(4) Power-settling is an unstable condition. If allowed to continue, the sink rate reaches sufficient proportions for the flow to be up through a large portion of the rotor system. The rate of descent can reach extremely high rates. If a large amount of excess power is applied, recovery can begin during the early stages of power-settling. This excess power may be enough to overcome the upflow near the center of the rotor. If the sink rate reaches a higher rate, power will not be available to break this upflow and alter the vortex ring state of flow.

(5) Aviators tend to recover from a descent by applying collective pitch and power. If not enough power is available for recovery, applying collective pitch may aggravate power-settling. This results in more turbulence and a higher rate of descent. The aviator can recover by increasing airspeed and lowering collective pitch. Normally, increasing airspeed is the preferred method of recovery. Usually less altitude is lost by this method than by the method of lowering collective pitch. The two methods may be combined if altitude permits.

(6) In tandem-rotor helicopters, recovery should be attempted using lateral cyclic/pedal inputs to make the transition to directional flight. Fore and aft cyclic inputs may aggravate the situation.

6-22. RESONANCE

Certain helicopter designs are subject to sympathetic and ground resonance.

a. Sympathetic Resonance. Sympathetic resonance is the harmonic beat between the main- and tail-rotor systems and other components or assemblies, which might damage the helicopter. This type of resonance is not usually a problem because most helicopters have been designed so that the main and tail gearboxes are in odd decimal ratios. The beat of one component (assembly) cannot--under normal conditions--harmonize with the beat of another component; sympathetic resonance is thus not of immediate concern to the aviator. However, when resonance ranges are not designed out, the helicopter tachometer is appropriately marked and the resonance range must be avoided.

b. Ground Resonance. Ground resonance may develop in helicopters having fully articulated rotor systems when a series of shocks causes the rotor blades in the system to become positioned in unbalanced displacement. If this oscillating condition progresses, it can be self-energizing and extremely dangerous. Structural failure usually results. Ground resonance is most common to three-bladed helicopters with landing wheels. The rotor blades in a three-bladed helicopter are equally spaced (120 degrees) but are constructed to allow some horizontal lead and lag action. Ground resonance occurs when the helicopter contacts the ground during landing or takeoff (Figure 6-43). If one wheel of the helicopter strikes the ground ahead of the others, a shock is transmitted through the fuselage to the rotor. Another shock is transmitted when the next wheel hits. The first shock from ground contact, shown in part A, Figure 6-43, causes the blades straddling the contact point to jolt out of angular balance. If repeated by the next contact, shown in part B, Figure 6-43, a resonance is established; this sets up a self-energizing oscillation of the fuselage. The oscillation severity away from its ideal position at the center of the rotor head and force the main rotor shaft to oscillate in a circle that follows the offset C of G. Because the helicopter has less mass on the sides than fore and aft, this will be felt as a lateral shake as the oscillation is transferred to the fuselage. Both of these will be felt once per revolution.

For a rotor system operating at 360 RPM, the frequency corresponding to 1 per revolution is 6 Hz (360 RPM is 6 cycles per second). At 2 per revolution it is 12 Hz, and so on. As rotor RPM are changed, so are the frequencies, which can cause complications, which is why a constant speed is used.

Otherwise, vibrations fall into three ranges:

- *Low*, with large amplitude, between 100-400 cycles per minute, generally associated with loose or worn components, such as gearbox mountings
- *Medium*, 1,000-2000 cycles per minute, usually stemming from the main rotor. They can usually be felt through the cyclic. A *wumper* is one kick per revolution (*one per*), and a vertical one-per is usually caused by blade flying out of track (a vibration could also occur with blade passage). A vibration in the stick and fuselage is possibly from the rotors or their support system, particularly friction dampers. If it is felt in the controls only, look in the linkages. A low frequency vertical vibration that is only apparent in high speed flight is due to a badly adjusted trim tab on a main rotor blade. Note that, although a blade might be out of track, any vibration is the fuselage's response to it
- *High*, over 2000 cycles per minute, usually from the engine, but bad transmission bearings, especially from the tail rotor, will produce vibrations with frequencies related to the speed of the engine. Also look out for the tail rotor and other items that rotate at high speeds. Vibration through the tail rotor or yaw pedals may indicate wear in either the tail rotor gimbal or the pitch change link bearings

The most likely causes of rotor head vibration are *faulty drag dampers*, *incorrect blade tracking* and *blades of unequal weight or balance.* Vibration through the tail rotor or yaw pedals may indicate wear in either the tail rotor gimbal or the pitch change link bearings.

VIBRATION MONITORING

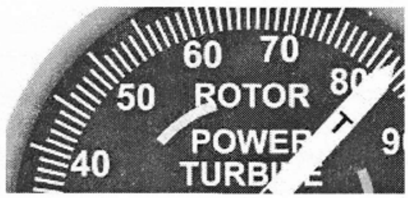
Vibration can be broken down into two basic components: *magnitude* and *frequency*. Magnitude encompasses *displacement*, *velocity*, *acceleration* and *jerk*, which you can measure through *transducers* or *sensors* (usually accelerometers), signal conditioning circuitry, preamplifiers that carry the signal, and digital processors that convert it to usable data and display equipment.

HUMS

Health & Usage Monitoring is a system of monitoring the components of a helicopter during its service with the intention of predicting when failures are likely, which is useful when you are a long way from home over the water. Safety and reliability are therefore increased, as well as operating costs being reduced, because more components will be able to be used for longer. In essence, data is gathered that can be used to modify maintenance and the helicopter's use on the fly. It's the meaningful interpretation and use of that data that is the critical factor.

RESONANCE

Most of the parts of a helicopter vibrate at their own natural frequency. *Sympathetic Resonance* is a harmonic beat created between components or assemblies that is usually designed out by making them run at different speeds, a common practice with tail rotor gearboxes. When vibrations cannot be designed out, look in the flight manual for ranges that should be avoided - you will often see yellow marks on the gauges on the instrument panel. For example, on the Bell 206, you should accelerate the rotors through 50-60% RRPM because the old one-piece tail rotor drive shaft (when fitted) will start to whip:



Ground Resonance

On the ground, vibrations will collect through the landing gear - if its natural vibration matches that of the main rotor, every time a blade rotates, the vibrations can receive another reflected pulse to increase their amplitude, which could cause the aircraft to rock back and forth and eventually tip over and be destroyed. This is especially problematical if the C of G of the rotor disc is away from the mast and creates a wobble, and if any damping effect from the undercarriage is not available (the oleos may be fully extended). Peculiar to helicopters with dragging hinges, Ground Resonance is indicated by an uncontrollable *lateral* oscillation (roll inertia is lower than for pitch) increasing rapidly in sympathy with rotor RPM.