Safety Assessments for Anchor Handling Conditions of Multi-purpose Platform Work Vessels

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2009.12.04

Outline

Ⅰ. Introduction

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Ⅰ. Introduction

1) Analyzes typical anchor handling conditions of work vessels.

2) Establishes the mechanics model of the work condition.

3) Analyzes floating state and buoyancy with the working condition.

4) Introduce a method for calculating critical safety tension with each typical deviation degrees of anchor wire.

5) Get the curve of the tensions under each typical conditions.

6) Put forward a safety assessment flow of the working state.

7) Make a proposal to design a safety system to control the maximum tension of wire or chain in safety scope.

Ⅱ. Issues Raised and Related work

1) Issues Raised

The loss of “Bourbon Dolphin” on 12 April 2007 shows that there will be some unpredictable factors to cause ship capsizing during anchor handling work.

This disaster accident takes people attention to further research about the safety assessment of work vessels.

2) Related work

(1) NMD (Norwegian Maritime Directorate) put forward a calculation guideline for safety anchor handling to calculate permissible tension in wire and limit the maximum heel angle by three giving angles.

(2) Ulstein group give a simplified calculation method to get the maximum safety tension.

(3) VS (Vik-Sandvik) ship design company does some research about wire tension in static stability field.

III. Anchor Handing work condition

Typical loading conditions of anchor-handling

condition 1

Ballast departure (100% FO & FW) , without roll reduction tanks, maximum downward load on the stern roller.

condition 2

Ballast arrival (10% FO & FW) , without roll reduction tanks, maximum downward load on the stern roller.

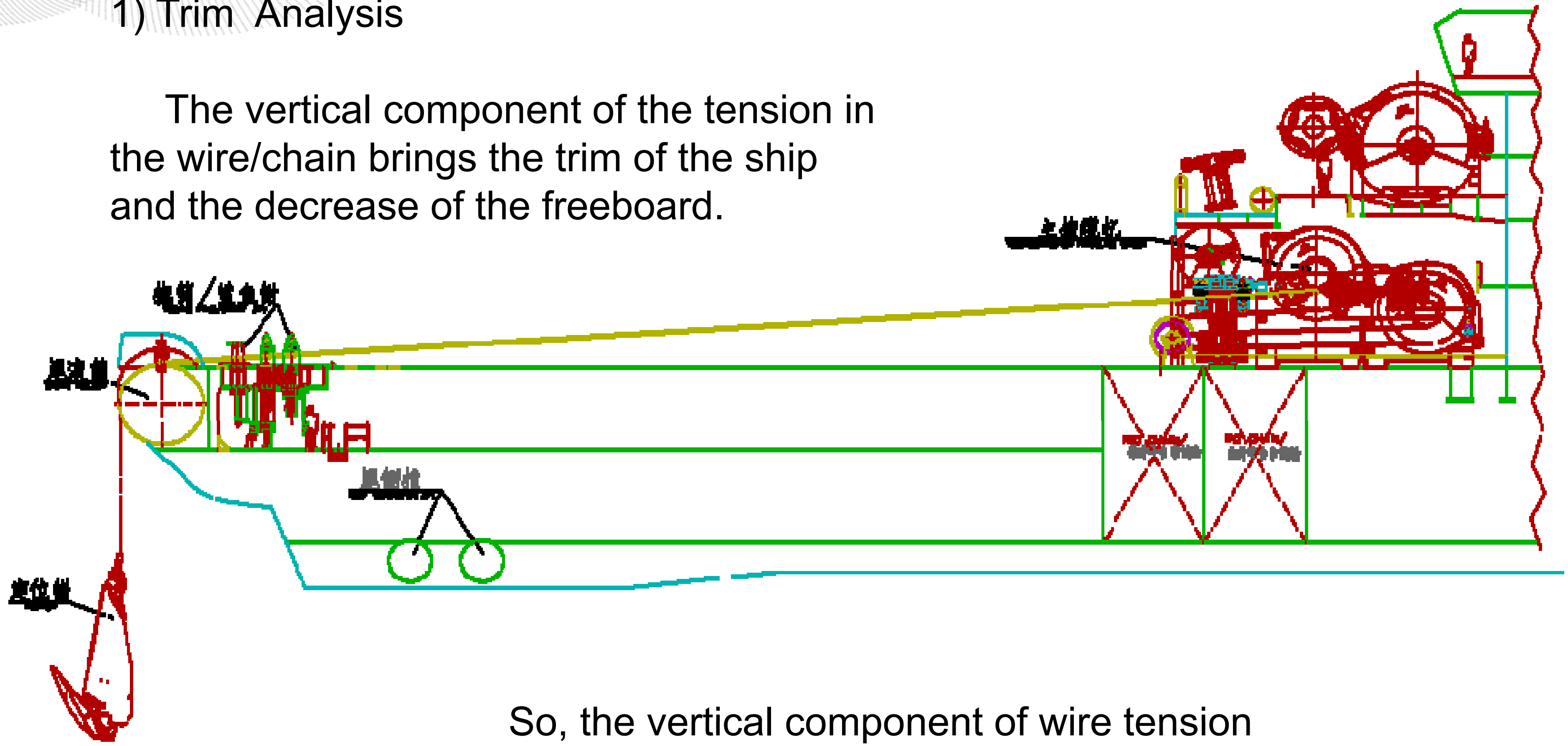
condition 3

No deck load, no liquid cargo, 50% consumables, without roll reduction tanks, maximum downward load on the stern roller

Ⅲ. Anchor Handing work condition

1) Trim Analysis

The vertical component of the tension in the wire/chain brings the trim of the ship and the decrease of the freeboard.



So, the vertical component of wire tension should be counted in when we calculating floating position.

III. Anchor Handing work condition

2) Heel Analysis :

Because of waves and currents actions, the work vessel rolls on the sea normally and the anchor wire is potentially deviated to the port or starboard.

