It's all in your head

Do you really understand the properties of your rotor? ***Richard Mornington Sanford*** *sets out the facts*

I am very often asked my views on the causes of Robinson helicopter accidents, and in particular, those where it has been reported that the aircraft suffered an in-flight break-up caused by what seemed to be the main rotor diverging from its normal path of rotation.

The aerodynamics involved in this emotive subject are complex and are not fully understood, as they are difficult for the design engineers and test pilot to simulate and still be around to discuss the results. I'm not trying to explain any more than the very basic aerodynamics, as I aim to provide some insight and understanding without over-complicating or overloading the pilot with minutiae. The helicopter pilot does not have a great deal of time to ponder the finer detail of aerodynamics when things go wrong – he or she needs basic understanding and awareness of:

- Those flight manoeuvres that can lead to main rotor divergence i.e. *extreme teetering or extreme blade flapping of the main rotor system* and how to avoid them.
- Identifying their incipient stages and correctly recovering.

In order for the main rotor to diverge from its normal path when operating at 104% (R22) and 102% (R44) the pilot has to cause it to happen; he or she must cause *'extreme main rotor teetering or extreme blade flapping'*. Now, this statement will have some people saying; 'Well, Dick would say that, wouldn't he! He's a Robinson man!' But ponder this: do you really think that having spent thousands of hours instructing in the Robinson I would still be around to write this article if the helicopter was inherently unsafe? Do you really think that I would fly my family and friends in a helicopter that I thought was "inherently unsafe"? Do you really think that Frank Robinson and his team of design engineers would purposely carry on building and selling a helicopter that they had any (and I mean ***any***) doubts about its design safety? Do you really think that the Robinson Helicopter Company would become the world's leading manufacture of helicopters (over 10,000 helicopters made, without the help of military contracts) if their product was inherently unsafe?

Of course not. Therefore we must look at why these events happen.

Extreme main rotor teetering or blade flapping' becomes a possibility when:

- The pilot loses sufficient rotor rpm (Low RPM Rotor Stall)
- Low 'G'
- Over-controlling during continued flight in severe turbulence, when the pilot tends to get behind the helicopter in

control inputs, causing those inputs to become ever larger.
- Over-controlling when flying fast, and in particular, fast and light in turbulence when even relatively small control inputs can make things happen very, very, quickly.

The first item usually causes extreme blade flapping, whereas the others generally cause extreme teetering.

The pilot has to understand that a main rotor to tail cone contact is a *symptom* and not the *cause* of the accident. For the main rotor blade to strike the tail cone the pilot has to have caused *extreme flapping* of the rotor blade, usually by having failed to maintain the rotor RPM, thus allowing a Low RPM Rotor Stall to occur, during which time the retreating main rotor blade can flap down, causing the disc to flap back or 'blow back'. During this time the tail cone can also pitch up as a result of the nose pitching down when the helicopter starts descending, increasing the chance of main rotor blade contact with the tail cone. This flap back tends to happen when the aircraft has a reasonable IAS; at lower IAS the blades tend to just slow down without contacting the tail cone.

The ensuing break up is a *result* of the pilot failing to maintain RRPM and not a *cause* of the accident. The severing of the tail cone is irrelevant, as the pilot prior to the "chop" had put the helicopter into an unrecoverable situation.

This is a "loss of control" accident, and not some inherent instability of the rotor system.

Once the pilot allows the low RPM Rotor Stall event to begin, things will progress in the wrong direction very quickly; when the RRPM starts to decay, the rotor system loses centrifugal force (CF), which causes an increase in the blade coning. The increased coning reduces the area producing lift, causing the aircraft to descend. When the aircraft descends, the blade angle of attack increases due to the change in the induced flow, causing an increase in drag. The increase in drag will further slow the blades down, thus reducing the CF, causing the blades to cone up further and so on until the blades stall, unless the pilot reacts correctly and in a timely manner.

Once the blades stall the pilot becomes a passenger for as long as it takes to hit the ground. It can happen very quickly and *it is not recoverable as the severe main rotor blade angle of attack due to the upward induced flow over the blade will never be less than the stall angle, even with the collective full down*.

In an aeroplane, your 'life blood' is the airspeed; in a helicopter it is your RRPM.

"Keep your RPM in the green"

The pilot needs to understand how he or she can get into a Low RPM situation and recognise the incipient stages:
- A change of sound.
- An increase in vibration
- Low RPM Caution activating (light and horn).

You need to know how to respond correctly. If you do not, then please read my previous article 'Lost Skills' for further details on this subject.

Turbulence

Another cause of main rotor divergence is extreme main rotor teetering, which is again the result of inappropriate pilot control inputs:
- 'Low G' manoeuvres
- Continued flight in severe turbulence.

