

Outcome 2

LESSON 8

Curves of Statical Stability for varying conditions of stability



Martin Rhodes
Faculty of Maritime Studies
GCNS

CURVES OF STATICAL STABILITY FOR VARYING CONDITIONS OF STABILITY

1. Curve of statical stability for a ship in a stable condition

A ship is in a stable condition of stability if, when heeled by an external force in still water to a small angle of inclination, it returns to the upright when the force is removed.

Consider the ship shown being progressively inclined from the upright.

Figure 1

$KM - KG = GM$; which is *positive*.

GZ is *zero*.

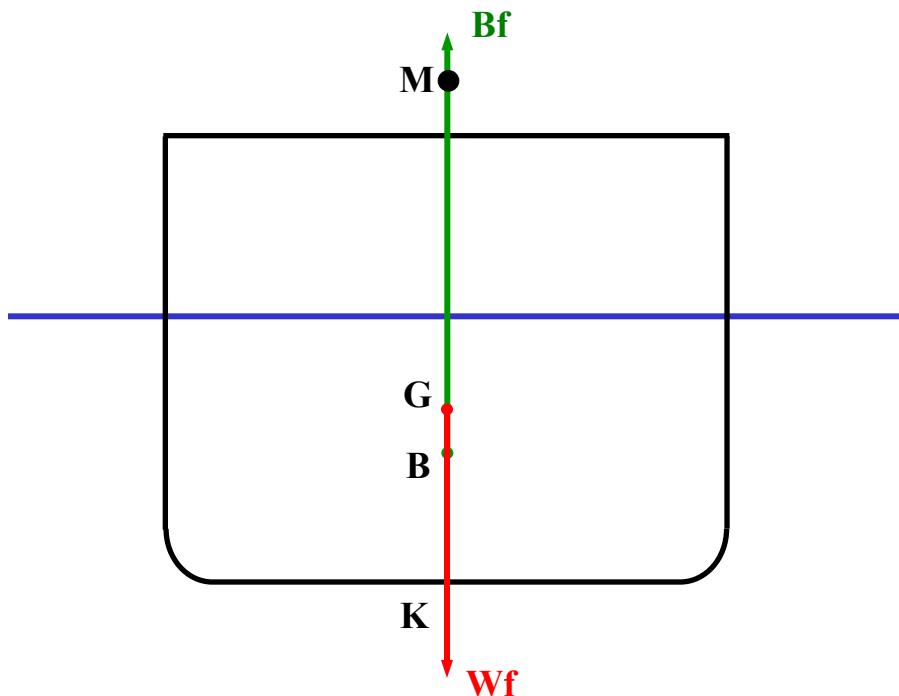
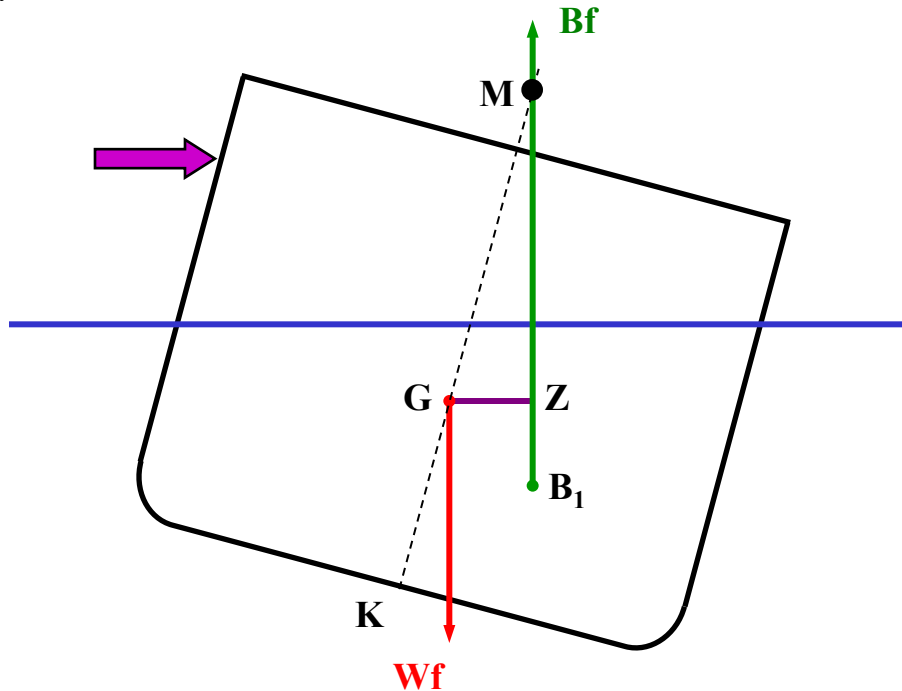


