

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 amidships 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
<i>Loa</i>	234.96	m
<i>Lpp</i>	231	m
<i>B</i>	38	m
<i>D</i>	20.62	m
<i>d</i>	15.013	m
<i>Dw</i>	100449	t
<i>v</i>	14	kn

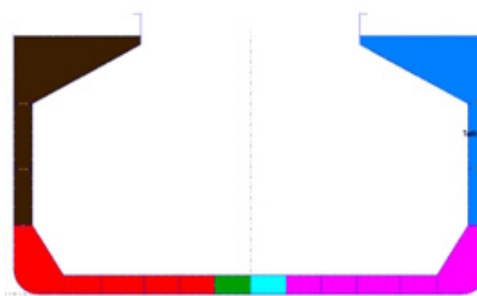


Fig.1 Bulk carrier 100499 tdw, midship section by DNV Poseidon [4].

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.

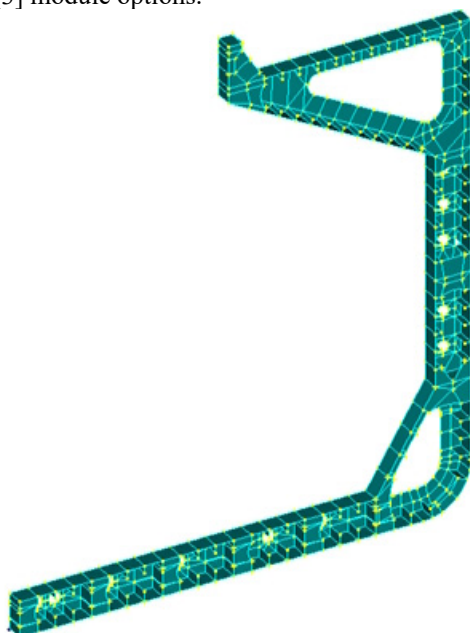


Fig.2 Bulk carrier 100499 tdw, amidships frame CAD(3D) model.

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 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

