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ON THE GLOBAL FREE VERTICAL VIBRATIONS ANALYSES OF AN 18000 TDW BULK-CARRIER SHIP

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ABSTRACT

For ships having the hull girder elastic, before the assessment of the vibration responses induced by waves, a preliminary step is the global free vibrations modes analysis. In this study there is considered an 18000 tdw bulk-carrier ship, with elastic hull structure, of 158.9 m overall length and full loading case. The numerical analyses involve 3D-FEM full hull models, with the main structural details, developed by two finite element programs. The analyses are focused on the first two global free vibration modes, with or without the added hydrodynamic masses, structure-fluid interaction. The numerical results provided by the two FEM models are compared with the values obtained by Kumai's statistical expression, pointing out the accuracy level of each approach.

Keywords: bulk-carrier ship, global free vertical vibration analysis, finite element method.

1. INTRODUCTION

The ships having the overall length larger than 150 m are considered with elastic hull girder, when the global vibrations induced by waves are usually recorded [5], [6], [9]. A preliminary step is the global free vibration modes analysis, assessing the ship hull elasticity level.

As study case, there is considered an 18000 tdw bulk-carrier ship, presented in reference [3], with the full loading case. In order to model the structure-fluid interaction, for the numerical models, the added hydrodynamic masses have to be considered [2], [7].

The 3D-FEM structural models for global vertical free vibration analyses are developed by SolidWorks Cosmos/M [8] and Femap NX Nastran [4] finite element programs. The eigen modes are computed by the subspace iteration or Lanzos methods [2], where the global vibration modes result among several local modes.

The FEM results are compared to the Kumai's [1] statistical values, for the assessment of the accuracy level of each approach.

2. THE BULK-CARRIER MODEL

The main characteristics of the 18000 tdw BK bulk-carrier ship [3] are:
- the ship main dimensions (Table 1);
- the ship off-set lines (Fig.1).

Table 1. The main dimensions of BK ship [3]

L_{OA} [m]	158.9	c_B	0.722
L_{BP} [m]	148.177	Δ [t]	23216
B [m]	22	v [knots]	14
D [m]	13	I_v [m^4]	49
T [m]	9	ρ [t/m^3]	1.025

The added hydrodynamic masses M_{33} for vertical global vibrations are computed considering the ship's sections parameterized by the Lewis conformal transformation [2] and Grim-Söding 2D fluid flow solution [2],[7].

$$M_{33n} = \int_{(L)} m_{33n}(x)dx\ ;\ c_T = \frac{A_t}{bd}\Big|_x\ ;\ H = \frac{b}{2d}\Big|_x\ ;$$

$$m_{33n}(x) = c_{33}^{\infty}(c_T, H)\cdot J_{3Dn}\Big|_{L_{BP}/B}\cdot\frac{\rho\pi b^2(x)}{8} \quad (1)$$

$$J_{3Dn}\Big|_{L_{BP}/B} = 1.02 - 3\cdot\left(1.2 - \frac{1}{n}\right)\cdot\frac{B}{L_{BP}};$$

where: c_{33}^{∞} is the non-dimensional coefficient of the vertical vibration hydrodynamic mass from Figure 2; b, d, c_T are the geometric characteristics of an x station; J_{3Dn} is the Townsin 3D/2D fluid flow correction coefficient [2]; $n \in N^*$ is the vertical vibration mode.

Table 2 includes the hydro masses M_{33n} for $n = 1,2$ vibration modes. The hydrodynamic masses are distributed over the external shell of the ship model by equivalent lumped mass elements, according to the technique presented in reference [2].

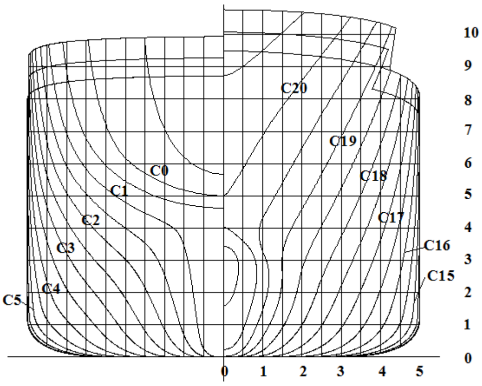

Fig.1 The BK ship off-set lines stations plan [3].

