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MODAL ANALYSIS OF A 100449 TDW BULK CARRIER FOR THE AMIDSHIPS CARGO HOLD STRUCTURE

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ABSTRACT

A modal analysis of the ships' structures is requested at any design step to check the possibility of local resonance occurring with onboard systems and equipment. The main study objective is to perform a local modal analysis of the amishships cargo hold structure of a 100449 tdw bulk carrier. The numerical modal analysis is done by 3D-FEM models, and besides the cargo mass, the vibration hydrodynamic added masses are included. Different elements' mesh size selection is done, and the modal solution convergence analysis is approached.

Keywords: bulk-carrier ship, 3D-FEM approach, modal vibration analysis.

1. INTRODUCTION

Structural vibrations are an unavoidable phenomenon during ship operation, induced by both external and internal dynamic loads that may compromise the vessel's structural integrity and the performance of the onboard systems. When the excitation frequencies are close to or coincide with the natural frequencies of the hull structure, resonance phenomena may occur, leading to adverse effects such as structural fatigue, equipment degradation, and crew discomfort [2], [5].

This paper addresses the local modal analysis of the amidships cargo hold of a 100499 tdw bulk carrier "*Dietrich Oldendorff*" JSEA [1] (Table 1), performed by 3D-FEM models with Femap/NX Nastran [3].

The ship's structural preliminary design is done by DNV Poseidon [4] software, in accordance with DNV [2] rules. The midship section and one cargo hold structure are scanted, including the main amidships structural panels, with shells, brackets, longitudinal and transversal elements (Fig.1).

Table 1. The 100499 tdw bulk carrier data [1]

Data	Value	Unit
Loa	234.96	m
Lpp	231	m
B	38	m
D	20.62	m
d	15.013	m
Dw	100449	t
v	14	kn

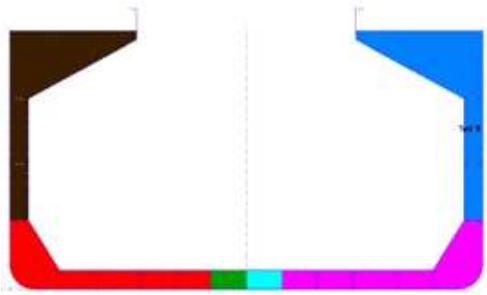

Fig.1 Bulk carrier 100499 tdw, midship section by DNV Poseidon [4]

2. BULK CARRIER 100499 TDW 3D-CAD/FEM MODELS

The CAD(3D) model (Fig.2) is developed as a primitive for the bulk carrier amidships frame, extended over a frame distance of 2.4, using the CAD Femap/NX Nastran [3] module options.

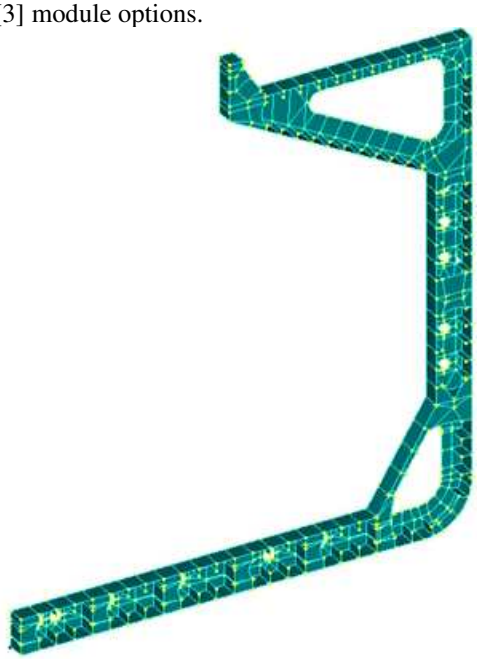

Fig.2 Bulk carrier 100499 tdw, amidships frame CAD(3D) model

The FEM(3D) model of the bulk carrier is extended over the amidships cargo hold, with triangular shell elements, and 3 mesh-sizes (Table 2), for a modal solution convergence test, and with 3 mass cases (Table 3).

Table 2. Mesh size cases

Case	Mesh size	No.ND	No.EL
Fine	0.100 m	509654	1019750
Medium	0.200 m	122971	257789
Coarse	0.400 m	81253	167290

Table 3. Mass cases

Case	Structural	Cargo	Hydro.
1	X	-	-
2	X	X	-
3	X	X	X

For the combined 9 modal analysis cases (Tables 2, 3), the cargo hold 3D-FEM models have applied the same nodal constraint sets (Table 4).

