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Slamming Analysis on a 35,000 Ton Class of Drillship

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ABSTRACT

Slamming is a phenomenon that occurs on floating structures. Drillship as floating structures have slamming when moving at a certain speed which resulted in the movement of relative vertical bow that exceeded full of water of the bow. This paper was performed on the drillship 35000 tons with variants of speed is 7 knots, 12 knots, 13 knots and 14 knots. The first stage taken was the design of the drillship structures by using *Maxsurf* in order to get lines plan. After the offset data of drillship has been obtained, modeling followed by *Hydrostar* to get the heave and pitch motion RAO's from head seas. The result of RAO is used to analyze the relative vertical motion of the bow in the form of RAO as well. That result is used to analysis of structural response by multiplying the wave spectra ITTC/ISSC. From these calculations will be known slamming parameters that can generate the probabilities, intensity and pressure of slamming on the drillship 35000 tons. Probabilities, intensities and pressure of slamming, the maximum occures while the drillship moving on 14 knot of speed, ie. each of 0.483 times, 124.451 times/hour and 492,232 kPa at 15 m of significant wave height.

KEY WORDS: *Drillship, RAO, Slamming*

NOMENCLATURE

S_R	Spectrum Respons
RAO	Respon Amplitude Operator
ω	Wave Frequency
$S(\omega)$	Wave Spectrum
Pr	The Relative Probabilities of Upraised The Bow
Z_{br}	Relative Motion of The Bow (m)
T_b	Water Level on The Bow (Position Slamming Reviewed)
V_{br}	Relative Vertical Velocity of The Bow
V_{th}	Threshold Velocity of Slamming
m_{oZbr}	The Area Under The Response of Relative Vertical Offset of The Bow
m_{oVbr}	The Area Under The Response of Relative Vertical Velocity of The Bow
N_{slam}	Intensity of Slamming
Ps	Pressure of Slamming
ρ	Density
k	Slamming Coefficient

1.0 INTRODUCTION

Drillship is a vessel which has function as an offshore exploration drilling in oil and gas operation. It has a capability of drilling at depths of more than 2500 meters. Drillship has more flexibility than other offshore drilling vessel, because it can transit from site to site in short time relatively. In transit condition, drillship usually in high speed and high wave elevation condition. Relativity between drillship motion and wave elevation will give a hydrodynamic impact. It produce the structural response in bow of drillship, usually called slamming [1].

Slamming is a phenomenon due to the head wave excitation which is interacted by ship bow. Slamming will be happened when the water level as impact of head wave excitation more than the draught of the ship and/or the relative velocity of vertical direction has a bigger value than threshold velocity. The safety of structure in operation condition will be affected by slamming condition [2]. As a slender ship, drillship can be got a significant impact on the bow section. The impact will become higher when the speed of drillship is increased gradually [3]. Slamming occurs more frequently especially with huge waves.

Characteristics of the bow motion to review slamming incident is conducted by observing the motion of coupling heave and pitch on the bow. The couple motion is use to get spectra response drillship on the bow by multiplying square of the coupling motion heave RAO and pitch against wave spectrum. For the purposes of analysis, calculation of response spectra use the distribution of water waves infinite ABS 2010 [3], while the wave spectrum used is ITTC/ISSC [2]. Then, the results of spectral response can be used to calculate the characteristic that occur in the drillship slamming with a certain speed.

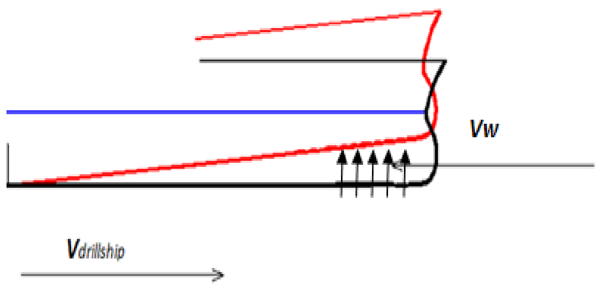

Figure 1: The phenomenon of slamming

Figure 1 illustrates how to slamming incident in this analysis. V_w represents wave velocity, it come from head seas and $V_{drillship}$ symbolizes speed of drillship.

