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Strength investigation of a small size floating dock unit by 3D-FEM models in head design waves

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Abstract. This study is focused on floating docks strength analysis by 3D finite element models, full extended over the dock length. The equilibrium position of the dock in the design equivalent quasi-static waves environment is obtained by own code, based on a non-linear iterative procedure. For the surrounding water and ballast tank water loads we have developed user procedures and functions implemented in the finite element programs. Also the still water conditions are analysed. The numerical study is developed for a small size floating dock, designed for multiple shipyards operation, with 60 m length and two constructive versions, having continuous and non-continuous side ballast tanks. As main operation cases of the small size floating dock are considered: light without docking ship, full ballast at maximum upper deck limit, three docking ship tests, with ship mass uniform, sagging and hogging type distributions, according to the shipbuilding classification societies rules. As assessment criteria, the 3D model yielding stress limit for global and local strength, buckling factor and maximum vertical deflection are considered. Also the freeboard criterion is considered. The results of the study are delivering the operation limits, in terms of design wave height, in order to ensure the strength safety rules requirements.

1. Introduction

The floating dock units are widely used in shipyards in many operation conditions [1]. At any floating dock design stage, for the main operating cases, the global and local strength in head equivalent design waves (EDW) has to be assessed, according to shipbuilding rules [2,3].

The floating dock strength by finite element method requires the development of 3D-FEM models, full extended over the length [4], and accurate procedures for the computation of the equilibrium position between the dock and the equivalent design wave [5]. A combination between Femap/NX Nastran program [6] and user procedures, functions and own developed codes for the dock-EDW equilibrium position are used. Section 2 presents the analysis linked codes and the strength criteria.

As study case we have developed the 3D-FEM models for a small size floating dock of 60 m length, with continuous (CWT) and non-continuous (NWT) side ballast tanks, placed on the dock pontoon [2,7]. Also a 1D model, by the equivalent beam method [5], is developed for the equilibrium position dock-EDW codes. Five main operation of the floating dock are considered, light, ballast and three docking ship types, according to the shipbuilding classification societies rules [2] (table 1). The numerical model details and the floating dock main characteristics are presented in section 3.

Section 4 presents the strength numerical analysis by 3D-FEM models of the two constructive versions of the floating dock. The dock structure is assessed by global - local admissible stress and buckling criteria, global vertical deflection and freeboard criteria. For each operation case a set of

EDW wave height is considered. Finally the operation limits of the floating dock, by strength safety criteria (table 2) [2, 3], are formulated in terms of the EDW equivalent design wave height.

2. Theoretical basis for the floating dock strength analysis by 3D-FEM and 1D-beam models

For global and local strength analysis of the small size dock we have used several own program codes and user procedures implemented in Femap/NX Nastran [6], linked as in the flowchart from figure 1.

