Vortex RING state

by Mott Stanchfield

Vortex ring state (VRS), sometimes inexactly referred to as 'settling with power', is an insidious aerodynamic phenomenon that can form rapidly when the helicopter is operating out of ground effect and below effective translational lift airspeeds.

THE NAME belies the adversity that the VRS may cause a pilot if allowed to reach maturity. In my opinion, a matured VRS is the most hazardous condition that exists in the realm of helicopter aeronautics.

I once gave a flight demo in Fort Rucker, Alabama, to the commanding general and staff. The demo was to end with a precision autorotation to the ground. During the last few feet, the ship fell through the flare, even though the flare and collective inputs were correct and well coordinated. It was suspected that a slight tail wind was responsible. Couldn't have been the pilot!

In that situation, VRS instantly formed when a stable autorotative approach into the flare passed a massive inflow of air up through the rotor, coupled with the added pitch increase. This is a formula for VRS, the consequence of which was an instantaneous partially stalled rotor system. Such a phenomenon had never happened to me before, nor has it happened since, during many hundreds of autorotations.

All airfoils create tip vortices as they pass through the air. The rotor tip vortices are present throughout powered flight and form on the blade tips causing aerodynamic losses in rotor tip lift efficiencies. If the helicopter is brought to a hover and the pilot initiates a vertical or near vertical descent at an airspeed below translational lift, the aircraft will be descending into its own downwash, causing enlargement of the tip vortices, disrupting lift and increasing descent rate. This is now a serious VRS.

As the descent rate continues to increase, the natural instinct of a pilot unfamiliar with VRS procedures is to increase collective pitch. Increasing collective pitch rapidly increases tip vortices and descent rate. When the descent rate reaches the point where the descent air inflow exceeds the down flow of the inboard rotor blade sections, a second and expanding VRS is created.

With so much of the rotor stalled at this point, cyclic control becomes less effective. The only option remaining is to lower the collective and enter into an autorotation. The VRS is now reduced or destroyed, and cyclic control is restored. Once the airspeed is increased beyond translational lift, the aircraft can return to normal flight. Descent rates can range upwards to 8,000 ft per minute.

The following excerpt is from emails I received from Gary Arthur, a pilot flying for the South African Power Company. Gary is rightfully concerned about VRS. All of the pilots working for South African Power were well trained by the South African Air Force. Their work requires extensive hover out of ground effect (HOGE) and steep to vertical descents from altitudes around 300 ft AGL.

Gary says, *"We have approval from our Civil Aviation Authority to carry personnel underslung (slingload). The total length of the underslung is 80 ft. The heights of power lines range from 80 ft to 100 ft.*

There are times when we have to go live, when a linesman sits on the skid next to us and works on the live power line. This sometimes necessitates hovering with the blades between the ground wire and the actual conductor.

The linesman will attach a wand to the wire, which energizes the entire helicopter and makes very impressive sparks next to you. It certainly tends to grab your attention. The chap on the skid who goes live wears a liveline suit, which is composed of 25% steel. This protects him to a certain extent from the high-voltage corona, which feels like bee stings. The lines we work on range from 132 kilovolts to 765 kilovolts. These tend to hurt the live-line guys quite a bit."

I have included this email as a useful illustration, albeit an extreme one, of the critical nature of maneuvering at low airspeeds. Any rotor roughness and these guys are out of there!

To avoid VRS, it helps to know what conditions can lead to their formation.

1. Powered vertical or near-vertical descents with airspeeds below translational lift;
2. High altitudes near or beyond the helicopters HOGE ceiling;
3. Autorotational flares during power-on recoveries; or
4. Rarely, autorotational flares during power-off recoveries.

These are some of the conditions under which the VRS can establish itself.

It must be understood that once a VRS is formed and matured no amount of power will terminate or diminish it. Only by reducing collective pitch and increasing airspeed beyond translational lift can there be successful VRS termination and this takes sufficient altitude to accomplish. Exceptional attention should always be given to approaches when airspeeds are near or below translational lift. The pilot should, under these conditions, immediately address any abnormal rotor vibrations. ■