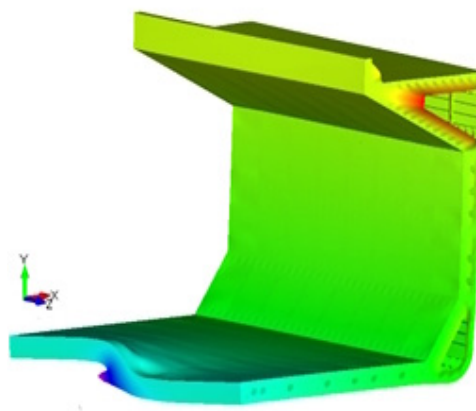


Fig.3.1 BK-CH,case 1 (0.1m),mode 1,7.507Hz

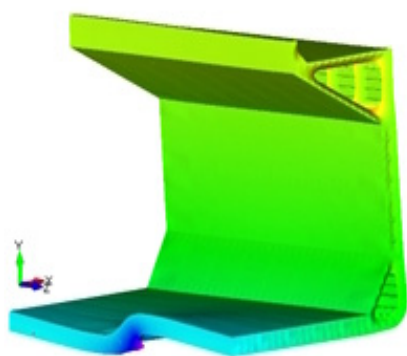


Fig.3.2 BK-CH,case 1 (0.2m),mode 1,7.753Hz

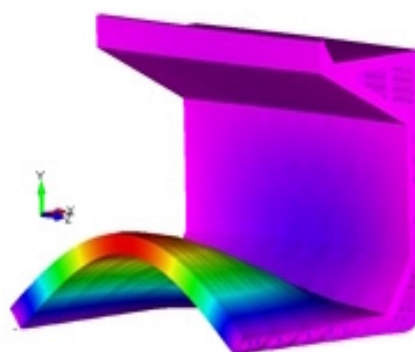


Fig.3.5 BK-CH,case 1(0.2m),mode 2,11.789Hz

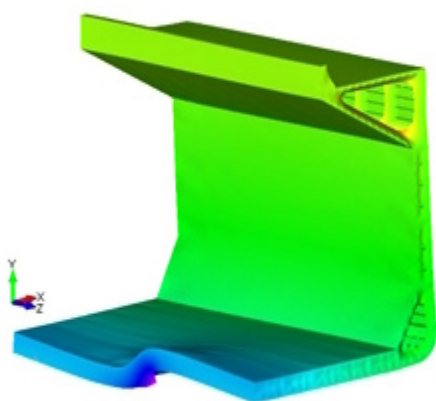


Fig.3.3 BK-CH,case 1 (0.4m),mode 1,8.136Hz

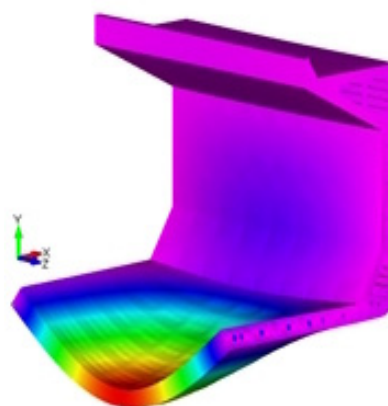


Fig.3.6 BK-CH,case 1(0.4m),mode 2,14.994Hz

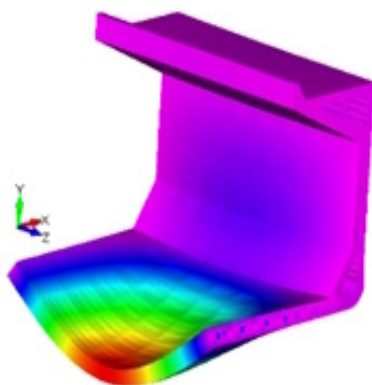


Fig.3.4 BK-CH,case 1(0.1m),mode 2,11.634Hz

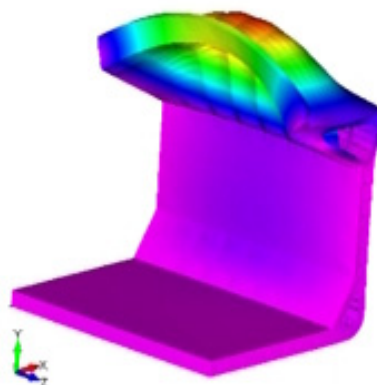


Fig.3.7 BK-CH,case 1(0.1m),mode 3,14.994Hz

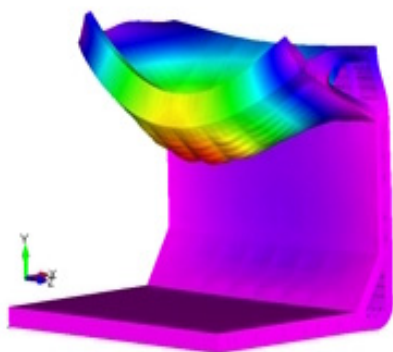


Fig.3.8 BK-CH,case 1(0.2m),mode 3,15.030Hz

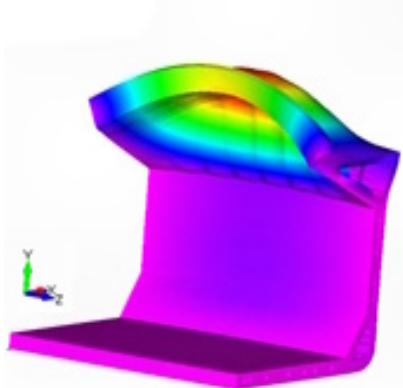


Fig.3.9 BK-CH,case 1(0.4m),mode 3,15.049Hz

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	18.897	L	18.624	L	19.106	L
27	21.871	L	21.244	L	21.949	L
28	21.917	P	21.244	L	21.963	L
29	21.953	L	21.267	L	21.970	L
32	22.215	L	21.447	L	22.031	L
33	22.388	L	21.504	L	22.154	P
34	22.464	L	21.658	L	22.316	L
44	22.676	L	23.795	L	24.318	L