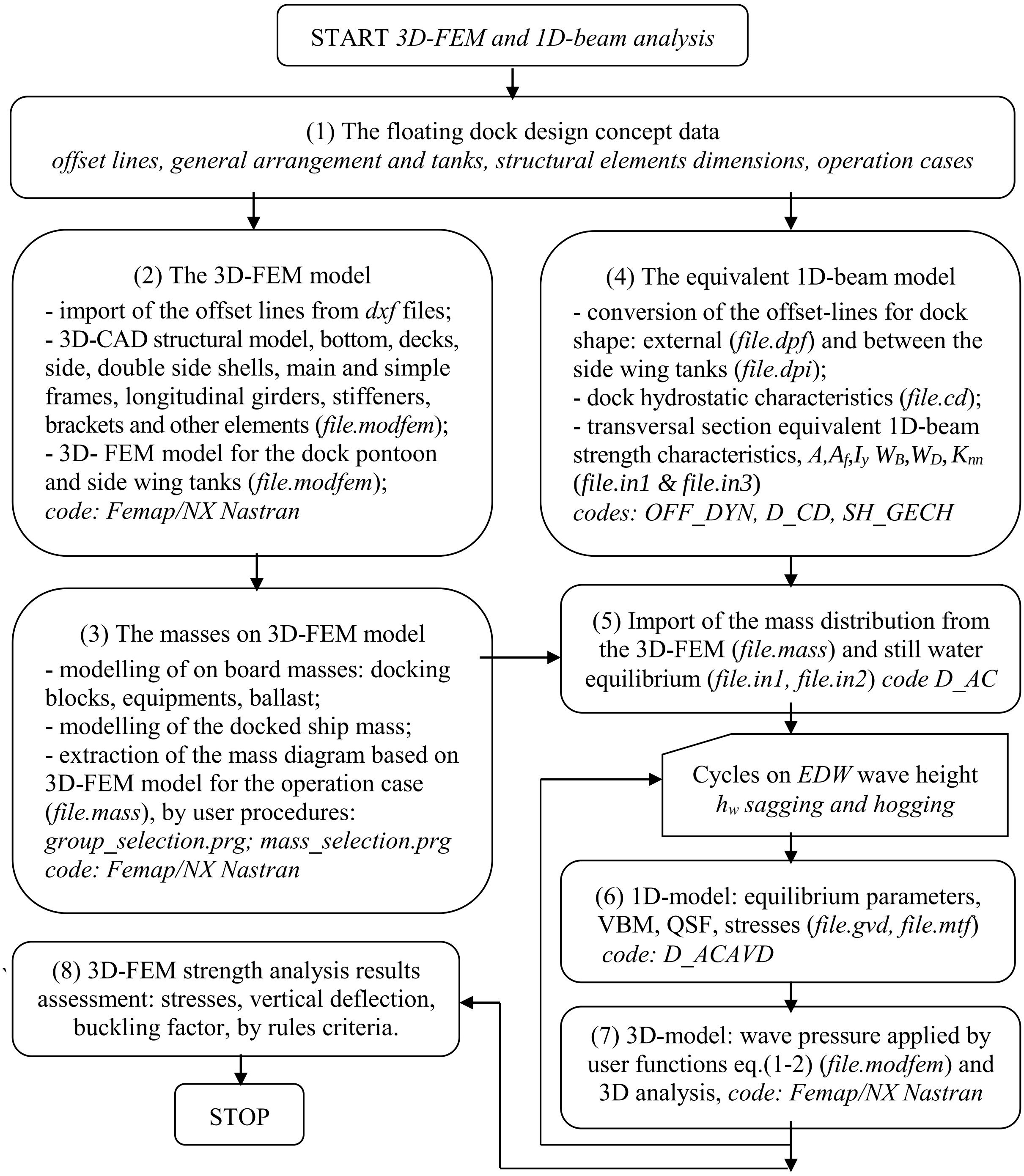

Figure 1. The flowchart for the floating dock strength analysis by 3D-FEM and 1D-beam models.

The global-local strength analysis of the dock by 3D/1D models has the next steps (figure 1):

- (1) *the floating dock design concept data* includes: the external shape and between the side tanks offset lines, the onboard tanks scheme and the general arrangement plan, the technical project for the structural design and the loading case, according to dock operation condition selected by rules [2].
- (2) *the 3D-FEM model*. Based on the Femap/NX Nastran [6] CAD modelling facilities, the offset lines for the floating dock are first imported. Using the data from the dock design concept, a 3D-CAD structural model is developed, including the main longitudinal panels, main and simple frames, longitudinal girders, stiffeners, brackets, etc. Based on the Femap/NX Nastran [6] FEM meshing facilities, the numerical 3D-FEM model of the small size dock is obtained, including two main parts: the dock pontoon and the side wing tanks (figures 2,3).
- (3) *the masses on 3D-FEM model*. Using the floating dock and the operation loading case data, the required on board masses, ballast and docking ship type mass are obtained. Using lumped masses or un-structural mass elements from Femap/NX Nastran [6], the mass distribution on the 3D-FEM model is done. By own user procedures (*group_selection.prg; mass_selection.prg*) developed for Femap/NX Nastran [6], the mass distribution per unit length for the 1D-beam model is extracted.
- (4) *the equivalent 1D-beam model*. Based on the floating dock data the 1D equivalent beam numerical model is developed. The 1D model includes: external and between side tanks offset lines (geometric 3D) imported from *dxf* files using *OFF_DYN* code, the dock hydrostatic curves by *D_CD* code, the transversal sections strength characteristics, A, A_f, I_y W_B, W_D, K_{nn} (table 3) by *SH_GECH* code.
- (5) *import of the mass distribution from the 3D-FEM*. A special care is to ensure the best correlation for the external hull shape and mass distributions between the 3D and 1D models used for the dock-waves equilibrium parameters. Also the still water equilibrium condition is obtained by *D_AC* code, in order to check out the accuracy of the loading case idealization using the 3D/1D models.
- (6) *1D-model: equilibrium parameters*. Using an iterative non-linear algorithm with two parameters, vertical position and trim angle [8,9] of the medium plane of the head equivalent design wave [5], the dock-EDW equilibrium position is obtained. The algorithm is implemented in *D_ACAVD* code, a subset of the code *P_QSW* [10] developed as a three parameters iterative algorithm for oblique equivalent design wave. Using the 1D-model equivalent beam [5], besides the T_{pp}, T_{pv} vertical position of the medium plane of the EDW head wave, at aft and fore of the dock, also the vertical bending moments (VBM) and shear forces (QSF), the normal stresses at bottom and upper deck, tangential side stress at neutral axis level are obtained. Equation (1) presents the EDW head wave free surface equation and the EDW wave pressure at *x* and *z* positions over the external and between sides dock shells.

$$\zeta_w(x) = T_{pp} + \left(T_{pv} - T_{pp}\right)\frac{x}{L} \pm \frac{h_w}{2} cos\left(\frac{2\pi x}{L}\right); T_m = \frac{T_{pp} + T_{pv}}{2}\ ;\ p_w(x,z) = \rho g\left(\zeta_w(x) - z\right);\ x \in [0,L];\ z \in [0,H] \quad (1)$$