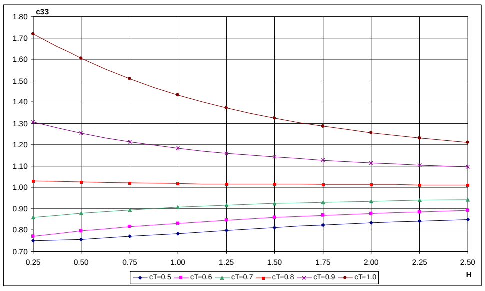

Fig.2 $c_{33}^{\infty}(c_T, H)$ hydrodynamic coefficient [2].

Table 2. BK ship's hydrodynamic masses

Mode n	J_{3Dn}	M_{33n} [t]	Δ+M_{33n} [t]
1	0.9309	23329	46545
2	0.7082	17748	40964

Preliminarily, the first two vertical natural vibration frequencies of BK are evaluated by the Kumai's statistical expression [1]:

$$f_{z1} = 3.07\cdot 10^6 \cdot \sqrt{\frac{I_v}{\Delta_z \cdot L_{BP}^3}}\cdot\frac{1}{60}\ \text{[Hz]}; \qquad (2)$$

$$\Delta_z = \left(1.2 + \frac{1}{3}\cdot\frac{B}{T}\right)\cdot\Delta\ ; \quad f_{z2} \approx 2\cdot f_{z1};$$

resulting: f_{z1} = 0.9181 Hz; f_{z2} = 1.8262 Hz.

The first structural model of the 18000 tdw bulk-carrier is developed by SolidWorks Cosmos/M [8] program. Table 3 presents the characteristics of the 3D-CAD/FEM model.

Table 3. BK 3D-CAD/FEM model characterises

No. PT	3830	*No. ND*	91458
No. CR	9357	*No. EL*	88886
No. SF	3853	*No. EG*	78

Figures 3.1-8 present in detail the 3D-CAD model of the BK ship, full length, one sided, by SWCM SolidWorks Cosmos/M [8].

Figures 4.1-11 present the 3D-FEM model of BK by SolidWorks Cosmos/M [8].

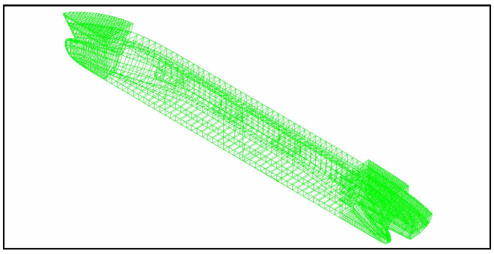

Fig.3.1 3D-CAD model, BK, SWCM, full.

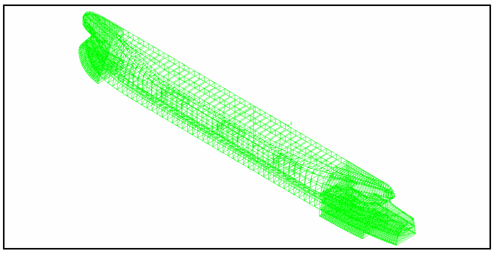

Fig.3.2 3D-CAD model, BK, SWCM, full.

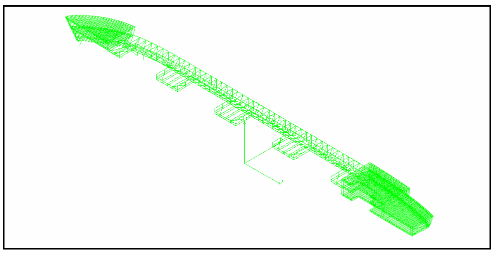

Fig.3.3 3D-CAD model, BK, SWCM, deck.