Table 4. Nodal constraints

Position	Constraints (model reference)					
DOF	*Tz*	*Tx*	*Ty*	*Rz*	*Rx*	*Ry*
CL	-	X	-	X	-	X
Aft BH	-	X	X	-	-	-
Fore BH	-	X	X	-	-	-
Mid Keel	X	-	-	-	-	-

3. CARGO HOLD MODAL ANALYSIS OF THE 100499 TDW BULK CARRIER

The local modal analysis of the bulk carrier amidship cargo hold is performed for the frequency range of 0.1 to 50 Hz, with the following results, natural modes of the cargo hold panels (without sub-harmonics) (BK-CH):
- Figs.3.1-9, case 1, mesh size 0.100-0.400m, bulk carrier cargo hold;
- Figs.4.1-9, case 2, mesh size 0.100-0.400m, bulk carrier cargo hold;
- Figs.5.1-9, case 3, mesh size 0.100-0.400m, bulk carrier cargo hold;
- Table 4.1-3, the natural frequencies of the bulk carrier cargo hold panels, cases 1-3.

Bulk carrier cargo hold – case 1, only with structural masses

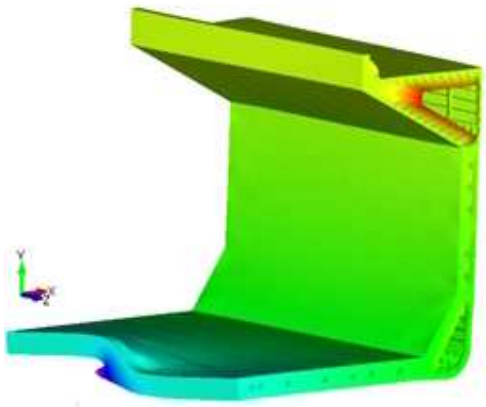

Fig.3.1 BK-CH,case 1 (0.1m),mode 1,7.507Hz

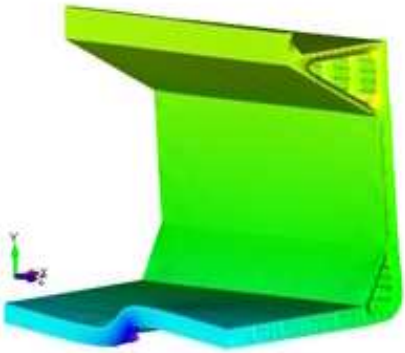

Fig.3.2 BK-CH,case 1 (0.2m),mode 1,7.753Hz

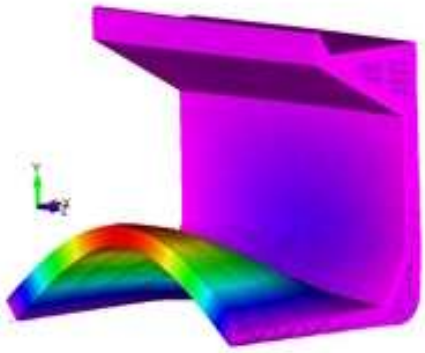

Fig.3.5 BK-CH,case 1(0.2m),mode 2,11.789Hz

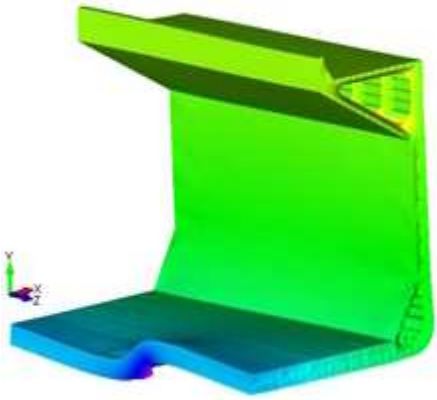

Fig.3.3 BK-CH,case 1 (0.4m),mode 1,8.136Hz

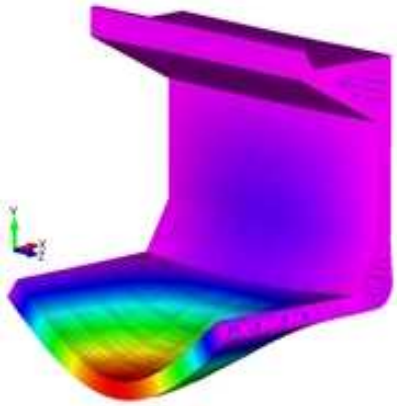

Fig.3.6 BK-CH,case 1(0.4m),mode 2,14.994Hz

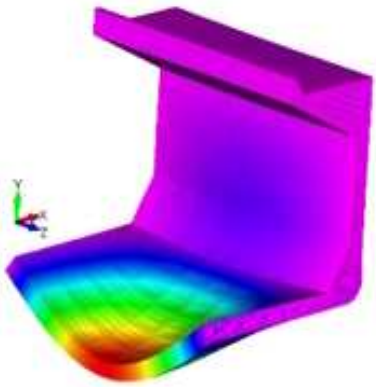

Fig.3.4 BK-CH,case 1(0.1m),mode 2,11.634Hz