Figure 2

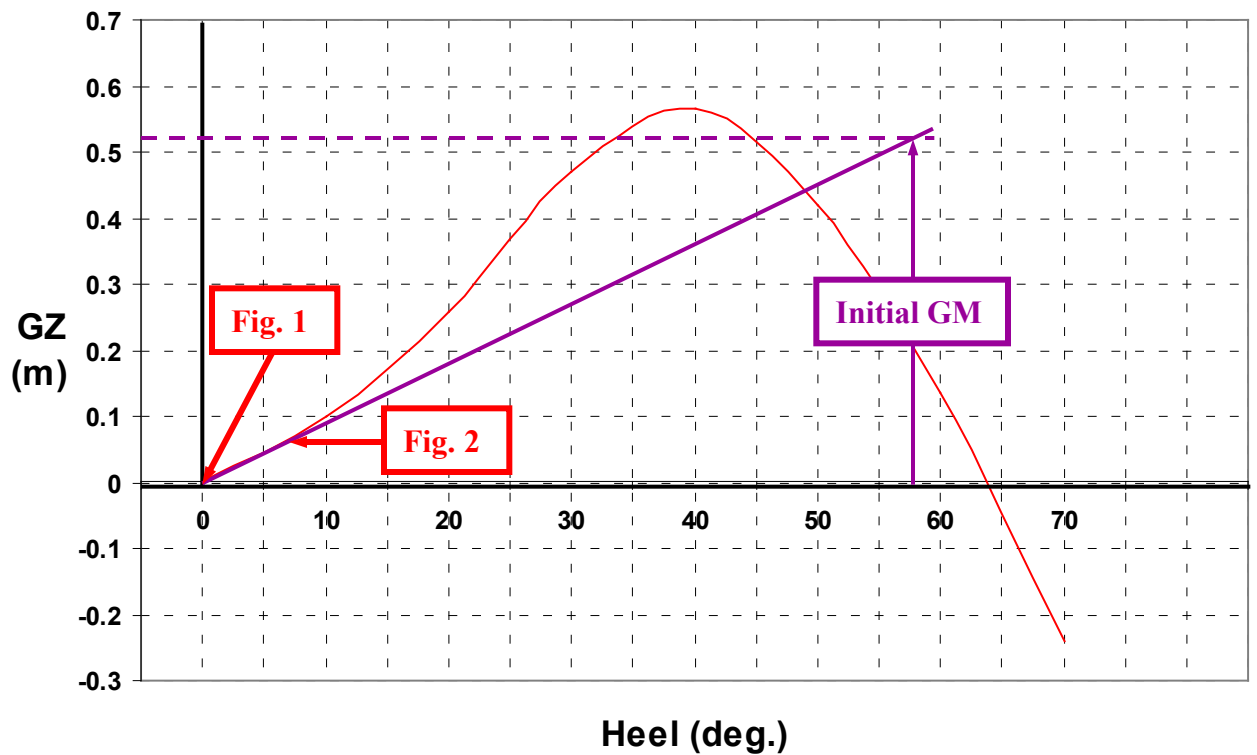
The ship is now heeled by an external force to a *small angle* of inclination.

GZ is *positive*, which will act to right the ship when the force is removed.



A typical curve of statical stability for a stable ship will be as shown. Figures 1 and 2 are related to the curve as indicated.

Curve of statical stability for a STABLE SHIP



2. Curve of statical stability for a ship in a neutral condition of stability

A ship is in a neutral condition of stability if, when heeled by an external force in still water to a small angle of inclination, it comes to rest at some indeterminate angle of heel within small angles of inclination.

Consider the ship shown being progressively inclined from the upright.

Figure 1

$$KM - KG = 0; \quad GM = 0$$

GZ is *zero*.

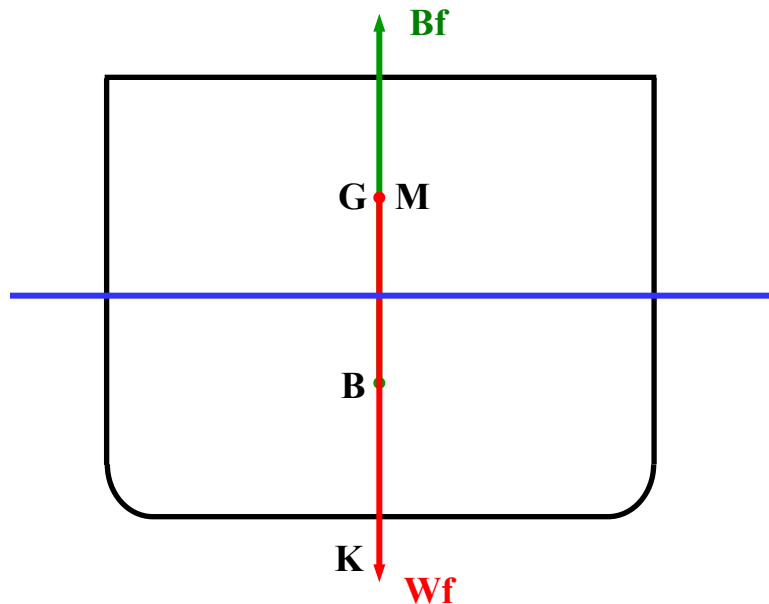


Figure 2

The ship is now heeled by an external force to a *small angle* of inclination.

GZ is still *zero*.