2.0 METHODS OF RESEARCH

The stags which used in this paper are numerical methods which refer to ship motion analysis. Coherently, it will be described in the following sub-subtitle:

2.1 Data Collection

The first primary data for this study is the reference ship, namely the drillship *Oribis One* as made available by Fossli and Hendriks [4]. In this data, new drillship had designed as reported in ref [1]. The general arrangement is exhibited in Figure 1 with principal particulars as presented in Table 1. More details about these data can be seen in the following data. The general arrangement is exhibited in Figure 2 and Figure 3 with principal particulars as presented in Table 1.

Table 1: Principal Dimension of Drillship

Parameter(unit)	Value
Displacement (ton)	35,193.0
Lpp (m)	156.0
B (m)	29.9
H (m)	15.6
T (m)	9.0
LCB to Midship (m)	3.265
LCF to Midship (m)	-7.203
KM_T (m)	13.29
KM_L (m)	222.82
BM_T (m)	8.64
BM_L (m)	218.17

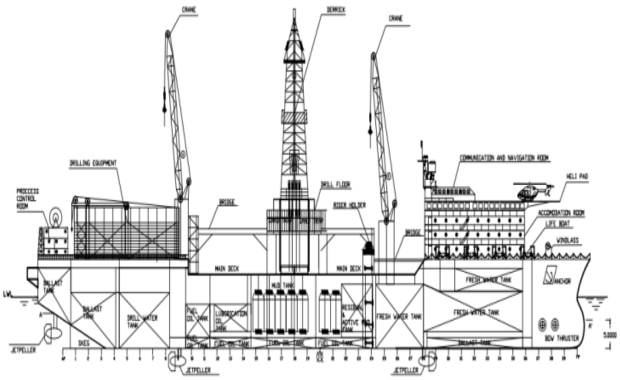

Figure 2: Drillship with a displacement of 35000 tons [1]

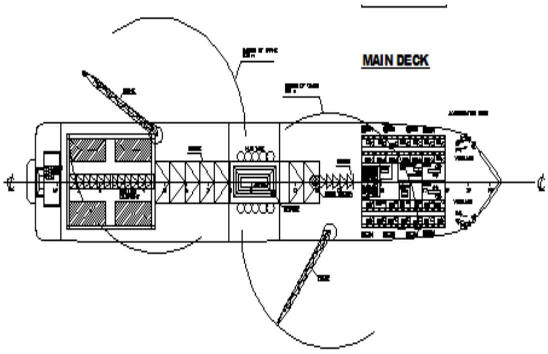

Figure 3: Drillship with a displacement of 35000 tons, top view [1]

The next data is related to the environment regarded as the primary source of excitation. The wave distribution data has been obtained from ABS in 2010 [3], related to the world wave scatter diagram, as contained in Table 2. On the basis of this data, wave spectral analysis is calculated as the increasing of Hs can seen in Figure 4.

	Wave period (s)											
Wave Height (m)	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	Sum Over All Periods
0.5	8	260	1344	2149	1349	413	76	10	1	0	0	5610
1.5		55	1223	5349	7569	4788	1698	397	69	9	1	21158
2.5		9	406	3245	7844	7977	4305	1458	351	65	10	25670
3.5		2	113	1332	4599	6488	4716	2092	642	149	28	20161
4.5			30	469	2101	3779	3439	1876	696	192	43	12625
5.5			8	156	858	1867	2030	1307	564	180	46	7016
6.5			2	52	336	856	1077	795	390	140	40	3688
7.5			1	18	132	383	545	452	247	98	30	1906
8.5				6	53	172	272	250	150	65	22	990
9.5				2	22	78	136	137	90	42	15	522
10.5				1	9	37	70	76	53	26	10	282
11.5					4	18	36	42	32	17	7	156
12.5					2	9	19	24	19	11	4	88
13.5					1	4	10	14	12	7	3	51
>14.5					1	5	13	19	19	13	7	77
	8	326	3127	12779	24880	26874	18442	8949	3335	1014	266	100000

Figure 4: Unrestricted worldwide wave data [3]

2.2 Design Model of the 35000 tons Drillship

Drillship design is completed by software which based on panel method and 3D diffraction to get a plan with regard principal lines dimension drillship in accordance with the actual data. Figure 5 is represented lines plan dimension of drillship with the actual data.