When the portside and starboard inner towing-pin both depress and the chain will smack over against from one side outer pin to the other side, the list moment will increase dramatically.

If the rotating direction is the same as the list moment under the condition, it will be one of the most dangerous conditions of anchor handling work.

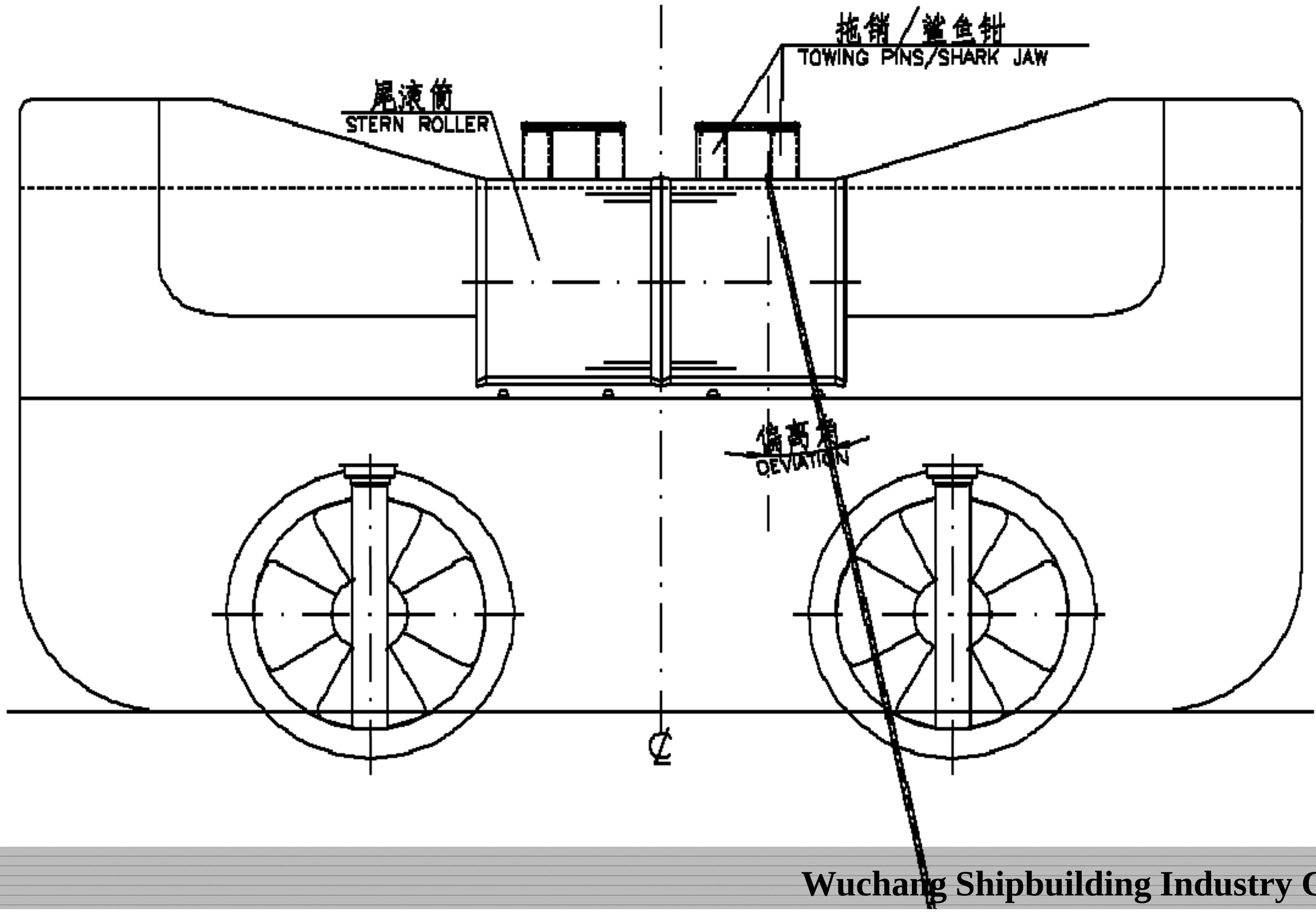
3) Free surface moment

Free surface moment should be taken into account with the calculation of anchor handling condition.

Ⅳ.Mechanics model

coordinate system:

Basically we adapt coordinate system of ship design to establish the mechanics model.



Ⅳ.Mechanics model

To simplify the mechanics analysis, we just take into account trimming of the vessel in the first step.

As a consequence, we take the trimming condition as an initial condition for heeling calculation.

During the anchor handling work, the angle between the chain and the vessel's longitudinal section always exists and we call this attack angle as angle d.

Tension in anchor chain will dynamically affect the vessel and the chains angle of attack is critical and this could vary from 0 to 90 degree. So we set the value collection of degree d as (0, 13, 25, 38, 50, 63, 75, 88, 90).