*max(0;(!ro*9.81*(-ZEL(!EL)+!Tpp+(!Tpv-!Tpp)*XEL(!EL)/!L±!hw/2*COS((2*180*XEL(!EL)/!L)))))* (2)

where: T_{pp} ,T_{pv},T_m are the aft, fore, average vertical positions of EDW head wave medium plane and represent the draught values in the case of SW still water; ζ_w, p_w, h_w are the *EDW* head equivalent design wave elongation, pressure and height; *XEL*, *ZEL* are Femap/NX Nastran [6] functions for element *EL* centre longitudinal *x* and vertical *z* positions selection; *L*, *H* are the dock length and height.
- (7) *3D-model wave pressure*. Based on the user function from equation 2 and the equilibrium parameters from step 6, corresponding to a wave height h_w in sagging (+) or hogging (-) conditions, by Femap/NX Nastran [6] program loading menu on each element from the external and between side tanks shells the EDW wave pressure (equation (1)) is applied automatically. Using the NX Nastran solver [6] with static linear option, the 3D-FEM model is analysed.
- (8) *3D-FEM strength analysis results assessment*. For each operation case, the maximum EDW head wave height h_w is selected according to the limits imposed by the freeboard criteria [2] (table 2). Then the 3D-FEM model analysis results are assessed by the global-local strength criteria according to the rules [2] (table 2): the admissible stresses to the yield stress limit, the admissible buckling factor and the admissible global vertical deflection of the floating dock hull. The results are presented in section 4.

3. The small size floating dock 3D-FEM and 1D-beam models

The main characteristics of the small size floating dock ,with the two constructive versions (figures 2,3), are presented in table 3. In order to ensure the local buckling strength, the structural initial design concept [7] of the small floating dock has been enhanced by adding longitudinal and horizontal stiffeners (FB400x5, figures 6, 4) and simple frames (figure 5) between the main frames (figure 6). The onboard ballast mass has been reconfigured in order to preserve the initial displacement cases (table 1).

The 3D model is developed by Femap/NX Nastran [6] program (steps 1-3) and includes the internal and external shell plates, main longitudinal girders and frames, with the corresponding cut-holes, longitudinal and transversal stiffeners, and also local brackets. The 3D-FEM model has shell, membrane and plate (Mindlin) elements, with an average element size of 200 mm, suitable for global and local stress investigation, plus the mass elements for onboard mass groups (step 3). Figures 4,5 present details of the 3D-FEM model. Table 1 presents the operation cases of the small floating dock, according to rules [2].

The 1D-beam model, developed by the equivalent beam method [5] (steps 1,4,5), has the characteristics in table 3. The mass diagrams are imported from the 3D-FEM models (steps 3 to 5).

Table 2 presents the strength criteria (step 8) used for the dock structure analysis (steps 6,7) assessment. Figure 7 presents the pressure from EDW wave sagging and hogging, on the NWT floating dock hull.

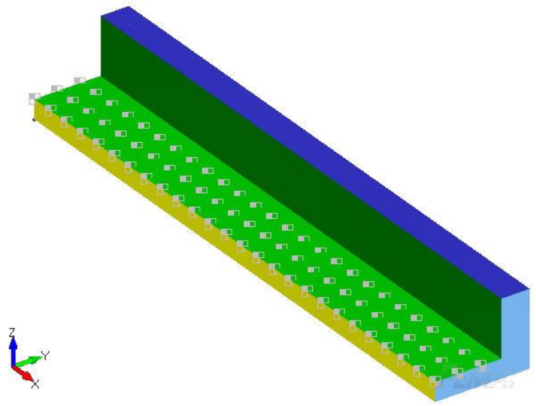

Figure 2. 3D-FEM model, CWT floating dock.

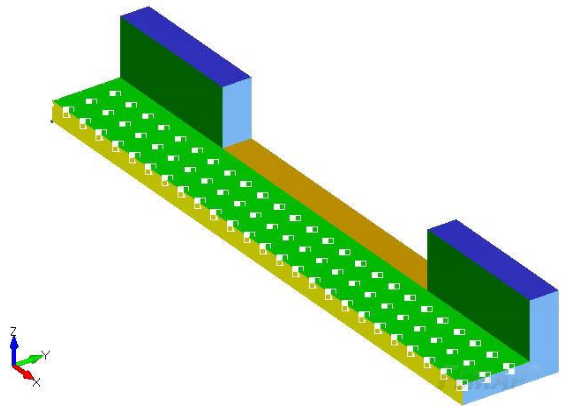

Figure 3. 3D-FEM model, NWT floating dock.