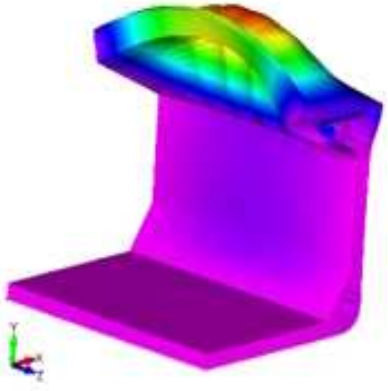

Fig.3.7 BK-CH,case 1(0.1m),mode 3,14.994Hz

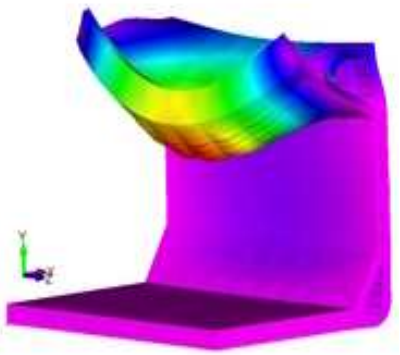

Fig.3.8 BK-CH,case 1(0.2m),mode 3,15.030Hz

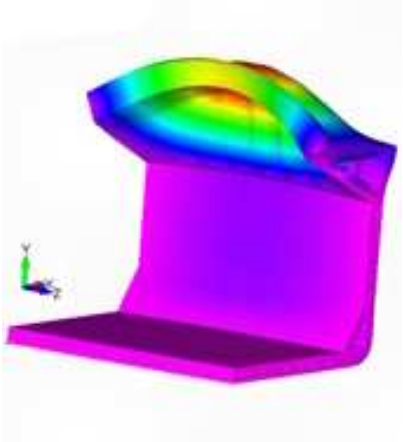

Fig.3.9 BK-CH,case 1(0.4m),mode 3,15.049Hz

Table 4.1. Bulk carrier cargo hold natural frequencies, case 1 (first 100 modes)

Mode	Fine(0.1)		Medium(0.2)		Coarse(0.4)	
1	7.507	**P**	7.753	**P**	8.136	**P**
2	11.634	**P**	11.468	**P**	11.789	**P**
3	14.994	**P**	15.030	**P**	15.049	**P**
4 27	18.897 21.871	L	18.624 21.244	L	19.106 21.949	L
28	21.917	**P**	21.244	L	21.963	L
29 32	21.953 22.215	L	21.267 21.447	L	21.970 22.031	L
33	22.388	L	21.504	L	22.154	**P**
34 44	22.464 22.676	L	21.658 23.795	L	22.316 24.318	L
45	22.676	L	23.937	L	24.333	**P**
46 60	22.676 22.685	L	23.949 24.553	L	24.458 25.160	L
61	22.868	L	25.353	**P**	25.161	L
62	24.204	L	26.106	L	25.161	L
63	24.250	**P**	26.114	L	25.161	L
64 80	24.351 25.369	L	26.114 26.138	L	25.162 25.366	L
81	25.864	**P**	26.140	L	25.368	L
82	26.056	L	26.141	L	25.374	L
83	27.886	**P**	26.142	L	25.381	L
84	27.952	L	26.142	L	26.417	**P**
85 91	28.044 28.497	L	26.358 27.942	L	27.372 27.788	L
92	28.513	**P**	27.984	L	27.788	L
93 100	28.582 29.244	L	27.987 28.283	L	27.820 28.571	L
293	49.416	L	50.056	L	47.142	L
313	50.045	L	-	-	47.559	L
355	-	-	-	-	50.050	L