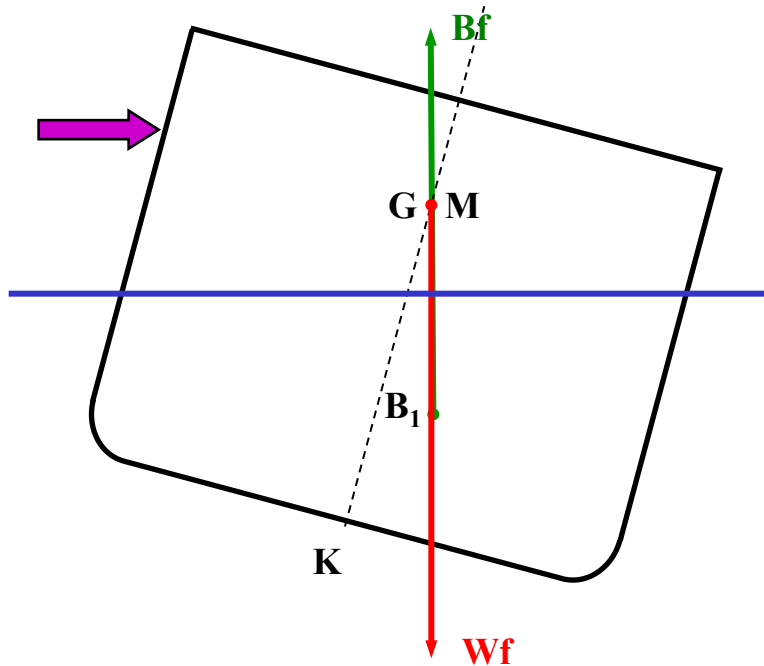
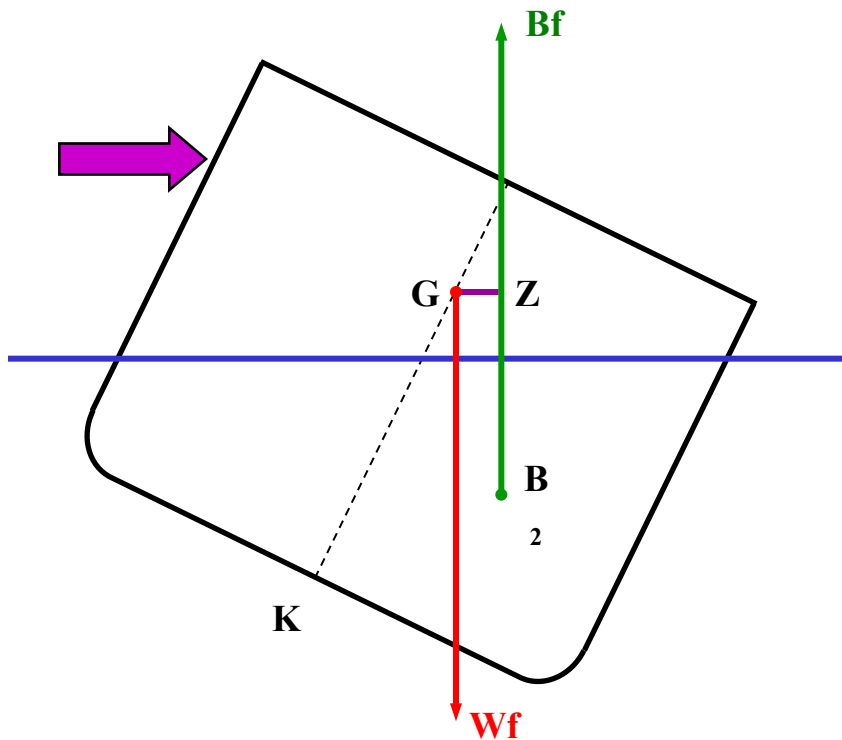


Figure 3

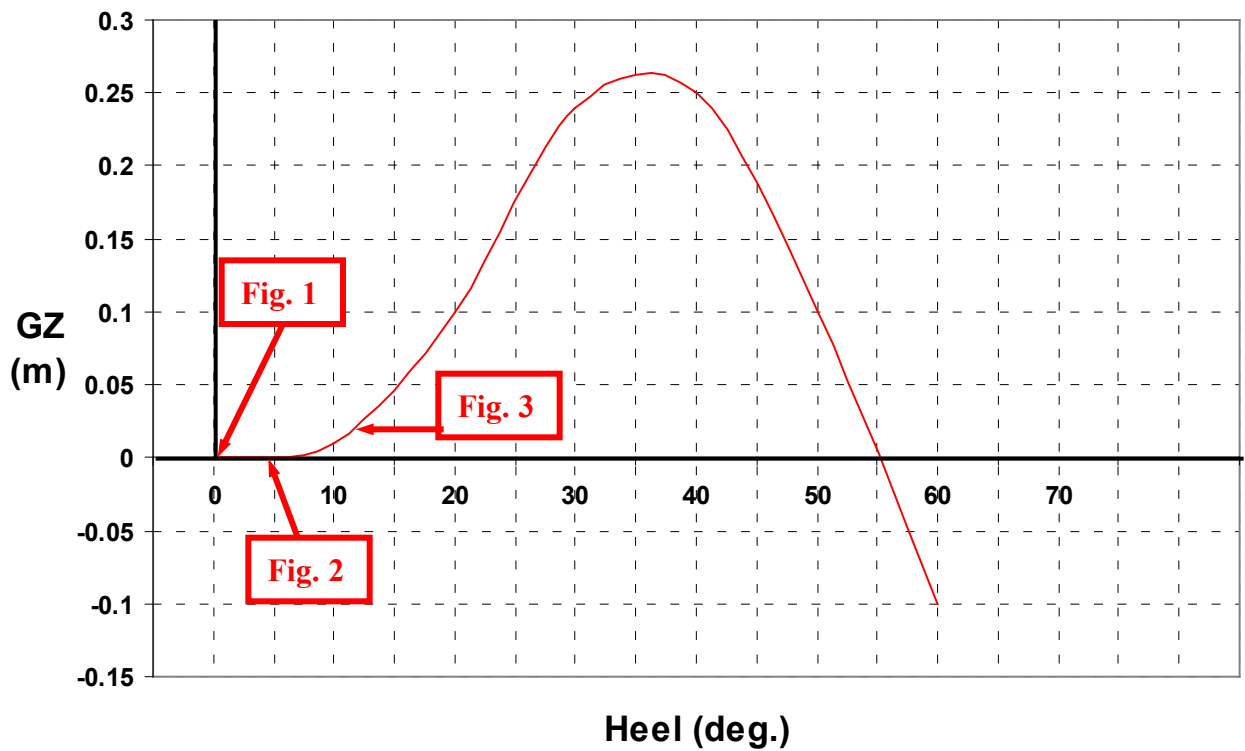
The ship is now heeled beyond small angles of heel.

