lower surface lifts act along the same vertical line. An increase in lift on the symmetrical airfoil produces no change in this situation and the center of pressure remains fixed at the aerodynamic center.

The location of the aerodynamic center of an airfoil is not affected by camber, thickness, and angle of attack. In fact, two-dimensional incompressible airfoil theory will predict the aerodynamic center at the 25 percent *chord* point for any airfoil regardless of camber, thickness, and angle of attack. Actual airfoils, which are subject to real fluid flow, may not have the lift due to angle of attack concentrated at the exact 25 percent chord point. However, the actual location of the aerodynamic center for various sections is rarely forward of 23 percent or aft of 27 percent chord point.

The moment about the aerodynamic center has its source in the relative pressure distribution and requires application of the coefficient form of expression for proper evaluation. The moment about the aerodynamic center is expressed by the following equation:

$$M_{a.c.}=C_{M_{a.c.}}\,qSc$$

where

$M_{a.c.}$ = moment about the aerodynamic center, a.c., ft.-lbs.

$C_{M_{a.c.}}$ = coefficient of moment about the a.c.

q = dynamic pressure, psf

S = wing area, sq ft.

c = chord, ft.

The moment coefficient used in this equation is the dimensionless ratio of the moment pressure to dynamic pressure moment and is a function

$$C_{M_{a.c.}}=\frac{Ma.c.}{qSc}$$

of the shape of the airfoil mean camber line. Figure 1.22 shows the moment coefficient, $c_{m_{a.c.}}$ versus lift coefficient for several representative sections. The sign convention applied to moment coefficients is that the nose-up moment is positive.

The NACA 0009 airfoil is a symmetrical section of 9 percent maximum thickness. Since the mean line of this airfoil has no camber, the coefficient of moment about the aerodynamic center is zero, i.e., the c.p. is at the a.c. The departure from zero $c_{m_{a.c.}}$ occurs only as the airfoil approaches maximum lift and the stall produces a moment change in the negative (nose-down) direction. The NACA 4412 and 63_1–412 sections have noticeable positive camber which cause relatively large moments about the aerodynamic center. Notice that for each section shown in figure 1.22, the $c_{m_{a.c.}}$ is constant for all lift coefficients less than $c_{l_{max}}$.

The NACA 23012 airfoil is a very efficient conventional section which has been used on many airplanes. One of the features of the section is a relatively high $c_{l_{max}}$ with only a small $c_{m_{a.c.}}$ The pitching moment coefficients for this section are shown on figure 1.22 along with the effect of various type flaps added to the basic section. Large amounts of camber applied well aft on the chord cause large negative moment coefficients. This fact is illustrated by the large negative moment coefficients produced by the 30° deflection of a 25 percent chord flap.

The $c_{m_{a.c.}}$ is a quantity determined by the shape of the mean-camber line. Symmetrical airfoils have zero $c_{m_{a.c.}}$ and the *c.p.* remains at the *a.c.* in unstalled flight. The airfoil with positive camber will have a negative $c_{m_{a.c.}}$ which means the *c.p.* is behind the *a.c.* Since the $c_{m_{a.c.}}$ is constant in unstalled flight a certain relationship between lift coefficient and center of pressure can be evolved. An example of this relationship is shown in figure 1.22 for the NACA 63_1–412 airfoil by a plot of *c.p.* versus c_l. Note that at low lift coefficients the center of pressure is well aft—even past the trailing edge—and an increase in c_l moves the *c.p.* forward toward the *a.c.* The *c.p.* approaches the