Ⅳ.Mechanics model

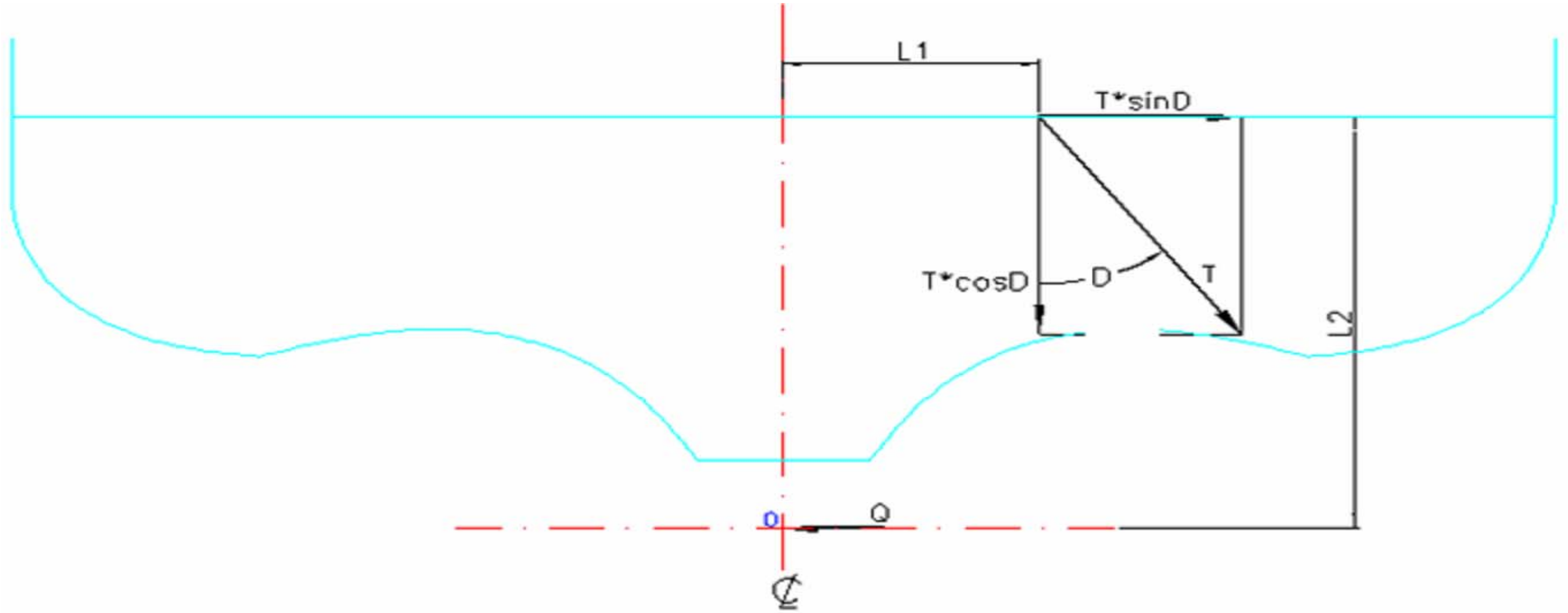
1) List lever

The heeling moment is calculated as the total effect of the horizontal side-force from circumstance & horizontal-components and vertical transversal-components of the tension in the wire or chain.

The heeling lever of the horizontal side-force & horizontal-components is calculated from the height of the work-deck at the towing pin with the center of the propellers or aft thrusters, whichever is deepest.

The horizontal transversal-components: $T \cdot \sin D = T \cdot \sin(d + \phi)$

d ---Attack angle: ϕ ---Slop angle:

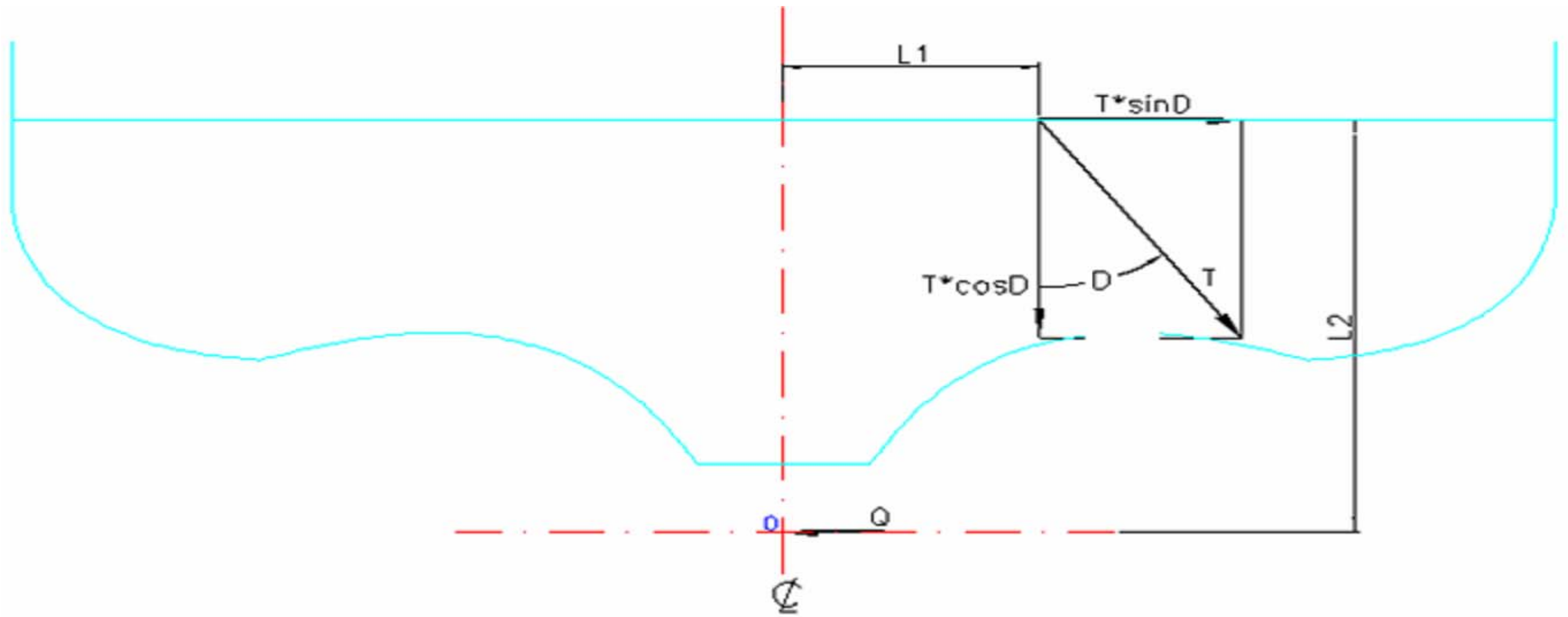


Ⅳ.Mechanics model

1) List lever

The heeling lever of the vertical-component is calculated from the center of the longitudinal section in center line with vertical point of attack at the upper edge of the stern roller.

