THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XI – SHIPBUILDING. ISSN 1221-4620
2016

ON THE SEAKEEPING RESPONSE ANALYSIS OF A LARGE OFF-SHORE DRILLSHIP

Leonard Domnisoru
"Dunarea de Jos" University of Galati,
Faculty of Naval Architecture,
Galati, Domneasca Street, No. 47, 800008, Romania,
E-mail: leonard.domnisoru@ugal.ro

ABSTRACT

For an off-shore structure the operation safety must be assessed by several criteria as those specific for the seakeeping, ship oscillations in irregular waves. In this study the seakeeping analyses of an off-shore drillship, with 210 m length and two displacement conditions, are carried out. The short-term irregular waves are modelled by the ITTC power density spectrum, for a full set of 360 deg oblique waves condition and maximum significant wave height of 12 m. The numerical seakeeping analyses are done by our own program DYN_OSC, based on a linear strip theory formulation, including heave, pitch and roll ship's oscillation components. The first drillship seakeeping analyses are done for the zero speed case, specific to the drill operation into a research location. The second drillship seakeeping analyses simulate the navigation for several speeds between operation locations. Based on the numerical results of this study, the operation safety assessment of the off-shore drillship by seakeeping criteria is accomplished.

Keywords: off-shore drillship, irregular oblique waves, seakeeping analysis, operation safety.

1. INTRODUCTION

The off-shore structures usually operate in heavy sea conditions, which has to be considered for each design step, according to the off-shore classification societies [6].

In this study, it is considered an initial design concept of an off-shore drillship DSH [5], with two displacement conditions and several speed conditions.

The assessment of the linear and non-linear hydroelastic structural response of the off-shore drillship is presented in detail in reference [5], including also the off-set lines and the mass distributions ship's data.

This study focuses on the assessment of the operation safety by seakeeping criteria, on motions and accelerations, in two cases: drill operation into a research location, for zero speed, and navigation between locations for several speeds.

The numerical seakeeping analyses are carried out by our own program DYN_OSC [4], based on the linear strip theory [1],[2],[3],[7], [10], delivering the oscillation responses on heave, pitch and roll. The irregular wave is modelled according to *ITTC* formulation [8], [9], [11]. The numerical results are pointing out the extreme seakeeping responses and the operation safety conditions of the off-shore drillship analyzed.

2. THE OFF-SHORE DRILLSHIP

The main characteristics of the DSH off-shore drillship are:
- the ship main dimensions (Table 1);
- the displacement conditions (Tables 2,3);
- the off-set lines and the mass distributions are presented in reference [5];
- the natural frequencies of ship oscillations on heave, pitch and roll (Table 4).

Table 1. The main dimensions of DSH ship

L [m]	210	ρ [t/m^3]	1.025
B [m]	34	g [m/s^2]	9.81
H [m]	17.5	μ [deg]	0 ÷ 360
L/B	6.176 > 5	$\delta\mu$ [deg]	5
v [knots]	0;5;8;11;14	ITTC $h_{1/3}$= 0 ÷ 12 m	

Table 2. Displacement condition 1 of DSH ship

Δ [t]	59217.5	F_s [m]	0
z_G [m]	10.075	x_F [m]	-8.447
V [m^3]	57670	A_w [m^2]	5990.532
J_x [t m^2]	8592836	x_B [m]	-3.695
T_m [m]	10.684	z_B [m]	5.609
T_{aft} [m]	10.892	r [m]	8.616
T_{fore} [m]	10.438	R [m]	339.493
F [m]	6.816	h_0 [m]	4.150

Table 3. Displacement condition 2 of DSH ship

Δ [t]	67868.5	F_s [m]	0
z_G [m]	10.119	x_F [m]	-8.104
V [m^3]	66143	A_w [m^2]	6051.630
J_x [t m^2]	9855374	x_B [m]	-4.283
T_m [m]	12.085	z_B [m]	6.351
T_{aft} [m]	12.358	r [m]	7.668
T_{fore} [m]	11.766	R [m]	303.595
F [m]	5.415	h_0 [m]	3.900

Table 4. DSH natural oscillations frequencies

D.O.F.	Cases	1	2
Heave ζ	ω [rad/s]	0.6977	0.6754
	T [s]	9.0055	9.3024
	f [Hz]	0.1110	0.1075
Pitch θ	ω [rad/s]	0.7435	0.7388
	T [s]	8.4514	8.5050
	f [Hz]	0.1183	0.1176
Roll φ	ω [rad/s]	0.4469	0.4449
	T [s]	14.0609	14.1224
	f [Hz]	0.0711	0.0708

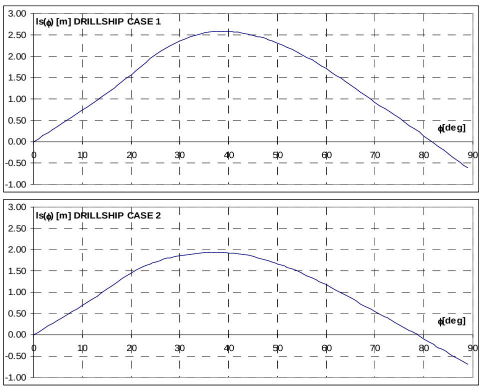

Fig.1. DSH transversal stability diagrams.

Figure 1 presents the off-shore drillship transversal stability diagrams.

The seakeeping criteria are formulated in terms of the maximum RMS_{max} most probable short-term statistical values for heave, pitch and roll motion and acceleration amplitudes, function to the μ ship-wave angle and $h_{1/3}$ wave statistic significant height [1],[3], [10]. Table 5 presents the seakeeping admissible RMS_{adm} values. Based on seakeeping criteria, the polar diagrams on each degree of freedom and cumulative $B(\mu,h_{1/3})$ for operation safety assessment are obtained [1],[3].