45	22.676	L	23.937	L	24.333	P
46	22.676	L	23.949	L	24.458	L
60	22.685	L	24.553	L	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	24.351	L	26.114	L	25.162	L
80	25.369	L	26.138	L	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	28.044	L	26.358	L	27.372	L
91	28.497	L	27.942	L	27.788	L
92	28.513	P	27.984	L	27.788	L
93	28.582	L	27.987	L	27.820	L
100	29.244	L	28.283	L	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

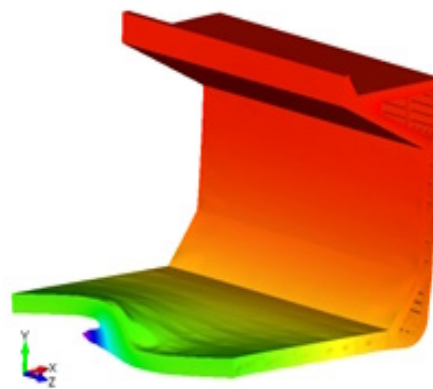


Fig.4.1 BK-CH,case 2 (0.1m),mode 1, 2.159Hz

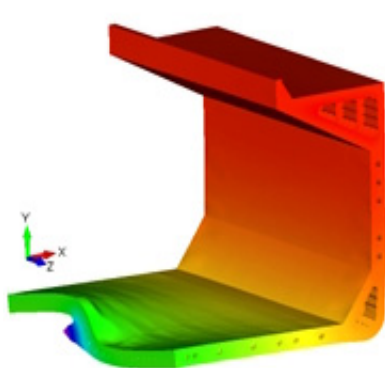


Fig.4.2 BK-CH,case 2 (0.2m),mode 1, 2.268Hz

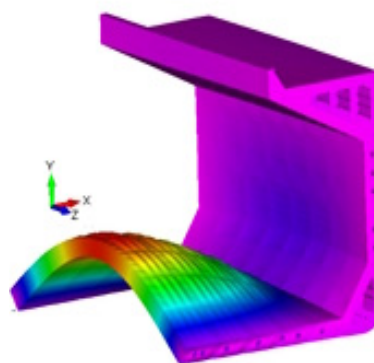


Fig.4.5 BK-CH,case 2 (0.2m),mode 2, 2.497Hz

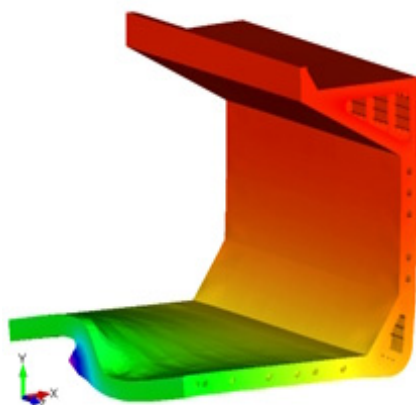


Fig.4.3 BK-CH,case 2 (0.4m),mode 1, 2.422Hz

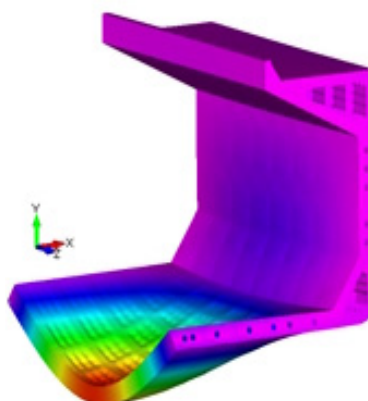


Fig.4.6 BK-CH,case 2 (0.4m),mode 2, 2.505Hz

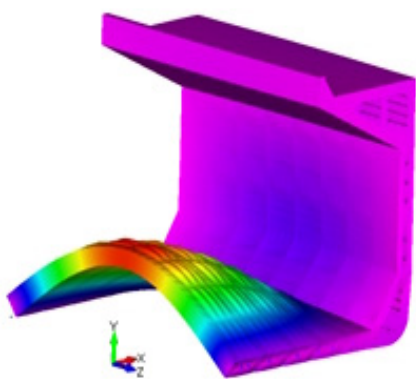


Fig.4.4 BK-CH,case 2 (0.1m),mode 2, 2.471Hz

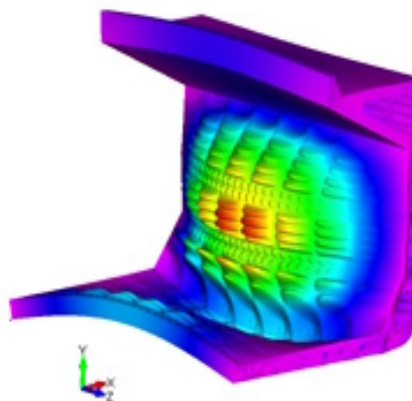


Fig.4.7 BK-CH,case 2 (0.1m),mode 3, 4.781Hz

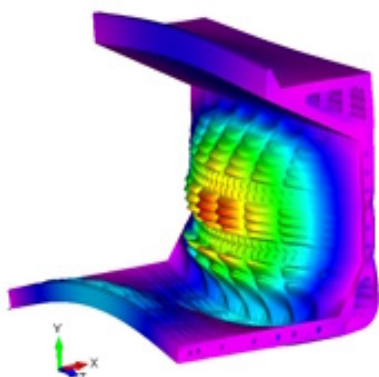


Fig.4.8 BK-CH,case 2 (0.2m),mode 3, 4.854Hz

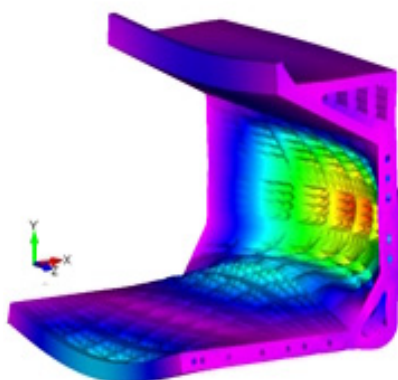


Fig.4.9 BK-CH,case 2 (0.4m),mode 3, 4.925Hz

