CHAPTER 32

DOCKING AND GROUNDING

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3201. General

a. A ship may be docked for normal maintenance or for repair work and may be grounded by accident or to prevent her total loss after damage. The stability problems associated with either of these situations are similar except that docking is a more controlled evolution with the hands on experience of a dockmaster to ensure the necessary precautions are taken.

b. This chapter examines the forces developed during docking or grounding and discusses the impact these can have on the stability of the ship.

c. Grounding and docking introduce an external force, the reaction between the floating body and the block or ground, consequentially buoyancy will not equal weight. The hydrostatic data for the positions of LCF, centre of buoyancy and the metacentres will all remain appropriate for the draught of the ship. However, the weight of the ship will not be equal to the mass displacement given for that draught in the hydrostatic data, rather this figure will represent the buoyancy force and to find the weight of the ship the reaction force has to be added to it. Since the body will be in equilibrium under 3 forces, weight, buoyancy and the reaction; buoyancy and weight will not necessarily act in the same straight line - B will not necessarily be under G.

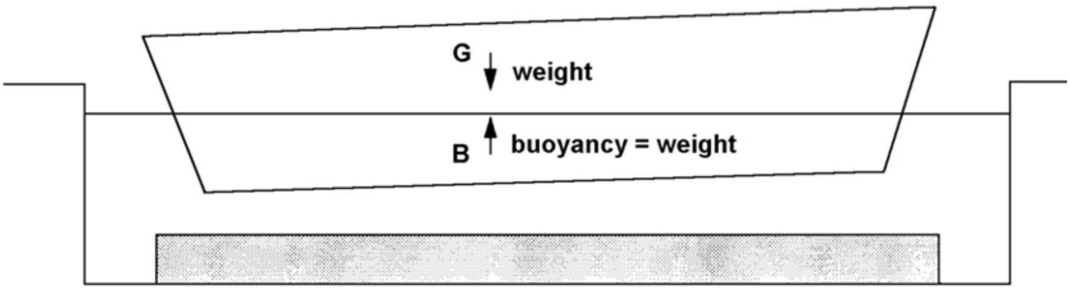
3202. Docking

During the docking procedure, as the water level in the dock falls, it can be difficult to keep the position of the ship accurately above the dock blocks she will rest on, especially if there is any wind. To minimise the risk of docking skew to the blocks, with consequential problems for the stability of the blocks and indeed the ship, and the possibility of excessive forces being produced, the normal practice is first to concentrate on centring one end of the keel on the blocks. Then, as the water level falls, the weight taken anchors that point and closer attention can be given to the other end. Most ships are designed to trim by the stern and the 'after cut up' (ACU) is made of sufficient width and strength to take the normal docking loads without undue damage to dock blocks. Hence it is usual before docking to arrange the draughts so that the ship is trimmed by the stern to ensure the 'after cut up' sues first.

3203. Flotation During Docking

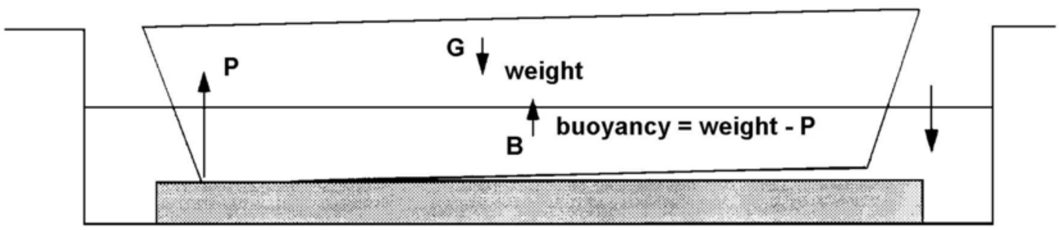
Assuming that the vessel is trimming by the stern relative to the blocks so that it sues first at the 'after cut up'.

Fig 32-1. Afloat in Dock



In Fig 32-1 until the keel touches aft the situation will be normal, ie buoyancy = weight. Once the keel touches and the water in the dock falls relative to the ship, a force P will be created. Being aft of the LCF, P will cause the ship to trim forward, thus moving B forward to regain equilibrium as shown in Fig 32-2.

Fig 32-2. Keel Touching the Dock Blocks



The conditions of equilibrium are now:

a. Weight = buoyancy + reaction P.

b. The moment of the three forces about any axis is zero.

If the ship is symmetrical and remains upright, the three forces will lie in the centre plane of the ship and only the longitudinal moments need to be considered. As a result of the trimming effect of the force P, the ship will eventually touch the dock blocks all along. Thereafter the reaction force will be distributed along the length of the keel and further considerations of the combined moments of the forces should become academic.