$$RMS_{\zeta\max} = F + F_s - z_{\theta,\varphi}\,;\; z_{\theta,\varphi} = \max\{z_\theta, z_\varphi\};$$
$$z_\theta = L/2 \cdot RMS_{\theta\max}\;;\; z_\varphi = B/2 \cdot RMS_{\varphi\max}\;;$$
$$RMS_{\theta\max} = \theta_{adm}\;;\; RMS_{\varphi\max} = \varphi_{adm}\;;$$
$$RMSac_{\zeta\max} = ac_{\zeta adm}\,;\, RMSac_{\theta peak\max} = ac^{peak}_{\theta adm}\,;$$
$$RMSac_{\varphi side\max} = ac^{side}_{\varphi adm}\;; \qquad (1)$$
$$RMSac_{\theta peak}(\mu, h_{1/3}) = L/2 \cdot RMSac_\theta(\mu, h_{1/3})\;;$$
$$RMSac_{\varphi side}(\mu, h_{1/3}) = B/2 \cdot RMSac_\varphi(\mu, h_{1/3})\;.$$

Table 5. Seakeeping RMS_{adm} admissible values

Condition	$RMS_{\zeta max}$	$RMS_{\theta max}$	$RMS_{\varphi max}$
drilling	0.10 m	0.15 deg.	0.15 deg.
navigation 1	3.15 m	2 deg.	7 deg.
navigation 2	1.75 m	2 deg.	7 deg.
Condition	$RMSac_{\zeta max}$	$RMSac_{\theta peakmax}$	$RMSac_{\varphi sidemax}$
drilling	0.010 g	0.015 g	0.015 g
navigation 1	0.10 g	0.15 g	0.15 g
navigation 2	0.10 g	0.15 g	0.15 g

The irregular waves are modelled by the short-term ITTC power density spectrum [8], [9],[11] (Fig.2), for the sea state parameters:

$h_{1/3}$=0 ÷12 m ; $\delta h_{1/3}$=0.25 m; $T_1 = 3.55\sqrt{h_{1/3}}$;
μ=0 ÷ 360 deg ; $\delta\mu$ = 5 deg. (2)

The short-term seakeeping analysis has the following computation steps [1],[3]: (3)

-transfer functions $H_Y(\omega_e,\mu)\big|_{v,\Delta}$, $Y \in \{\zeta,\theta,\varphi\}$, ω_e [rad/s] the wave encountering frequency;

-spectrum $S_Y(\omega_e) = H_Y^2(\omega_e) \cdot S_{ITTC}(\omega_e)\big|_{\mu,v,\Delta}$;

-statistics $RMS_Y = \sqrt{m_{0Y}}$; $RMSac_Y = \sqrt{m_{4Y}}$;

-polar diagrams by seakeeping criteria.

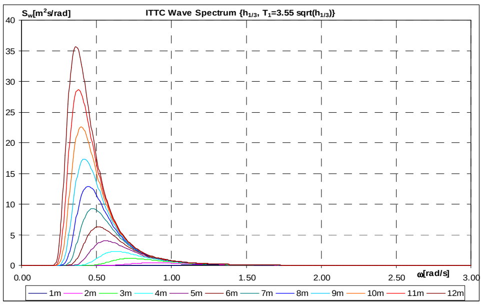

Fig.2. ITTC wave power density spectrum.

3. THE OSCILLATIONS TRANSFER FUNCTIONS OF DRILLSHIP

Based on a linear strip theory approach [3], the transfer functions on heave, pitch and roll oscillations of the DSH off-shore drillship by own program DYN_OSC[4] are calculated:
- Figures 3.1-2, 6.1-2 present the heave transfer functions for *v*=0, 11 knots, on both cases;
- Figures 4.1-2, 7.1-2 present the pitch transfer functions for *v*=0, 11 knots, on both cases;
- Figures 5.1-2, 8.1-2 present the roll transfer functions for *v*=0, 11 knots, on both cases.

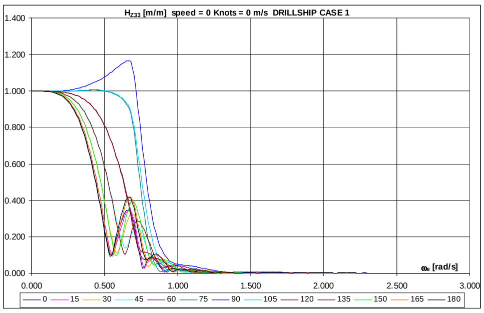

Fig.3.1 Heave transfer function, *v*=0 knots, Δ1.

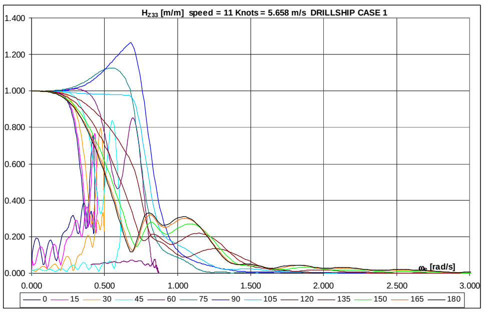

Fig.3.2 Heave transfer function,*v*=11 knots, Δ1.

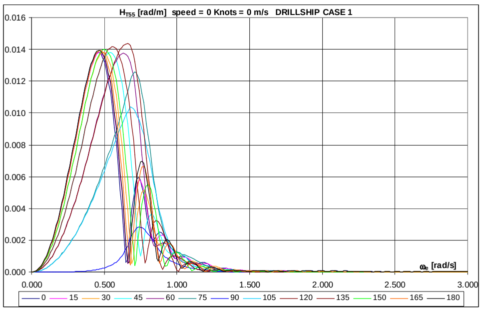

Fig.4.1 Pitch transfer function, *v*=0 knots, Δ1.

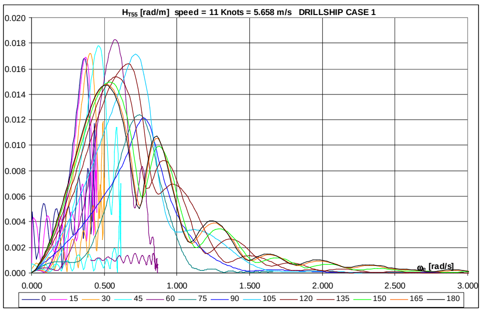

Fig.4.2 Pitch transfer function, *v*=11 knots, Δ1.

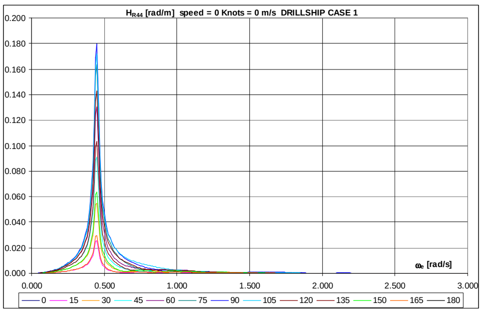

Fig.5.1 Roll transfer function, *v*=0 knots, Δ1.