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	5.909	L	6.161	L	6.215	L
8	6.213		6.332		6.285	
9	6.190	P	6.396	L	6.319	L
10	6.314	L	6.423	P	6.350	L
11	6.385	L	6.446	L	6.375	L
12	6.425		6.479		6.392	

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	7.110	L	7.475	L	7.489	L
25	7.730		7.943		7.847	
26	7.767	P	8.000	P	7.848	L
27	7.788	L	8.012	L	7.850	L
28	7.791		8.031		7.874	
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	7.819	L	8.120	L	7.938	L
37	7.953		8.247		8.042	
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	8.001	L	8.754	L	8.793	L
46	8.031		8.916		8.817	
47	8.034	P	8.989	L	8.821	L
48	8.058	L	9.001	L	8.855	L
49	8.110		9.025		8.894	
50	8.113	P	9.084	L	8.895	L
51	8.131	P	9.107	L	8.910	L
52	8.167	L	9.108	L	8.910	L
55	8.237		9.237		8.983	
56	8.261	P	9.237	L	8.988	L
57	8.294	L	9.238	L	9.000	L
61	8.324		9.381		9.062	
62	8.327	L	9.400	P	9.078	L
63	8.333	L	9.454	P	9.097	L
64	8.337	L	9.467	L	9.102	L
79	8.824		9.884		9.307	
80	8.852	L	9.886	L	9.309	P
81	8.882	L	9.890	L	9.313	L
82	8.903		9.925		9.319	
83	8.924	P	9.926	L	9.327	P
84	8.985	L	9.927	L	9.337	L
89	9.101		10.014		9.428	

90	9.109	P	10.020	L	9.434	L
91	9.118	L	10.027	L	9.436	L
100	9.418		10.138		9.561	
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