Bulk carrier cargo hold – case 2, with structural and cargo masses

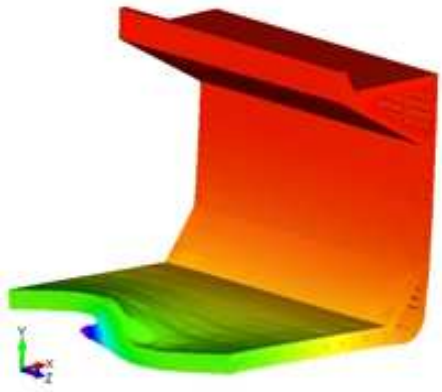

Fig.4.1 BK-CH,case 2 (0.1m),mode 1, 2.159Hz

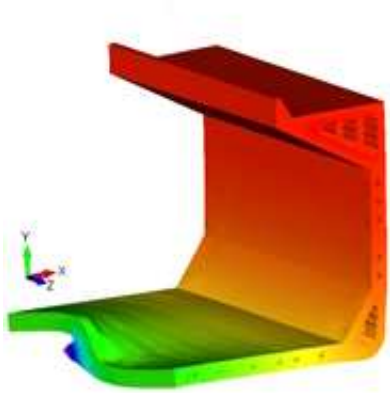

Fig.4.2 BK-CH,case 2 (0.2m),mode 1, 2.268Hz

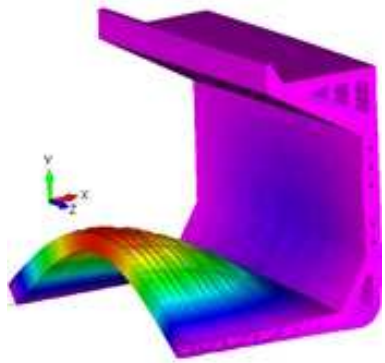

Fig.4.5 BK-CH,case 2 (0.2m),mode 2, 2.497Hz

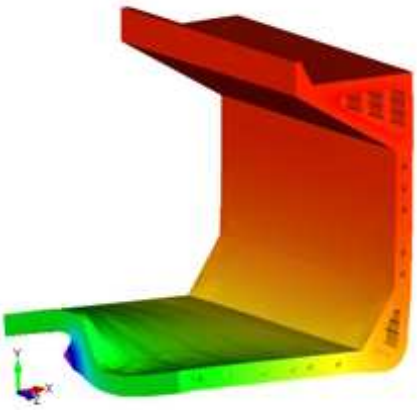

Fig.4.3 BK-CH,case 2 (0.4m),mode 1, 2.422Hz

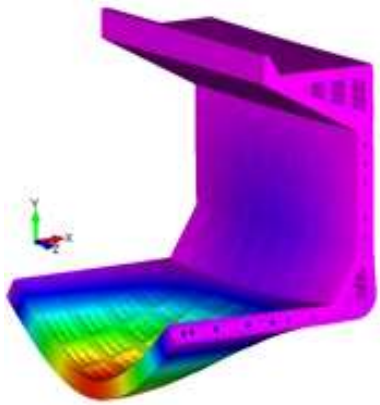

Fig.4.6 BK-CH,case 2 (0.4m),mode 2, 2.505Hz

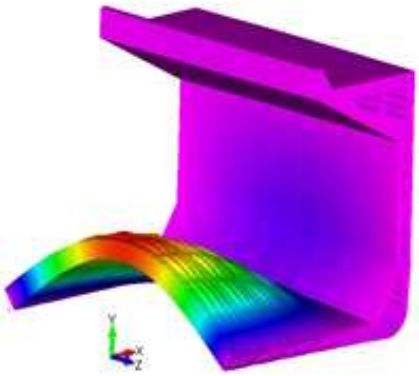

Fig.4.4 BK-CH,case 2 (0.1m),mode 2, 2.471Hz

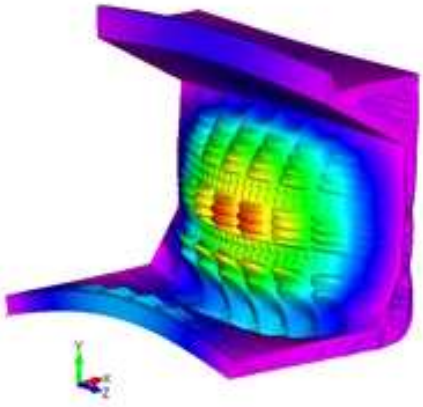

Fig.4.7 BK-CH,case 2 (0.1m),mode 3, 4.781Hz

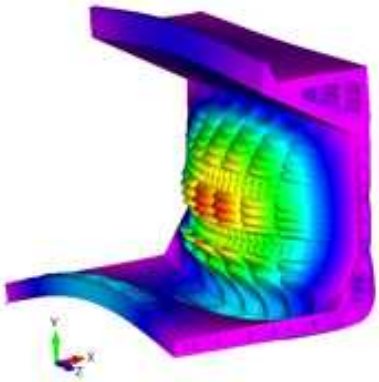

Fig.4.8 BK-CH,case 2 (0.2m),mode 3, 4.854Hz

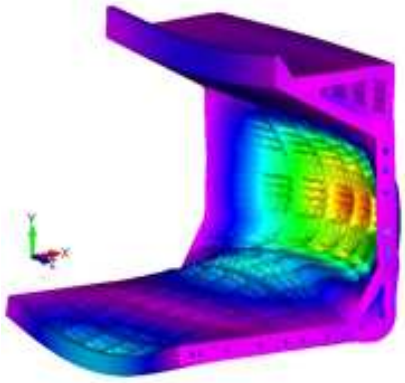

Fig.4.9 BK-CH,case 2 (0.4m),mode 3, 4.925Hz

Table 4.2. Bulk carrier cargo hold natural frequencies, case 2 (first 100 modes)