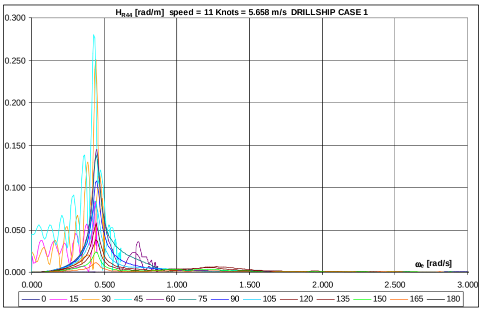

Fig.5.2 Roll transfer function, *v*=11 knots, Δ1.

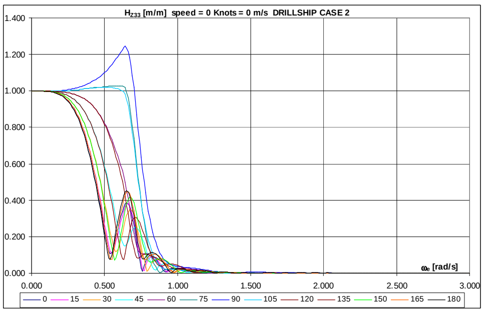

Fig.6.1 Heave transfer function, *v*=0 knots, Δ2.

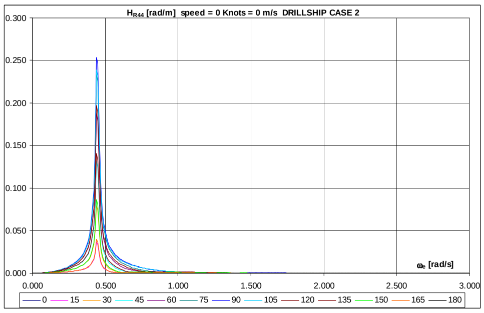

Fig.8.1 Roll transfer function, *v*=0 knots, Δ2.

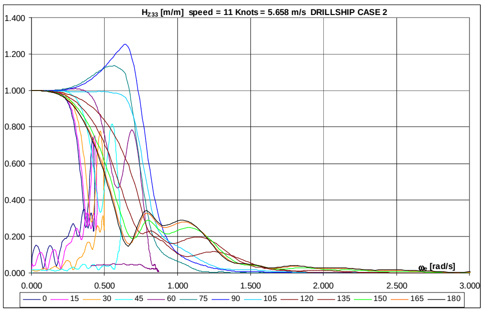

Fig.6.2 Heave transfer function,*v*=11 knots, Δ2.

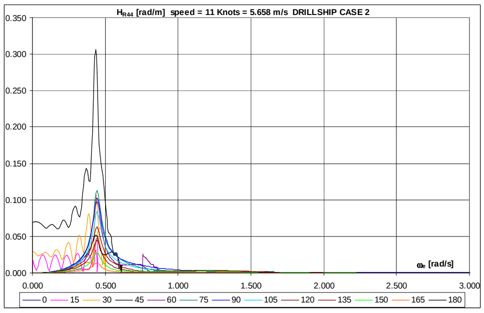

Fig.8.2 Roll transfer function, *v*=11 knots, Δ2.

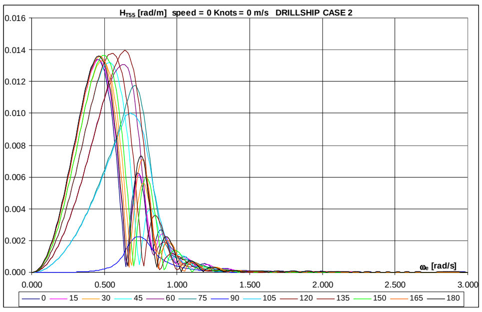

Fig.7.1 Pitch transfer function, *v*=0 knots, Δ2.

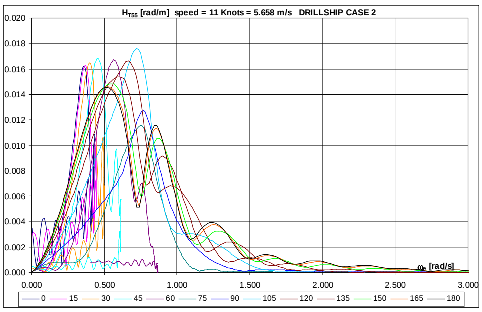

Fig.7.2 Pitch transfer function, *v*=11 knots, Δ2.

4. THE DRILLING OPERATION SEAKEEPING POLAR DIAGRAMS

Based on the off-shore drillship transfer functions (Figs.3-8) and the ITTC wave spectrum (Fig.2), for the seakeeping criteria (Table 5) in the case of drilling operation, with ship's speed v=0, the next results are obtained:

- Figures 10.1-3, 12.1-3 present the polar diagrams on heave, pitch and roll, on both cases;
- Figures 11.1-2, 13.1-2 and Tables 6,7 present the cumulative polar diagrams, on both cases, in terms of $h_{1/3}$ and Beaufort level B limit.

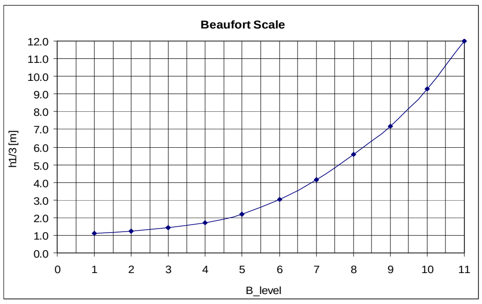

Fig.9 Conversion scale $h_{1/3}$ to Beaufort [2],[8].

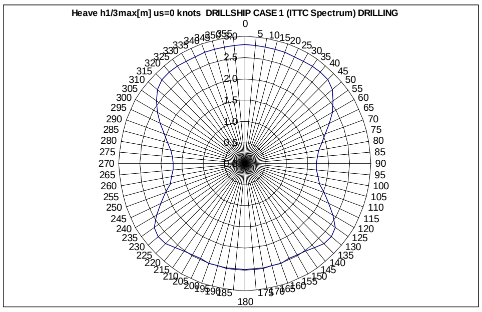

Fig.10.1 Heave polar diagram,*v*=0, Δ1,drilling.