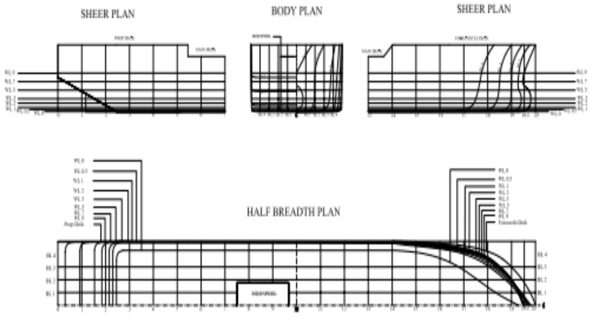

Figure 5: Lines plan of drillship [5]

Validation was performed to compare the existing hydrostatic with hydrostatic results in numerical models of drillship. Tolerance on this validation is less than 5%. Table 2 shows the results of validation model with the data existing hydrostatic. These results will be used for further analysis.

Table 2: Validation of model with the data

Parameter	Data	Hydrostar	Difference (%)
Displacement (ton)	35,193.0	35,421.7	0.65
Lpp (m)	156.0	156.0	0.00
B (m)	29.9	29.9	0.00
H (m)	15.6	15.6	0.00
T (m)	9.0	9.0	0.00
LCB to Midship (m)	3.265	3.270	0.15
LCF to Midship (m)	-7.203	-7.164	0.54
KM_T (m)	13.29	13.33	0.30
KM_L (m)	222.82	223.21	0.17
BM_T (m)	8.64	8.68	0.41
BM_L (m)	218.17	218.55	0.18

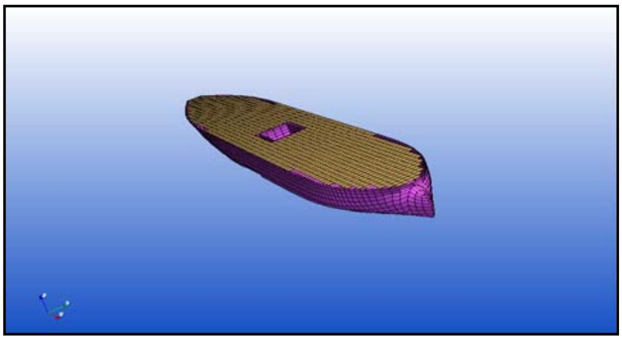

Figure 6: Modelling result with *hydrostar*

Numerical modeling with regard of displacement parameters, water level, the angle of incidence wave, COG coordinates and speed of drillship are computed by using *Hydrostar* software. Figure 6 shown the *Hydrostar* modelling of drillship in SWL condition. The purpose of this modeling is to obtain a model that fits with the data structure. Response Amplitude Operator (RAO) of heave and pitch motions for head seas wave direction had obtained to get the analysis of responses in random waves.

2.3 Motion Analysis

This paper was performed by *Hydrostar* to obtain Response Amplitude Operator (RAO) of heave and pitch motions for head seas wave direction. Results of the analysis of responses are used in the analysis of random waves.

Wave spectrum calculation is used spectra ITTC / ISSC for unrestricted water is required as a condition of the environment in where the drillship operations. Response spectra obtained by multiplying square of the relative vertical RAO bow wave spectrum [2, 6, 7].

$$S_R = [RAO(\omega)]^2 S(\omega) \tag{1}$$

From the response spectra analysis can be searched variants relative velocity response spectra (m_{0Vbr}) and response of the drillship movement (m_{0Zbr}) to calculate slamming criteria.

2.4 Calculation of Slamming

The probabilities of slamming are obtained by using the equation 2 [6,7]:

$$\Pr\,(Z_{br}>T_{b\ dan}V_{br}>V_{th}) = \mathrm{eks}\left(-\frac{T_b{}^2}{2m_{ozbr}} - \frac{V_{th}{}^2}{2m_{oVbr}}\right) \tag{2}$$

The value of m_{0Zbr} and m_{0Vbr} are generated from calculation in the step of response spectra analysis. The results of the calculation of the probabilities of slamming are used in equation intensity of slamming as equation 3:

$$N_{slam} = \frac{1}{2\pi}\sqrt{\frac{m_{2Zbr}}{m_{oZbr}}}\, x exp\left(-\frac{T_b{}^2}{2m_{oZbr}} - \frac{V_{th}{}^2}{2m_{2Zbr}}\right) 1/sec \tag{3}$$