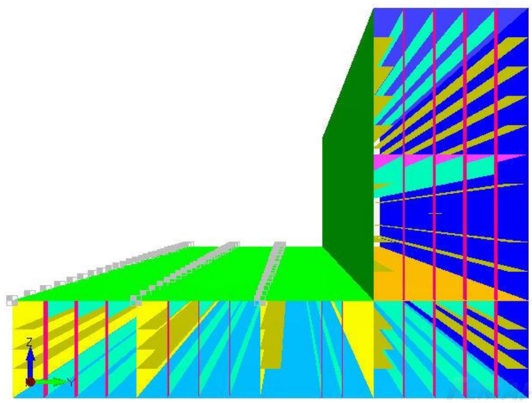

Figure 4. 3D-FEM model, longitudinal elements.

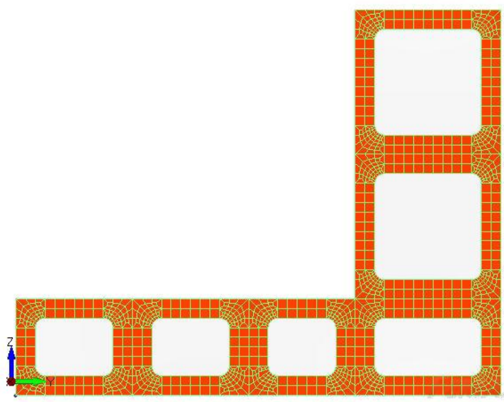

Figure 5. 3D-FEM model, simple frames elements

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Table 1. CWT and NWT operation cases [7].

	LCG = 30 m	Light	Ballast	Ships 1-3*
CWT	Δ [t]	1152	4092	1980
	T_{mSW} [m]	0.960	6.700	1.650
NWT	Δ [t]	960	3252	1788
	T_{mSW} [m]	0.800	6.733	1.490

Table 2. The strength and freeboard criteria [2].

σ_{adm} [MPa]	175	Freeboard adm[m]	CWT	NWT
τ_{adm} [MPa]	110	light dock	1.925	1.700
$B_{buckling\_adm}$	1.50	ballast dock	7.00	
w_{adm}[mm]	150	docking 1,2,3	1.925	1.700

*docking ships: uniform, sagg. & hogg. mass types

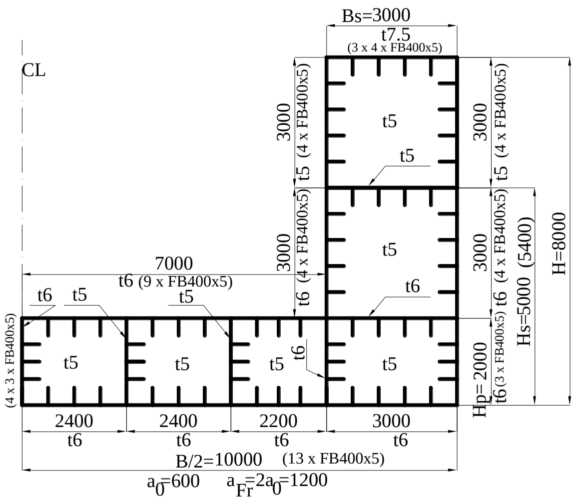
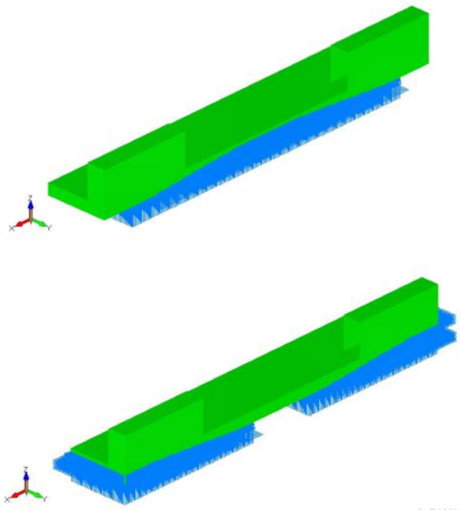


Figure 6. Small floating dock structure dimensions [7]



(sagg)

(hogg)

Figure 7. The EDW pressure on NWT, sagg., hogg.

Table 3. The main characteristics of the small size floating dock [7].

Floating dock type (side WT type)		CWT	NWT
Length overall	LOA [m]	60	
Breadth	B [m]	20	
Height pontoon	H_P [m]	2	
Height side wing tank	H_{WT} [m]	8	
No. elements 3D-FEM	N_{EL}	237928	162065
Element type 3D-FEM	shell (plate Mindlin) and mass		
No. nodes 3D-FEM	N_{ND}	201153	190618
Average EL length 3D	dx [mm]	200	
Main frames distance	a_{Fr} [mm]	1200	
Simple frames distance	a_0 [mm]	600	
No. elements 1D model	N_{EL}	300	
Element type 1D model	1D beam (Timoshenko)		
No. nodes 1D model	N_{ND}	301	
Average EL length 1D	dx [m]	0.200	
Gravity acceleration	g [m/s^2]	9.81	
External condition	EDW head eq. design wave		
Material	steel grade A		

