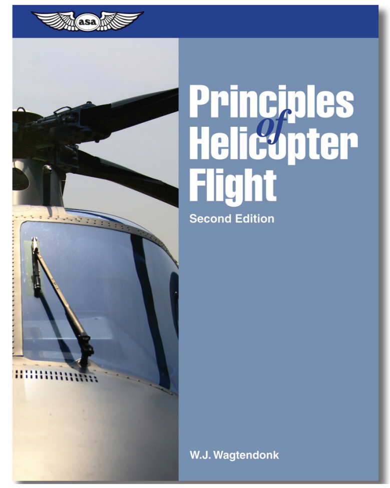
Principles of Helicopter Flight 2nd Edition Update

By W.J. Wagtendonk

Principles of Helicopter Flight, by Walter J. Wagtendonk, explains the complexities of helicopter flight in clear, easy-to-understand terms. The worldwide helicopter industry has waited a long time to see a manual of this caliber. This update provides details of the changes that have been made since the 2nd Edition was published.

This update is effective May 2018.



Page 157, first paragraph, first line, insert new text following the text that reads "Vortex ring state, or settling with power":

(a term much argued about)

Page 159, top bullet, add asterisk inside closing parentheses. Bullet now reads:

- a low or zero airspeed (below translational lift speed*)

Page 159, after the last bullet in the "Requirements for the Development of Vortex Ring State" section, add the following text:

* Recent research suggests that vortex ring state can be experienced at speeds somewhat higher than translational speed.

Page 160, after Figure 19-6 caption, add the following paragraph:

It should be noted that the magnitude of induced flow is influenced by factors such as aircraft all-up weight (AUW), altitude and power required. For a given helicopter the risk of entering VRS is less when at high AUW compared to low AUW and high altitude versus low altitude. In both cases the induced flow and the downwash are stronger and therefore better able to oppose a given upward flow.

Page 160, change the "Flight Conditions Likely to Lead to Vortex Ring State" section to read:

All conditions require that there must be an induced flow, some power in use and interference to the induced flow by an airflow upward towards the rotor disc. This upward flow does not necessarily mean the helicopter must be in a descent; a rising flow such as anabatic (uphill) wind while hovering or in slow horizontal flight could produce the same result.

It has been shown that, depending on helicopter type, a rate of descent in the region of 400–800 ft/min is required to get into the vortex ring state situation. A rough conversion changes that to a speed of approximately 4–7 kt upward towards the rotor disc.

Typical conditions are:

- a powered descent at low or zero airspeed at a vulnerable rate of descent
- recovery from low airspeed autorotation using power (before increasing airspeed)
- allowing descent during a harsh flare (e.g., quickstop)
- maneuvering during high OGE hover
- steep approach and termination
- Downwind approaches (see reference to downwind approaches further down)

These factors are all associated with pilot actions in maneuvering the helicopter but an unwelcome surprise can lie in wait for a pilot who, while hovering close to a cliff face, experiences rising air in an anabatic wind or a wind caused orographically. Some might ignore these types of wind considering they're only a few knots but as said above, 4 knots vertically might be all it takes to cause vortex ring state. A number of flights fall in this close-to-valley-walls category—wand spraying, winching, and rescue flights to name but a few.

Early mornings in clear conditions are popular times for some of these operations and it is well to remember the associated risks.

Page 161, at the end of the "Recovery from Vortex Ring State" section, add the following new text:

Traditionally the recovery from vortex ring state comprised forward cyclic (and/or slightly to one side), brief pause for the airspeed to build up, apply power. However, the resultant low nose attitude and brief pause tend to cause a considerable height loss, commonly hundreds of feet.

The newly recommended Vuichard recovery technique has shown to be effective in substantially reducing height loss to mere tens of feet. The following simultaneous steps assume a helicopter with the main rotor rotating anti-clockwise viewed from above:

- Positive roll to the right, angle of bank up to 20°
- Smooth increase in power to climb power
- Left pedal to stop yaw

Once rate of descent has decreased, pitch forward to regain speed.