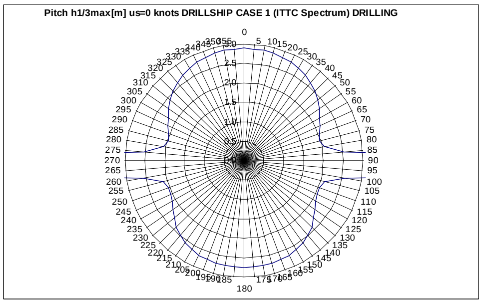

Fig.10.2 Pitch polar diagram, *v*=0, Δ1, drilling.

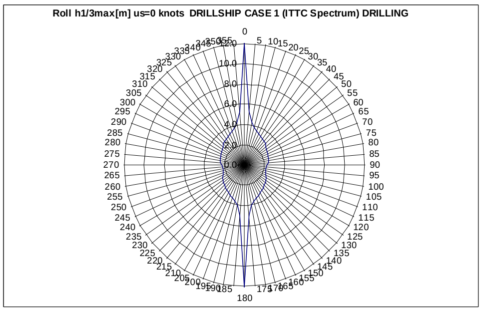

Fig.10.3 Roll polar diagram, *v*=0, Δ1, drilling.

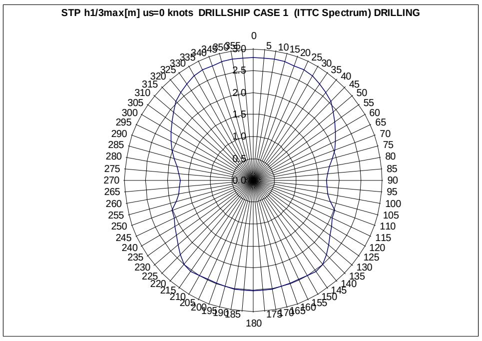

Fig.11.1 Cumulative $h_{1/3}$, *v*=0, Δ1, drilling.

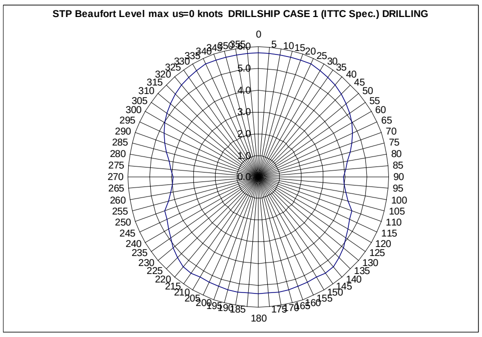

Fig.11.2 Cumulative *B*, *v*=0, Δ1, drilling.

Table 6. Cumulative $h_{1/3}$, *B*, v=0, Δ1, drilling.

μ	heave	pitch	roll	$h_{1/3max}$	Beaufort
0	2.799	2.879	12.000	2.799	5.74
5	2.797	2.875	5.232	2.797	5.73
10	2.793	2.864	4.246	2.793	5.73
15	2.787	2.846	3.838	2.787	5.72
20	2.781	2.820	3.587	2.781	5.71
25	2.779	2.786	3.401	2.779	5.71
30	2.784	2.742	3.259	2.742	5.67
35	2.795	2.681	3.121	2.681	5.59
40	2.802	2.609	3.013	2.609	5.50
45	2.784	2.523	2.893	2.523	5.39
50	2.711	2.417	2.792	2.417	5.26
55	2.577	2.304	2.689	2.304	5.12
60	2.402	2.193	2.592	2.193	4.98
65	2.220	2.096	2.523	2.096	4.77
70	2.047	2.000	2.471	2.000	4.58
75	1.903	1.968	2.442	1.903	4.38
80	1.799	2.070	2.423	1.799	4.16
85	1.733	2.540	2.373	1.733	4.02
90	1.700	12.00	2.271	1.700	3.93
95	1.709	4.773	2.150	1.709	3.96
100	1.760	2.570	2.103	1.760	4.08
105	1.854	2.104	2.138	1.854	4.27
110	2.011	1.998	2.222	1.998	4.57
115	2.212	2.018	2.322	2.018	4.61
120	2.432	2.086	2.441	2.086	4.75
125	2.615	2.177	2.559	2.177	4.94
130	2.698	2.286	2.674	2.286	5.10
135	2.666	2.395	2.788	2.395	5.24
140	2.585	2.499	2.893	2.499	5.36
145	2.523	2.575	3.017	2.523	5.39
150	2.493	2.633	3.133	2.493	5.36
155	2.485	2.673	3.283	2.485	5.35
160	2.489	2.700	3.460	2.489	5.35
165	2.498	2.718	3.697	2.498	5.36
170	2.506	2.728	4.077	2.506	5.37
175	2.512	2.734	4.962	2.512	5.38
180	2.514	2.735	12.00	2.514	5.38
180 – 360 deg. analogues 0 – 180 deg.					

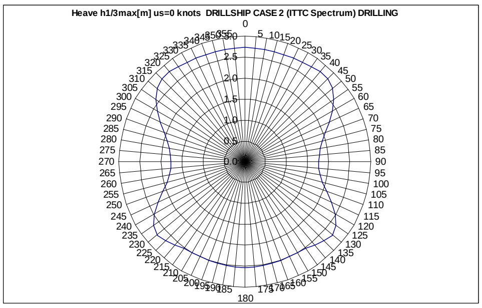

Fig.12.1 Heave polar diagram,*v*=0, Δ2,drilling.

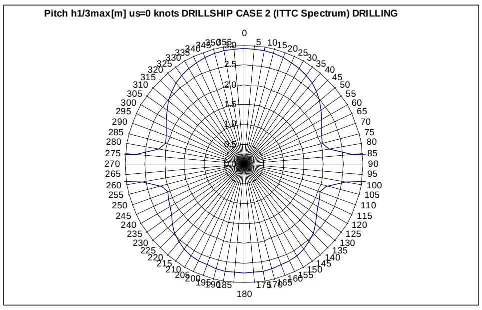

Fig.12.2 Pitch polar diagram, *v*=0, Δ2, drilling.