The vertical transversal-components: $T \cdot \cos D = T \cdot \cos(d + \phi)$



Ⅳ.Mechanics model

1) List lever

The horizontal side-force:

$$T_{side} = Q$$

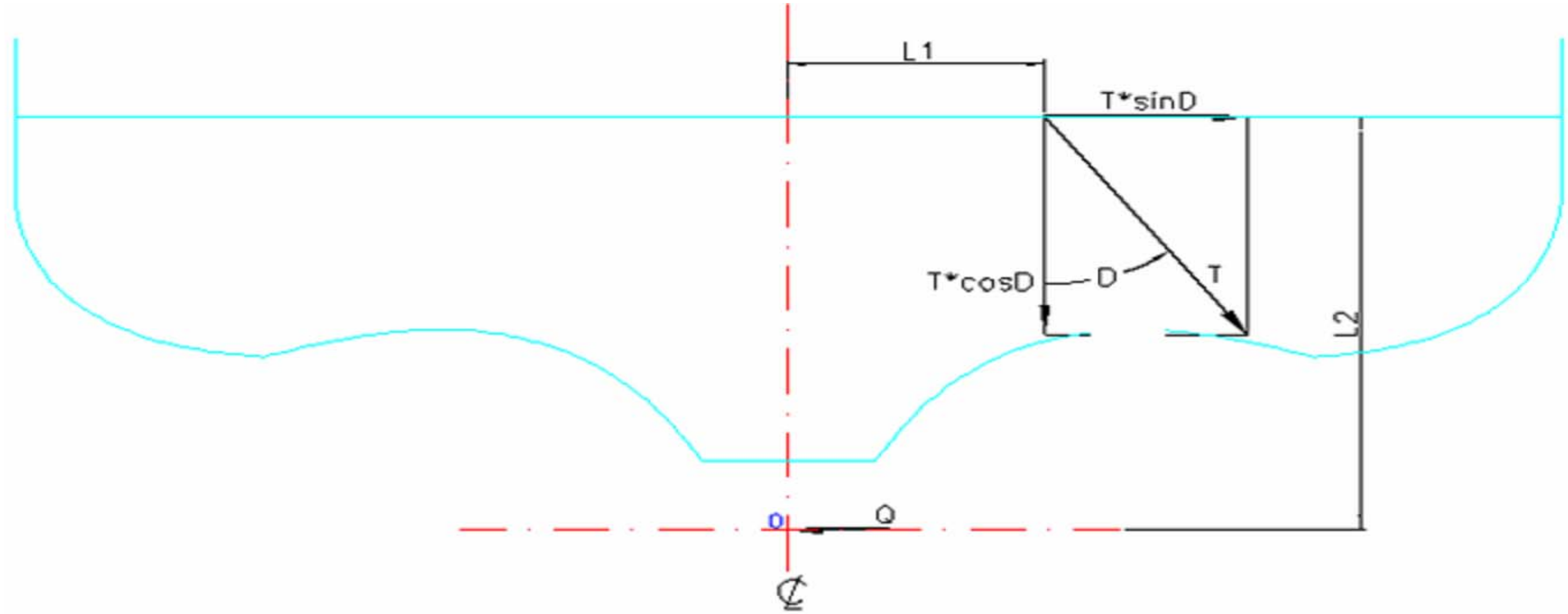
Includes:

external environment side forces

wind force, current force , wave force;

ship side forces

rudder, aft thrusters.



Ⅳ.Mechanics model

2) List moments

Because the horizontal transversal-components force is far more than the horizontal side-force, so we use the horizontal side-force to calculate the list moment which generate by horizontal forces.

As the result, the whole list moment should be calculated as follow:

MT=L1*T*cos D+L2* Tside

And we find the residual force, which equals to:

$$(T \cdot \sin(d + \phi) - T_{side})$$

Which just make the ship drift on the water plane and no cause any list moment.

