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Helicopter Ground Resonance

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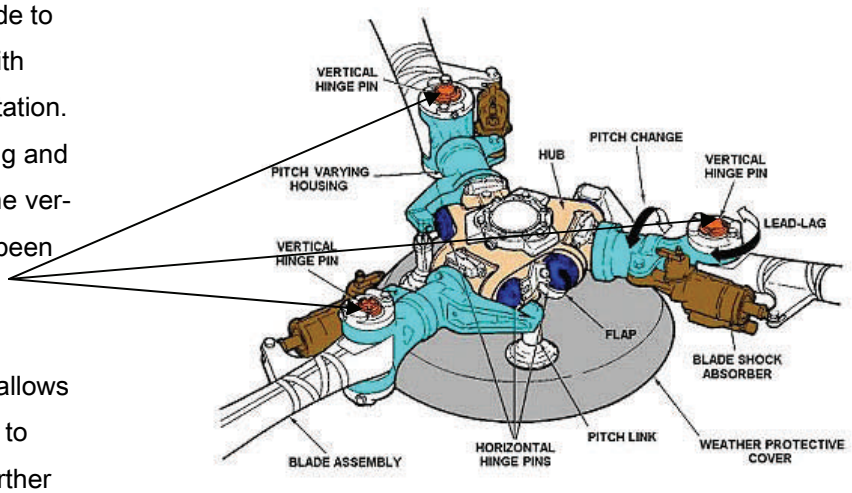
Ground Resonance

Ground resonance is one of the most dangerous situations a helicopter pilot can face. This emergency situation can result in the entire hull being ripped apart by the aircraft's own extreme oscillations. Ground resonance can be safely prevented, every pilot should know what the causes are, what to do if it does occur, and how to prevent an incident."

Ground resonance develops when the rotor blades move out of phase with each other and cause the rotor disc to become unbalanced. Ground resonance only occurs on helicopters with a fully articulated rotor system such as the Chinook, TH-55, OH-6 and MD500. Go to this INTERNET site to see a CH-47 destroy itself in ground resonance: http://video.google.com/videoplay?docid=-7722389053980760993&pl=true

On a fully articulated system the individual rotor blades use a lead-lag hinge at the rotor hub to allow a blade to catch up or slow down along its path to be in sync with the other blades. The term "fully-articulated" means that the rotor head allows the blade to move in three independent planes. A horizontal hinge pin allows the blade to move up and down. This is known as "flapping". Components within the pitch varying housing allow the blade to rotate about its span (the distance from end-to-end). This is known as "feathering". A vertical hinge pin allows the blade to swing forward and aft with respect to rotor-head rotation. This is known as "leading and lagging" (hunting). The vertical hinge pin has also been called the "drag hinge".



It is the drag hinge that allows any given pair of blades to either get closer to or farther away from each other. When the pair of blades get too close or too far away, the blades go out of sync and the balance of the entire rotor disk becomes off-center.

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When they fall out of sync this creates oscillations within the aircraft. This is because the center of gravity of the main rotor, acting as a flywheel, is displaced from in line with the axis of rotation, or the main rotor shaft., causing a “ wobble. ” In flight this causes no ill effect, however, if the skids or wheels are touching the ground, especially lightly, the wobble becomes exaggerated. If the frequency of these oscillations matches the helicopter’ s natural frequency, then ground resonance occurs. As each oscillation occurs, within seconds the amplitude increases until the aircraft has a hull breach.

Many modern helicopters implement measures to prevent ground resonance.
The U.S. Federal Aviation Administration defines ground resonance prevention as :

(a) The reliability of the means for preventing ground resonance must be shown either by analysis and tests, or reliable service experience, or by showing through analysis or tests that malfunction or failure of a single means will not cause ground resonance.

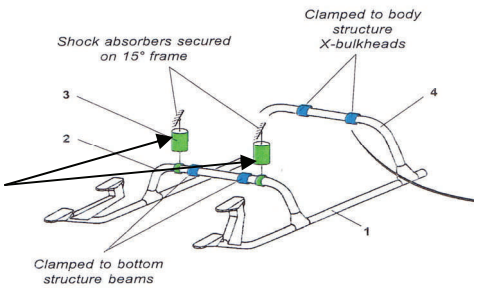
(b)

The probable range of variations, during service, of the damping action of the ground resonance prevention means must be established and must be investigated during the test required by 14 CFR Sec. 27.241 (U S) .