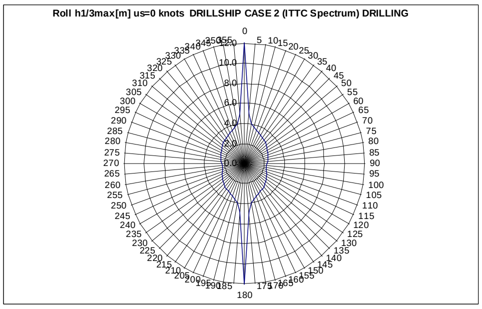

Fig.12.3 Roll polar diagram, *v*=0, Δ2, drilling.

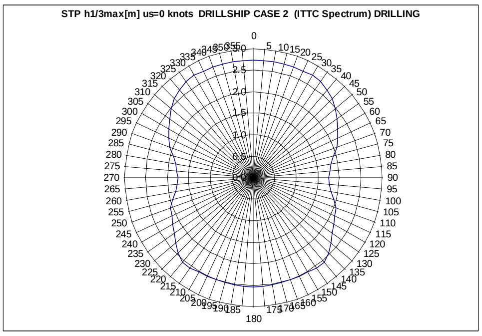

Fig.13.1 Cumulative $h_{1/3}$, *v*=0, Δ2, drilling.

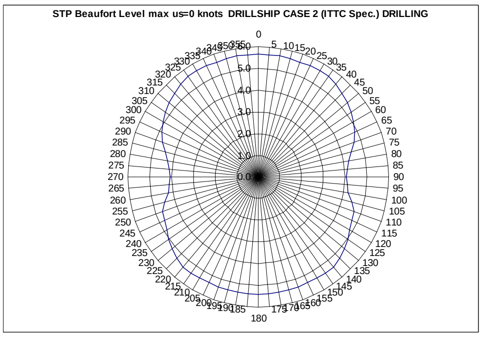

Fig.13.2 Cumulative *B*, *v*=0, Δ2, drilling.

Table 7. Cumulative $h_{1/3}$, *B*, *v*=0, Δ2, drilling.

μ	heave	pitch	roll	$h_{1/3max}$	Beaufort
0	2.725	2.907	12.000	2.725	5.64
5	2.724	2.903	4.908	2.724	5.64
10	2.721	2.892	4.086	2.721	5.64
15	2.718	2.874	3.738	2.718	5.64
20	2.717	2.848	3.522	2.717	5.63
25	2.723	2.816	3.358	2.723	5.64
30	2.739	2.775	3.238	2.739	5.66
35	2.768	2.723	3.120	2.723	5.64
40	2.796	2.656	3.029	2.656	5.56
45	2.795	2.576	2.932	2.576	5.46
50	2.729	2.481	2.840	2.481	5.34
55	2.588	2.368	2.761	2.368	5.20
60	2.404	2.256	2.660	2.256	5.06
65	2.220	2.157	2.571	2.157	4.90
70	2.053	2.078	2.500	2.053	4.69
75	1.920	2.051	2.418	1.920	4.41
80	1.826	2.168	2.354	1.826	4.22
85	1.771	2.742	2.294	1.771	4.10
90	1.752	12.00	2.225	1.752	4.06
95	1.768	4.595	2.167	1.768	4.10
100	1.824	2.581	2.173	1.824	4.21
105	1.930	2.137	2.242	1.930	4.43
110	2.086	2.045	2.334	2.045	4.67
115	2.284	2.078	2.454	2.078	4.74
120	2.495	2.141	2.565	2.141	4.87
125	2.656	2.239	2.673	2.239	5.04
130	2.724	2.346	2.779	2.346	5.18
135	2.680	2.453	2.865	2.453	5.31
140	2.598	2.543	2.966	2.543	5.42
145	2.540	2.608	3.060	2.540	5.42
150	2.511	2.655	3.165	2.511	5.38
155	2.503	2.686	3.294	2.503	5.37
160	2.506	2.707	3.448	2.506	5.37
165	2.513	2.721	3.657	2.513	5.38
170	2.520	2.729	3.995	2.520	5.39
175	2.525	2.734	4.770	2.525	5.40
180	2.527	2.735	12.00	2.527	5.40
180 – 360 deg. analogues 0 – 180 deg.					

5. THE NAVIGATION OPERATION SEAKEEPING POLAR DIAGRAMS

For the navigation operation case 1, *v*=0-14 knots, the next results are obtained:
- Figures 14.1-3 present the polar diagrams on heave, pitch and roll, on both cases;
- Figures 15.1-2 and Tables 8.1-2 present the cumulative polar diagrams.

