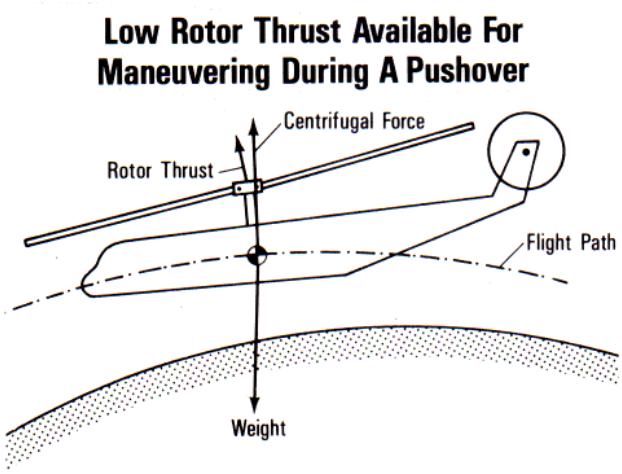
ACCIDENTS WAITING TO HAPPEN

MAST BUMPING

Juan de la Cierva's invention of the flapping hinge led to the successful development of rotary-winged aircraft--but it also opened the door to a variety of problems. The mechanical design and the geometry of the total aircraft dictate that the downward flapping--or teetering--must have some physical limit.

The designer tries to allow normal motions--plus some margin for abnormal motions--but, as per Murphy, "If anything can go wrong, it will."

Mast bumping occurs with two-bladed teetering rotors when the rotor teeters further than the designers allowed for. Most of these cases are caused by trying to maneuver with low rotor thrust. Since teetering rotors obtain pitch and roll control solely by tilting the thrust vector (exceptions are two-bladed rotors with hub springs such as on the Bell 222), control power depends entirely on maintaining load on the rotor.



Low rotor thrust may exist during "contour flying" when going over the top of a hill and then diving into the next valley. During this maneuver, the centrifugal force on the helicopter supports a large portion of its weight and so the rotor thrust can be small--or in extreme conditions zero or even negative.

A similar low thrust condition can exist following the reduction of collective pitch during an entry into autorotation.

If the helicopter begins to roll--perhaps because of tail rotor thrust--the pilot will tend to use corrective, lateral cyclic pitch, as he would do in normal flight. But in this situation of low rotor thrust, there will be little or no reaction so he will use more and more. Even at zero thrust, the rotor tip-path plane will happily respond to cyclic pitch inputs by teetering. As a matter of fact, it will override any mechanical limit by simply bending the blades since the aerodynamic effects are much stronger than the structural stiffness.

If the teetering being requested is more than the designers had in mind, mast bumping will result. Several accidents have occurred because the violent repeated pounding has broken the mast in flight.

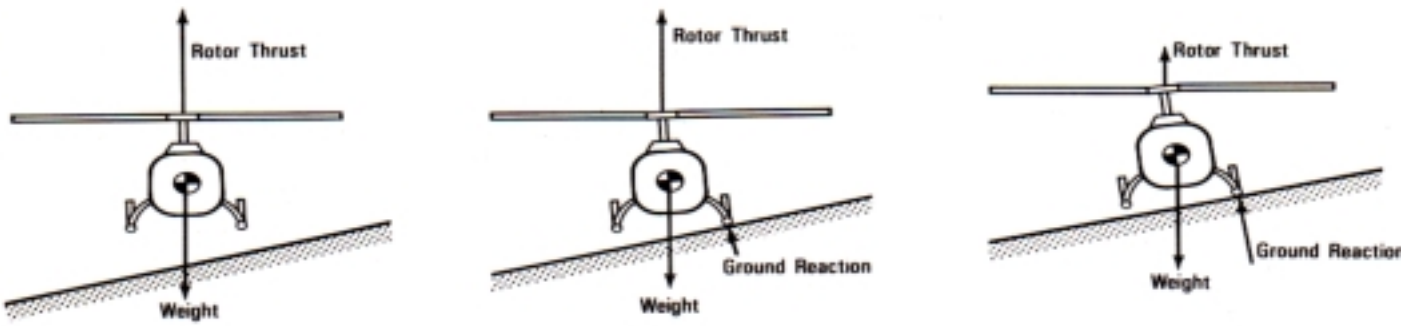
Operator's manuals and training guides for helicopters with teetering rotors recommend that the load factor should never be reduced to below 0.5--but very few helicopters are equipped with a g-meter.

Multi-bladed rotors with flapping hinges can experience a similar situation, but it is seldom so catastrophic. In this case, the result is "droop stop pounding." If the rotor has offset flapping hinges, it maintains a somewhat higher level of control power as rotor thrust is decreased. Thus the pilot will not be as tempted to use quite as much rotor tilt to perform the corrective action. At low thrust, a rotor with hinged blades does,

however, have a factor penalizing it, since the coning will be low and the blades will be closer to their droop stops than in normal straight and level flight.

Another condition in which mast bumping or droop stop pounding may occur is during a slope landing. This is especially true during the cautious planting of the downhill landing gear while trying to prevent the helicopter from sliding down hill as shown below. Takeoffs from a slope, on the other hand, can usually be done with less flapping by making a "hop-takeoff" at right angles to the slope. This will rapidly clear the landing gear.

Slope Landing Sequence



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