Ⅳ.Mechanics model

3) Calculate trimming floating condition

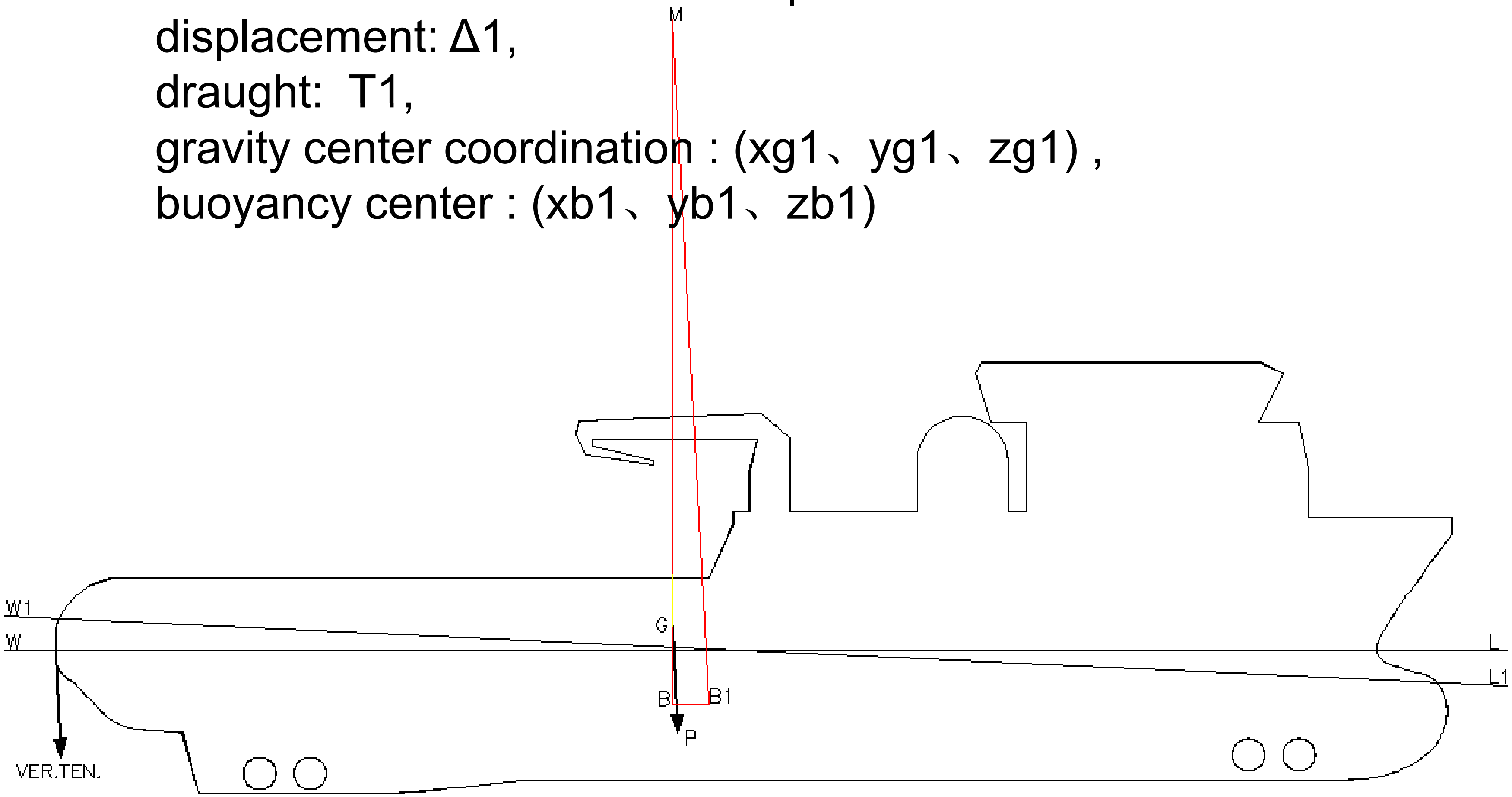
(1) we assume that the ship floating in still water and no tension in stern roller. And the parameters are:

displacement: Δ1,

draught: T1,

gravity center coordination : (xg1、yg1、zg1) ,

buoyancy center : (xb1、yb1、zb1)



Ⅳ.Mechanics model

3) Calculation of trimming floating condition

We get the information with the floating position without trim and heeling of displacement D

Trim Moment

$$M_L = (\Delta_1 + P) \cdot (x_g - x_{b1})$$

Trim

$$t = \frac{M_L}{100 M_{Lcm}}$$

Draught of for. & aft.

$$T_f = T + \frac{(L/2 - x_f) \cdot t}{L_{pp}}$$

$$T_a = T + \frac{(L/2 + x_f) \cdot t}{L_{pp}}$$

Ⅳ.Mechanics model

3) Calculation of trimming floating condition

The vertical transversal-component force (P) which calculate as follows:

P=T·cos(d+Φ)

The action point is (x、y、z)

We take that vertical force as an additional weight on the action point .

We get the floating information after stern roller tension action as follows:

New displacement： $\Delta = \Delta_1 + P$

New equivalent gravity： $x_g = \dfrac{\Delta \cdot x_{g1} + P \cdot x}{\Delta_1 + P}$

$$z_g = \frac{\Delta \cdot z_{g1} + P \cdot z}{\Delta_1 + P}$$

Ⅴ.Research of static stability

Relevant criteria:

-IMO A.749(18) Code on Intact Stability

Ch . 4.5.6.2 Offshore supply vessels

1) MAXGZ15, 'Min. angle for GZ max 15deg'

   Position of the maximum of the GZ curve > 15 deg

2) MAXGZ30, 'GZ min 0.2 when heel > 30deg'

   Maximum GZ > 0.2 m

   Range: 30, FAUN

3) GM0.15, 'GM > 0.15 m'

   GM > 0.15 m

The list moment caused by wire tension should be taken into account with the checking of intact stability.

Ⅴ.Research of static stability

-NMD Requirements

The maximum permissible tension in wire/chain is calculated so that the vessels maximum angle of heel is limited to the lea following angles:

1) Angle corresponding to a GZ value equal to 50% of GZ-max.——$\theta 1$

2) Angle giving water on deck when the deck is assume flat. ——$\theta 2$

3) 15 degree.

V .Research of static stability

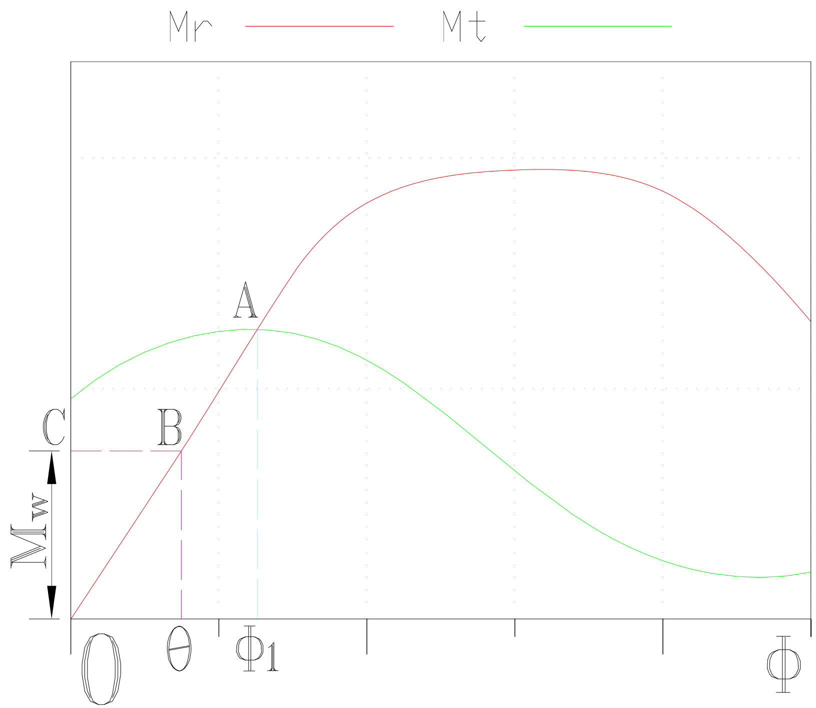
Our Calculation of maximum permissible tension of static stability