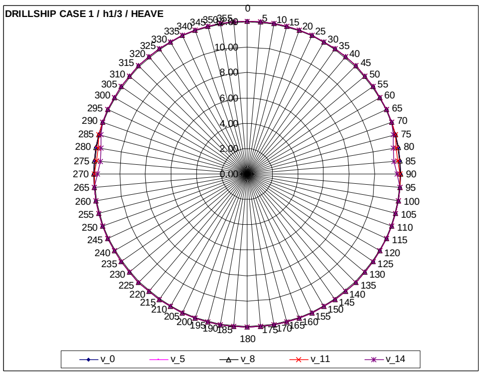

Fig.14.1 Heave polar diagram, Δ1, navigation 1

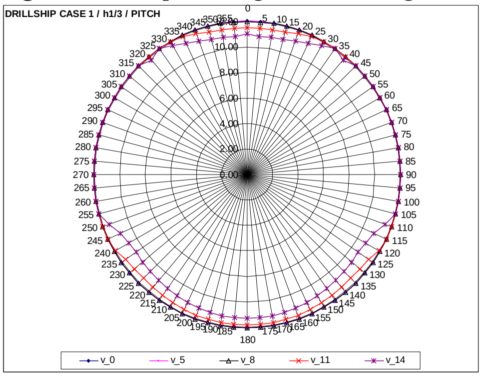

Fig.14.2 Pitch polar diagram, Δ1, navigation 1

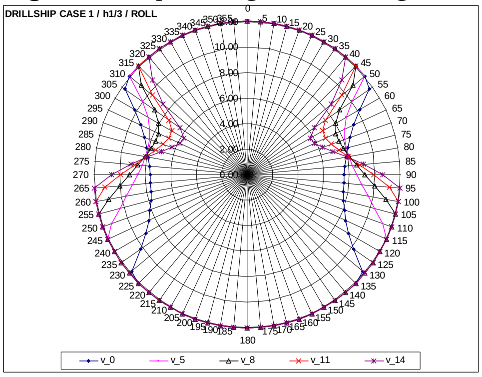

Fig.14.3 Roll polar diagram, Δ1, navigation 1

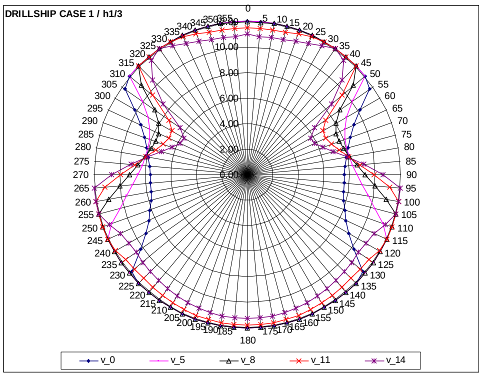

Fig.15.1 Cumulative $h_{1/3}$, Δ1, navigation 1.

Table 8.1 Cumulative $h_{1/3}$, Δ1, navigation 1.

μ	0 kn	5 kn	8 kn	11 kn	14 kn
0	12.000	12.000	11.947	11.462	11.014
5	12.000	12.000	11.953	11.460	10.856
10	12.000	12.000	11.992	11.490	10.890
15	12.000	12.000	12.000	11.542	10.921
20	12.000	12.000	12.000	11.691	11.133
25	12.000	12.000	12.000	11.878	11.313
30	12.000	12.000	12.000	12.000	11.646
35	12.000	12.000	12.000	12.000	12.000
40	12.000	12.000	12.000	12.000	11.661
45	12.000	12.000	12.000	12.000	10.488
50	12.000	12.000	10.819	9.658	8.627
55	11.626	10.044	8.787	7.443	6.402
60	10.144	8.965	7.958	6.802	5.708
65	9.205	8.390	7.644	6.776	5.756
70	8.574	8.114	7.614	6.984	6.267
75	8.140	8.031	7.783	7.419	6.954
80	7.845	8.091	8.119	8.053	7.904
85	7.658	8.276	8.597	8.879	9.117
90	7.562	8.578	9.222	9.898	10.612
95	7.552	9.005	10.009	11.162	12.000
100	7.629	9.570	11.023	12.000	12.000
105	7.801	10.307	12.000	12.000	12.000
110	8.088	11.320	12.000	12.000	11.455
115	8.522	12.000	12.000	12.000	10.936
120	9.169	12.000	12.000	11.888	10.706
125	10.151	12.000	12.000	11.609	10.629
130	11.752	12.000	12.000	11.486	10.639
135	12.000	12.000	12.000	11.452	10.700
140	12.000	12.000	12.000	11.469	10.782
145	12.000	12.000	12.000	11.519	10.879
150	12.000	12.000	12.000	11.573	10.962
155	12.000	12.000	12.000	11.631	11.052
160	12.000	12.000	12.000	11.684	11.121
165	12.000	12.000	12.000	11.730	11.188
170	12.000	12.000	12.000	11.767	11.224
175	12.000	12.000	12.000	11.786	11.253
180	12.000	12.000	12.000	11.791	11.267
180 – 360 deg. analogues 0 – 180 deg.					

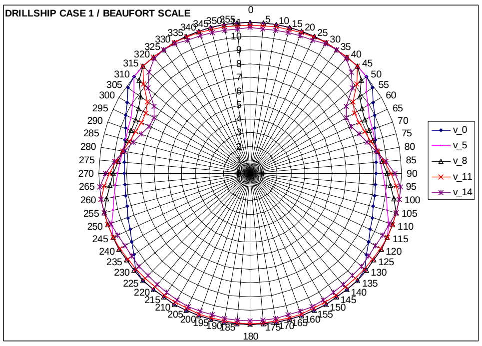

Fig.15.2 Cumulative *B*, Δ1, navigation 1.

Table 8.2 Cumulative *B*, Δ1, navigation 1.

μ	0 kn	5 kn	8 kn	11 kn	14 kn
0	11.00	11.00	10.98	10.80	10.64
5	11.00	11.00	10.98	10.80	10.58
10	11.00	11.00	11.00	10.81	10.59
15	11.00	11.00	11.00	10.83	10.60
20	11.00	11.00	11.00	10.89	10.68
25	11.00	11.00	11.00	10.96	10.75
30	11.00	11.00	11.00	11.00	10.87
35	11.00	11.00	11.00	11.00	11.00
40	11.00	11.00	11.00	11.00	10.88
45	11.00	11.00	11.00	11.00	10.44
50	11.00	11.00	10.57	10.14	9.69
55	10.86	10.28	9.76	9.12	8.51
60	10.32	9.85	9.37	8.76	8.07
65	9.96	9.57	9.22	8.74	8.10
70	9.66	9.44	9.20	8.87	8.42
75	9.45	9.40	9.28	9.11	8.85
80	9.31	9.43	9.44	9.41	9.34
85	9.22	9.52	9.67	9.81	9.92
90	9.18	9.66	9.97	10.23	10.49
95	9.17	9.87	10.27	10.69	11.00
100	9.21	10.10	10.64	11.00	11.00
105	9.29	10.38	11.00	11.00	11.00
110	9.43	10.75	11.00	11.00	10.80
115	9.64	11.00	11.00	11.00	10.61
120	9.94	11.00	11.00	10.96	10.52
125	10.32	11.00	11.00	10.86	10.50
130	10.91	11.00	11.00	10.81	10.50
135	11.00	11.00	11.00	10.80	10.52
140	11.00	11.00	11.00	10.80	10.55
145	11.00	11.00	11.00	10.82	10.59
150	11.00	11.00	11.00	10.84	10.62
155	11.00	11.00	11.00	10.86	10.65
160	11.00	11.00	11.00	10.88	10.68
165	11.00	11.00	11.00	10.90	10.70
170	11.00	11.00	11.00	10.91	10.71
175	11.00	11.00	11.00	10.92	10.72
180	11.00	11.00	11.00	10.92	10.73
180 – 360 deg. analogues 0 – 180 deg.					