Yielding stress limit		R_{eH} [MPa]	235	
Elasticity module		E [MPa]	2.1 10^5	
Poisson ratio		ν	0.3	
Material density		ρ_{mat}[t/m^3]	7.8	
Aft and fore part length		L(1) [m]	0-15 & 45-60	
Middle part length		L(2) [m]	15 – 45	
Area of sections	(1)	A [m^2]	0.80700	0.80860
	(2)			0.50400
Shear area	(1)	A_f [m^2]	0.36800	0.36960
	(2)			0.20400
Bending moment of inertia	(1)	I_y [m^4]	5.23698	5.29335
	(2)			0.34768
Section modulus bottom	(1)	W_B[m^3]	1.94078	1.94881
	(2)			0.34768
Section modulus deck	(1)	W_D[m^3]	0.98781	1.00181
	(2)			0.34768
Shearing coefficient	(1)	K_{nn}[m^{-2}]	6.86328	6.86436
	(2)			11.1942

4. The small size floating dock strength analysis by 3D-FEM and 1D-beam models

Based on the analysis flowchart from figure 1, the strength analyses by 3D-FEM and 1D-beam models for the small size floating dock, with the two constructive versions CWT and NWT, are done.

Figures 8 and 12 present the equivalent von Mises stress (*vonM*) [MPa] values for hogging condition, h_w=0.550 m (CWT) and h_w=0.186 m (NWT), in the case of docking ship 3, for 3D-FEM model.

Figures 9 and 13 present the buckling collapse mode and factor (B) values for hogging condition, h_w=0.550 m (CWT, frame) and h_w=0.186 m (NWT, bottom), in the case docking ship 3, 3D-FEM model.

Figures 10,14 and 11,15 present the normal stresses distributions in upper deck / deck (σ_x) [MPa] on still water, sagging and hogging conditions, for CWT and NWT floating dock constructive versions, in the case of docking ship 3, for 3D-FEM and 1D-beam models.

Tables 4 and 6 present the maximum equivalent von Mises stress (*vonM*), buckling factor (*B*), freeboard and the assessment by criteria from table 2, for CWT and NWT floating dock versions, for all the five operation cases (table 1), by 3D-FEM model.

Tables 5 and 7 present maximum normal deck stress (σ_x) and vertical deflection (w) and the assessment by criteria from table 2, both dock versions (CWT, NWT), for all five operation cases (table 1), by 3D-FEM and 1D-beam models.

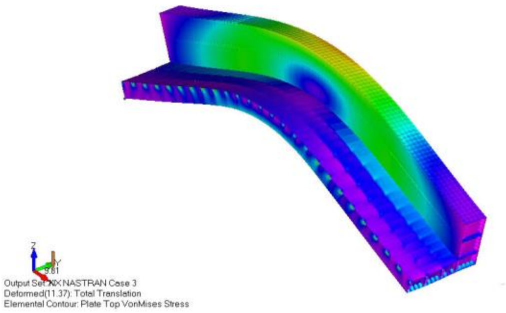


Figure 8. CWT, 3D-FEM, ship3, *vonM*, H0.550 m

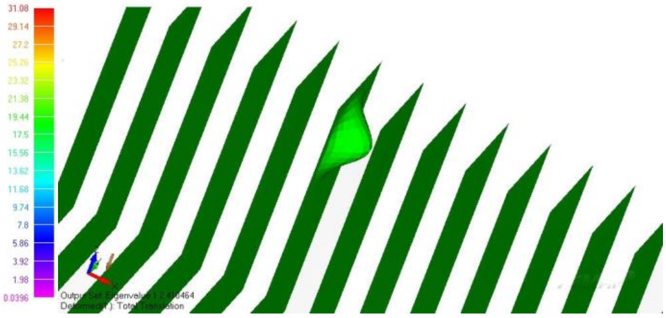


Figure 9. CWT,3D-FEM,ship3,*B*=2.411,H0.550 m

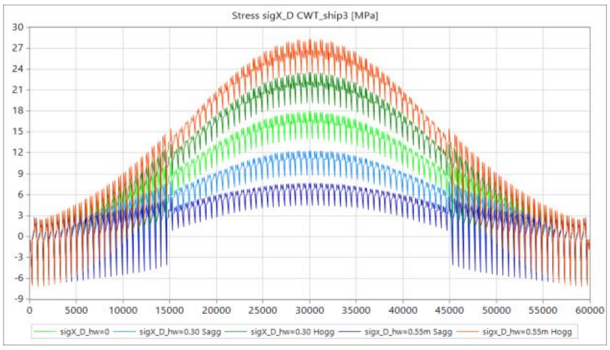


Figure 10. CWT, 3D-FEM, ship3, σ_x, deck

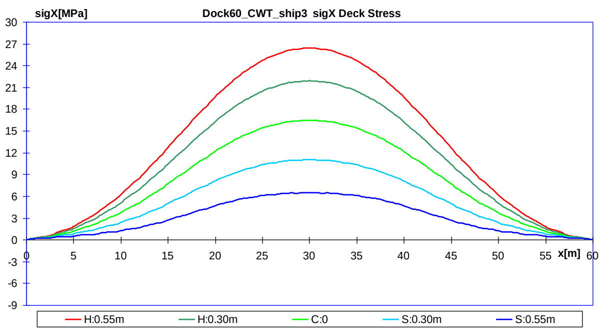


Figure 11. CWT, 1D-beam, ship3, σ_x, deck

Table 4. CWT 3D-FEM model, maximum equivalent von Mises stress and buckling factor, freeboard.