GZ becomes *positive* and the curve now departs from the tangential line drawn from the origin. The initial transverse metacentre no longer applies to the ship since it is now heeled to a large angle.



A typical curve of statical stability for a ship in a neutral condition of stability will be as shown. Figures 1, 2 and 3 are related to the curve as indicated.

Curve of statical stability for a NEUTRAL CONDITION ship



Note

Since $GM = 0$, the x-axis of the graph is also the tangent along which the GZ curve initially follows.

3. Curve of statical stability for a ship in an unstable condition

A ship is in an unstable condition if, when heeled by an external force in still water to a small angle, it continues to heel further when the external force is removed.

Consider the ship shown being progressively inclined from the upright.

Figure 1

$KM - KG = GM$; which is a *negative* value.

GZ is *zero*.

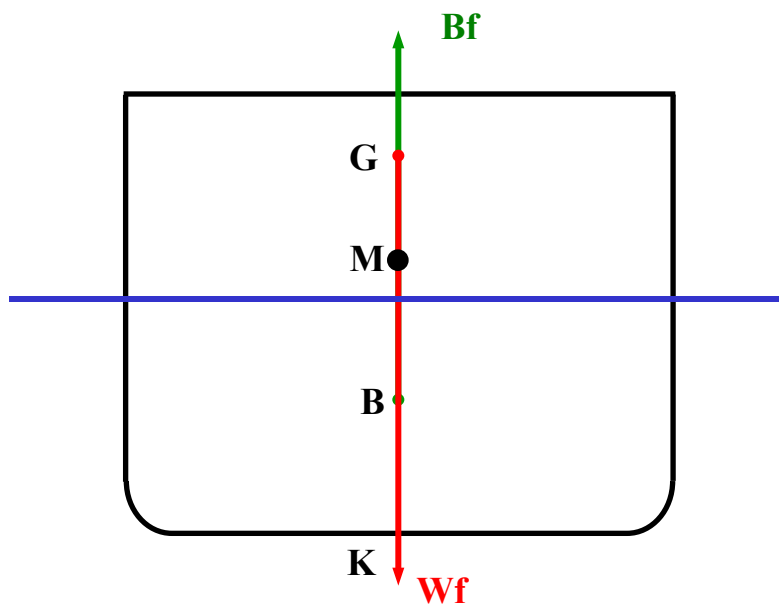


Figure 2

The ship is now heeled by an external force to a *small angle* of inclination whereby the line of action of the buoyancy force (B_f) still passes through the initial transverse metacentre (M).

GZ is *negative*; it represents a *capsizing* lever.

(If the external force is now removed the ship would continue to heel further over!)

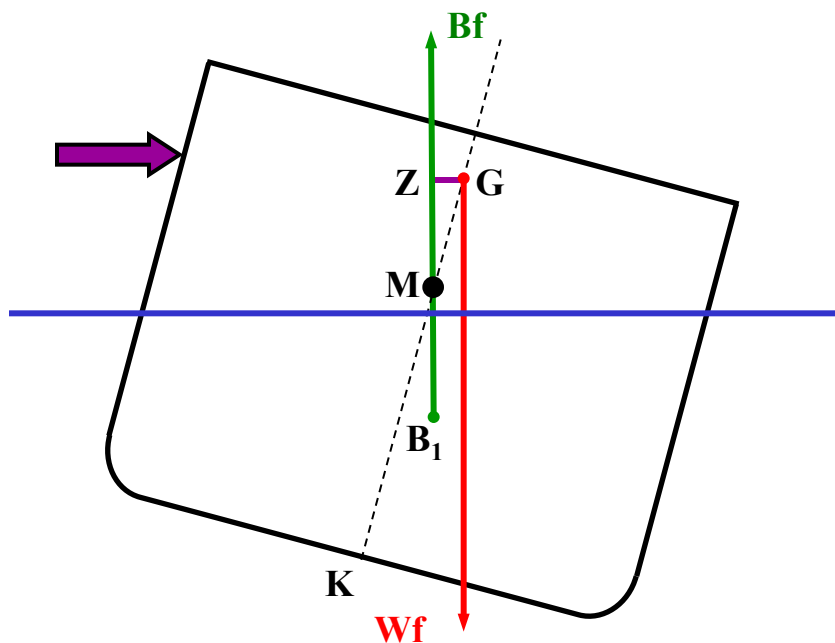


Figure 3

The ship continues to heel over until B attains a position vertically below G as shown. It is now that the ship comes to rest at an *angle of loll*.