Clearly, for main rotors rotating clockwise the initial roll is to the left and apply right pedal to prevent unwelcome yaw.

The early application of power has two consequences—it will cause yaw which must be prevented with the appropriate pedal and it will increase translating tendency (explained in Chapter 9, Figure 9-4). As the latter becomes stronger through increased power, it assists in moving the helicopter sideways and thereby removes it quicker from the disturbed vortex below.

Page 161, after the "Recovery from Vortex Ring State" section, add two additional sections, along with a figure for each section, to read as follows:

Vortex Ring State during Mountain Ridge Approaches

Wind conditions in mountainous terrain can be unpredictable and fickle. Many pilots, experience notwithstanding, have been caught unawares and often so during mountain ridge approaches.

Referring to Figure 19-7 the pilot would be correct in assuming that the approach and landing are into wind and provided the approach remains above ridge level and rate of descent small, there should be no risk of entering the vortex ring state. However, if thermally-induced action or orographic effects cause an updraft on the approach side of the mountain, the stage is set for vortex ring state when the helicopter enters this zone with a low airspeed. These freak wind conditions are not uncommon in prevailing light winds.

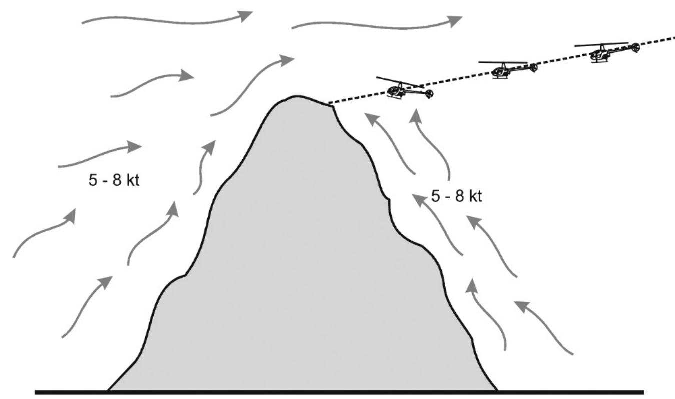


Figure 19-7 *Mountain ridge approach and risk of vortex ring state.*

The moral of course is: avoid straight approaches that preclude the option of a quick escape route. Whenever possible, make an oblique approach to the ridge so that in the event of an unwelcome and sudden drop in altitude, it only takes a small direction change to vacate the area and recover from the hazardous condition. And if at all possible, in U.S.-built helicopters approach with the ridge to your left and vice versa for helicopters with rotors rotating the other way.

Vortex Ring State and Downwind Approaches

It was mentioned above that downwind approaches could lead to vortex ring state conditions. This requires more thought because it might lead one to believe that the tailwind is the culprit.

The wind is simply a block of air that moves in a given direction. When embedded in this air the direction or speed of the wind has no influence on the performance of a helicopter except for making it go faster or slower in terms of groundspeed and possibly causing it to divert from a given track; aerodynamically there's no effect. Remembering that vortex ring state is a battle between induced flow downward versus an upward flow resulting from rate of descent or rising air, the wind per se should not cause vortex ring state; it could happen in a headwind, tailwind or no wind at all.

However, when a helicopter is flown with reference to a spot on the surface the effect of the wind on the rotor increases until it is equal to the total wind strength when stationary over the spot.

Thus during a headwind approach the downwash could be blown rearward relative to the disc and in strong winds translational benefits will be retained as the landing spot is approached, so vortex ring state should be less of a threat.

