

How does Unanticipated Right Yaw occur?

The explanation can be found in a diagram/curve which charts pedal position according to helicopter heading relative to true wind direction (while at trim and in hover). Such a curve exists for each combination of weight, altitude, temperature and wind speed.

An example is provided in **Figure 1**. The well-known critical azimuth, which gives the smallest pedal margin, corresponds in this Figure to about -90° heading (wind coming from the right hand side with respect to the helicopter).

The blue curve corresponds to hover trim conditions. From there, when right pedal is added (i.e. the pedal position moves above the blue curve) the helicopter yaws to the right, and when left pedal is added it yaws to the left (the pedal position moves below the curve).

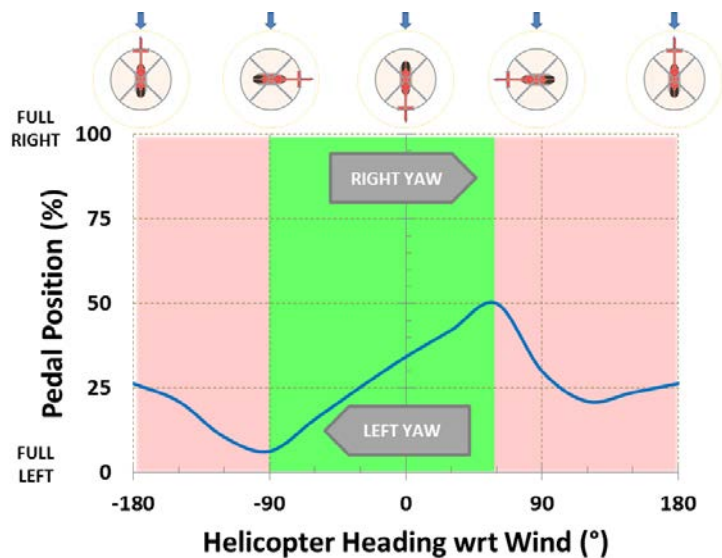


Figure 1: Example of hover pedal curve

Where a headwind is present (green area in **Figure 1**) the helicopter is stable in yaw. If a gust alters the heading of the helicopter, from 0° to -10° for example, the pedal position is now above the curve (the heading was brought to -10° with the pedal position that existed at 0°). The helicopter yaws right until it crosses the trim curve, which happens at the initial 0° heading. Shifted away from the trim position, it comes back to it.

On the opposite side of Figure 1 the red area represents an area of a yaw instability. When the helicopter is shifted from its trim position, it moves further away until a stable headwind condition is found. This tailwind instability is well known by helicopter pilots who are aware that yaw must be very carefully controlled when the wind approaches from behind (tailwind).

Stabilizing surfaces are installed downstream of the center of gravity. The tail rotor and the fin have this role and are well located for forward flight conditions. In a tailwind, however, their position on the helicopter is not ideal. As a result, they cause yaw instability.

This can be managed as long as the pilot is aware of the wind direction relative to the helicopter. It becomes more difficult when information about wind direction and strength is not available, especially when yaw maneuvering is required. The pilot can reach the upper limit of the stable range (about 60° heading in **Figure 1**) without much advance warning and, as a result, switch from experiencing stable yaw behavior to fully unstable yaw behavior. This can give the pilot the feeling that the helicopter rotates of its own accord - even if though it is the result of his control inputs and the consequence of the change of wind heading on tail rotor thrust.