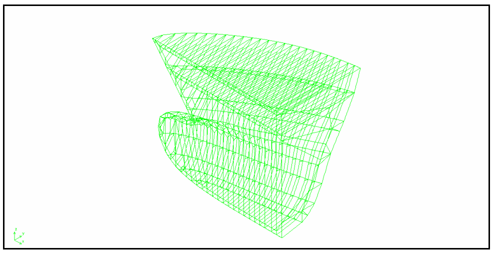

Fig.3.4 3D-CAD, BK, SWCM, fore-peak.

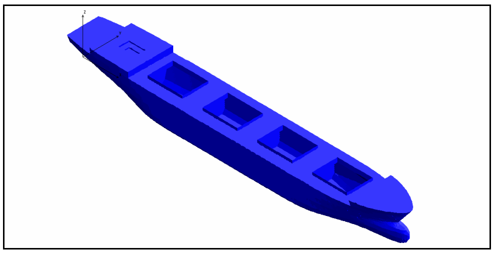

Fig.4.1 3D-FEM, BK, SWCM, full.

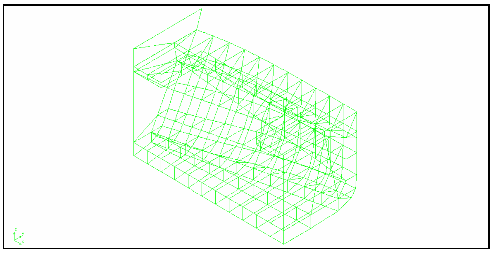

Fig.3.5 3D-CAD, BK, SWCM, cargo-hold 4.

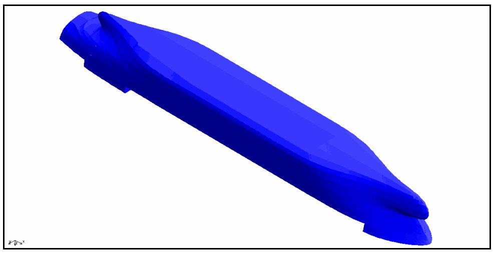

Fig.4.2 3D-FEM, BK, SWCM, full.

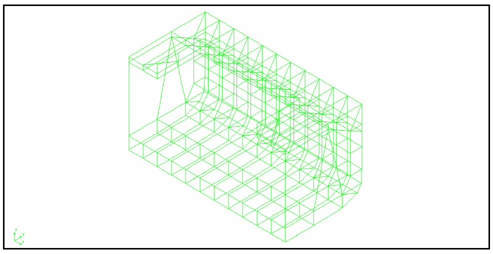

Fig.3.6 3D-CAD, BK, SWCM, cargo-hold 3.

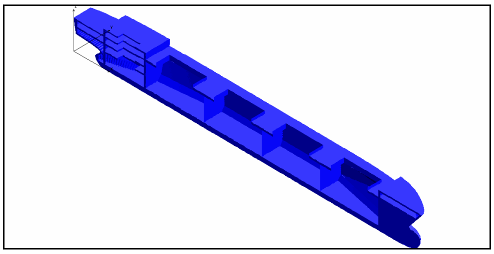

Fig.4.3 3D-FEM (1/2), BK, SWCM, full.

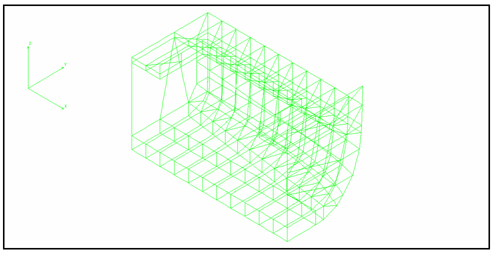

Fig.3.7 3D-CAD, BK, SWCM, cargo-hold 1.