When lying at an angle of loll:

GZ is *zero*.

The angle of loll is a *large angle of heel* since the line of action of the buoyancy force (Bf) is no longer passing through the initial transverse metacentre (M).

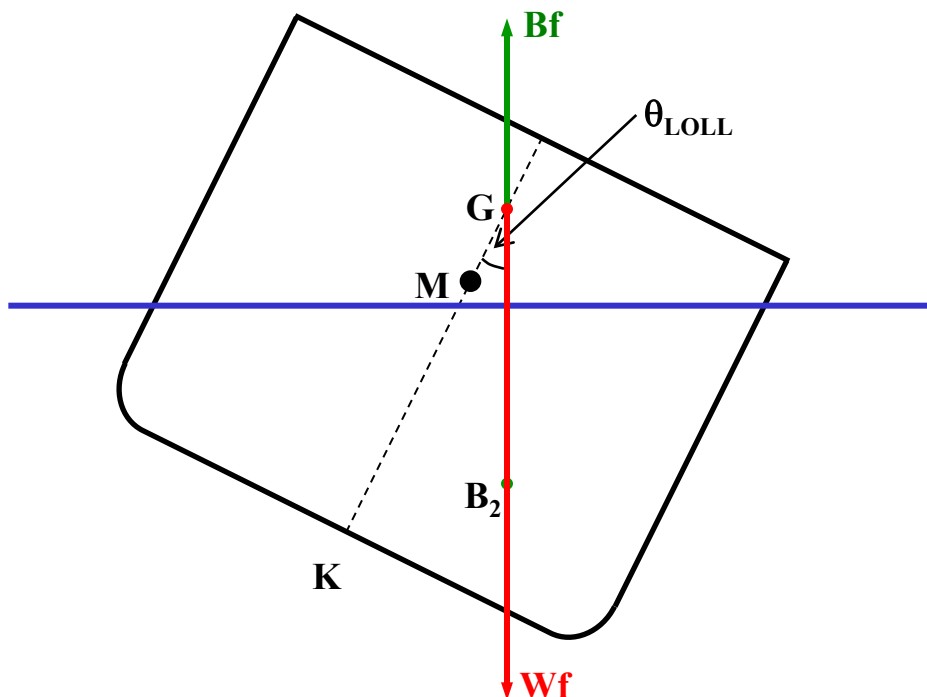
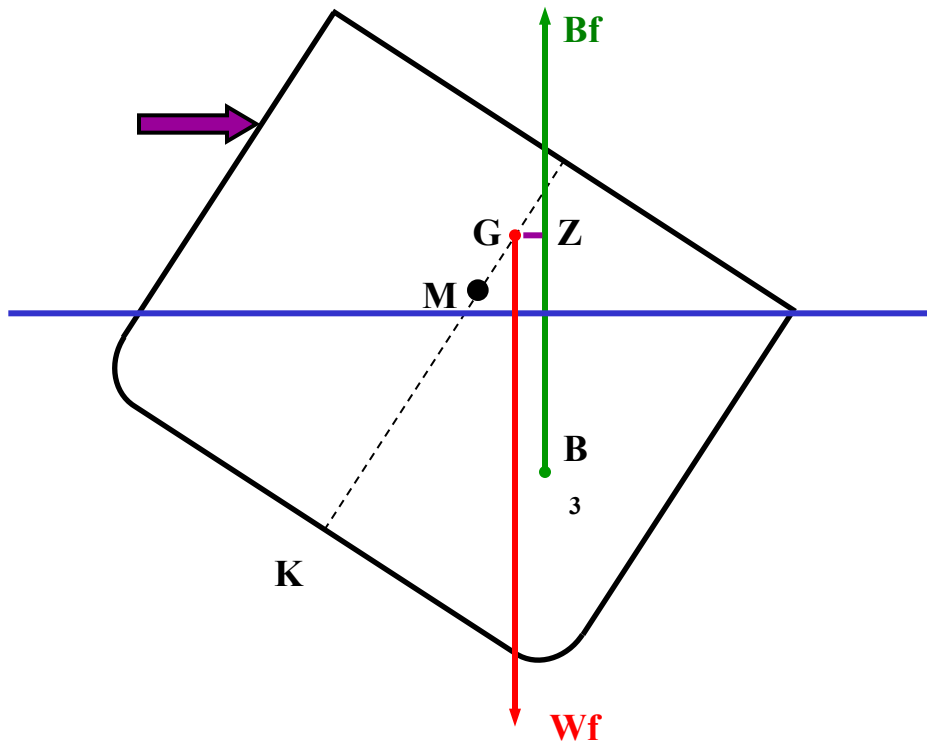