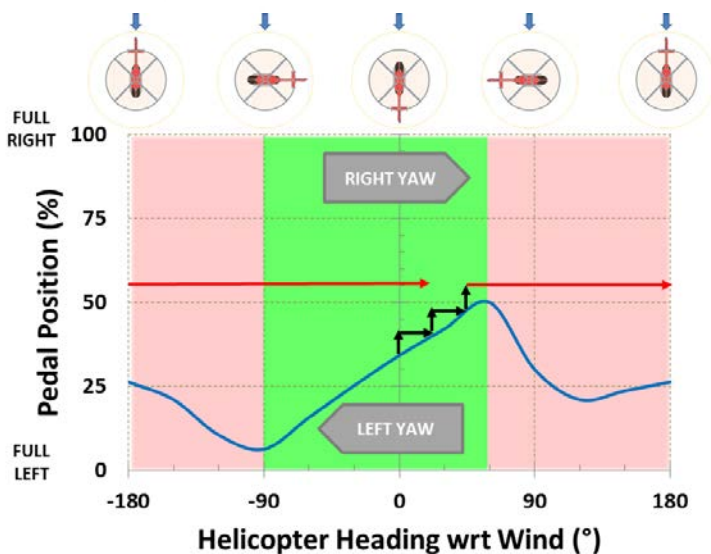


Figure 2: Starting an Unanticipated Right Yaw

position beyond the highest point of the pedal curve. This means a nose-right rotation will occur, as indicated by a red arrow. As the trim curve is never reached, however, rotation of the helicopter (i.e. spinning) will not stop unless left pedal is added. On the basis of the previous behavior of the helicopter, a 20° heading step with a limited yaw rate was expected. On the third pedal step, however, spinning is reached, with strong yaw acceleration. This is the "uncommanded rapid yaw rate which does not subside of its own accord" which defines unanticipated yaw.

The gap between the current pedal position (red arrow) and the blue trim curve gives an indication of the encountered yaw rate. In the **Figure 2** example, after passing the maximum of the blue curve (about 60° heading), that gap increases drastically. It is not due to a pedal input, but to a trim position that is moving away. The pilot has no indication of this changing trim position and the resulting yaw acceleration is therefore wrongly perceived as being uncommanded, attributable to some external factor.

This is not the only way unanticipated yaw can start. Under-monitoring of the helicopter's yaw axis behavior while at low speed in tailwind conditions can lead to the same result. It would depend on the direction of the initial wind disturbance and should be equally distributed between right and left rotations. The same problem demonstrated in **Figure 2** can also appear on the other side of the stability range (circa -90° heading). The unanticipated yaw developing there can only be to the left.

Most instances of unanticipated yaw which lead to accidents are to the right when the main rotor rotates counterclockwise. This shows that the main problem is not a tailwind or wind in the vicinity of the critical azimuth, where the pedal coming close to the 0% stop gives a clear warning. The main problem area for unanticipated right yaw is on the other side of the stability range, when the pedal position is much more benign.

This is illustrated in the graph in **Figure 2**. Starting from 0° wind heading, a right pedal step is made (indicated by a vertical black arrow). This brings the control position above the trim curve and the helicopter therefore rotates to the right until it crosses the trim curve, where it stops. In headwind conditions, pedal provides an attitude command: a control step mainly produces a heading step.

A second right pedal step is included in **Figure 2**. It has a similar effect to the first pedal step, leading to a second heading step.

When a third right pedal step is made with the same amplitude, the same heading change in the order of 20° can be anticipated, but unexpectedly this third step brings the pedal

Why does the tail rotor appear to be ineffective?

Following unanticipated right yaw occurrence depicted in **Figure 2**, three recovery strategies have been plotted in **Figure 3**. Here, the pilot is assumed to have been caught unaware by the helicopter's behavior and reacted late in the vicinity of a 90° heading.

No control input (as shown by the red line), or a very small control input based on the tail rotor efficiency as perceived prior to the event, is not an option for the pilot. It cannot stop the yawing.

A large and slow input (as shown by the yellow line) can zero the yaw rate, but halting it will occur quite late. The trim curve is only crossed 270° after the step input. This can appear to be a very long time to any pilot who does not appreciate what is happening. This is why the tail rotor can seem ineffective: large but slow inputs make a clearly visible effect only at the end of a 360° rotation.

A large and rapid input is represented by the green line. The yaw stops much more quickly, but the trim is found in the unstable tailwind range. The heading must be closely monitored and headwind conditions recovered as soon as practicable. For example, in one accident recorded by video, a decreasing yaw rate could be seen, followed by further acceleration, indicating that the pilot seemed to have been unknowingly affected twice by unanticipated yaw.

The key feature of an unanticipated right yaw recovery is large amplitude left pedal input. Recovery may not be immediate, but will occur if the pilot persists in maintaining left pedal. In some instances, the pilot re-centered the pedal before entering again a left pedal input. This cannot help and only delays recovery from the yaw. If the yaw deceleration is not enough, more left pedal must be added, reaching the pedal end-stop if necessary.

