

constant vibration tends to weaken the blade and eventually causes failure.

Aerodynamic Factors

To understand the action of a propeller, consider first its motion, which is both rotational and forward. Thus, as shown by the vectors of propeller forces in *Figure 7-9*, a section of a propeller blade moves downward and forward. As far as the forces are concerned, the result is the same as if the blade were stationary and the air coming at it from a direction opposite its path. The angle at which this air (relative wind) strikes the propeller blade is called angle of attack (AOA). The air deflection produced by this angle causes the dynamic pressure at the engine side of the propeller blade to be greater than atmospheric pressure, creating thrust.

The shape of the blade also creates thrust because it is shaped like a wing. As the air flows past the propeller, the pressure on one side is less than that on the other. As in a wing, this difference in pressure produces a reaction force in the direction of the lesser pressure. The area above a wing has less pressure, and the force (lift) is upward. The area of decreased pressure is in front of a propeller which is mounted in a vertical instead of a horizontal position, and the force (thrust) is in a forward direction. Aerodynamically, thrust is the result of the propeller shape and the AOA of the blade.

Another way to consider thrust is in terms of the mass of air handled. In these terms, thrust is equal to the mass of air handled multiplied by the slipstream velocity minus the velocity of the airplane. Thus, the power expended in producing thrust depends on the mass of air moved per second. On the average, thrust constitutes approximately 80 percent of the torque (total horsepower absorbed by the propeller). The other 20 percent is lost in friction and slippage. For any speed of rotation, the horsepower absorbed by the propeller balances the horsepower delivered by the engine. For any single revolution of the propeller, the

amount of air displaced (moved) depends on the blade angle, which determines the quantity or amount of mass of air the propeller moves. Thus, the blade angle is an excellent means of adjusting the load on the propeller to control the engine rpm. If the blade angle is increased, more load is placed on the engine, tending to slow it down unless more power is applied. As an airfoil is moved through the air, it produces two forces: lift and drag. Increasing propeller blade angle increases the AOA and produces more lift and drag; this action increases the horsepower required to turn the propeller at a given rpm. Since the engine is still producing the same horsepower, the propeller slows down. If the blade angle is decreased, the propeller speeds up. Thus, the engine rpm can be controlled by increasing or decreasing the blade angle.

The blade angle is also an excellent method of adjusting the AOA of the propeller. On constant-speed propellers, the blade angle must be adjusted to provide the most efficient AOA at all engine and airplane speeds. Lift versus drag curves, which are drawn for propellers as well as wings, indicate that the most efficient AOA is a small one varying from 2° to 4° positive. The actual blade angle necessary to maintain this small AOA varies with the forward speed of the airplane. This is due to a change in the relative wind direction, which varies with aircraft speed.

Fixed-pitch and ground-adjustable propellers are designed for best efficiency at one rotation and forward speed. In other words, they are designed to fit a given airplane and engine combination. A propeller may be used that provides the maximum propeller efficiency for takeoff, climb, cruising, or high speeds. Any change in these conditions results in lowering the efficiency of both the propeller and the engine. A constant-speed propeller, however, keeps the blade angle adjusted for maximum efficiency for most conditions encountered in flight. During takeoff, when maximum power and thrust are required, the constant-speed propeller is at a low propeller blade angle or pitch. The low blade angle keeps the AOA small and efficient with respect to the relative wind. At the same time, it allows the propeller to handle a smaller mass of air per revolution. This light load allows the engine to turn at high rpm and to convert the maximum amount of fuel into heat energy in a given time. The high rpm also creates maximum thrust. Although the mass of air handled per revolution is small, the engine rpm is high, the slipstream velocity (air coming off the propeller) is high, and, with the low airplane speed, the thrust is maximum.

After liftoff, as the speed of the airplane increases, the constant-speed propeller changes to a higher angle (or pitch). Again, the higher blade angle keeps the AOA small and efficient with respect to the relative wind. The higher blade angle increases the mass of air handled per revolution. This

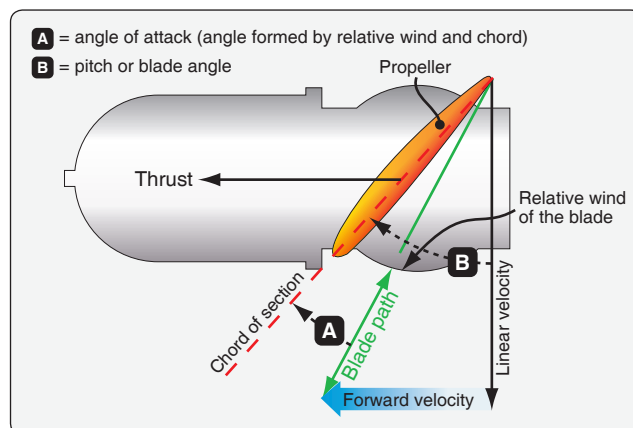


Figure 7-9. Propeller forces.