No	case	wave	h_w[m]	T_m[m]	Z[m]=$T_m \pm h_w/2$	*Z/adm≤1*	σ_{vM}[MPa]	σ_{vM} */adm≤1*	$B_{buckling}$	*B/adm≥1*
1	Light	sw.	0	0.96	0.960	0.499	18.92	0.108	5.550	3.700
		sagg.	1.93		-0.005	0	36.37	0.208	2.828	1.885
		hogg.	1.93		**1.925**	**1**	48.30	0.276	**1.518**	**1.012**
2	Ballast	sw.	0	6.70	6.700	0.957	43.78	0.250	3.102	2.068
		sagg.	0.60		6.400	0.914	46.45	0.265	2.928	1.952
		hogg.	0.60		**7.000**	**1**	44.98	0.257	2.953	1.969
3	Dock-ing ship1	sw.	0	1.65	1.650	0.857	31.20	0.178	4.511	3.007
		sagg.	0.55		1.375	0.714	31.07	0.177	3.844	2.563
		hogg.	0.55		**1.925**	**1**	31.26	0.179	2.849	1.899
4	Dock-ing ship2	sw.	0	1.65	1.650	0.857	30.56	0.175	4.377	2.918
		sagg.	0.55		1.375	0.714	31.89	0.182	3.738	2.492
		hogg.	0.55		**1.925**	**1**	31.47	0.180	3.995	2.663
5	Dock-ing ship3	sw.	0	1.65	1.650	0.857	30.81	0.176	3.606	2.404
		sagg.	0.55		1.375	0.714	30.63	0.175	3.909	2.606
		hogg.	0.55		**1.925**	**1**	31.08	0.178	2.411	1.607

Table 5. CWT 3D and 1D models, maximum normal deck stress and vertical deflection.

No	case	wave	h_w[m]	σ_{xD} [MPa] (3D)	σ_{xD} [MPa] (1D)	*3D/1D* (σ_{xD})	$\sigma_{xD(3D)}$ */adm≤1*	*w*[mm] *(3D)*	*w*[mm] *(1D)*	*3D/1D* *(w)*	$w_{(3D)}$ */adm≤1*
1	Light	sw.	0	10.440	9.567	1.091	0.060	3.616	3.124	1.157	0.024
		sagg.	1.93	29.190	25.349	1.152	0.167	11.77	7.960	1.479	0.078
		hogg.	1.93	46.910	44.543	1.053	0.268	18.47	14.21	1.300	0.123
2	Ballast	sw.	0	15.085	12.782	1.180	0.086	4.428	4.020	1.101	0.030
		sagg.	0.60	18.617	16.042	1.161	0.106	5.392	5.054	1.067	0.036
		hogg.	0.60	11.579	9.522	1.216	0.066	3.472	2.986	1.163	0.023
3	Dock-ing ship1	sw.	0	13.198	12.032	1.097	0.075	5.523	4.007	1.378	0.037
		sagg.	0.55	4.706	2.293	2.052	0.027	1.434	0.858	1.671	0.009
		hogg.	0.55	23.400	21.994	1.064	0.134	9.717	7.176	1.259	0.065
4	Dock-ing ship2	sw.	0	6.962	4.545	1.532	0.040	1.780	1.452	1.226	0.012
		sagg.	0.55	9.346	5.501	1.699	0.053	2.978	2.560	1.163	0.020
		hogg.	0.55	15.623	14.506	1.077	0.089	5.880	4.612	1.275	0.039
5	Dock-ing ship3	sw.	0	17.949	16.455	1.091	0.103	7.133	5.147	1.386	0.048
		sagg.	0.55	7.670	6.493	1.181	0.044	2.941	1.988	1.479	0.020
		hogg.	0.55	28.379	26.416	1.074	0.162	11.330	8.306	1.364	0.076