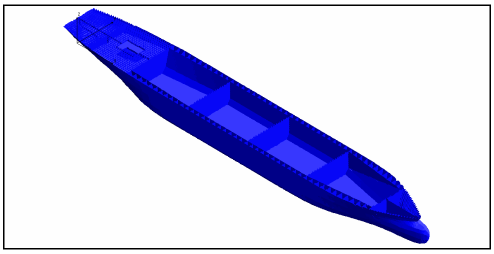

Fig.4.4 3D-FEM (*z*=0-10 m), BK, SWCM.

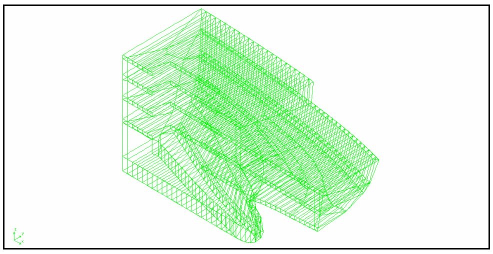

Fig.3.8 3D-CAD, BK, SWCM, aft-peak.

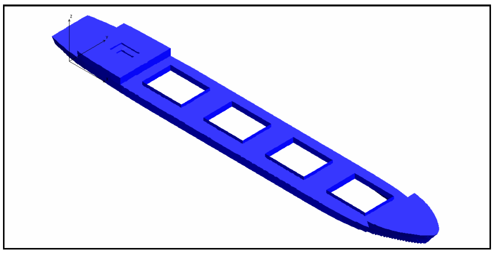

Fig.4.5 3D-FEM, BK, SWCM, deck.

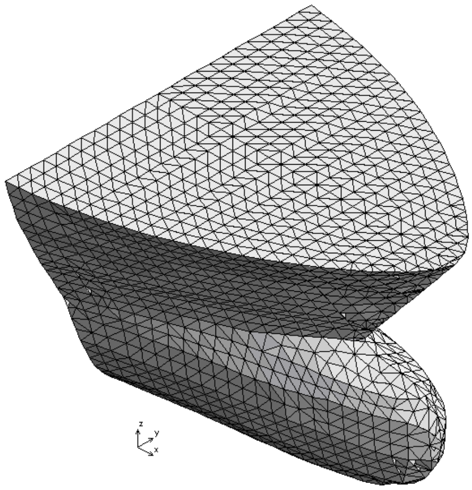

Fig.4.6 3D-FEM, BK, SWCM, fore-peak.

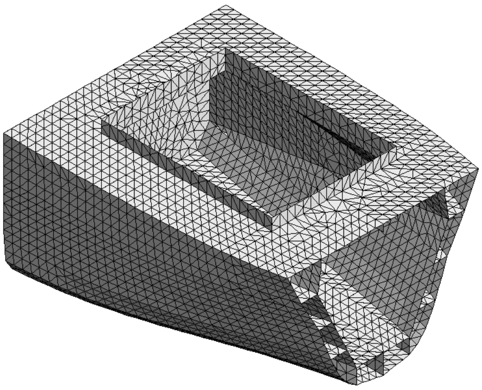

Fig.4.7 3D-FEM, BK, SWCM, cargo-hold 4.

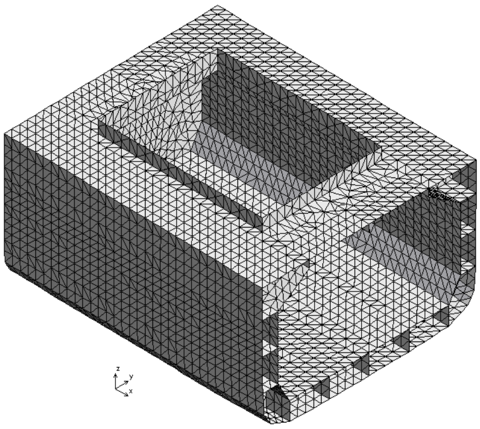

Fig.4.8 3D-FEM, BK, SWCM, cargo-hold 3.

