Why Hovering Helicopters Are Unstable

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A hovering helicopter is unstable. The reason can be traced to the tendency of the rotor to flap back when forward speed is increased.

The phenomenon may be followed by first picturing a helicopter hovering in calm air when for some reason it is nosed down slightly and the pilot does nothing with his controls. The resulting sequence of events is shown in Figure 1:

![Figure 1: Hover Instability Sequence](image)

- **Start**—The forward tilt of the rotor produces a forward acceleration.
- **1 second**—The helicopter is moving forward, and as the rotor flaps back with respect to the shaft, it produces a nose-up pitching moment.
- **3 seconds**—Maximum nose-up flapping and pitch acceleration occur here. Pitch damping begins to reduce flapping.
- **5 seconds**—Maximum forward speed is attained. The fuselage is coming through the horizontal attitude with a nose-up pitching velocity.
- **6 seconds**—Flapping changes from nose-up to nose-down due to pitch damping. The pitch acceleration becomes negative, but pitch rate is still nose-up. Forward speed begins to decay due to the nose-up attitude of the rotor's tip-path plane.
- **9 seconds**—The forward speed is reduced to zero by the aft tilt of the rotor. The fuselage still has some residual nose-up pitching velocity due to its inertia, and it is tilted further nose-up than it was nose-down at the start.

**What it means**

The fact that the helicopter has a greater pitch angle when the velocity goes to zero than when it began means that the sequence will start all over going backward with greater acceleration than it had originally. This is the sign of an unstable system.

The degree of instability can be traced directly to the magnitude of the pitching moment caused by flapping. This is a function both of the height of the rotor above the center of gravity and the distance the flapping hinges are offset from the center of the hub. Thus the effect would be the smallest on a helicopter with a very low-placed teetering rotor. In fact, placing the rotor below the center of gravity can in some cases provide hover stability.

My first experience with hover instability was as a enthusiastic model-building teenager. Model Airplane News magazine published plans for a very lightweight rubber-powered, coaxial helicopter that had set a record in a large hangar. I modified the plans somewhat to make it more rugged and suitable for mid-winter flying in our living room. The two rotors on the model (Figure 2) were close together and a freewheeling empennage was installed.

My model was very unstable. It would make some wild gyrations and end up diving for the floor. In frustration, I gave it to my little brother. He—though clever in other ways—did a stupid thing. He wound it up backward!

Upon launching, it dove for the floor, but quickly turned over and ended up with its "tail" happily pressed against the ceiling until the motor ran down. I evoked a big brother's prerogative by taking it back and subsequently had many successful flights with my upside-down helicopter.

The aft-flapping tendency that produces instability in hover has the opposite effect in forward flight. Here it is a stabilizing influence and is known as "speed stability."

This is because an uncommanded increase in speed will cause the helicopter to pitch up and slow down. Since it will not slow down to zero, there is no bad effect as in hover.