Figure 4

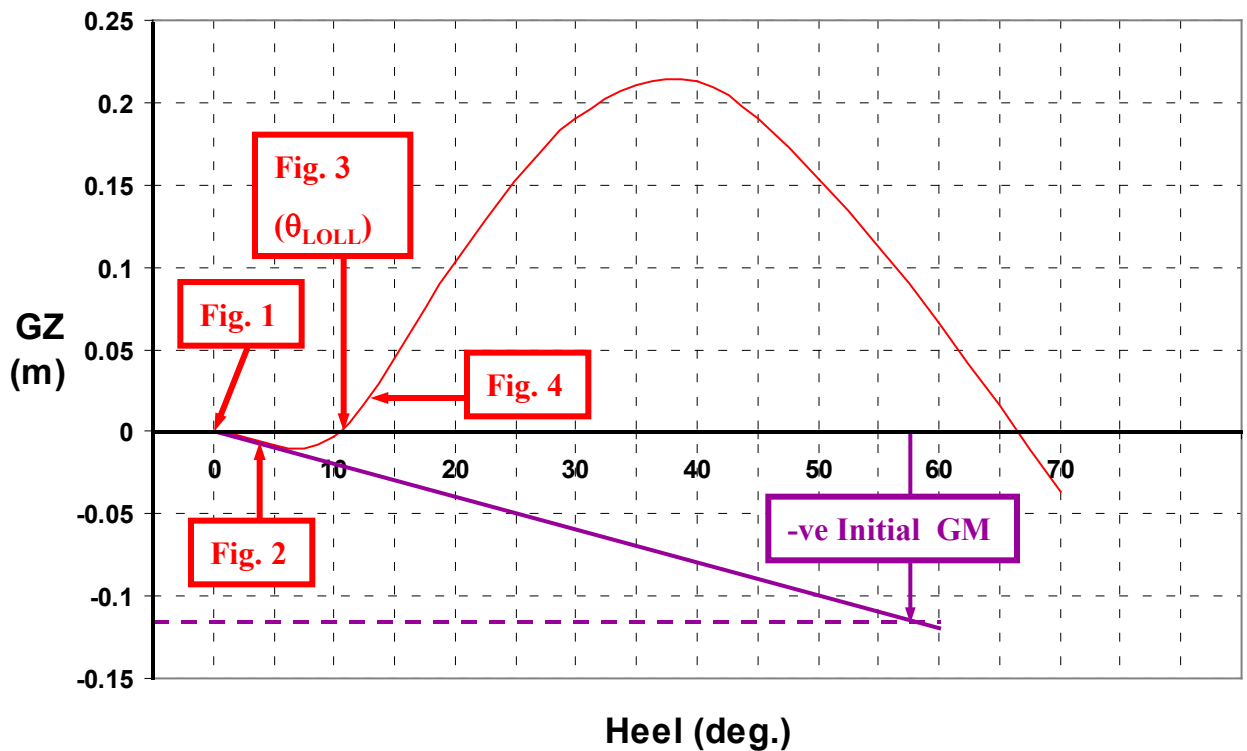
If the ship is heeled further by an external force B moves outboard of G.

GZ is now *positive* which will act to right the ship back to the angle of loll.



A typical curve of statical stability for a ship in an unstable condition of stability will be as shown. Figures 1, 2, 3 and 4 are related to the curve as indicated.

Curve of statical stability for an UNSTABLE ship



Note

Since GM is negative, the tangent along which the GZ curve initially follows runs **below** the base. As the vessel heels over to larger angles of inclination the GZ curve departs from the tangent and where it crosses the base is the angle of loll (approximately 11° in this case). In theory this could be to the port or the starboard side since G is assumed to be on the centre-line whereby port and starboard moments are equal.

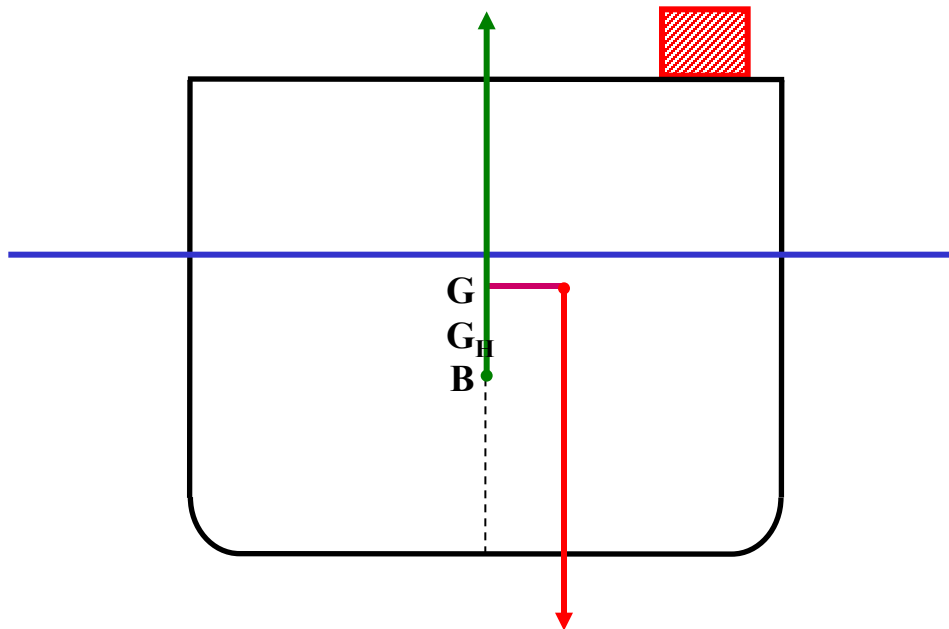
4. Curve of statical stability for a ship that is listed

When a ship is listed the centre of gravity of the ship is off the centre-line to port or starboard by a distance we have termed GG_H .

Figure 1

Consider the ship shown that has G off the centre-line to starboard that is initially in the upright condition.

GG_H represents a *capsizing lever*; a *negative* value of GZ .



The ship will start to list over.

Figure 2

As the ship lists over the capsizing lever caused by G being off the centre-line becomes less and less.

