversely, the retreating blades of a helicopter will flap down and creating a greater angle of attack and therefore creating more lift to compensate.

Semi-rigid and fully articulated rotors are two common designs used to further compensate for the effect.

In addition to blade flap, the helicopter's cyclic pitch control is also used to increase the pitch of the retreating blade and decrease the pitch of the advancing blade. This differential in pitch generates less lift on the advancing side of the aircraft, balancing out the effect of the higher airspeed of the advancing blade.

When one considers helicopters such as the Chinook CH47 with two sets of counter rotating rotor blades the dissymmetry of lift of one rotor disc is virtually cancelled by the increased lift of the other rotor disc, owing to the fact that the two main rotor discs are rotating in opposite directions.

It is important to note that as the forward speed increases the Chinook's rotor tips will approach supersonic speeds which will result in unstable forward flight conditions and as such, event the CH47 has a never-exceed speed. In addition to that the actual physical size of the helicopter with the resultant aerodynamic drag, as well as limited absolute engine power, may also contribute to the machine not being capable of getting close to the Vne imposed by the dissymmetry of lift.

Conditions leading to retreating blade stall:

- High Air Speed
- High Blade Loading (high gross weight)
- Low Rotor RPM
- High Density Altitude
- Steep or Abrupt Turns
- Turbulent Air

In addition to the above, a helicopter pilot