The former can be caused by the pilot, usually pulling up (aft cyclic) and following this control input with a push forward, or just by a large forward application of cyclic – this might be typical of a high-time aeroplane pilot reacting incorrectly to a Low RPM caution indication – thus causing a reduction in the main rotor blade angle of attack via a change in the induced flow through the disc.

This loss of lift or 'unloading of the disc' is due to the increase in the induced flow through the top of the disc, causing the angle of attack to decrease, and the subsequent change in pitch attitude of the helicopter which places the tail rotor (still producing an anti-torque thrust to the right) above the aircraft's C of G. This results in a rolling couple in the direction of the tail rotor thrust i.e. to the right. The right roll-rate can end up being very high – around 100 degrees per second, accelerating.

The pilot's instinctive reaction is to apply opposite cyclic at the same rate as the right roll. He or she slams the cyclic over to the left; but although the rotor disc will follow the control input (it is mechanically attached), the main rotor is no longer producing thrust and the pilot has given up the weight of the aircraft during the manoeuvre, so there is no corresponding thrust-weight rolling couple to change to the aircraft lateral attitude.

With the aircraft rolling right and a large left cyclic input by the pilot, extreme rotor teetering will occur and may result in the blade spindle contacting the main rotor drive shaft (mast bumping), deforming the drive shaft, and in extreme cases causing a torsional overload and complete rotor system separation.

Even if the aircraft does not suffer classic rotor separation, several unpleasant things can and do happen. The rotor will excessively teeter and can strike the left side of the cabin structure (windscreen) and the front of the left side skid gear. The excessive teetering can result in the main rotor components being subjected to loads far beyond anything they could possibly be designed to cope with. A main rotor pitch link can fail due to overload, which will free the blade to take up any pitch angle it likes (positive or negative); this can (and has) led to the main rotor blade effectively becoming a ‘paddle’, thus also causing a Low RPM Rotor stall. The excessive dynamic loads placed on the main rotor blade as it becomes a paddle can cause the blade to break free of the rotor hub at their attachment points and be thrown some distance from the main impact point.

You need to understand the things that can put you into Low ‘G’, and the incipient stages of Low ‘G’ – the feeling you get in your stomach when driving over a hump-backed bridge. When you do feel this sensation, you have to apply an aft cyclic *pressure* to re-load the disc (do not over-control).

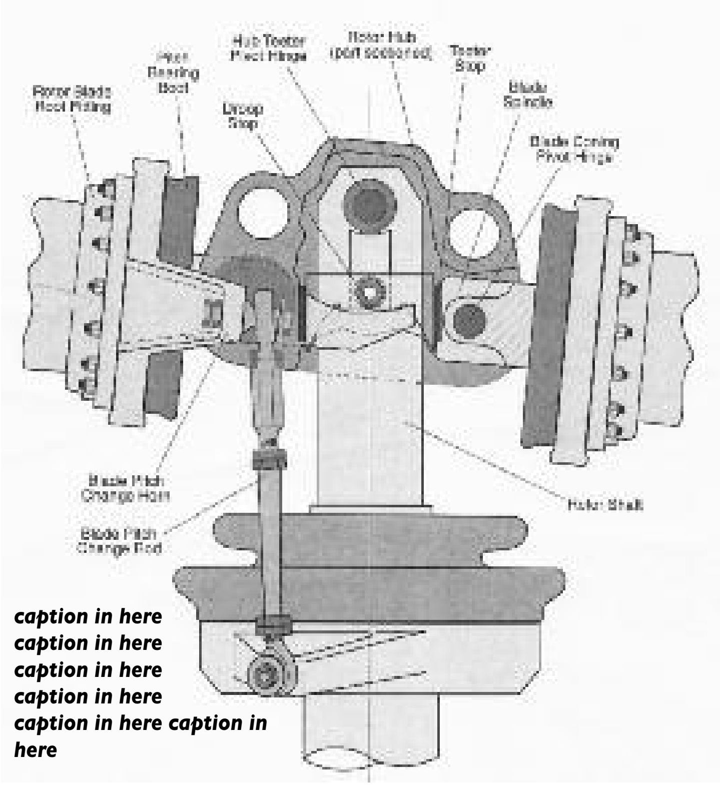
How do you avoid Low ‘G’?

- Do not push over (excessive forward cyclic)
- Do not pull up and push over.
- When you encounter turbulence, slow down. If it becomes severe, fly out of it or land.

