

Objective and calculation approach

The objective of this calculation is:

Determine how a Floater's stability varies as it lifts a load by crane.

The approach to be followed is:

- Show that crane load acts through crane sheave tangency point.
- Calculate change in GM when the load is just raised from the deck.
- Determine if there is any change in stability as the crane continues to raise the load.

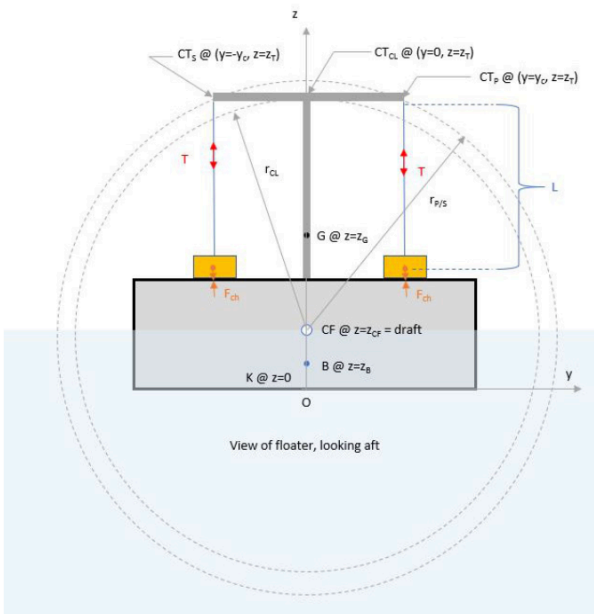
References















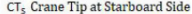


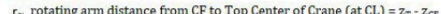
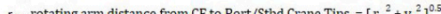

[R1] Principles of Naval Architecture, Volume I, Stability and Strength, 1988, Society of Naval Architects and Marine Engineers

Definition of Terms

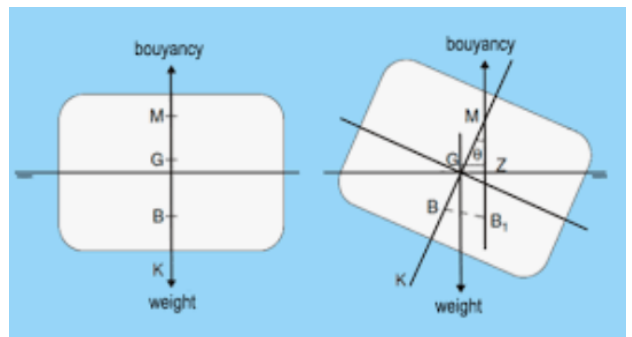
Center of Gravity: A point from which the weight of a body or system may be considered to act.

Definition of Variables and Geometry



-  Floating Barge, with total mass = m_b , made up of lightship mass plus two movable cargo boxes. $m_b = m_{LS} + 2m_c$
-  Movable Cargo Boxes, each having mass = m_c
-  Center of gravity of Movable Cargo Boxes
-  Center of buoyancy
-  Center of flotation
-  Center of gravity of Floating Barge with TOTAL MASS (including 2 movable Cargo boxes, when they are resting on the hull)
-  T; Tension on lifting crane cable, T, varies between 0 and $g \cdot m_c$
-  F_{ch} ; Cargo Load resting on hull, F_{ch} , varying between $g \cdot m_c$ and 0
-  K Keel
-  B Center of Buoyancy
-  CF Center of Flotation
-  G Center of gravity of floating Barge with TOTAL MASS (including 2 movable Cargo Boxes)
-  C Center of Gravity of Movable Cargo Boxes
-  CT_c , Crane Top at Centerline
-  CT_s , Crane Tip at Starboard Side
-  CT_p , Crane Tip at Port Side
-  $m_{tot} = 2m_c + m_{rest}$
-  r_{cl} , rotating arm distance from CF to Top Center of Crane (at CL) = $z_t - z_{CF}$
-  $r_{p/s}$, rotating arm distance from CF to Port/Stbd Crane Tips = $[r_{cl}^2 + y_c^2]^{0.5}$
-  L, Apparent Length of Cable (from Crane tip to CG of cargo box)

- M = Metacentric Height
- GZ = Righting Arm
- θ = Angle of Heel
- KB = Height to Center of Buoyancy B
- BM = Height from Center of Buoyancy to Metacenter M
- ∇ = Volumetric displacement of the hull
- I_T = Transverse Moment of Inertia of the Waterplane
- KG = G (as defined above)
- KM = KB + BM
- GZ \approx GM \cdot sin θ
- GM = KM - KG
- KB + BM - KG
- GZ \approx (KB + BM - KG) \cdot sin θ
- C_{LS} = Height of m_{LS}



Analysis

Initial Condition, Cargo Resting on the Deck

$$GZ = (KB_i + BM_i - KG_i) \cdot \sin \theta$$

$$KG_i = \frac{m_{LS} \cdot C_{LS} + 2m_c \cdot C}{m_{LS} + 2m_c}$$

KB depends on the total displacement $m_{LS} + 2m_c$ which remains the same regardless of the height of $2m_c$.

So, $KB_i = KB$ a constant

$$BM = \nabla / I_T$$

∇ depends on the weight $m_{LS} + 2m_c$ which remains the same.

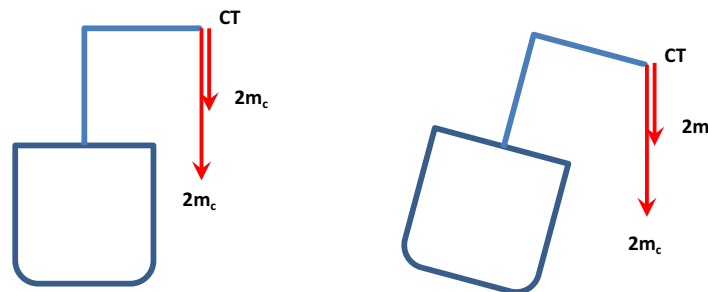
So, $\nabla_i = \nabla$ a constant

I_T depends on the shape of the waterplane which for infinitesimal angles of heel remains constant as well.

So, $I_{Ti} = I_T$ a constant

New Condition, Cargo Suspended from the tip of the Crane

Now, by definition, the center of gravity of a body is a point from which the weight of a body or system may be considered to act. Consider the following diagram, with a weight suspended from a point CT.



Regardless of the angle of inclination, once suspended from CT, the load $2m_c$ acts through the point CT. Hence, CT is by definition the new center of gravity of $2m_c$.

Calculate the new GZ. If GZ is more, the Floater is stiffer, if GZ is less the Floater is more tender.

$$GZ = (KB + BM - KG_n) \cdot \sin \theta$$

From this equation, it is clear that as KG_n increases, GZ is less.

$$KG_n = \frac{m_{LS} \cdot C_{LS} + 2m_c \cdot (C + L_{max})}{m_{LS} + 2m_c}$$

With the addition of the L_{max} term, KG_n increases in magnitude, which makes KG_n larger which makes GZ smaller. Hence with smaller GZ, the Floater is more tender.

The diagram immediately above, shows two cargo loads $2m_c$ acting through CT, at different heights with different hoist lengths L . By inspection, it can be seen that since CT does not move as the load $2m_c$ is elevated, there is no change in the KG. Hence, the length of the hoist has no influence over the GZ of the Floater.

Demonstration

There is a very dramatic demonstration of this phenomenon on Youtube. It shows loss of control of the lifted load, as soon as the load begins to swing:

https://youtu.be/LJevke4_i5Y