1) when Mr=Mt， the heeling angle is $\boldsymbol{\Phi_1}$

2) $\boldsymbol{\theta_{min}}$=min($\boldsymbol{\theta_1}$ 、$\boldsymbol{\theta_2}$ 、15° 、$\boldsymbol{\Phi_1}$)

3) T_w : the max tension that winch could provide

4) Calculation of maximum permissible tension :



If ($\Phi_1=\theta_{min}$) Then $T_{max}=T_w$

else (means $\Phi_1>\theta_{min}$ and $T_{max}<T_w$)

$Mw=L_1*T_1*\cos(d+\theta_{min})+L_2*T_1*\sin(d+\theta_{min})$

$T_2= L_2*T_1*\sin(d+\theta_{min})$

If $T_2< T_{side}$

Then $T_{max}=T_1$;

else

$T_2> T_{side}$, $M_w=L_1*T_{max}*\cos(d+\theta_{min})+L_2*T_{side}$

VI.Research of dynamical stability

Relevant criteria of dynamical stability :

-IMO A.749(18) Code on Intact Stability

Ch . 4.5.6.2 Offshore supply vessels

1) AREAUPTO30, 'Minarea 0-30deg'

   Area under the GZ curve > BY, MAX, 0.055, 0.001, 30 mrad

   Range: -, MIN(MAX, 30)

2) AREA3040, 'Minarea 30-40deg'

   Area under the GZ curve > 0.03 mrad

   Range: 30, MIN(40, FAUN)

VI.Research of dynamical stability

Our Calculation of dynamical stability

differential equations :

$$dP_R = M_R d\phi$$

$$dP_T = M_T d\phi = (M_{T\,safe} + M_{T\,side})d\phi$$

When Φ=Φ$_d$

$$\int_0^{\phi_d} dP_R = \int_0^{\phi_d} dP_T + E_0$$

$$\int_0^{\phi_d} M_R d\phi = \int_0^{\phi_d} M_T d\phi + E_0$$

$$GZ = y_\phi \cos\phi + z_\phi \sin\phi - z_G \sin\phi \qquad \text{(formula 3)}$$