For the navigation operation case 2, *v*=0-14 knots, the next results are obtained:
- Figures 16.1-3 present the polar diagrams on heave, pitch and roll, on both cases;
- Figures 17.1-2 and Tables 9.1-2 present the cumulative polar diagrams.

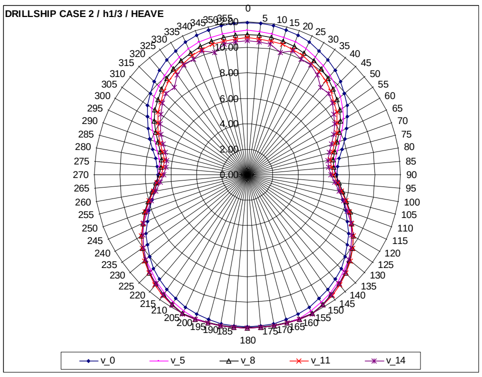

Fig.16.1 Heave polar diagram, Δ2, navigation 2

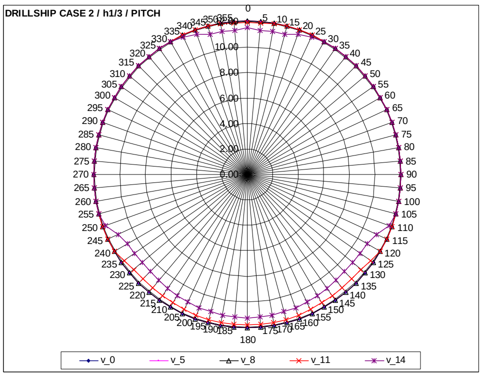

Fig.16.2 Pitch polar diagram, Δ2, navigation 2

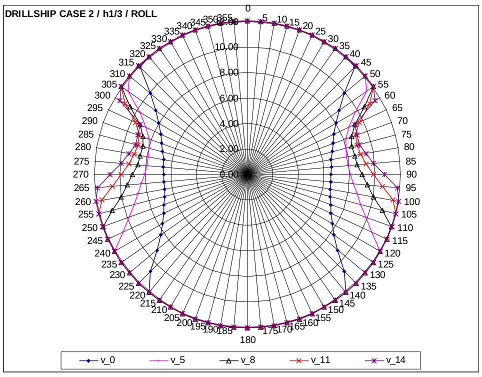

Fig.16.3 Roll polar diagram, Δ2, navigation 2

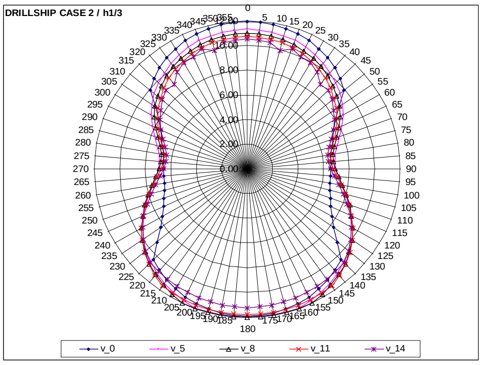

Fig.17.1 Cumulative $h_{1/3}$, Δ2, navigation 2.

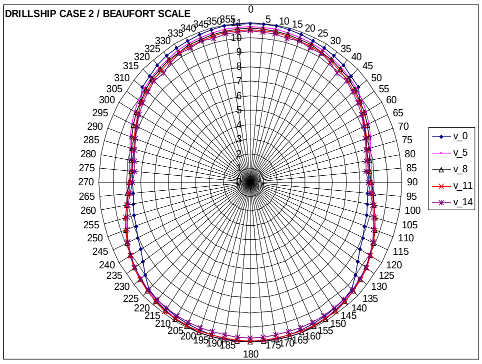

Fig.17.2 Cumulative *B*, Δ2, navigation 2.

Table 9.1 Cumulative $h_{1/3}$, Δ2, navigation 2.

μ	0 kn	5 kn	8 kn	11 kn	14 kn
0	11.885	11.280	10.967	10.706	10.492
5	11.865	11.268	10.942	10.680	10.420
10	11.806	11.207	10.886	10.624	10.359
15	11.708	11.122	10.797	10.521	9.914
20	11.572	10.982	10.669	10.408	10.309
25	11.397	10.814	10.489	10.248	9.975
30	11.183	10.610	10.289	10.047	9.895
35	10.931	10.370	10.059	9.804	9.551
40	10.639	10.097	9.776	9.534	8.884
45	10.307	9.799	9.466	9.223	8.972
50	9.875	9.470	9.140	8.871	8.664
55	8.734	9.090	8.782	8.490	8.280
60	7.988	8.656	8.386	8.104	7.865
65	7.472	8.184	7.942	7.682	7.434
70	7.105	7.706	7.469	7.235	6.999
75	6.846	7.293	7.070	6.848	6.623
80	6.668	7.004	6.815	6.606	6.385
85	6.559	6.887	6.745	6.567	6.344
90	6.510	6.947	6.867	6.724	6.512
95	6.520	7.171	7.148	7.039	6.842
100	6.590	7.527	7.547	7.470	7.284
105	6.725	7.967	8.024	7.966	7.795
110	6.936	8.457	8.536	8.501	8.338
115	7.241	8.952	9.044	9.033	8.884
120	7.674	9.435	9.543	9.549	9.413
125	8.293	9.884	10.008	10.030	9.909
130	9.216	10.297	10.428	10.469	10.366
135	10.344	10.677	10.815	10.862	10.740
140	10.664	11.011	11.152	11.214	10.804
145	10.945	11.301	11.439	11.521	10.886
150	11.189	11.552	11.702	11.611	10.956
155	11.397	11.766	11.915	11.656	11.034
160	11.567	11.941	12.000	11.700	11.095
165	11.701	12.000	12.000	11.740	11.154
170	11.797	12.000	12.000	11.770	11.185
175	11.854	12.000	12.000	11.787	11.211
180	11.874	12.000	12.000	11.791	11.224
180 – 360 deg. analogues 0 – 180 deg.					

Table 9.2 Cumulative *B*, Δ2, navigation 2.