Robinson Helicopter Company have a number of very good Safety Notices (SN) that cover the subjects of this article:

- SN-10 Fatal Accidents Caused By Low RPM Rotor Stall
- SN-11 Low G Pushovers – Extremely Dangerous
- SN-24 Low RPM Rotor Stall Can Be Fatal
- SN-29 Airplane Pilots High Risk When Flying Helicopters

What the pilot must understand is that when the events I have mentioned happen, they happen very quickly. For example, many years ago (June 1992), there was an R22 accident involving an instructor and a student. The student had fitted a small device which recorded cockpit communications. The instructor had some 2,000hrs flight time in the R22. The student had four hours total time, all on the R22. The helicopter was at 2,000ft in cruise flight at 85kts when an undetermined event interrupted the instructor’s speech and culminated in the break-up of the helicopter.



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The recording revealed no pilot concern about the helicopter’s operation prior to the break-up, and no unusual rotor system noises. Sound-spectrum analysis of the recording revealed no main rotor decay; the low rotor RPM warning was not recorded before or during break-up. However, the system had activated during the pre take-off checks.

I am not going to try and analyse the accident in any way – that has been done and the NTSB have issued their report. I am trying to get you to think about those situations where the pilot can cause *‘extreme main rotor teetering’* and the speed at which it all happens.

The reported airspeed was 85kts.

The student had very few hours.

The R22 is a light helicopter and has a very sensitive cyclic control system, particularly in pitch.

This combination gives rise to the possibility of the student (who is still coming to terms with the cyclic control sensitivity) over-controlling, and its effect being magnified by the high airspeed.

Couple that with the relatively high RRPM of the R22 and its low inertia main rotor system.

Net result is a situation where things happen very quickly – an abrupt cyclic input can cause things to happen within 2 to 3 revolutions of the rotor blade, or within half a second.

This could be the reason for the lack of verbal response from the instructor: i*t just happened too quickly*.

Why no Low RPM caution recorded?

Well, with Low G the main rotor is still at 104% when the event happens so the Low RRPM caution system is not activated.

Divergence

There are usually two main reasons for main rotor divergence:

- Low RPM Rotor Stall
- Low G or a combination of both.

Low RPM Rotor Stall is inherent

in all helicopters and low G is inherent in two-bladed rotor systems. However, the pilot has to cause these events to happen by his or her actions or inactions.

When I started to fly the R22 it became quite clear to me that the cyclic flight controls were very, very sensitive: they required a pressure, not a movement, and the faster the helicopter was travelling the faster it would respond to my control inputs and the more quickly things would happen. It is a light helicopter, therefore there is very little inertia to overcome to get it to do something.

When I later became an instructor I laboured the point that the early stages of their flying training would involve upper air work in order to become accustomed to the flight controls, in particular the cyclic control sensitivity. This training was going to be conducted at a maximum of 70kts IAS and more often at 60kts, thus reducing the effect of their *guaranteed* heavy-handedness on the controls to a manageable and safe level for the instructor – me.

As a new flight instructor I did not necessary have to know finer details of why the early stages of the student's fight training should be conducted at a reasonable airspeed. However, I did know the logic and consequences.

Flying an R66 solo at 120kts with full fuel or heavy is one thing; flying it at 120kts with much less fuel or light will increase the sensitivity of the aircraft. If you now add some turbulence, your control inputs can cause things to happen very quickly. As the pilot tends to tense up when flying in turbulence, it makes it difficult to apply small smooth control movements. So slow down when encountering turbulence.

One-off test pilot

If you fly the aircraft within the manufactures designed limitations you will become an old pilot.

If you fly the aircraft outside of the manufactures design limits, or ignore their cautions and advice, you become a test pilot for a short period, then you become a dead test pilot, taking your innocent passengers with you.

RHC are incredibly good at passing on information in their Safety Notices. They form a very important part of the Pilot's Operating Handbook – READ THEM.

One of the biggest problems the recreational pilot faces is the transition from their Non-Aviation World to their Helicopter World. They need to put their 'flying head' on. There are key opportunities for this transition to take place; preflight planning and preflight inspection, for example. Take your time, do a through job, take care, allow the transition to take place, build up to the flight. 'Think aviation'. Over 80% of the accidents in the Robinson are down to inappropriate pilot actions or inactions. Take responsibility for yourself, those that you take flying, their families and your family. I have often said that most accidents could have been prevented on the ground prior to take-off. Poor decisions are being made due to the absence of awareness, collated information or outside/self-induced pressures. However, without knowledge a realistic judgement of risk is not possible. Generally speaking, it is risk misperception and not risk tolerance that is associated with exposure to hazardous aviation events.

For what it is worth, my door is always open to those pilots wishing to discus the safe operation of the Robinson; I am more than willing to have a group of pilots come to Sywell and have a 'fly safely' morning or afternoon (my time is free). Further information on flight safety matters and operational procedures can be found on my website: *www.morningtonsanfordaviation.com*

Enjoy your flying, take responsibility for yourself and your passengers, keep your RPM in the green and I will keep harping on. ❑


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