$$E_0 = \int_0^{\phi_a} M_R d\phi$$

$$M_R = \Delta \cdot GZ$$

$$\boldsymbol{M_T = M_{T\,safe} + M_{T\,side}}$$

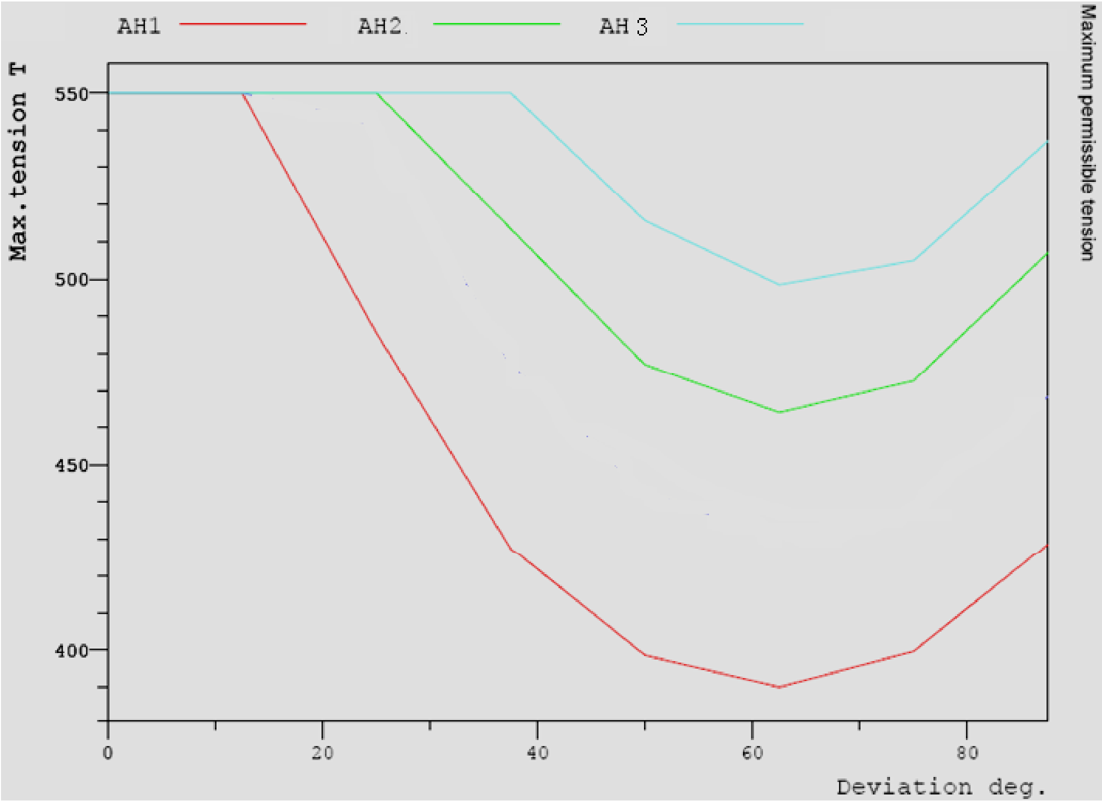
L_1、L_2——list force level

y_Φ、z_Φ——coordinate of buoyancy center

z_G——coordinate of gravity center

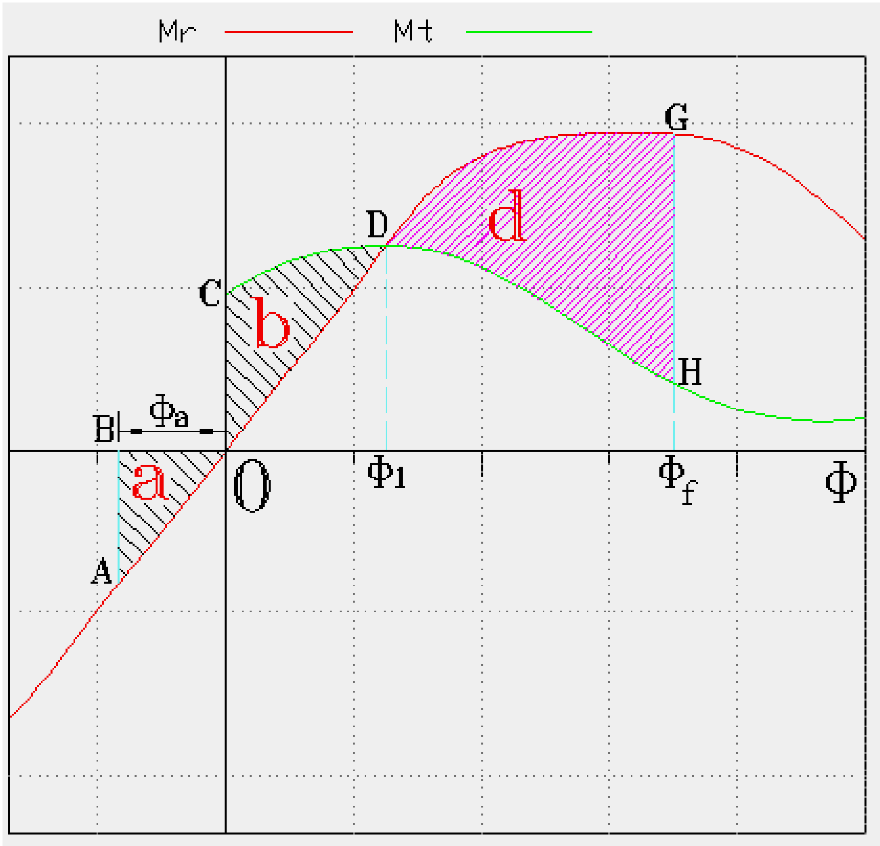
VI.Research of dynamical stability

we could calculate the safety critical tension M_{TSAFE} for dynamical stability Using this method , we calculate T_{max} with each attack angle d= （0° 、13° 、25° 、38° 、50° 、63° 、75° 、88° ） and get curves as follow:



VI.Research of dynamical stability

And we take flooding angle into account of stability checking. If ($\Phi_f > \Phi_d$) or area d>(a+b), it is a judgment that the vessel in anchor handling working condition is safe.



Ⅶ. Heel instantaneous condition Analysis

In the case of emergency accidents , we are supposed to analyze the instantaneous force condition of the ship.

So it is necessary to establish the mathematics model in accordance with accidents and get an emergency response instantly.

We use D'Alembert principle to establish moment equation considering accelerated rotate speeds.