Amount of pressure which occurs at the bow base of the vessel due to slamming can be calculated by considering the relative speed of the vertical bow extreme V_{br}. Relative speed V_{br} extreme vertical direction can be calculated by the equation 4 and the last one slamming pressure can be calculated by equation 5:

$$V_{br} = 2xln\left\{\frac{3600xT_0}{2\pi} exp\left(-\frac{T_b{}^2}{2m_{oZbr}} - \frac{V_{th}{}^2}{2m_{2Zbr}}\right)\right\}\sqrt{\frac{m_{4Vbr}}{m_{2Vbr}}x\sqrt{m_{2Vbr}}} \tag{4}$$

$$p_s = \rho k \times \ln\left\{\frac{3600\,T_0}{2\pi}\exp\left(-\frac{T_b^2}{2m_{0Zbr}} - \frac{V_{th}^2}{2m_{2Zbr}}\right)\right\}\sqrt{\frac{m_{4Zbr}}{m_{2Zbr}}} \times m_{2Zbr} \tag{5}$$

3.0 RESULTS AND DISCUSSION

3.1 Analysis of behavior motion drillship on transit conditions

This analysis is assisted by *Hydrostar software*, which transit conditions means that the drillship is moving with speeds. In this case, speed variations are 7 knots, 12 knots, 13 knots and 14 knots. For slamming analysis purposes, the coupled motion are heave and pitch motions. Head seas will be reviewed wave direction in this study.

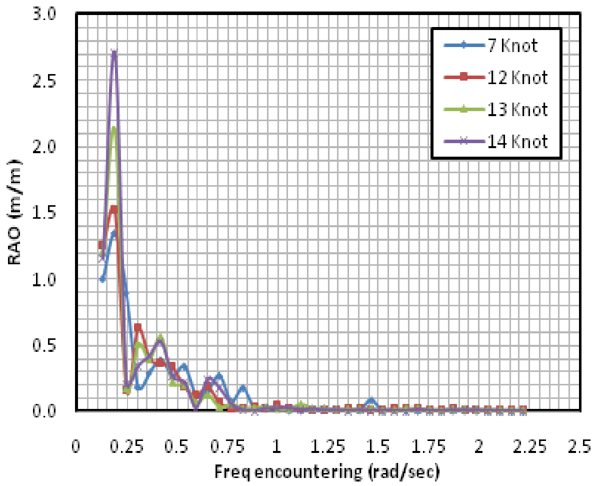

Figure 7: Heave RAO

Figure 7 represented heave RAO motion at the speed of 14 knots, which RAO peak occurs at low frequency 0.187 rad/s is 2.702 m/m. As for the pitch motion mode is shown in Figure 8.

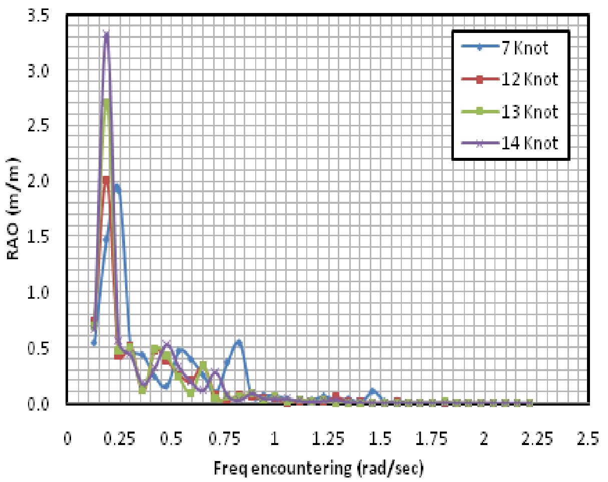

Figure 8: Pitch RAO

Pitch RAO motion reaches the highest point when the drillship has speed of 14 knots. Maximum RAO occurs at low frequency, it is about 0.187 rad/s in 3.33 deg/m.

After RAO of heave and pitch motions are obtained, the next step is calculate the vertical motion of the bow of drillship with point of view within 82.76 m of COG. The vertical relative motion of bow is obtained in the form of RAO as shown in a Figure 9.

