Stability of a Floating Body

The stability of a floating body is more complex than that for a **submerged body**. For a wholly submerged body, the center of volume and therefore the center of buoyancy remains fixed within a framework fixed in the body and therefore the moment causing a return to or departure from equilibrium is relative easily evaluated. However, as the orientation of a floating body changes, the shape of the displaced body of fluid changes and therefore the location of the center of buoyancy shifts even in a framework fixed in the body. This makes the evaluation of stability more difficult. One of the major differences between a submerged and floating body is the fact that a submerged body is always unstable when the center of mass is above the center of buoyancy; in contrast, this configuration is often stable in the case of a floating body.

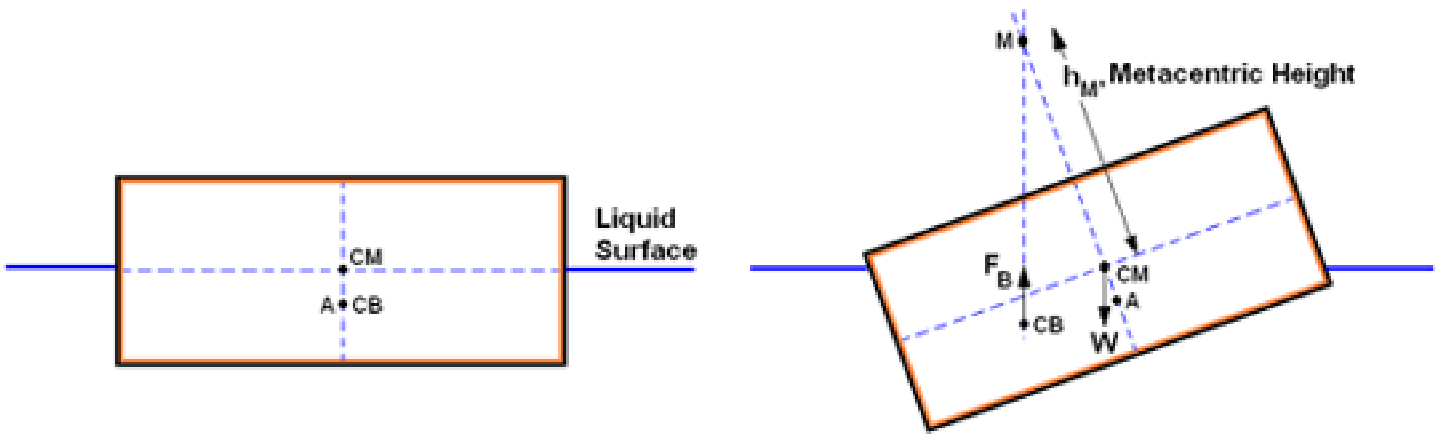

Figure 1: The stability of a floating body (CB = center of buoyancy, CM = center of mass, M = metacenter, A = CB in level orientation).

The basic geometric features are shown in Figure 1 where the floating body on the left is shown tilted in the right-hand diagram. Note that when the floating body is tilted, the displaced volume below the waterline changes and, in the case sketched, there is much more displaced volume on the left side of the boat. Consequently, as shown, the center of the displaced volume, the center of buoyancy, CB, is no longer at the original location A but has moved to the left. If the shape of the floating body is such that CB moves to a position to the left of the center of mass, CM, then the resulting moment due to the weight, W, and the buoyancy force, F_B, is stabilizing and tends to return the boat to its original orientation. (If this shift in CB had not occurred the buoyancy force would act though the point A and the orientation shown would be unstable).

The location of the tilted center of buoyancy, CB, is a function of the shape of the body below the waterline and can be calculated by breaking the displaced volume into convenient simple pieces, identifying the centers of each of these component volumes and then using the usual rules for finding the center of volume for the combination. One specific way of doing this is by identifying the added volume on one side caused by the tilt and the subtracted volume on the other side and combining these positive and negative volumes with the displaced volume in the horizontal orientation.

It is convenient and conventional to present the result of this calculation by identifying the position of the metacenter which is the intersection of a vertical through the center of buoyancy with the centerline of the boat. The distance from the center of mass to the metacenter is called the "metacentric height". For a given boat geometry, this height will be independent of the angle of tilt provided that angle is small; non-linear effects will cause it to begin to change at larger angles of tilt. Clearly the higher the metacenter, the more stable the boat since the moment arm of the correcting moment will be linearly proportional to the metacentric height. In vessels like lifeboats that have to be very stable, considerable effort is expended to make the metacentric height as large as possible.