The acceleration of the airplane at any instant during takeoff roll is a function of the net accelerating force and the airplane mass. From Newton's second law of motion:

$$a = Fn/M$$

or

$$a = g(Fn/W)$$

where

$a$ = acceleration, ft. per se
$Fn$ = net accelerating force,
$W$ = weight, lbs.
$g$ = gravitational accelerat
= 32.17 ft. per sec.$^2$
$M$ = mass, slugs
= $W/g$

The net accelerating force on the airplane, $F_n$, is the net of thrust, $T$, drag, $D$, and rolling friction, $F$. Thus, the acceleration at any instant during takeoff roll is:

$$a = \frac{g}{W}(T - D - F)$$

Figure 2.32 illustrates the typical variation of the various forces acting on the aircraft throughout the takeoff roll. If it is assumed that the aircraft is at essentially constant angle of attack during takeoff roll, $C_L$ and $C_D$ are constant and the forces of lift and drag vary as the square of the speed. For the case of uniformly accelerated motion, distance along the takeoff roll is proportional also to the square of the velocity hence velocity squared and distance can be used almost synonomously. Thus, lift and drag will vary linearly with dynamic pressure ($q$) or $V^2$ from the point of beginning takeoff roll. As the rolling friction coefficient is essentially unaffected by velocity, the rolling friction will vary as the normal force on the wheels. At zero velocity, the normal force on the wheels is equal to the airplane weight but, at takeoff velocity, the lift is equal to the weight and the normal force is zero. Hence, rolling friction decreases linearly with $q$ or $V^2$ from the beginning of takeoff roll and reaches zero at the point of takeoff.

The total retarding force on the aircraft is the sum of drag and rolling friction $(D+F)$ and, for the majority of configurations, this sum is nearly constant or changes only slightly during the takeoff roll. The net accelerating force is then the difference between the powerplant thrust and the total retarding force,

$$Fn = T - D - F$$

The variation of the net accelerating force throughout the takeoff roll is shown in figure 2.32. The typical propeller airplane demonstrates a net accelerating force which decreases with velocity and the resulting acceleration is initially high but decreases throughout the takeoff roll. The typical jet airplane demonstrates a net accelerating force which is essentially constant throughout the takeoff roll. As a result, the takeoff performance of the typical turbojet airplane will compare closely with the case for uniformly accelerated motion.

The pilot technique required to achieve peak acceleration throughout takeoff roll can vary considerably between airplane configurations. In some instances, maximum acceleration will be obtained by allowing the airplane to remain in the three-point attitude throughout the roll until the airplane simply reaches lift-equal-to-weight and flies off the ground. Other airplanes may require the three-point attitude until the takeoff speed is reached then rotation to the takeoff angle of attack to become airborne. Still other configurations may require partial or complete rotation to the takeoff angle of attack prior to reaching the takeoff speed. In this case, the procedure may be necessary to provide a smaller retarding force $(D+F)$ to achieve peak acceleration. Whenever any form of pitch rotation is necessary the pilot must provide the proper angle of attack since an excessive angle of attack will cause excessive drag and hinder (or possibly preclude) a successful takeoff. Also, insufficient rotation may provide added rolling resistance or require that the airplane accelerate to some excessive speed prior to becoming airborne.