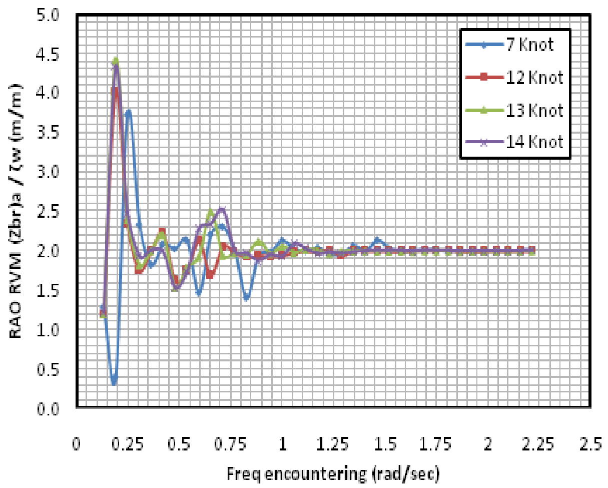

Figure 9: RAO relatively vertical bow

The result of relative vertical bow is combined with wave spectra ITTC/ISSC to get the response with significant wave height variation (Hs) is 3 m, 7 m, 11 m, 13 m and 15 m. Figure 10 illustrates the wave spectra using ITTC/ISSC form and unrestricted world wave data. Figure 11 up to Figure 14 show the response spectra of drillship with speed variation. The speed variation is 7 knot, 12 knot, 13 knot and 14 knot.

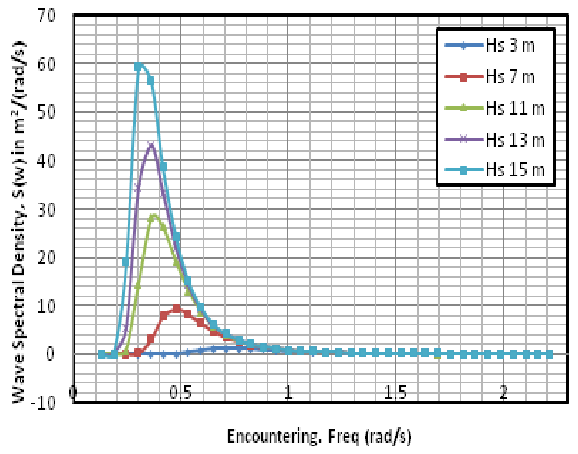

Figure 10: Spectra of ITTC/ISSC

Response spectra is obtained by multiplying square of relative vertical motion on the bow with wave spectra, in order to obtain results in the form of the response spectrum relative velocity spectra variants and vertical direction relative acceleration response spectra of vertical bow. These results are used for the calculation of slamming analysis.

