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Hydrostatic stiffness for pitch mode #403

Closed **Liam-Guerrero** opened this issue on Aug 19, 2020 · 4 comments

Assignees

Labels Theory

Liam-Guerrero commented on Aug 19, 2020 • edited

Hi Guys,

I wonder if you could give me a hand to understand how wecSim computes Hydrostatic stiffness for pitch mode.

I am working with the scaled-wavestar-like model developed for the WECCCOMP and ran the model for regular wave, height 0.06 m and period 1.2 s.

Now, I want to compute the restoring moment using the linear equation Mhd(t) = −K_5*θ(t).

First, I had understood that the hydrostatic stiffness for pitch mode is computed as:
K_5 = rho * g * Iyy, and for the wavestar-like model would be: **K_5=rho * g * body(1,1).momOfInertia(2) = 14.58 Nm/rad**;

However, if I extract the value from the hydroForce structure (which bodyClass.m file indicate % Hydrodynamic forces and coefficients used during simulation.)
body(1,1).hydroForce.linearHydroRestCoef(5,5) is equal to 0.2175, which I think has the units of Nm/rad.

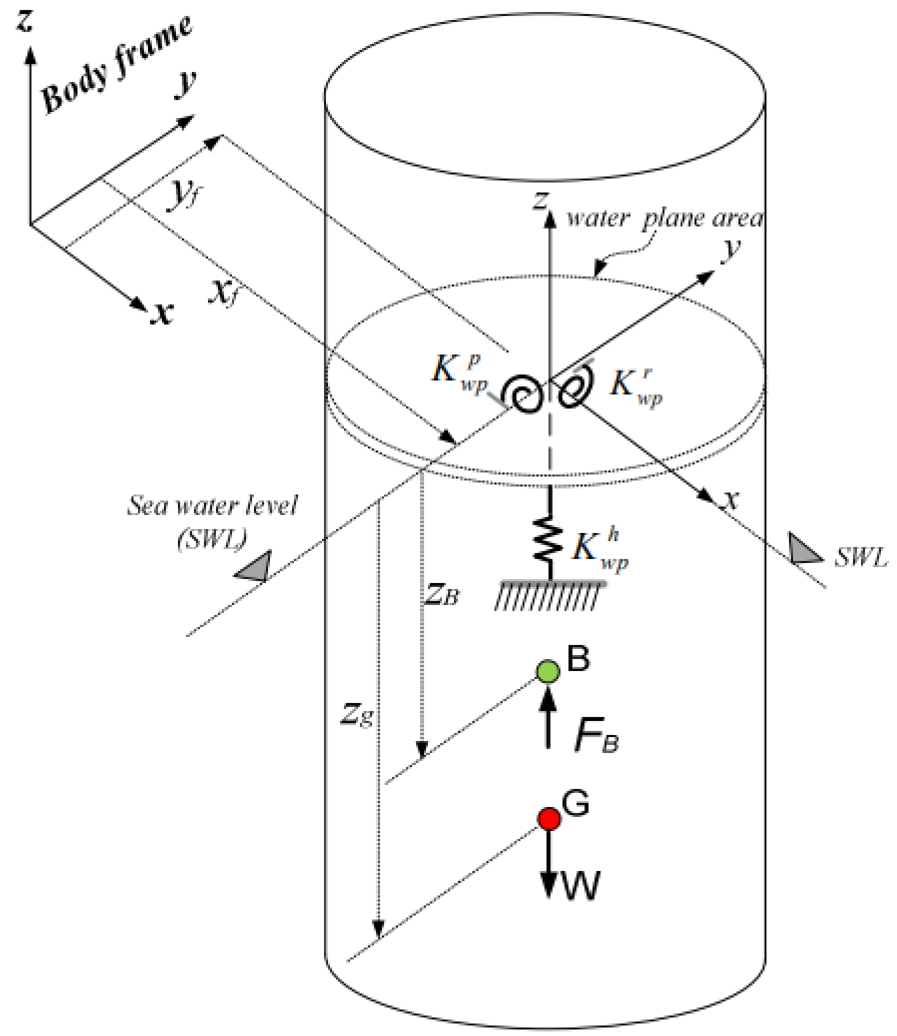


Fig. 1: Buoyancy restoring forces and moments at zero rotation angles

$$
\boldsymbol{K}_h = \begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & K_{wp}^{h} & K_{wp}^{h} y_f & -K_{wp}^{h} x_f & 0 \\
0 & 0 & K_{wp}^{h} y_f & K_h^{44} & -K_{wp}^{h} x_f y_f & (W - F_B) x_f \\
0 & 0 & -K_{wp}^{h} x_f & -K_{wp}^{h} x_f y_f & K_h^{55} & (W - F_B) y_f \\
0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix} \quad (7)
$$

where

$$
K_{wp}^{h} = \rho g\, A_c , \qquad K_{wp}^{r} = \rho g\, I_{xx} , \qquad K_{wp}^{p} = \rho g\, I_{yy} ,
$$