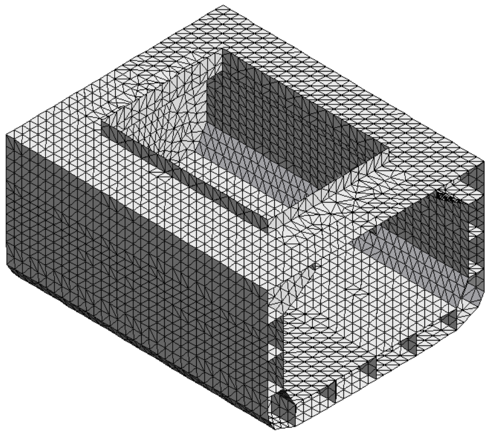

Fig.4.9 3D-FEM, BK, SWCM, cargo-hold 2.

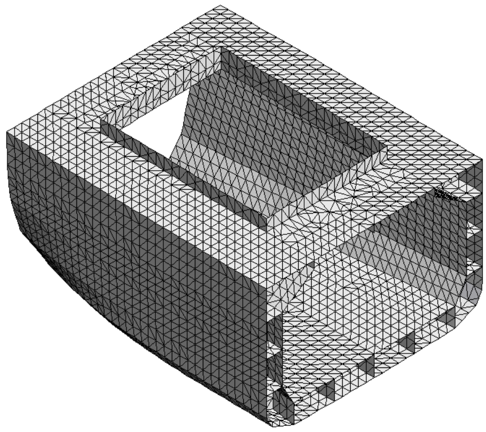

Fig.4.10 3D-FEM, BK, SWCM, cargo-hold 1.

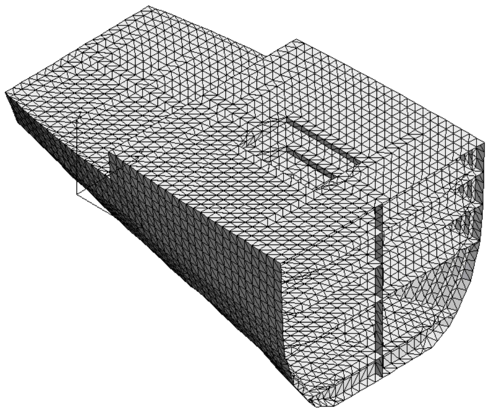

Fig.4.11 3D-FEM, BK, SWCM, aft-peak.

Figure 5 presents the 3D-FEM model of BK by FNN Femap NX Nastran [4], obtained by FEM model options transformation from SWCM Solid-Works Cosmos/M [8] model.

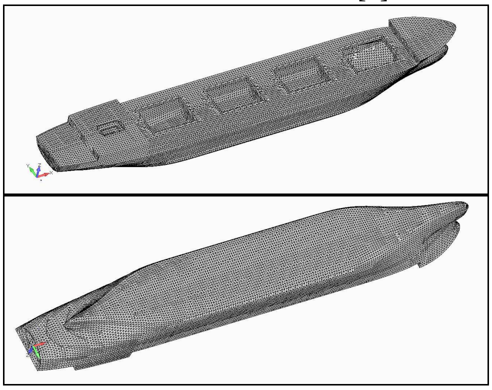

Fig.5 3D-FEM model, BK, FNN, full.

In the case of the SWCM 3D-FEM model, no boundary conditions are considered, so that for the numerical procedure the eigen value auto-shift option is activated.

In the case of the FNN 3D-FEM model, at one node aft-peak, placed in the centre plane, all the six degrees of freedom are restrained.

3. NUMERICAL RESULTS

Figures 6.1-2 & 8.1-2 present the n=1,2 modal shapes, without hydro masses.

Figures 7.1-2 & 9.1-2 present the n=1,2 modal shapes, with hydro masses.

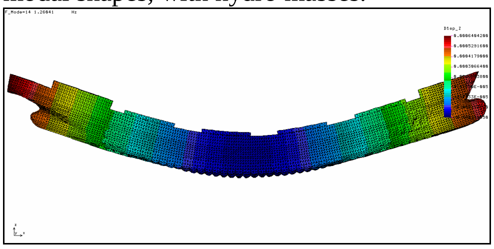

Fig.6.1 Mode 1(14) dry , SWCM, 1.2604Hz.