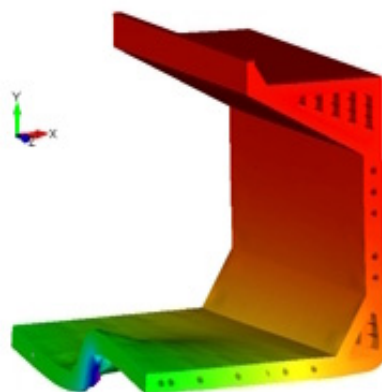


Fig.5.3 BK-CH,case 3 (0.4m),mode 1, 1.618Hz

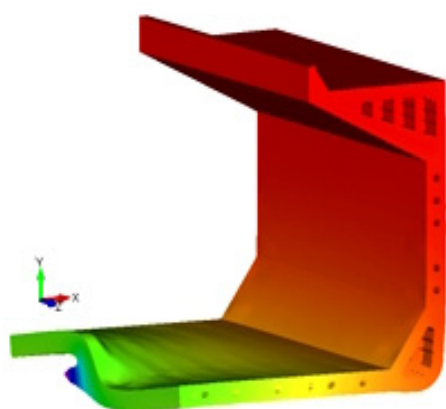


Fig.5.1 BK-CH,case 3 (0.1m),mode 1, 1.441Hz

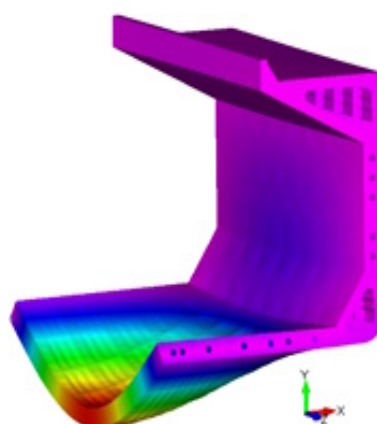


Fig.5.4 BK-CH,case 3 (0.1m),mode 2, 1.698Hz

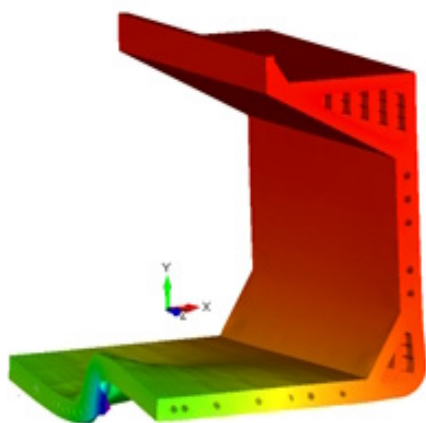


Fig.5.2 BK-CH,case 3 (0.2m),mode 1, 1.747Hz

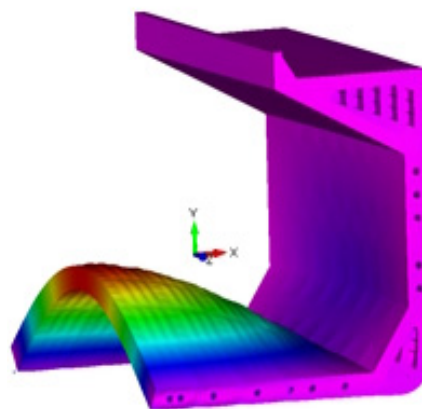


Fig.5.5 BK-CH,case 3 (0.2m),mode 2, 1.759Hz

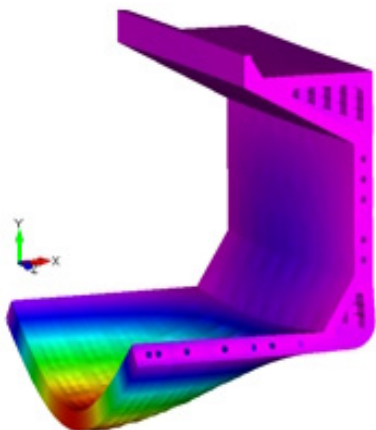


Fig.5.6 BK-CH,case 3 (0.4m),mode 2, 1.721Hz

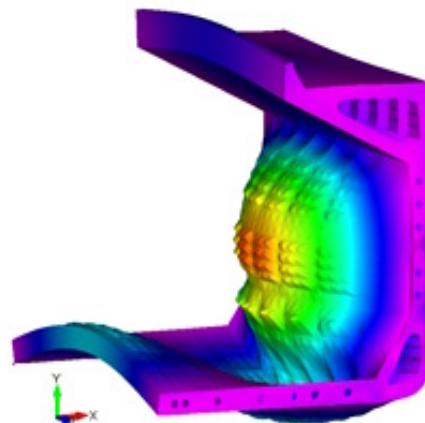


Fig.5.9 BK-CH,case 3 (0.4m),mode 3, 3.370Hz

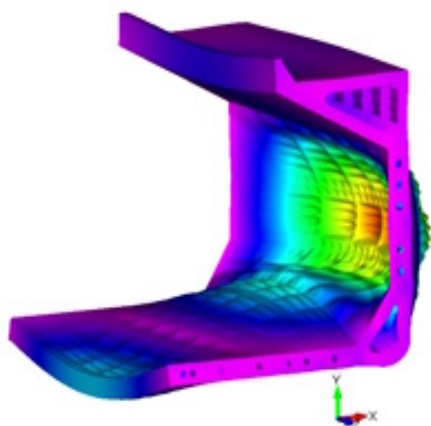


Fig.5.7 BK-CH,case 3 (0.1m),mode 3, 3.283Hz

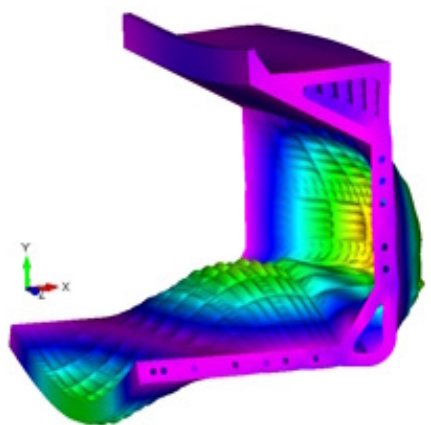


Fig.5.8 BK-CH,case 3 (0.2m),mode 3, 4.092Hz

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	6.645	L	7.533	L	6.842	L
23	6.687	L	7.611	L	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	6.768	L	7.809	L	6.991	L
28	6.780	L	7.885	L	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	6.884	L	8.031	L	7.100	L