$$
K_h^{44} = -W z_g + F_B z_B + K_{wp}^{r} + K_{wp}^{h} y_f^{\,2}
$$

$$
K_h^{55} = -W z_g + F_B z_B + K_{wp}^{p} + K_{wp}^{h} x_f^{\,2}
$$

`rho=1025;
g=9.81;
A=0.25*pi*0.254^2;
W=body(1,1).mass;
zg=body(1,1).cg(3);
zb=body(1,1).cb(3);
Fb=body(1,1).dispVol * rho * g;
Kp=rho * g * body(1,1).momOfInertia(2)
Kh=rho * g * A
xf=0.5487;

k55=-W*zg+Fb*zb+Kp+Kh*xf^2`
k55=1.664560999380456e+02

So in summary, I would like to know how the hydrostatic stiffness for the pitch mode (which I think is the one we should use for this model) and how wecSim computes it.

All these topic of hydrodynamics forces/coefficients is new for me, and I have not had any course on my university curriculum before. So I really appreciate any guidance to understand how to compute these coefficients.

Kind Regards
Juan Guerrero

kmruehl added the question label on Aug 19, 2020

nathanmtom commented on Aug 21, 2020

@Liam-Guerrero Thank you for your question and we are happy to try our best to answer your question.

To your first question, it appears that you have misinterpreted I_{yy} as the body pitch moment of inertia when instead it should be the second moment of area of the water plane area. If you checked the dimensions of the equation for K_{5} you should see that it does not end up with Nm/rad.

For the WECCCOMP model, the hydrodynamic restoring coefficients were calculated using WAMIT and I will refer you to their user manual, see Section 3.1, for the derivation of the K_{55} hydrostatic restoring coefficient.

To your question about the derivation from your linked paper, you should first replace I_{yy} with the second area moment of area and check your answer. After reviewing the equation you have listed with the WAMIT definition, I believe the two equations are the same. The expression in WAMIT is more general and if you were to complete the integral calculation, written for C(5,5), you would get the expression from your paper when using the parallel axis theorem to calculate the second area moment of area.

If you would like to see more information on how the hydrostatic and gravitational forces are calculated in WEC-Sim, you can look in the Hydrodynamic Body Block -> Hydrostatic Restoring Force Calculation -> Linear and Nonlinear Restoring Force Variant Subsystem -> Linear Hydrostatic Restoring Force.

I hope these responses have helped answer your question, but please let us know if you are still having issues on this topic.

Cheers,
Nathan

Liam-Guerrero commented on Aug 26, 2020

Hi Nathan,

Thanks for your support, it really helped me a lot.

I still have some questions regarding the linearHydroRestCoef matrix.

0 0 519.33 -0.6095 25.8771 0
0 0 -0.6095 -1.0710 -0.0303 0
0 0 25.8771 -0.03036 0.21749 0
0 0 0 0 0 0

If I compared some of those values with the WAMIT definition, they do not match:

Matrix of hydrostatic and gravitational restoring coefficients:

$$C(3,3) = \rho g \iint_{S_b} n_3 dS \qquad \overline{C}(3,3) = C(3,3)/\rho g L^2$$
$$C(3,4) = \rho g \iint_{S_b} y n_3 dS \qquad \overline{C}(3,4) = C(3,4)/\rho g L^3$$
$$C(3,5) = -\rho g \iint_{S_b} x n_3 dS \qquad \overline{C}(3,5) = C(3,5)/\rho g L^3$$
$$C(4,4) = \rho g \iint_{S_b} y^2 n_3 dS + \rho g \forall z_b - m g z_g \qquad \overline{C}(4,4) = C(4,4)/\rho g L^4$$
$$C(4,5) = -\rho g \iint_{S_b} x y n_3 dS \qquad \overline{C}(4,5) = C(4,5)/\rho g L^4$$
$$C(4,6) = -\rho g \forall x_b + m g x_g \qquad \overline{C}(4,6) = C(4,6)/\rho g L^4$$
$$C(5,5) = \rho g \iint_{S_b} x^2 n_3 dS + \rho g \forall z_b - m g z_g \qquad \overline{C}(5,5) = C(5,5)/\rho g L^4$$
$$C(5,6) = -\rho g \forall y_b + m g y_g \qquad \overline{C}(5,6) = C(5,6)/\rho g L^4$$

See for example:

C(3,3) = rho* g* Ac = 1025* 9.81* 0.25* pi* (0.256)^2 = 517.56, which is different from the body(1).hydroForce.linearHydroRestCoef(3,3), let's say that is maybe due to round errors.

But
C(4,6)

$$C(4,6) = -\rho g \forall x_b + m g x_g$$

which from the body(1).hydroForce.linearHydroRestCoef(4,6) it could be either that xf=0 or that rho* Vo = m, however xf is not zero, neither the second option:

0.00344635* 1025 = 3.5325, which is different from the mass of the float = 3.075

same for C(5,6).