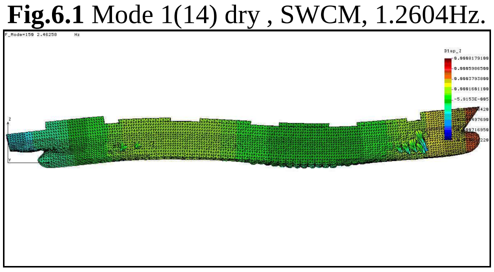

Fig.6.2 Mode 2(150) dry, SWCM, 2.4626Hz.

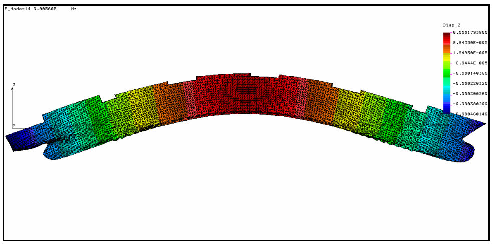

Fig.7.1 Mode 1(14) hyd , SWCM, 0.9056Hz.

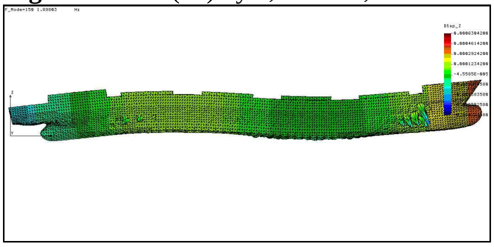

Fig.7.2 Mode 2(150) hyd, SWCM,1.8980Hz.

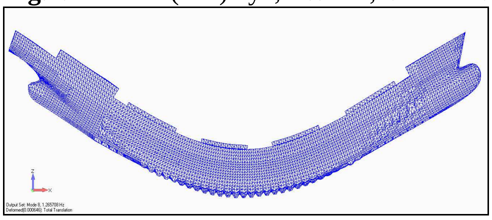

Fig.8.1 Mode 1(8) dry , FNN, 1.2657 Hz.

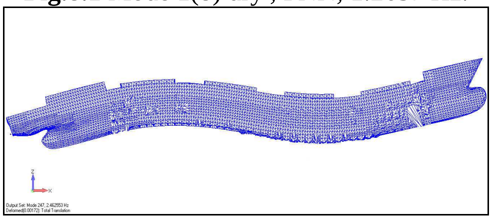

Fig.8.2 Mode 2(247) dry, FNN, 2.4626 Hz.

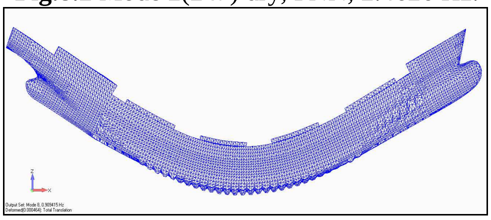

Fig.9.1 Mode 1(8) hyd , FNN, 0.9094 Hz.

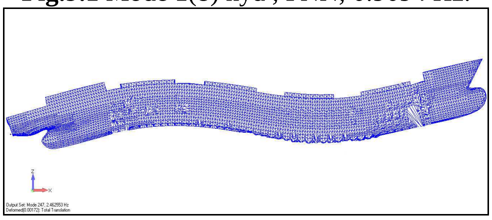

Fig.9.2 Mode 2(247) hyd, FNN, 1.8980 Hz.