Common factors that may cause or aggravate ground resonance are:

- Unbalanced rotor head or blades
- Faulty blade tracking
- Damaged or malfunctioning lead-lag dampers
- Uneven oleo struts or tire pressures
- One-skid/wheel landing
- Hard landing or running takeoff /landing over rough ground
- Takeoff from, landing on or lightly touching, a pitching ship's deck

Being able to dampen the vibrations is the key to prevention. Implementation of shock struts, lead lag dampers, and properly inflated tires are among the solutions. One type of damper is described in the following quote from heli-chair.com. “ Ground resonance is mitigated...by employing the use of damping vibration isolators to attach the landing gear to the airframe. The

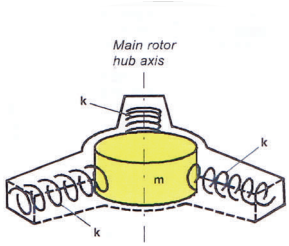


dampers are tuned to absorb energy at the proper frequencies of ground resonance and typically can prevent this destructive event. ” Proper maintenance of dampers is critical for safe flight.

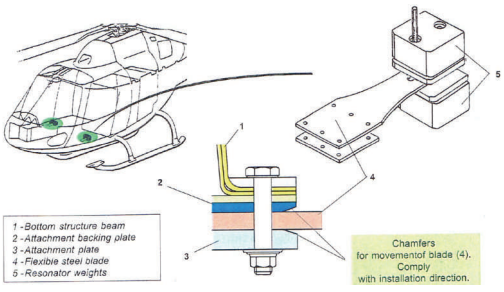
Ground resonance most often occurs when a helicopter is attempting to set down although it can occur while sitting on the ground although the rotor must be turning. The first step occurs when either the right or left skid or wheel touches down before the other side. The shaft normally is perpendicular with the hull of the helicopter but in this case it becomes tilted to one side of the aircraft, causing an out-of-balance condition. This loss of balance causes the rotor blades to fall out of their natural synchronization. This initial contact sends a shock to the main rotor shaft and throws off its center of gravity.

Also poorly maintained shock struts or low tire pressure can induce ground resonance. Landing gear shock absorbers between the aircraft body and landing skids are designed to attenuate any divergent vibration.

Various engineering arrangements are useful in intervening in the resonance scenario.



For example a Rotor Hub Vibration Absorber may be used to counteract divergent excitation vibrations in the rotor mast. The resonator acts on excitation loads at their source. A weight is located on the rotor hub axis and is held in place by 3 springs allowing it to vibrate. The weight/springs system is excited by the periodic cyclic loads on the rotor hub, and responds at the excitation frequency by counteracting the excitation load.



Another engineering intervention is a Cabin Resonators system, used to cancel out vibrations at the aircraft natural frequency, which is normally near three (3) Hertz . The cabin resonator acts on a principle of physics called the resonator principle. It acts by damping the aircraft vibration at the attachment point, thereby reducing the vibration level.

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Predicting ground resonance is difficult but possible. As the last intervention strategy the pilot must know what to do during a ground resonance emergency. If the pilot has maintained the rotor RPM within the normal operating range after touchdown, breaking contact with the ground is the best way to break free of a ground resonance incident. If there is not enough rotor energy (RPM) present then shutting down the helicopter, lowering collective reduces lift and the tendency for the individual blades to "hunt" is reduced. Reducing this hunting may allow the blades to return to their normal in-phase position. Engaging the rotor brake may stop the event before it becomes destructive. Guidance in the manufacture's operating instructions should be referenced for design-specific procedures.

The Canadian Aeronautics and Space Journal has an excellent report on this topic at:
http://pubs.nrc-cnrc.gc.ca/casj/q02-021.html

The American Institute of Aeronautics and Astronautics publishes
Influence of landing gear design on helicopter ground resonance :
http://www.aiaa.org/content.cfm?pageid=406&gTable=mtgpaper&gID=3006

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