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.

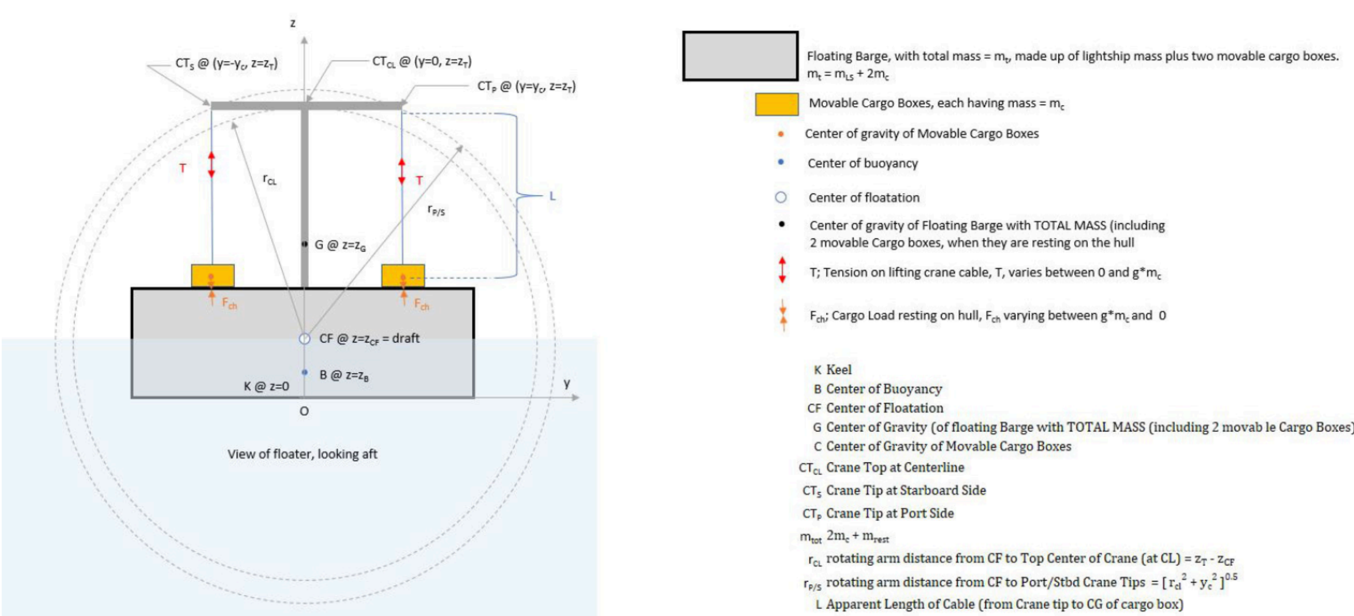
References

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

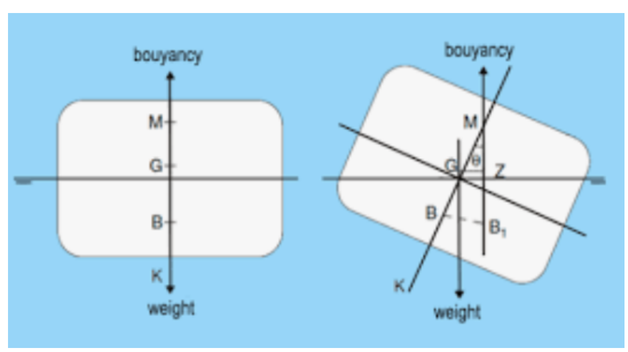
Definition of Terms

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

Definition of Variables and Geometry



M = Metecentric 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 ≈ GM • sin θ
GM = KM - KG
KB + BM - KG
GZ ≈ (KB + BM - KG) • 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

$BM = \nabla_i / I_T$

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

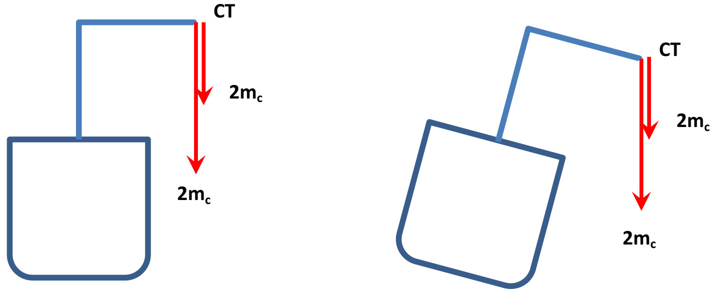
So, $\nabla_i = \nabla$ a constant

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 drammatic 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