Table 4.1 Eigen frequencies by SWCM model

Mode	Dry	Hyd_M1	Hyd_M2
1..6	-	-	-
7	0.828354	0.595175	0.638450
8	0.828834	0.595519	0.638820
9	0.829258	0.595825	0.639147
…	…	…	…
12	1.085550	0.779970	0.836682
13	1.122760	0.806708	0.865364
14	**1.260410**	**0.905605**	0.971452
15	1.536480	1.103970	1.184240
16	1.537630	1.104790	1.185120
…			
148	2.458450	1.766400	1.894840
149	2.460140	1.767610	1.896140
150	**2.462580**	1.769370	**1.898030**
151	2.467860	1.773160	1.902090
152	2.468080	1.773330	1.902260
…	…	…	…

Table 4.2 Eigen frequencies by FNN model

Mode	Dry	Hyd_M1	Hyd_M2
1	0.811304	0.582924	0.625309
2	0.812031	0.583447	0.625869
3	0.812448	0.583747	0.626191
4	1.068497	0.767718	0.823539
5	1.069037	0.768106	0.823955
6	1.069535	0.768464	0.824339
7	1.087140	0.781113	0.837908
8	**1.265708**	**0.909415**	0.975539
9	1.510426	1.085246	1.164154
10	1.510898	1.085584	1.164517
…	…	…	…
244	2.454898	1.763854	1.892104
245	2.460190	1.767657	1.896183
247	2.461358	1.768493	1.897081
248	**2.462553**	1.769351	**1.898002**
249	2.465397	1.771395	1.900194
…	…	…	…

Table 5 The BK vibration natural frequencies

Model	Without M_{33}		With M_{33}	
SWCM	1 (14)	2 (150)	1 (14)	2 (150)
	1.26041	2.46258	0.90561	1.89803
		Hyd/ Dry :	*0.71850*	*0.77075*
FNN	1 (14)	2 (150)	1 (14)	2 (150)
	1.26571	2.46255	0.90942	1.89800
		Hyd/ Dry :	*0.71850*	*0.77075*
Kumai	-	-	0.91810	1.82620
SW/FN	0.99581	1.00001	0.99581	1.00002
SW/K	-	-	0.98640	1.03933
FN/K	-	-	0.99055	1.03932

Tables 4.1 and 4.2 present the global and local 3D-FEM natural frequencies.

Table 5 presents the first two vertical global vibration frequencies, selected according to the modal shapes (Figs.6-9) and the Kumai's values (2).

4. CONCLUSIONS

Based on the data from section 3, which are synthesized in Table 5, results:

1. The frequency on the first mode differs by 0.419% < 0.5% between the two 3D-FEM models. The second mode frequency has no differences for the two models.
2. Comparing the 3D-FEM results to the Kumai's statistical values, the differences are on the first frequency 0.945÷1.36% < 1.50% and on the second frequency 3.933% < 5%.
3. The influence of the structure-fluid interaction, modelled by the added hydrodynamic masses, is significant, with differences on the first frequency of 28.15% and on the second frequency of 22.93%.
4. Further work will include the free vibration analyses in the horizontal plane and torsion for the bulk-carrier ship, extended also to the other ship types.

REFERENCES

[1]. **ABS,** "*Guidance Notes on Ship Vibrations*", American Bureau of Shipping, Houston, 2006.

[2]. **Domnisoru, L., Gavan, E., Popovici, O.,** "*Ship Structures Analysis by the Finite Element Method*", E.D.P. Bucharest, 2005.

[3]. **Dragomir, D.,**"*The Ships' Shapes Album*", "Dunarea de Jos" University Foundation Publishing House, Galati, 2008.

[4]. **FNN,** "*Femap NX Nastran Guide*", 2007.

[5]. **GL,** "*Ship Vibrations*", Germanischer Lloyd, Hamburg, 2001.

[6]. **LR,** "*Ship Vibrations and Noise. Guidance Notes*", Lloyd's Register, London, 2006.

[7]. **Söding, H.,** "*Hydrodynamische Massen und Dämpfungen*", TUHH Hamburg, 1994.

[8]. **SWCM,** "*SolidWorks Cosmos/M Guide*",2007.

[9]. **Vorus, W.S.,** "*Vibrations*", SNAME, New Jersey, 2010.

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