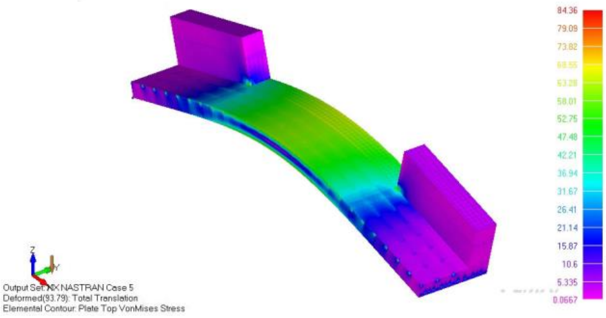


Figure 12.NWT, 3D-FEM, ship3, *vonM*, H0.186m

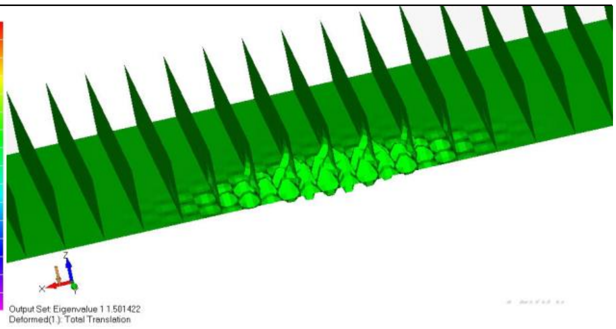


Figure 13. NWT,3D-FEM,ship3,*B*=1.501,H0.186 m

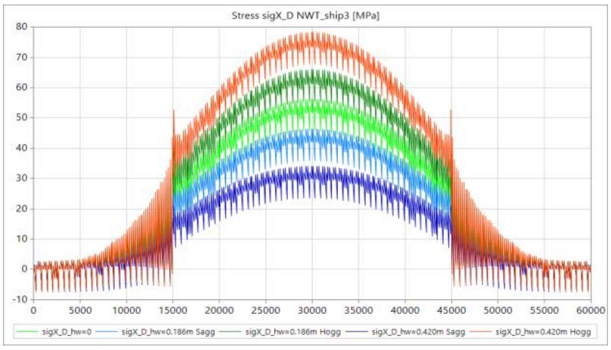


Figure 14. NWT, 3D-FEM, ship3, σ_x, deck

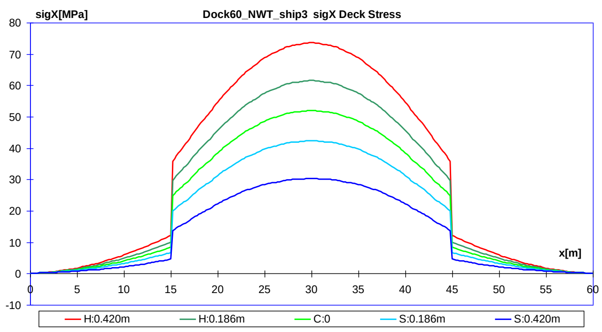


Figure 15. NWT, 1D-beam, ship3, σ_x, deck

Table 6. NWT 3D-FEM model, maximum equivalent von Mises stress and buckling factor, freeboard.

No	case	wave	h_w[m]	T_m[m]	Z[m]=$T_m \pm h_w/2$	*Z/adm≤1*	σ_{vM}[MPa]	σ_{vM} */adm≤1*	$B_{buckling}$	*B/adm≥1*
1	Light	sw.	0	0.80	0.800	0.471	46.66	0.267	2.841	1.894
		sagg.	0.582		0.509	0.299	21.61	0.123	5.391	3.594
		hogg.	0.582		1.091	0.642	89.30	0.510	**1.503**	**1**
2	Ballast	sw.	0	6.7333	6.7333	0.962	107.3	0.613	2.395	1.597
		sagg.	0.326	6.6856	6.5226	0.932	108.2	0.618	2.452	1.635
		hogg.	0.326	6.8370	**7.0000**	**1**	106.4	0.608	2.303	1.535
3	Dock-ing ship1	sw.	0	1.49	1.490	0.876	68.11	0.389	2.278	1.519
		sagg.	0.420		1.280	0.753	53.97	0.308	3.398	2.265
		hogg.	0.420		**1.700**	**1**	98.97	0.566	**1.503**	**1**
4	Dock-ing ship2	sw.	0	1.49	1.490	0.876	57.97	0.331	3.799	2.533
		sagg.	0.420		1.280	0.753	53.60	0.306	4.452	2.968
		hogg.	0.420		**1.700**	**1**	66.82	0.382	2.264	1.509

5	Dock-ing ship3	sw.	0	1.49	1.490	0.876	70.68	0.404	1.767	1.178
		sagg.	0.186		1.397	0.822	65.38	0.374	2.147	1.431
		hogg.	0.186		1.583	0.931	84.36	0.482	**1.501**	**1**

Table 7. NWT 3D and 1D models, maximum normal deck stress and vertical deflection.