43	7.128	L	8.344	L	7.667	L
44	7.145	L	8.665	P	7.685	L
45	7.169	L	8.722	P	7.711	L
46	7.186	L	8.754	L	7.724	L
47	7.205	L	8.806	L	7.725	L
48	7.228	L	8.826	L	7.751	P
49	7.251	L	8.866	P	7.754	L
50	7.264	L	8.908	L	7.780	L
52	7.324	L	8.936	L	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	7.532	L	9.107	L	7.873	L
61	7.706	L	9.217	L	7.969	L
62	7.718	P	9.241	L	7.971	L
63	7.738	P	9.251	L	7.982	L
64	7.788	L	9.255	L	8.011	L
66	7.798	L	9.272	L	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	7.884	L	9.554	L	8.219	L
75	7.947	L	9.671	L	8.302	L

76	7.947	L	9.731	L	8.321	P
77	7.948	L	9.741	L	8.331	L
85	8.003	L	9.881	L	8.553	L
86	8.012	L	9.882	L	8.565	P
87	8.021	L	9.884	L	8.578	P
88	8.058	L	9.889	L	8.587	L
92	8.166	L	9.906	L	8.640	L
93	8.171	P	9.907	L	8.651	L
94	8.173	L	9.910	L	8.671	L
97	8.237	L	9.915	L	8.733	L
98	8.240	P	9.917	L	8.767	L
99	8.282	L	9.920	L	8.767	L
100	8.290	L	9.924	L	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

For the first case, the only 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, 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.