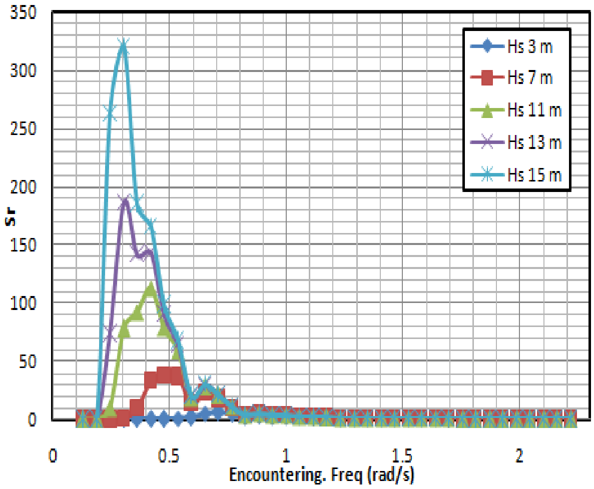

Figure 11: Response spectra of relative vertical motion on bow, 7 knot

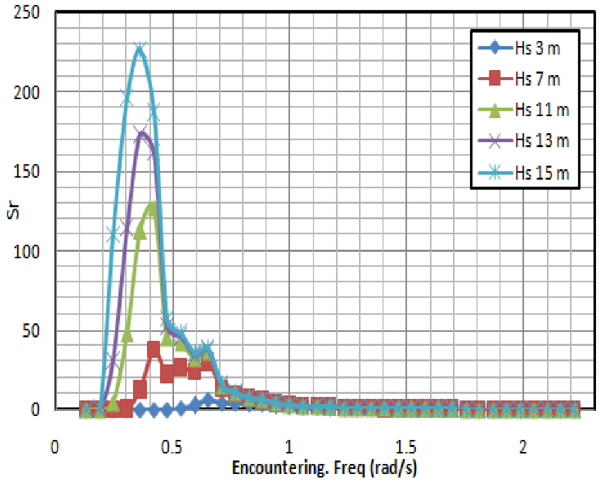

Figure 13: Response spectra of relative vertical motion on bow, 13 knot

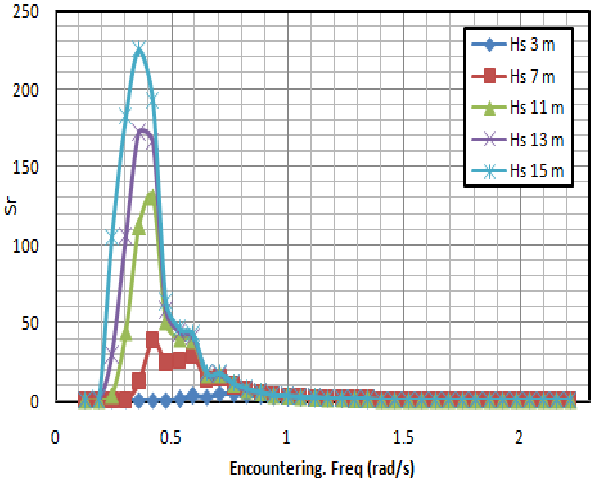

Figure 12: Response spectra of relative vertical motion on bow, 12 knot

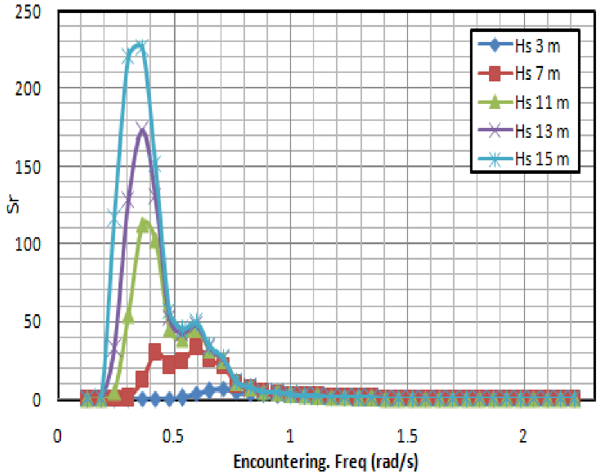

Figure 14: Response spectra of relative vertical motion on bow, 14 knot

Figure 11 illustrates vertical relative response spectra on the condition in speed of 7 knots. Maximum condition occurs at a frequency of 0.303 rad/s which has up to 320.25 (m^2/(rad/s)) at 15 m of Hs. Figure 12 provides vertical relative response spectra on the condition of 14 knots. Maximum condition occurs at a frequency of 0.361 rad/s which has up to 225.668 (m^2/(rad/s)) at 15 m of Hs. In terms of wave energy spectra, area under the curve is more important factor than the height [2].

Figure 13 shows vertical relative response spectra on the condition in speed of 13 knots with Hs variant 3 m, 7 m, 11 m, 13 m and 15 m. Maximum condition occurs at a frequency of 0.361rad/s which has up to 226.38 (m^2/(rad/s)) at 15 m of Hs. Figure 14 illustrates vertical relative motion of the bow on the condition of 14 knots. Maximum occurs at a frequency of 0.361 rad/s which has up to 226.40 m at 15 of Hs.

After getting acquiring the value of the relative response spectra of each speed and wave height. The calculation of slamming, threshold velocity used is V_{th} = 0.5 m/s in accordance with the provisions [8]. The results of calculations for the probabilities, intensities and pressures of slamming can be seen in Table 3.