Mode	Fine(0.1)		Medium(0.2)		Coarse(0.4)	
1	2.159	**P**	2.268	**P**	2.422	**P**
2	2.471	**P**	2.497	**P**	2.505	**P**
3	4.781	**P**	4.854	**P**	4.925	**P**
4	5.577	**P**	5.697	**P**	5.751	**P**
5 8	5.909 6.213	L	6.161 6.332	L	6.215 6.285	L
9	6.190	**P**	6.396	L	6.319	L
10	6.314	L	6.423	**P**	6.350	L
11 12	6.385 6.425	L	6.446 6.479	L	6.375 6.392	L
13	6.507	**P**	6.545	**P**	6.553	**P**
14	6.917	**P**	7.121	**P**	7.197	**P**
15	7.001	**P**	7.165	**P**	7.309	**P**
16 25	7.110 7.730	L	7.475 7.943	L	7.489 7.847	L
26	7.767	**P**	8.000	**P**	7.848	L
27 28	7.788 7.791	L	8.012 8.031	L	7.850 7.874	L
29	7.798	L	8.053	**P**	7.881	**P**
30	7.804	L	8.068	L	7.911	L
31	7.808	L	8.100	**P**	7.919	L
32 37	7.819 7.953	L	8.120 8.247	L	7.938 8.042	L
38	7.957	L	8.304	L	8.104	**P**
39	7.959	L	8.344	L	8.237	**P**
40	7.962	L	8.709	P	8.656	L
41	7.991	**P**	8.725	**P**	8.658	**P**
42 46	8.001 8.031	L	8.754 8.916	L	8.793 8.817	L
47	8.034	**P**	8.989	L	8.821	L
48 49	8.058 8.110	L	9.001 9.025	L	8.855 8.894	L
50	8.113	**P**	9.084	L	8.895	L
51	8.131	**P**	9.107	L	8.910	L
52 55	8.167 8.237	L	9.108 9.237	L	8.910 8.983	L
56	8.261	**P**	9.237	L	8.988	L
57 61	8.294 8.324	L	9.238 9.381	L	9.000 9.062	L
62	8.327	L	9.400	**P**	9.078	L
63	8.333	L	9.454	**P**	9.097	L
64 79	8.337 8.824	L	9.467 9.884	L	9.102 9.307	L
80	8.852	L	9.886	L	9.309	**P**
81 82	8.882 8.903	L	9.890 9.925	L	9.313 9.319	L
83	8.924	**P**	9.926	L	9.327	**P**
84 89	8.985 9.101	L	9.927 10.014	L	9.337 9.428	L

90	9.109	**P**	10.020	L	9.434	L
91 100	9.118 9.418	L	10.027 10.138	L	9.436 9.561	L
2513	37.099	L	37.397	L	50.072	L
4066	50.007	L	48.625	L	-	-
4311	-	-	50.000	L	-	-

Bulk carrier cargo hold – case 3, with structural, cargo, and hydrodynamic masses