μ	0 kn	5 kn	8 kn	11 kn	14 kn
0	10.96	10.73	10.62	10.52	10.44
5	10.95	10.73	10.61	10.51	10.42
10	10.93	10.71	10.59	10.49	10.40
15	10.89	10.68	10.56	10.46	10.23
20	10.84	10.62	10.51	10.41	10.38
25	10.78	10.56	10.44	10.35	10.25
30	10.70	10.49	10.37	10.28	10.22
35	10.61	10.40	10.29	10.19	10.10
40	10.50	10.30	10.18	10.09	9.81
45	10.38	10.19	10.07	9.97	9.85
50	10.22	10.07	9.93	9.80	9.70
55	9.74	9.91	9.76	9.62	9.52
60	9.38	9.70	9.57	9.44	9.32
65	9.13	9.47	9.36	9.23	9.12
70	8.95	9.25	9.13	9.02	8.88
75	8.78	9.05	8.92	8.79	8.64
80	8.67	8.88	8.77	8.63	8.50
85	8.60	8.81	8.72	8.61	8.47
90	8.57	8.85	8.80	8.71	8.58
95	8.58	8.99	8.97	8.91	8.78
100	8.62	9.16	9.17	9.13	9.04
105	8.71	9.37	9.40	9.37	9.29
110	8.84	9.61	9.64	9.63	9.55
115	9.02	9.84	9.88	9.88	9.81
120	9.23	10.06	10.10	10.10	10.05
125	9.53	10.22	10.27	10.27	10.23
130	9.97	10.37	10.42	10.44	10.40
135	10.39	10.51	10.56	10.58	10.54
140	10.51	10.64	10.69	10.71	10.56
145	10.61	10.74	10.79	10.82	10.59
150	10.70	10.83	10.89	10.86	10.62
155	10.78	10.91	10.97	10.87	10.64
160	10.84	10.98	11.00	10.89	10.67
165	10.89	11.00	11.00	10.90	10.69
170	10.93	11.00	11.00	10.92	10.70
175	10.95	11.00	11.00	10.92	10.71
180	10.95	11.00	11.00	10.92	10.71
180 – 360 deg. analogues 0 – 180 deg.					

6. CONCLUSIONS

Table 10 Drilling operational sea state limits

Case	μ	heave	pitch	roll	$h_{1/3max}$	Beaufort
1	90	1.700	12.00	2.271	1.700	3.93
2		1.752	12.00	2.225	1.752	4.06

Table 11 Navigation operational sea state limits

Case 1	0 kn	5 kn	8 kn	11 kn	14 kn
heave	12.000	12.000	12.000	11.799	11.524
pitch	12.000	12.000	11.947	11.452	10.629
roll	7.552	8.031	7.614	6.776	5.708
$h_{1/3}$	7.552	8.031	7.614	6.776	5.708
B	9.173	9.401	9.202	8.741	8.073
Case 2	0 kn	5 kn	8 kn	11 kn	14 kn
heave	6.973	6.887	6.745	6.567	6.344
pitch	12.000	12.000	12.000	11.537	10.700
roll	6.510	7.869	8.475	8.838	9.031
$h_{1/3}$	6.510	6.887	6.745	6.567	6.344
B	8.574	8.810	8.722	8.610	8.471

Based on the data from sections 4 and 5, synthesized in Tables 10 and 11, results:

1. In the case of drilling, the operational sea state limits are derived out due to the high restrictions on heave motion, based on the drilling equipment operation conditions. The limit of the significant wave height is 1.700-1.752 m, which represents in average a Beaufort Sea state level 4 (Table 10).
2. In navigation condition loading case 1, the operational sea state limits are derived out by the restrictions on roll motion, due to the high level of the gravity centre vertical position. The maximum restrictions are recorded at the highest speed of 14 knots, with the limit of the significant wave height 5.708 m, which represent in average a Beaufort Sea state level 8 (Table 11).
3. In navigation condition loading case 2, the operational sea state limits are mainly derived out by the restrictions on heave motion, due to the higher draught and smaller free ship board in compare to the loading case 1. The maximum restrictions are recorded at the highest speed of 14 knots, with the limit of the significant wave height 6.344 m, which represent in average a Beaufort Sea state level 8.5 (Table 11).
4. Further work will be focused on the seakeeping analysis of the drillship for other sea state scenarios, based on several wave spectrums, other loading cases and drilling operational restrictions.

Acknowledgements

This study has been accomplished in the frame of the research project "*The linear and non-linear analysis of the hydroelastic dynamic response for DRILLSHIP 12000" (seakeeping preliminary analysis)*, of ICE ICEPRONAV ENGINNERING Galati (1041/2.04.2013).

REFERENCES

[1]. **Bertram, V.,** "*Practical Ship Hydrodynamics"*, Butterworth Heinemann, Oxford, 2000.
[2]. **Bidoae, I., Ionaş, O.,** "*Complements of Naval Architecture"*, Porto-Franco Publishing House, Galati, 1998.
[3]. **Domnișoru, L.,** "*Ship Dynamics. Oscillations and Vibrations"*, Technical Publishing House, Bucharest, 2001.
[4]. **Domnișoru, L., Rubanenco, I., Mirciu, I.,** *"The DYN programs package for the analysis of ship dynamic loads from oscillations and global vibrations", (module DYN_OSC)* Naval Architecture Faculty, "Dunarea de Jos" University, Galati, 2009-2014.
[5]. **Domnișoru, L.,Rubanenco, I.,Domnișoru, D.,** *"On the linear and non-linear dynamic hydroelastic response analysis of an off-shore drillship elastic structure"*, The Annals of "Dunarea de Jos" University of Galati, Fascicle XI Shipbuilding, pp. 5-14, 2013.
[6]. **DNVGL,** "*Offshore Structures Rules"*, 2015.
[7]. **Faltinsen, O.M.**, "*Sea Loads on Ships and Off-shore Structures*", Cambridge University Press, 1993.
[8]. **ITTC,** "*Recommended Procedures and Guidelines. Loads and Responses. Seakeeping"* (7.5-02-07-02), International Towing Tank Conference, 2011.
[9]. **Price, W.G., Bishop, R.E.D.,** "*Probabilistic Theory of Ship Dynamics"*, Chapman and Hall, London, 1974.
[10]. **Söding, H.,** "*Bewegungen und Belastungen der Schiffe im Seegang*", TUHH Hamburg, 1994.
[11]. **Söding, H.,** "*Windsee Spektrum"*, TUHH Hamburg, 1994.

Paper received on October 20th, 2016

