4 Initial stability

The metacentre relates to extremely small angles of heel, and its position depends on the displacement volume of the hull and on the area of the waterplane at which she floats. The term metacentric radius is used in connection with greater angles of heel and is conventionally known as BM.

Without going into details by working an example, we can say that metacentric radius is the quotient of the transverse moment of inertia of the waterplane, I_x, and the displacement volume of the hull, ∇, i.e. $r = I_x/\nabla$, and that the value of initial $r - a$ (metacentric height $\overline{GM}$) indicates the boat's initial stability.

Because the transverse moment of inertia of the waterplane is a function of the cube of waterline beam, it is clear that the metacentric radius will increase as waterline beam increases and as displacement decreases. This is typical of lightweight dinghies and, especially, of multihulls.

It would be tempting to choose a high $\overline{GM}$ value so as to obtain maximum stability at those angles where it is most beneficial for performance, but this should not be overdone because it would result in the boat having an unpleasant motion in a cross sea, with a very short period of roll and very jerky movements. We will return to this point in Chapter VIII.

Because the moment of inertia increases to the power of 4, while volume only increases as the cube, metacentric height should increase linearly. In fact, however, the length/beam ratio decreases with size, but the metacentric height varies much more slowly and values can be taken as ranging from 0.90 m for a boat with a waterline length of 5 m to 1 m or 1.20 m at 15 m.

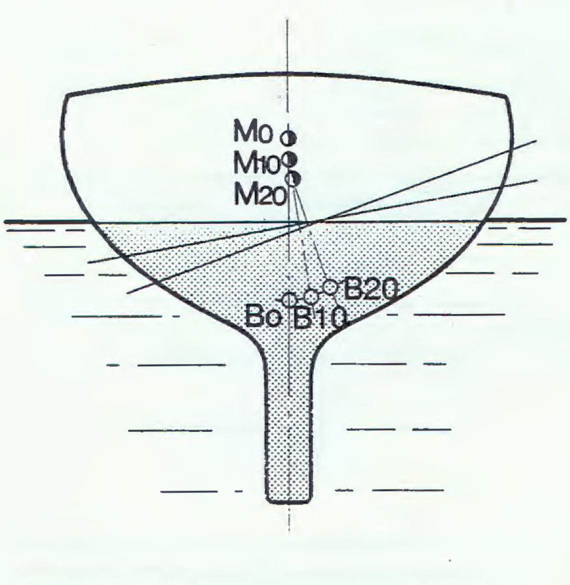

Figure IV.6 *As the centre of buoyancy shifts, the metacentre follows its own path.*

5 B, M, F and Z curves

When the boat's angle of heel changes from θ_n to one that is infinitessimally greater θ_{n+1}, its section pivots about a new metacentre M_n (fig. IV.6). As the section performs a complete rotation, the centre of buoyancy B and the metacentre M follow paths that can be traced in the transverse plane. Because a sailing boat is symmetrical in shape, the curves will be symmetrical either side of the vertical axis; they will also be closed, that is to say that the starting and finishing points of the curves coincide.

The B curve of buoyancy is generally convex, regular and nearly an ellipse, whereas the metacentric curve M, that of the metacentric radius, may reverse sharply in direction (fig. IV.7). The peaks that interrupt the smooth line of the M curve indicate particular positions, such as the immersion of the edge of the deck or of the superstructure, and the emergence of the fin keel. Apart from these special points, which sometimes need closer study, the remainder of the curves can be drawn by plotting points corresponding to 10–30° changes in the angle of heel.

A line normal to the curve of buoyancy, corresponding to a given angle of heel θ_h, is tangential to the M curve at the corresponding point M_n. B_nM_n is the metacentric radius at angle θ_n.

When the shape of the section is simple, as in fig. IV.7, waterline beam and, consequently, the corresponding moment of inertia and the metacentric radius BM are least at an angle of heel of about 100–110°. A reversal of the metacentric curve corresponds to that angle of heel (fig. IV.8a).

If the shape is more complex, and for example includes a keel or a coachroof, the metacentric radius will increase and decrease in turn, and a reversal of the metacentric curve will occur on each occasion (fig. IV.8b).

In the case of a sailing boat, the metacentric radius BM generally has a maximum value when $\theta = 0$ and 180°, and a minimum value when θ = about 90°, and the completed curve looks like a curvilinear lozenge, rather similar to an ace of diamonds (fig. IV.8a). However, when the sections are so shaped that waterline beam increases initially as the boat starts to heel, the curved lozenge can become convex in shape.

If the value of BM is maximum not when $\theta = 0$ and 180°, but at an intermediate angle (for example in the case of boats with small waterline beam), the trace will curve the opposite way initially before reversing at an angle of heel that corresponds to maximum BM (fig. IV.9b). This is typical of most boats designed for an IOR Mk III rating, when low initial stability is required so as to reduce the CGF as much as possible. The boat's stability increases as soon as she heels, and this shows how inefficient this method of measuring is when it comes to determining the real value of stability (fig. IV.9).