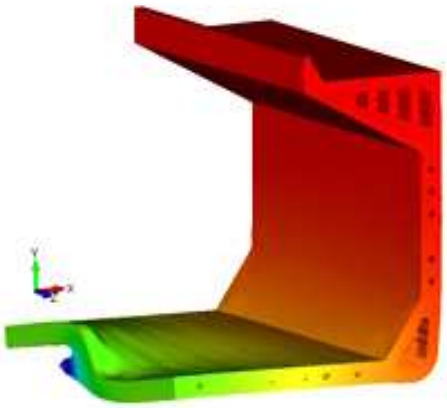

Fig.5.1 BK-CH,case 3 (0.1m),mode 1, 1.441Hz

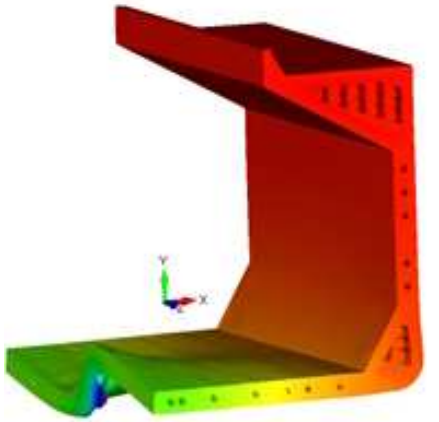

Fig.5.2 BK-CH,case 3 (0.2m),mode 1, 1.747Hz

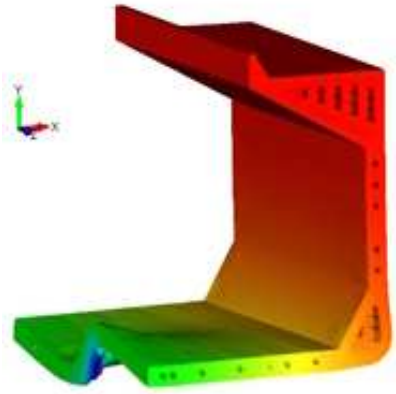

Fig.5.3 BK-CH,case 3 (0.4m),mode 1, 1.618Hz

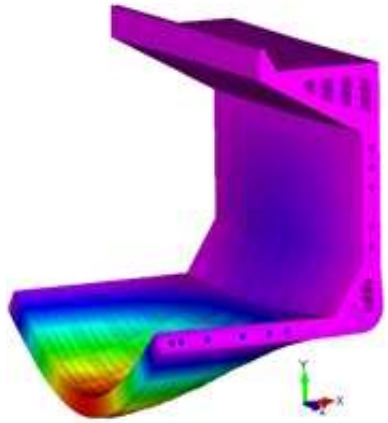

Fig.5.4 BK-CH,case 3 (0.1m),mode 2, 1.698Hz

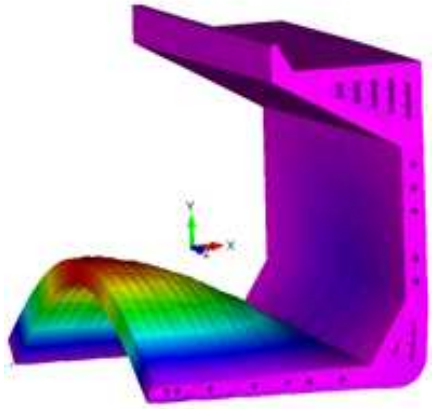

Fig.5.5 BK-CH,case 3 (0.2m),mode 2, 1.759Hz

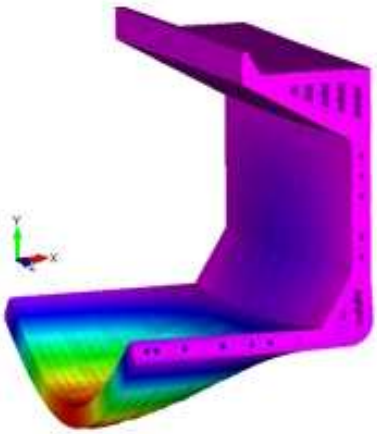

Fig.5.6 BK-CH,case 3 (0.4m),mode 2, 1.721Hz

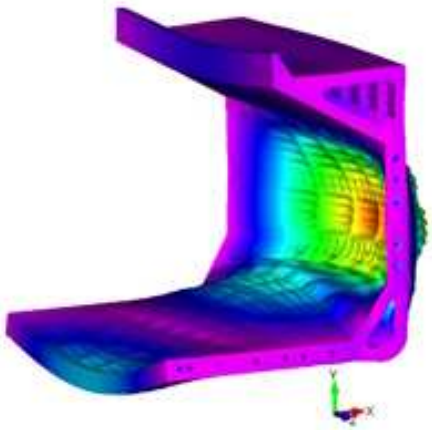

Fig.5.7 BK-CH,case 3 (0.1m),mode 3, 3.283Hz

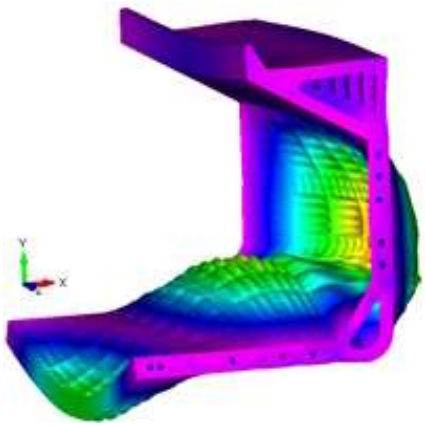

Fig.5.8 BK-CH,case 3 (0.2m),mode 3, 4.092Hz

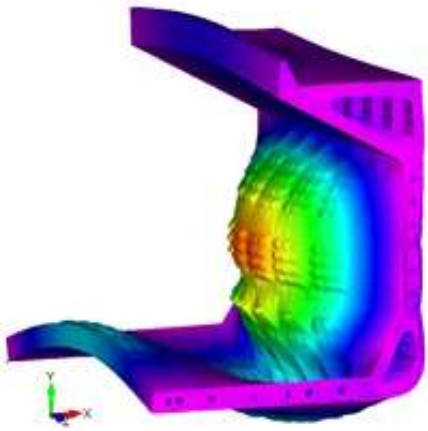

Fig.5.9 BK-CH,case 3 (0.4m),mode 3, 3.370Hz

Table 4.3. Bulk carrier cargo hold natural frequencies, case 3 (first 100 modes)

Mode	Fine(0.1)		Medium(0.2)		Coarse(0.4)	
1	1.441	**P**	1.747	**P**	1.618	**P**
2	1.698	**P**	1.759	**P**	1.721	**P**
3	3.283	**P**	4.085	**P**	3.370	**P**
4	3.944	**P**	4.092	**P**	4.042	**P**
5	4.605	**P**	5.173	**P**	4.718	**P**
6	5.049	**P**	6.161	L	5.254	**P**
7	5.211	**P**	6.191	L	5.420	**P**
8	5.622	**P**	6.209	**P**	5.785	**P**
9	5.909	L	6.258	L	6.150	**P**
10	5.963	L	6.269	**P**	6.215	L
11	5.974	**P**	6.332	L	6.226	L
12	6.084	L	6.395	L	6.251	L
13	6.174	**P**	6.444	L	6.284	L
14	6.211	L	6.475	L	6.318	L
15	6.237	**P**	6.512	**P**	6.349	L
16	6.310	L	6.517	L	6.373	L
17	6.315	**P**	6.671	**P**	6.380	**P**
18	6.407	L	6.838	**P**	6.394	L
19	6.408	L	7.175	**P**	6.517	**P**

20	6.478	L	7.474	L	6.779	**P**
21 23	6.645 6.687	L	7.533 7.611	L	6.842 6.891	L
24	6.745	**P**	7.667	L	6.927	L
25	6.747	L	7.734	L	6.958	L