3204. Magnitude of Reaction when a Vessel Sues All Along the Blocks

The reaction force, P, will reach its maximum just prior to the keel touching all the way along its length. At this time the blocks and the keel structure at the after cut up must be capable of withstanding this force without crushing or tripping. Apart from structural concerns the magnitude of P at this time is also important for transverse stability. As P increases, draught reduces, the LCF will, in general, change position and MCT will change, though for small initial trims the effect of their change can be ignored. Thus, a first estimate of P is made as:

Pj = (trim change required to align keel with blocks) x MCT1cmBP

where: j is the separation of the ACU from CF
trim change required = trim by stern - declivity of dock blocks

$$p = \frac{\text{(trim change required to align keel with blocks) x MCT1cmBP}}{j}$$

The resulting draught reduction at LCF will be P/TPC. This will provide a new mean draught from which new hydrostatic data for the position of LCF, TPC and MCT 1m can be found. Using these new figures a second iteration of the above calculations can be made to find a more accurate answer for P.

Note. *Most Naval dockyards no longer have any dock block declivity, however this maybe experienced in some areas of the world.*

3205. Transverse Stability During Docking

The introduction of a force p at the keel reduces the righting moment generated when the ship is disturbed from the upright condition. From Fig 32-3 it can be seen that by taking moments about the keel (K) the net righting moment allowing for the effects of the reaction force P is:

Righting Moment $= (\Delta - P)\ KM \sin\varphi - \Delta KG \sin\varphi$

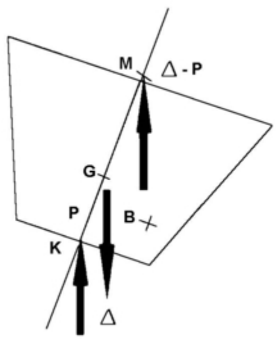
$= (\Delta KM - \Delta KG - P.KM) \sin\varphi$

$= (\Delta GM - P.KM) \sin\varphi$

$= \Delta \left(GM - KM.\frac{P}{\Delta}\right) \sin\varphi$

This parallels the normal afloat relationship (righting couple = $\Delta GM\sin\varphi$ and so the expression $(GM - KM.P/\Delta)$ is sometimes referred to as the 'effective GM'. However it must be remembered that the GM in this expression changes as the ship sues because as the water level falls away from the ship the position of M will move.

Fig 32-3. Transverse Stability During Docking



The ship will remain stable so long as (KM.P/Δ)<GM. It will be seen that this condition will be threatened if either GM is low, or if the reaction force P is high. As we have seen the magnitude of P is determined by the trim change required to align the keel with the blocks, the distance of the point the keel first touches (usually the ACU) from the LCF, and the ship MCT 1 m at the docking draught. Assuming MCT 1 m is outside control, to minimise the risk of instability during suing, the following conditions should be sought:

a. Maximum GM practical (this may sometimes demand ballasting, and may be stipulated in the Stability Statement). As usual, free surfaces must be kept to a minimum.

b. The change in trim required to sue all along should be the minimum consistent with the requirements for the docking procedure (no more than about 0.6 m should be necessary). There may however be occasions when in a light condition the ship has a very large trim, in which case ballasting may be necessary to reduce P - not just for stability but also to protect the dock blocks.

c. The point at which the ship first touches should be as far as possible from the LCF. Although the LCF is usually abaft midships for surface warships, and the ACU is well forward of the stern, as stated above it is normal to use the ACU for this purpose rather than the forefoot as it presents less problems when strengthening the local structure in this area.

3206. Grounding

With the exception of the special cases of docking or amphibious landings, grounding is a condition to be avoided in ships such as warships that are not designed with grounding in view. Ships so designed have flat bottoms and ground on mud or soft sand which equalises the bearing pressures. Analysis of the reaction force apparent after grounding requires the following information:

a. The point at which the ship has grounded.

b. The state of the tide relative to that at which the ship grounded:

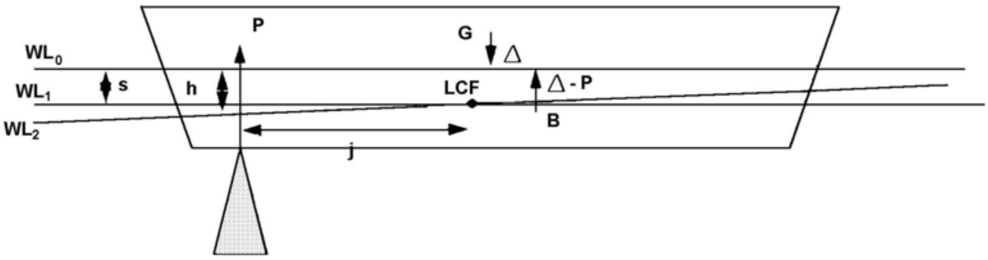
(1) *If the tide rises* the vessel will be able to float off providing there has been no increase of weight and no flooding has resulted from the grounding.

(2) *If the tide falls* the reaction between ship and ground will increase. The additional upward force will reduce the buoyancy and hence the volume of displacement. For equilibrium, the centre of buoyancy will move away from the point of grounding as in docking and the vessel will take up a heel or trim away from the point of grounding to accomplish this.