The most probable reason for accidents following unanticipated yaw events is a late and too limited pedal input. The pedal curve shows that this cannot stop the yaw in the short term. During an unanticipated yaw event, the tail rotor remains fully effective and provides the best chance to recover. Yaw rate and wind conditions reduce its thrust if it is at a constant pitch. There must be counterbalance by a huge pitch increase. The only warning the pilot may get of potential loss of control is the onset of unanticipated yaw.

The apparent lack of efficiency of a limited pedal input can lead to misinterpretation of an unanticipated yaw as a full loss of tail rotor thrust (for example, as would be the case after rupture of the tail rotor drive). The symptom (unexpected intense right yaw) is similar and the short term response to a small and late pedal input is almost zero for both. Only full left pedal input will make the required difference and enable the pilot to identify whether he is experiencing unanticipated yaw or full loss of tail rotor thrust (due to malfunction) and, as a result, enable him to take the most appropriate action. If full left pedal has no effect on the yaw, it is clear that there has been a definite full loss of thrust, necessitating an immediate landing. If, however, full left pedal decelerates the yaw, it becomes clear that the issue is unanticipated yaw in character, which necessitates staying well clear of the ground and obstacles until a full recovery has been achieved.

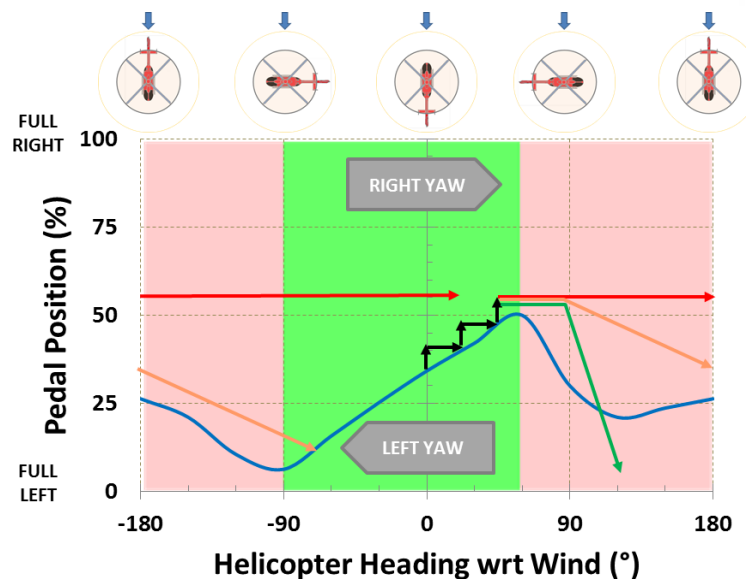


Figure 3: Recovering from an Unanticipated Right Yaw

Unanticipated yaw when performance limited

In pure hover, about 10 % of the total power is spent on the tail rotor. Applying full left pedal can more than triple the tail rotor power consumption. When the helicopter is power-limited (engine or MGB torque limit), it is possible that full pedal cannot be reached while staying inside the helicopter's performance limitations. If the power is available, applying full left pedal means an over-torque resulting in only maintenance actions rather than loss of control and possible accident. If a hard power limitation exists (MGB torque limit or engine limit monitored by the engine FADEC), the additional power required on the tail rotor can be unavailable. This will result in RPM droop, which further increases the need for anti-torque while impairing the tail rotor thrust capability.

Most unanticipated yaw accidents do not occur in performance-limited conditions and, therefore, allow using full left pedal to secure a straightforward recovery. Be aware, however, that when performance is limited, prevention of unanticipated yaw occurrence becomes even more important (3 first points in the next paragraph).

What to do?

- Take particular care when wind comes from the left side or forward-left quadrant. Do not fly unnecessarily in those conditions.
- Prefer, as much as possible, yaw maneuvers to the left, especially in performance-limited conditions. It is easier to monitor the torque demand at the start of the maneuver than when responding to an abrupt unanticipated yaw.
- To make a yaw maneuver, apply a low angular rate of turn and closely monitor it. Yaw acceleration will be more obvious than during an aggressive maneuver.
- If unanticipated yaw occurs, react immediately and with large amplitude opposite pedal input. Be ready to use full pedal, if necessary. Do not limit yourself to what you feel sufficient, your feeling can be wrong. Never bring the pedal back to neutral before the yaw is stopped.