26	6.765	L	7.749	L	6.989	**P**
27 28	6.768 6.780	L	7.809 7.885	L	6.991 7.017	L
29	6.797	L	7.908	**P**	7.033	L
30	6.852	L	7.910	L	7.054	L
31	6.871	L	8.012	L	7.057	**P**
32 43	6.884 7.128	L	8.031 8.344	L	7.100 7.667	L
44	7.145	L	8.665	**P**	7.685	L
45	7.169	L	8.722	**P**	7.711	L
46 47	7.186 7.205	L	8.754 8.806	L	7.724 7.725	L
48	7.228	L	8.826	L	7.751	**P**
49	7.251	L	8.866	**P**	7.754	L
50 52	7.264 7.324	L	8.908 8.936	L	7.780 7.846	L
53	7.373	**P**	9.001	L	7.848	L
54	7.381	L	9.025	L	7.855	L
55	7.451	L	9.084	L	7.857	**P**
56	7.453	L	9.089	**P**	7.872	L
57 61	7.532 7.706	L	9.107 9.217	L	7.873 7.969	L
62	7.718	**P**	9.241	L	7.971	L
63	7.738	**P**	9.251	L	7.982	L
64 66	7.788 7.798	L	9.255 9.272	L	8.011 8.027	L
67	7.804	L	9.381	L	8.035	**P**
68	7.808	L	9.466	L	8.039	L
69	7.818	**P**	9.484	L	8.077	L
70	7.819	L	9.518	L	8.084	L
71	7.858	L	9.536	**P**	8.097	L
72	7.864	L	9.550	P	8.133	**P**
73 75	7.884 7.947	L	9.554 9.671	L	8.219 8.302	L
76	7.947	L	9.731	L	8.321	**P**
77 85	7.948 8.003	L	9.741 9.881	L	8.331 8.553	L
86	8.012	L	9.882	L	8.565	**P**
87	8.021	L	9.884	L	8.578	**P**
88 92	8.058 8.166	L	9.889 9.906	L	8.587 8.640	L
93	8.171	**P**	9.907	L	8.651	L
94 97	8.173 8.237	L	9.910 9.915	L	8.671 8.733	L
98	8.240	**P**	9.917	L	8.767	L
99 100	8.282 8.290	L	9.920 9.924	L	8.767 8.793	L
4920	35.877	L	41.126	L	50.016	L
7287	45.429	L	50.002	L	-	-
8624	50.001	L	-	-	-	-

4. CONCLUSIONS

The first case, the only one with structural mass, without cargo and additional hydrodynamic mass, exhibits vibration modes within the frequency range of 7.507 – 50 Hz, with a total of 12 panel modes (P), and 343 local structural parts modes (L), of the bulk carrier amidship cargo hold (Fig.3.1-9, Table 4.1).