The condition to apply is that the reduction in draught at the point of grounding due to the parallel rise, the change in trim, and effects of heel, must be equal to the fall in tide. There are two situations of grounding that are best examined separately centreline grounding when heel effects can be ignored and grounding off the centreline when all three effects must be considered.

3207. Analysis for Grounding On the Centreline

Fig 32-4. Grounding On the Centreline



Referring to Fig 32-4, with no heeling moment let:

s = parallel rise
h = the fall in tide
j = the distance from the CF of the point of grounding
t = the change in trim between perpendiculars caused by the moment of the grounding force P

then, the reaction force P will cause parallel sinkage s given by:

$$s = \frac{P}{TPC} \text{ (in cms)}$$

and the change in trim caused by the reaction force P will be:

$$t = \frac{P \times j}{MCT1cmBP} \text{ (in cms)}$$

(j and MCT 1 cm being the respective figures for the waterline after parallel rise s (WL_1))

The effect of parallel rise and trim at the point of grounding must equal the fall in tide. Hence:

$$h = s + \left[t \times \frac{j}{L_{BP}} \right]$$

These 3 equations can now be solved to give P.

> ***Note.*** *Using the TPC and position of LCF between WL_0 and WL_1 an improvement in accuracy can be made, but it should be appreciated that when a ship is grounded, precise calculations will rarely be necessary.*

3208. Grounding Countermeasures

In considering countermeasures to grounding, the moment of P x j (Fig 32-4) gives an indication of the moment required by:

a. Counterflooding.

b. The removal of weights from the grounded end.

c. The transfer of weights to the free end.

While counterflooding may have the advantage of being the quickest of the three methods, it will incur an element of parallel sinkage and in practice there is a limit to the number of tanks available for this purpose. The removal of weights from the area of impact will reduce pounding at this point, thereby limiting the degree of structural damage, and the transfer of liquid and solid weight to the free end, if sufficiently large, will trim the ship to the point where it can be pulled free. In most ships the limited capacity for each of these procedures may necessitate a combination of all three to be effective. The removal and transfer of solid weights and liquids, combined with counterflooding may be insufficient to release the ship. Therefore early consideration should be given to the flooding of other compartments in addition to tanks and void spaces.

3209. Transverse Stability after Grounding On the Centreline

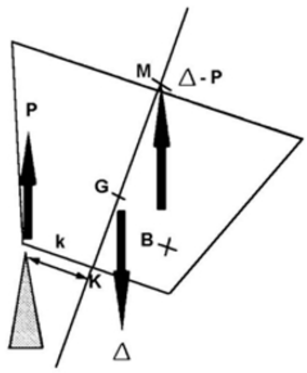
It will be evident that if grounding occurs towards either end the point of contact will be approximately on the middle line. Under these circumstances transverse stability will be affected similarly to stability after docking, such that the ship has an effective GM:

$$\text{Effective GM} = GM - KM \times (P/\Delta)$$

3210. Grounding Off the Centreline

Grounding away from the centreline presents more problems, as the reaction force will also result in the ship heeling.

Fig 32-5. Grounding Off the Centreline



With reference to Fig 32-5, if the grounding force P acts a distance ‘k’ off the centreline, it will cause a heeling moment $P \times k(\cos\varphi)$ which will be resisted by the righting moment $\Delta \times (GM - (P/\Delta)KM)\sin\varphi$.

$$Pk(\cos\varphi) = \Delta(GM - (P/\Delta)KM)\sin\varphi$$

$$\tan\varphi = \frac{Pk}{\Delta(GM - (P/\Delta)KM)}$$

The result of the angle of heel is to cause the draught at the point of grounding to fall by an amount, say f:

Therefore $\tan\varphi = f/k$

It can be said that:

$$f = \frac{PK^2}{\Delta(GM - (P/\Delta)KM)}$$

Hence it can be seen that the effect of an upward force P at any point will cause the draught to decrease at that point by an amount due to parallel sinkage, an amount due to trim, and an amount due to heel. A first approximation to that total, which will equal the fall in tide, will following the earlier analysis be:

$$h = \frac{P}{(100TPC)} + \frac{PJ^2}{MCT1cmBPL_{BP}} + \frac{Pk^2}{\Delta(GM - (P/\Delta)KM)}$$

3211. Transverse Stability after Grounding Off the Centreline

Assessment of the transverse stability of a ship grounding off the centreline is somewhat more difficult than before. Essentially, the righting moment itself is the same as for the centreline grounding case but the ship has already adopted an angle of heel due to the grounding reaction force and any additional movement of weight will act about this angle not the upright. It is important to note that this analysis of stability after grounding relies on small angle theory and angles of heel due to off centreline grounding will quickly exceed 10° so that this theory is invalid. This situation is exceptionally dangerous and difficult to predict, particularly if the range of tide experience is high, resulting in angles of heel approaching the angle of downtake immersion. Earlier advice to increase GM, so increasing the ships stability, by ballasting low in the ship still holds except that obviously ballasting on the centreline will in this case increase the angle of heel, this problem could be eased by ballasting low in the ship on the same side as the grounding point.