No	case	wave	h_w[m]	σ_{xD} [MPa] (3D)	σ_{xD} [MPa] (1D)	*3D/1D* (σ_{xD})	$\sigma_{xD(3D)}$ */adm≤1*	*w*[mm] *(3D)*	*w*[mm] *(1D)*	*3D/1D* *(w)*	$w_{(3D)}$ */adm≤1*
1	Light	sw.	0	36.092	32.461	1.112	0.206	48.55	45.88	1.058	0.324
		sagg.	0.582	6.016	3.031	1.985	0.034	3.866	3.52	1.098	0.026
		hogg.	0.582	66.846	62.410	1.071	0.382	93.54	87.34	1.071	0.535
2	Ballast	sw.	0	21.400	6.933	3.087	0.122	17.37	10.06	1.727	0.116
		sagg.	0.326	19.909	6.393	3.114	0.114	15.54	9.18	1.693	0.104
		hogg.	0.326	22.904	7.473	3.065	0.131	19.23	10.95	1.756	0.128
3	Dock-ing ship1	sw.	0	43.781	39.380	1.118	0.250	64.20	56.33	1.140	0.428
		sagg.	0.420	21.578	17.767	1.214	0.123	31.71	26.38	1.202	0.211
		hogg.	0.420	65.938	60.992	1.081	0.377	96.68	86.23	1.121	0.645
4	Dock-ing ship2	sw.	0	22.304	18.108	1.232	0.127	29.88	25.33	1.180	0.199
		sagg.	0.420	12.361	6.062	2.039	0.071	4.17	3.68	1.133	0.028
		hogg.	0.420	44.461	39.720	1.119	0.254	62.35	55.25	1.141	0.416
5	Dock-ing ship3	sw.	0	56.296	51.946	1.084	0.321	79.39	71.34	1.113	0.529
		sagg.	0.186	46.465	42.375	1.097	0.266	64.99	58.09	1.119	0.433
		hogg.	0.186	66.110	61.517	1.075	0.378	93.79	84.59	1.109	0.625

5. Conclusions

The strength analysis of the floating dock [7] (section 4), with two versions section 3 (figures 2,3), based on the algorithm in section 2 (figure 1), for five operation cases (table 1), leads to the next conclusions:

1. A complex algorithm (figure 1) for the floating docks global and local strength analysis using 3D-FEM and 1D-beam models has been developed, including iterative numerical methods for dock-EDW equilibrium by own codes and user procedures & functions implemented into the Femap/NX Nastran [6].
2. In order to ensure the local buckling strength, the initial dock structure [7] has been enhanced (figure 6), by adding horizontal & longitudinal stiffeners (figure 4) and simple frames (figure 5).
3. Both floating dock versions, CWT, NWT, are initial loaded with EDW head wave pressure, sagging and hogging conditions, up to the wave height h_w limits imposed by the freeboard criterion (table 2). The most restrictive operations are on the three docking ships and ballast cases (tables 4, 6), resulting the following limits h_w=0.550-0.600 m (CWT) and h_w=0.326-0.420 m (NWT), which are around or under the IN(0.6) navigation area, requiring sheltered harbour conditions. At light case, by freeboard criterion, the limits (tables 4, 6) are h_w=1.930m (CWT) and h_w=1.829 m (NWT), which are around the IN(2.0) navigation area, being suitable for relocation operation of the floating dock.
4. In the case of CWT dock, the buckling criterion adds no supplementary restrictions, only being overlapped with freeboard criterion in the case of light operation, hogging h_w=1.930m (table 4). The admissible stress and vertical deflection criteria (tables 4, 5) induce no restrictions.
5. In the case of NWT dock, the buckling criterion induces significant limits for the light case, hogging h_w=0.582 m, and docking ship 3 case, hogging h_w=0.186 m (table 6). There are no buckling restrictions for docking ship 2 case and is overlapped with the freeboard criterion on docking ship 1 case. For the wave conditions already reduced by the freeboard and buckling criteria, the admissible stress and vertical deflection criteria (tables 6, 7) induce no extra restrictions in the case of the NWT dock.
6. The comparison between 3D&1D models (tables 5,7; figs.10,11,14,15) points out the deck hotspots stresses.
7. By combined criteria, table 8 presents the operation restrictions for the small size floating dock. The operation of NWT dock is more restrictive in compare to the CWT, having less strength. Further study shall include also the case of oblique EDW waves [10] for the assessment of the floating dock strength.

Table 8. CWT and NWT floating dock analysis results by 3D &1D models and combined criteria.

Type		Light	Ballast	D-Ship 1	D-Ship 2	D-Ship 3
CWT	$h_{w\ limit}$ [m]	1.930	0.600	0.550	0.550	0.550

	criteria	freeboard & buckling	freeboard	freeboard	freeboard	freeboard
	inland	≈ IN(2.0)	IN(0.6)	≈ IN(0.6)	≈ IN(0.6)	≈ IN(0.6)
	costal	special approval	unsheltered / sheltered harbour			
NWT	$h_{\mathrm{w\ limit}}$ [m]	0.582	0.326	0.420	0.420	0.186
	criteria	buckling	freeboard	freeboard & buckling	freeboard	buckling
	inland	≈ IN(0.6)	SW	SW	SW	SW
	costal	special approval	sheltered harbour			

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