Also for:

$$C(3,4) = \rho g \iint_{S_b} y n_3 dS$$

$$
\boldsymbol{K}_h = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & K_{wp}^{h} & K_{wp}^{h} y_f & -K_{wp}^{h} x_f & 0 \\ 0 & 0 & K_{wp}^{h} y_f & K_h^{44} & -K_{wp}^{h} x_f y_f & (W - F_B) x_f \\ 0 & 0 & -K_{wp}^{h} x_f & -K_{wp}^{h} x_f y_f & K_h^{55} & (W - F_B) y_f \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}
$$

If this equation is compared with body(1).hydroForce.linearHydroRestCoef(3,4) I could be interpreted as if there is a lever arm in the y-direction. However, I could not understand the meaning of this yf

yf = body(1).hydroForce.linearHydroRestCoef(3,4) / body(1).hydroForce.linearHydroRestCoef(3,3) = -0.0012

Finally, I could not compute the K55 as the discretisation presented on the paper, Is there any chance to some help with this?

Kind Regards,
Juan Guerrero

nathanmtom commented on Aug 28, 2020

@Liam-Guerrero Thank you for the following on question and I will do my best to respond to your questions.

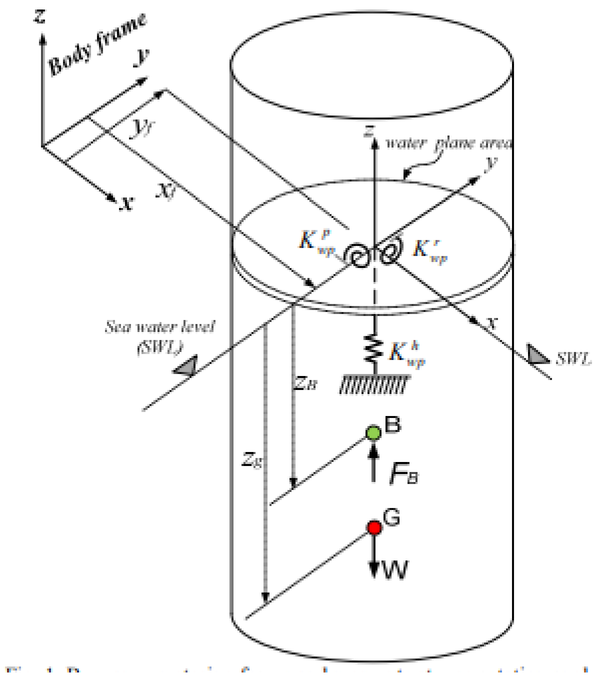
First, please note that in this model the water density was originally set at 1,000 kg/m^{3}. The model was built to represent an experimental apparatus that was tested in a fresh water tank and the initial mass of the float was determined assuming this.

Second, the C(3,3) term is slightly different from your theoretical derivation. In WAMIT, the various integrations are completed over a mesh of the floating body and at times the mesh resolution may result in a slightly different value.

For the C(4,6) term, in our calculation we have used the Alternative Form 1 of the FRC file, so WAMIT will assume that the mass and displaced mass are equal. You are correct in pointing out that there is a discrepancy between the material mass in the wecSimInputFile.m and the displaced volume from the .h5 file, but the WAMIT calculation assumes they are equal.

In C(4,4), C(4,6), C(5,5) and C(5,6), m denotes the body mass. When Alternative form 1 is used for the FRC file (Section 4.3) the body mass is computed from the relation $m = \rho \forall$. When Alternative form 2 is used for the FRC file (Section 4.4) the body mass is defined by EXMASS(3,3).

$\theta\ \psi]\approx\mathbf{0}$. The weight (W) and buoyancy (F_B) forces are assumed to be located along the platform centerline. The coordinates of the platform weight and buoyancy force (at equilibrium) points of action are (x_f ,y_f, z_g) and (x_f, y_f, z_B), respectively, as shown in Fig. 1. The heave restoring stiffness can be modeled as a translational spring while the water plane restoring moments in roll and pitch are represented as torsional springs, as shown in Fig. 1.



For C(5,5), I have followed the equation giving in the table listed in your response and have obtained a value close to that reported from the WAMIT output; however, I did have to adjust the diameter at the water plane area slightly from 0.256 m to 0.2549 m). This feeds off my point about C(3,3) where the numerical integration of the provided mess may differ from the input values.

I hope these responses have answered your questions, but please let me know if you still have concerns or additional questions.

Cheers,
Nathan
National Renewable Energy Laboratory

nathanmtom added Theory and removed question labels on Sep 2, 2020

Liam-Guerrero commented on Sep 2, 2020

Dear Nathan,

Thanks for your help, It really helped me to clarify my doubts.

Liam-Guerrero closed this on Sep 2, 2020

Assignees

nathanmtom

Labels

Theory

Projects

None yet

Milestone

No milestone

Linked pull requests

Successfully merging a pull request may close this issue.

None yet

3 participants