$G_H Z$ is *negative*.

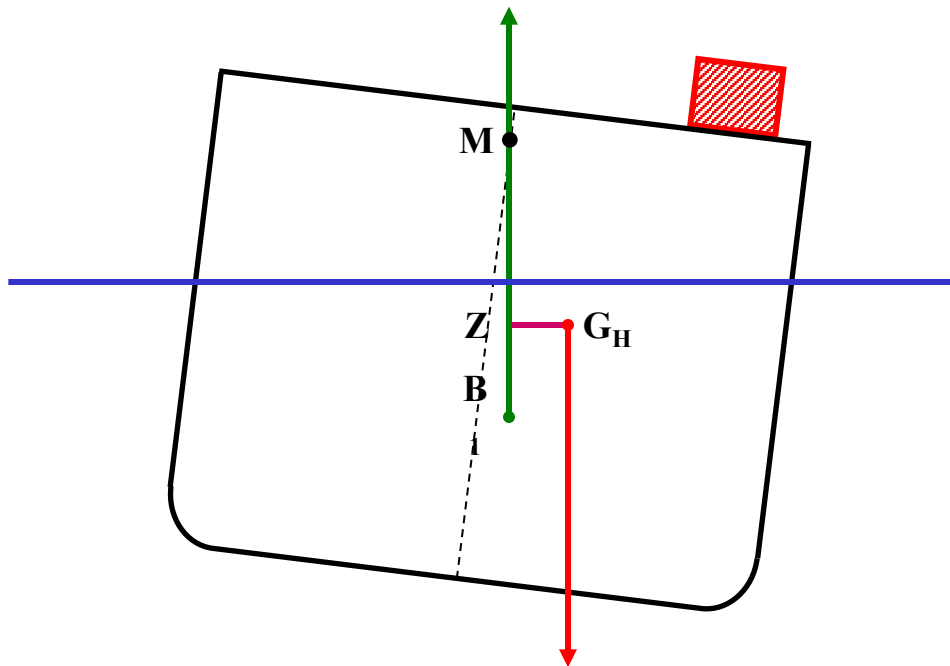


Figure 3

The ship will come to rest at an angle of *list* when B reaches a position vertically below the centre of gravity (G_H).

GZ is *zero*.

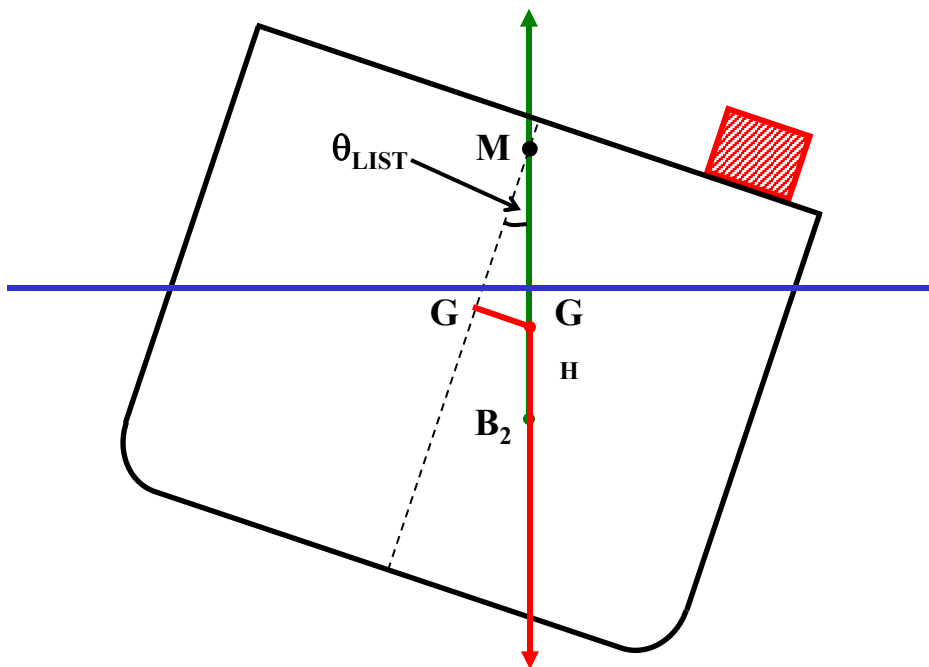
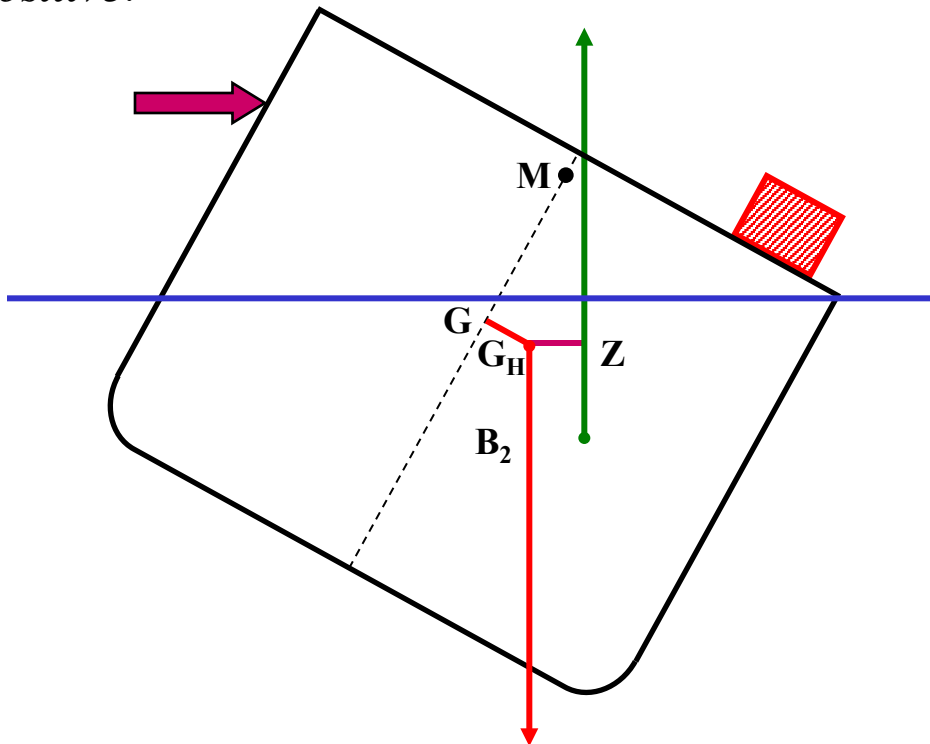