Ⅶ. Heel instantaneous condition Analysis

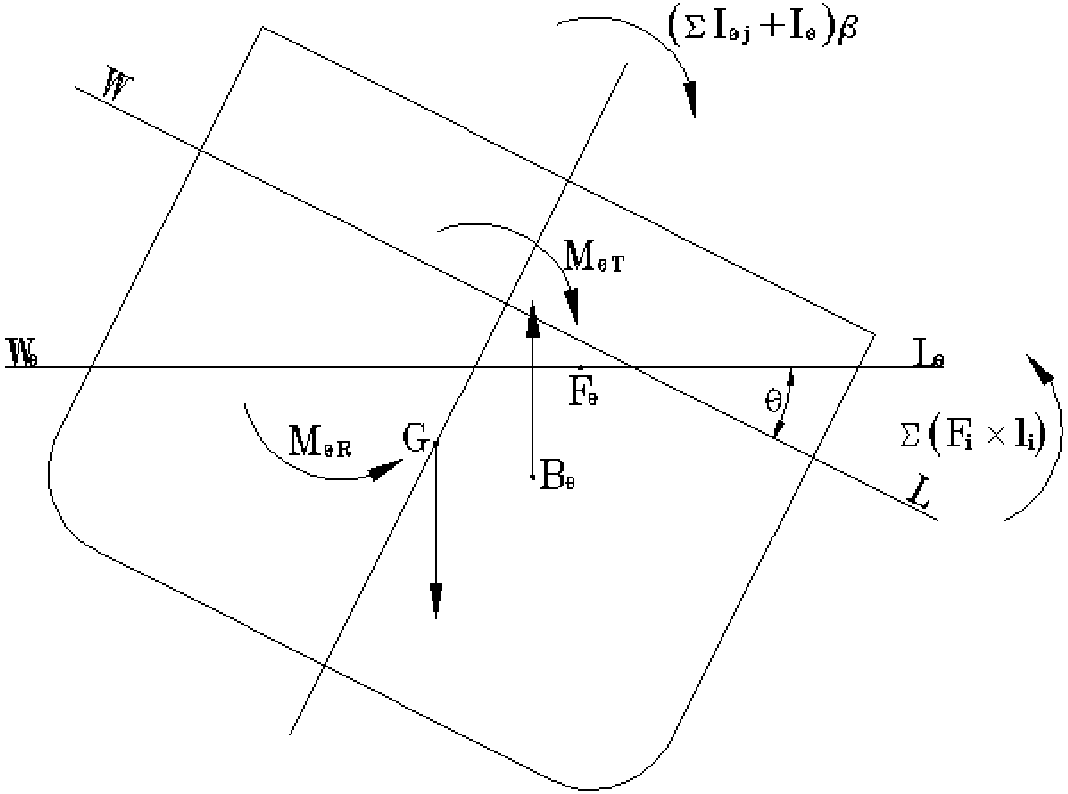
moment equation

$$M_{\theta R}+(\sum I_{\theta j}+I_{\theta})\cdot\beta-M_{\theta T}-\sum(F_i\cdot l_i)=0$$

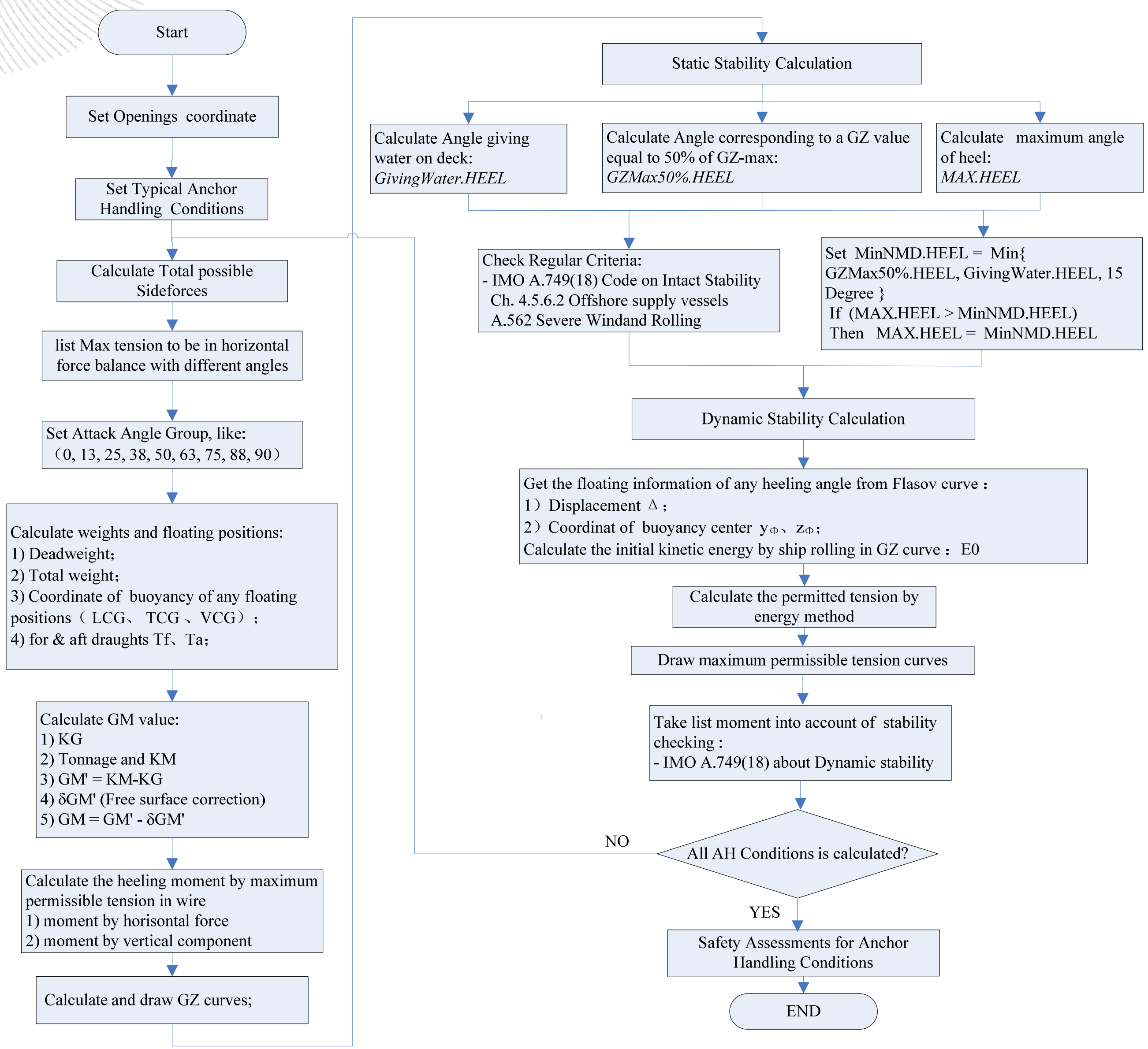
Then:

$$\beta=\frac{M_{\theta T}-M_{\theta R}+\sum F_i\cdot l_i}{\sum I_{\theta j}+I_{\theta}}$$

---- instantaneous rotate acceleration



Ⅷ. Work Flow of safety Assessments



IX. Safety Protection measures

It is necessary to design a safety wire tension control system which can control the tensions in dangerous anchor-handling condition immediately. In this system, the sensors can capture real-time tension value. And then we get the in-time information about vessel's motion by our calculation method.

The system will estimate the ship motion at the next moment and get the motion

track of buoyancy center and centroid of the water plane. We add this track into our stability checking and will have the instantaneous conclusion about whether it has any threaten to stability. By the analysis, we tell the handling winch whether need to release the tension of anchor wire or not, and the ship safety is guaranteed.

Thanks!

Our anchor handling multi-purpose platform work vessel

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