In a tailwind the situation is a little more complex in that the downwash and the helicopter and its disc move in the same direction, increasing the risk to vortex ring state. However, the higher nose attitude and rearward slanted rotor disc will cause the vertical component of

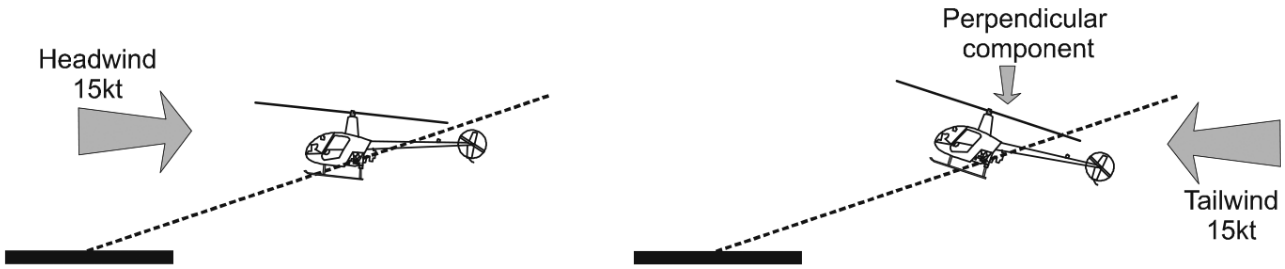


Figure 19-8 *Effect of a headwind and tailwind on vortex ring state.*

the wind to increase the downward induced flow to some extent.

Essentially, vortex ring state and tailwind depend on how a pilot handles the tailwind. If the approach angles are the same as shown in Figure 19-8, the higher momentum in a tailwind requires a larger and more aft-orientated total rotor thrust which could lead to over-pitching especially when at very low airspeed and OGE. The resulting increase in rate of descent might well give the impression of vortex ring state and it might also explain why, in some reported cases, the typical "rumble" was absent. Alternatively, a rapidly approaching touchdown spot might well force the pilot into executing a harsh flare which would increase the risk of vortex ring state. But that was the result of pilot action and not the tailwind. The message is clear: downwind approaches should be treated with the greatest respect and avoided whenever possible.

Page 161—All subsequent figures and figure references in text to the end of Chapter 19 are renumbered to reflect the insertion of the new Figures 19-7 and 19-8, as follows.

Page 161, first paragraph in "Tail Rotor Vortex Ring State" section, replace the last sentence in this paragraph with:

Thus if an airflow is present from left to right onto the tail rotor, vortex ring state can develop (Figure 19-9).

Page 162, Figure 19-7, change figure number to:

Figure 19-9.

Page 165, Figure 19-8, change figure number to:

Figure 19-10.

Page 165, paragraph beneath figure, replace first sentence with:

The forces involved in dynamic rollover are shown in Figure 19-10.

Page 166, two lines above the figure, update the figure reference "(Figure 19-9)" in text so it now reads:

… which strengthens the moment about the skid contact point with the ground (Figure 19-11).

Page 166, Figure 19-9, change figure number to:

Figure 19-11.

Page 167, Figure 19-10, change figure number to:

Figure 19-12.

Page 168, first paragraph, replace the last sentence in this paragraph with:

The effect of low, zero or negative g on total main rotor thrust production (Figure 19-12) is devastating.

Page 168, paragraph above top figure, change second-to-last sentence to read:

As the aircraft continues to roll right (while cyclic is forward but not to the side), the clearance between the rotor head and the mast is reduced (Figure 19-13).

Page 168, Figure 19-11, change figure number to:

Figure 19-13.

Page 168, Figure 19-12, change figure number to:

Figure 19-14.

Page 172, in the "Review" section, change the following numbers to read as follows:

2. When vortex ring state has developed, (it is/is not) good practice to reduce the rate of descent with raised collective because the (higher/lower) blade angles cause the stalled region to (contract/expand).

3. To recover from a vortex ring state situation at low altitude you must use (collective/cyclic) to increase (rate of descent/airspeed) and after a brief pause re-apply power.

4. Vortex ring state of the tail rotor may be experienced during a high-rate hover turn to the (left/right).

5. When surrounding terrain forces you to approach a landing site downwind, you must be conscious of the risk of ______ particularly when you are (above/below) translational speed.