blade must operate at a greater angle of attack. If the blade pitch is increased or the forward speed increased the stalled portion of the rotor disc becomes larger with the stall progressing in toward the hub from the tip of the retreating blade. When approximately 15 percent of the rotor disc is stalled, control of the helicopter will be impossible. Flight tests have determined that control becomes marginal and the stall is considered severe when the outer one-quarter of the retreating blade is stalled. Retreating blade stall can be recognized by rotor roughness, erratic stick forces, a vibration and stick shake with a frequency determined by the number of blades and the rotor speed. Each of the blades of a three-bladed rotor will stall as it passes through the stall region and create a vibration with three beats per rotor revolution. Other evidence of retreating blade stall is partial or complete loss of control or a pitch-up tendency which can be uncontrollable if the stall is severe.

Conditions favorable for the occurrence of retreating blade stall are those conditions that result in high retreating blade angles of attack. Each of the following conditions results in a higher angle of attack on the retreating blade and may contribute to retreating blade stall:

1. High airspeed
2. Low rotor RPM—operation at low rotor RPM necessitates the use of higher blade pitch to get a given thrust from the rotor, thus a higher angle of attack
3. High gross weight
4. High density altitude
5. Accelerated flight, high load factor
6. Flight through turbulent air or gusts—sharp updrafts result in temporary increase in blade angle of attack
7. Excessive or abrupt control deflections during maneuvers

Recovery from a stalled condition can be effected only by decreasing the blade angle of attack below the stall angle. This can be accomplished by one or a combination of the following items depending on severity of the stall:

1. Decrease collective pitch
2. Decrease airspeed
3. Increase rotor RPM
4. Decrease severity of accelerated maneuver or control deflection

If the stall is severe enough to result in pitch-up, forward cyclic to attempt to control pitch-up is ineffective and may aggravate the stall since forward cyclic results in an increase in blade angle of attack on the retreating blade. The helicopter will automatically recover from a severe stall since the airspeed is decreased in the nose high attitude but recovery can be assisted by gradual reduction in collective pitch, increasing RPM, and leveling the helicopter with pedal and cyclic stick.

From the previous discussion, it is apparent that there is some degree of retreating blade stall even at moderate airspeeds. However, the helicopter is able to perform satisfactorily until a sufficiently large area of the rotor disc is stalled. Adequate warning of the impending stall is present when the stall condition is approached slowly. There is inadequate warning of the stall *only* when the blade pitch or blade angle of attack is increased rapidly. Therefore, unintentional severe stall is most likely to occur during abrupt control motions or rapid accelerated maneuvers.

COMPRESSIBILITY EFFECTS. The highest relative velocities occur at the tip of the advancing blade since the speed of the helicopter is added to the speed due to rotation at this point. When the Mach number of the tip section of the advancing blade exceeds the critical Mach number for the rotor blade section, compressibility effects result. The critical Mach number is reduced by thick, highly cambered airfoils and critical Mach number decreases with increased lift coefficient. Most helicopter blades have symmetrical sections and therefore have relatively high critical Mach numbers at low lift coefficients. Since the principal effects of compressibility are the