Figure 4

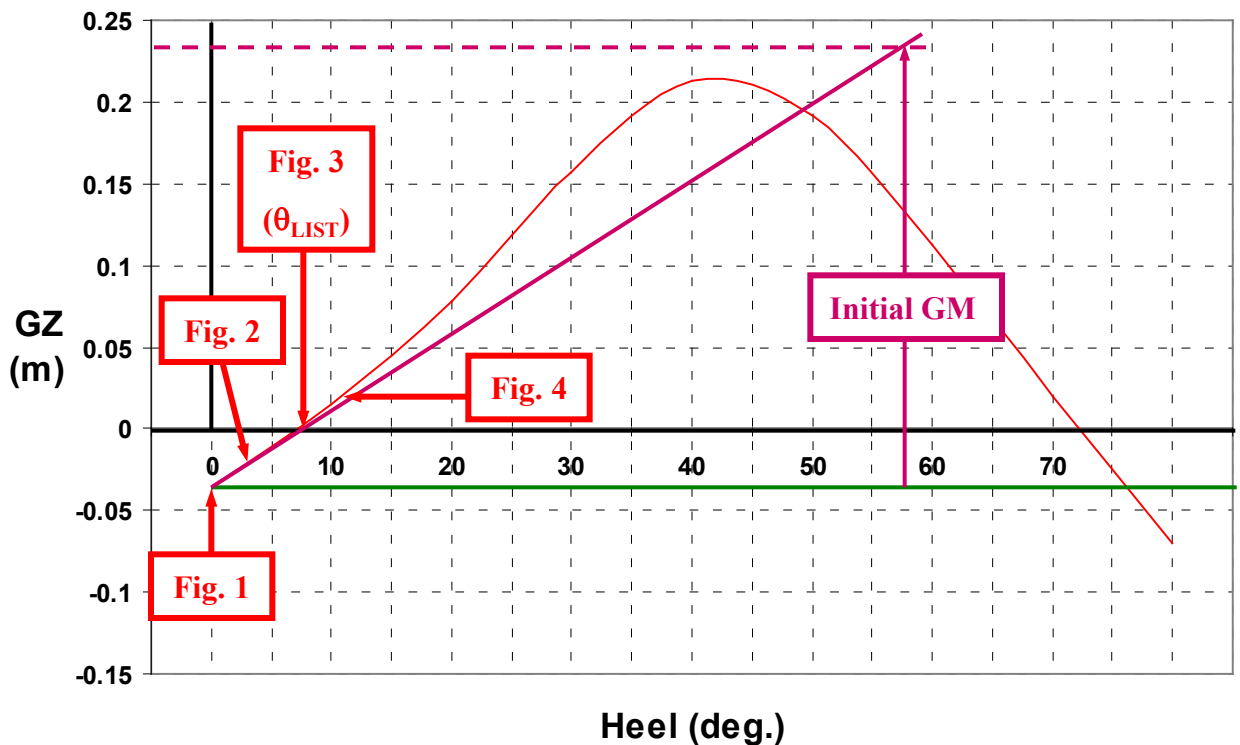
If the ship is heeled beyond the angle of list by an external force the righting lever becomes positive to right the ship back to the listed position.

GZ is *positive*.



A typical curve of statical stability for a listed ship will be as shown. Figures 1, 2, 3 and 4 are related to the curve as indicated.

Curve of statical stability for a LISTED ship



Note

At 0° heel, the GZ value is negative by an amount equal to the distance that G is off the centre-line (GG_H). This causes the base of the graph to be dropped vertically to coincide with the new origin - the green line being shown as the base of the graph. The initial GM used to produce the tangent to the curve at the origin is measured from the new base as shown.

The angle of list is identified as the point on the curve where it crosses the original base of the curve as shown.

The curves for LOLL and LIST are easily confused since they look similar. It must be remembered that:

In a lolled situation:

Initial GM is negative - the ship being in an unstable condition.

The angle of loll could be to either side, port or starboard.

The ship will loll even if the port and starboard listing moments are equal.

In a listed situation:

Initial GM is positive - the ship is in a stable condition.

The angle of list will be to the same side that G is off the centre-line.