For the second case, the structural and cargo masses are considered, without the additional hydrodynamic mass. It indicates that the vibration modes are within the frequency range of 2.159 – 50 Hz, comprising 28 panel modes (P), and 4311 structural parts local modes (L), of the bulk carrier amidship cargo hold (Fig.4.1-9, Table 4.2).

For the third case, all the mass groups are included, having vibration modes frequency in the range 1.441 – 50 Hz, resulting in 25 panel modes (P), and 8599 structural parts local modes (L), of the bulk carrier amidship cargo hold (Fig.5.1-9, Table 4.3).

Figures 6.1-9 display the first five vibration modes for each case and mesh size, pointing out the FEM model idealization setup on the modal analysis solution convergence.

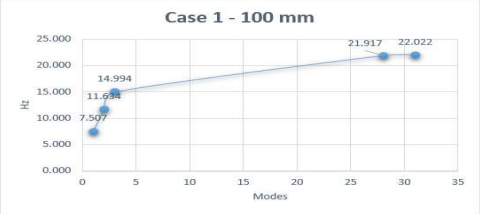

Fig.6.1 BK-CH, case 1 (0.1m), panel modes (P)

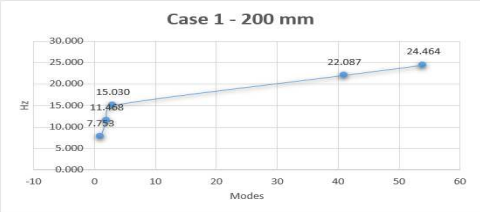

Fig.6.2 BK-CH, case 1 (0.2m), panel modes (P)

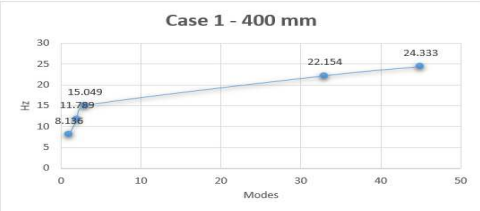

Fig.6.3 BK-CH, case 1 (0.4m), panel modes (P)

Fig.6.4 BK-CH, case 2 (0.1m), panel modes (P)

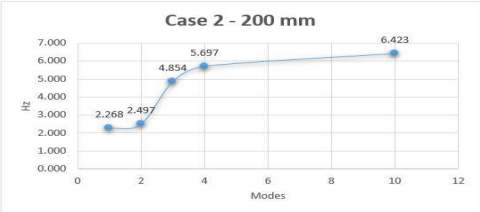

Fig.6.5 BK-CH, case 2 (0.2m), panel modes (P)

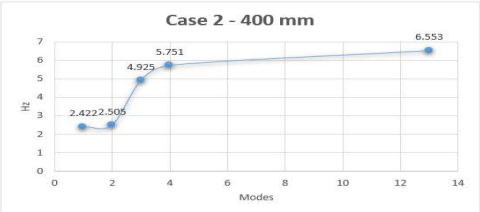

Fig.6.6 BK-CH, case 2 (0.4m), panel modes (P)

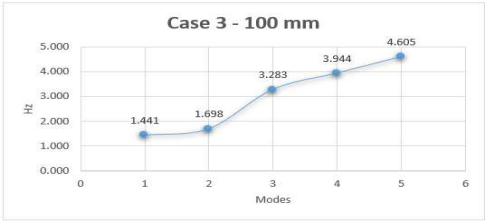

Fig.6.7 BK-CH, case 3 (0.1m), panel modes (P)

Fig.6.8 BK-CH, case 3 (0.2m), panel modes (P)

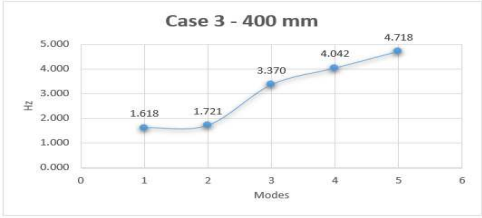

Fig.6.9 BK-CH, case 3 (0.4m), panel modes (P)

In conclusion, the influence of cargo mass and additional hydrodynamic masses is reflected in the reduction of panel modes (P) frequencies, and the increase in the number of subharmonics associated with the structural parts' local modes (L).

Acknowledgments

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