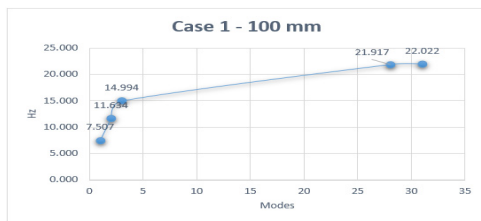


Fig.6.1 BK-CH, case 1 (0.1m), panel modes (P)

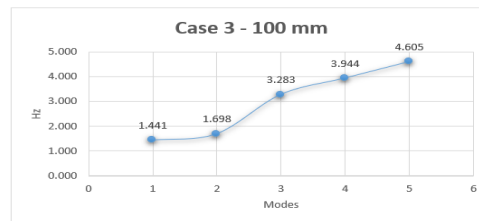


Fig.6.7 BK-CH, case 3 (0.1m), panel modes (P)

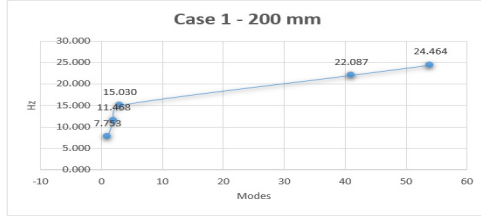


Fig.6.2 BK-CH, case 1 (0.2m), panel modes (P)

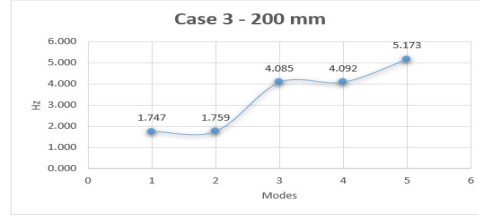


Fig.6.8 BK-CH, case 3 (0.2m), panel modes (P)

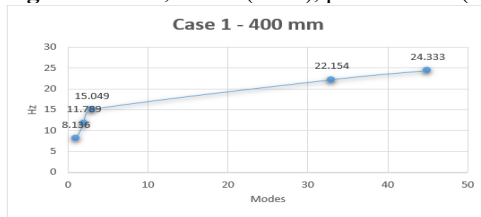


Fig.6.3 BK-CH, case 1 (0.4m), panel modes (P)

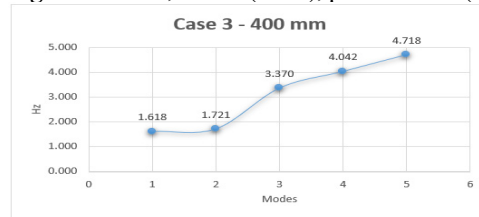


Fig.6.9 BK-CH, case 3 (0.4m), panel modes (P)

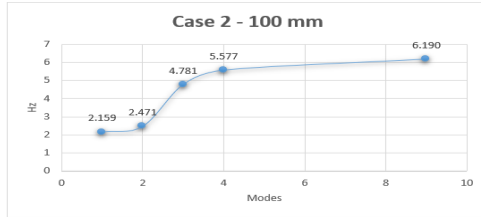


Fig.6.4 BK-CH, case 2 (0.1m), panel modes (P)

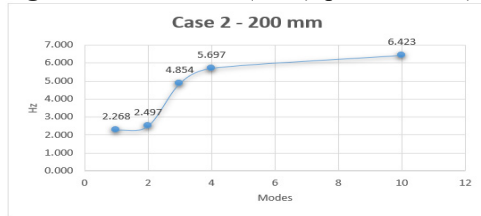


Fig.6.5 BK-CH, case 2 (0.2m), panel modes (P)

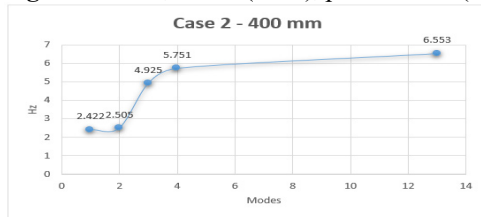


Fig.6.6 BK-CH, case 2 (0.4m), panel modes (P)

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).

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