Table 3: Result of slamming criteria analysis

Speed (Knot)	Hs (m)	Prob. (m)	Intensity (times/hour)	Pressure (kPa)
7	3	0.000	0.001	134.994
	7	0.010	6.799	254.754
	11	0.186	60.148	338.706
	13	0.283	87.112	383.047
	15	0.361	105.990	425.797

Table 3: Result of slamming criteria analysis (continue)

Speed (Knot)	Hs (m)	Prob. (m)	Intensity (times/hour)	Pressure (kPa)
12	3	0.000	0.000	137.712
	7	0.028	10.595	265.658
	11	0.209	71.382	368.889
	13	0.333	98.932	420.918
	15	0.441	118.985	470.459
13	3	0.000	0.000	141.389
	7	0.032	12.256	274.095
	11	0.227	72.978	377.529
	13	0.351	100.307	429.434
	15	0.465	121.940	483.991
14	3	0.000	0.000	143.714
	7	0.034	12.959	278.324
	11	0.247	75.132	386.674
	13	0.372	103.734	439.990
	15	0.483	124.451	492.232

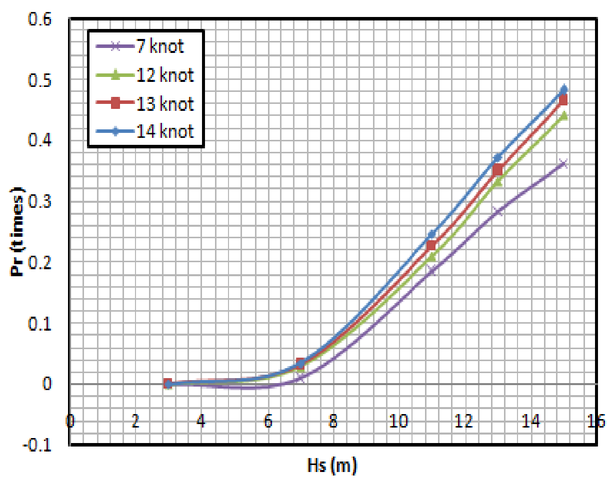

Figure 15: Slamming probability of drillship

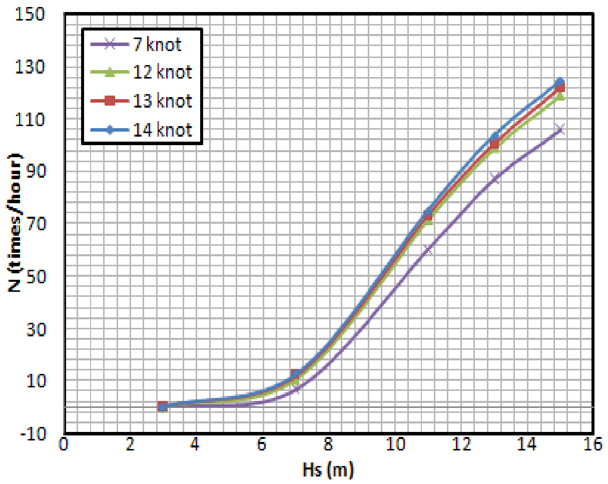

Figure 16: Slamming intensity of drillship

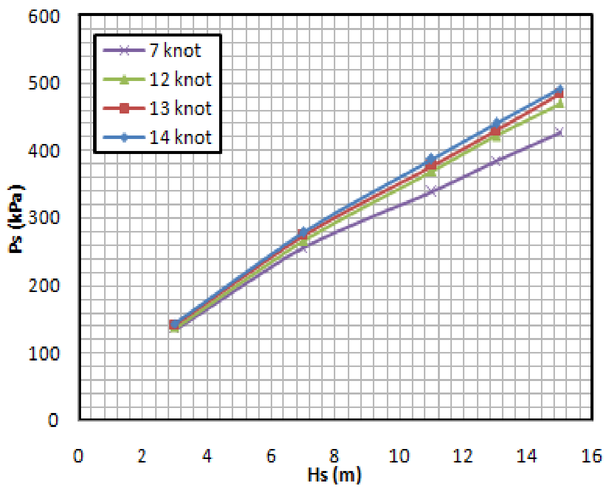

Figure 17: Slamming pressure of drillship

Table 3 describes the slamming criteria on the 35000 tons drillship, it can be seen that the probability of slamming occurs in transit condition with a maximum speed of 7 knots occur on 15 m Hs which is equal to 0.36times. while in transit at speeds of 14 knots, the probability of maximum slamming occurs on 15 m Hs which is equal to 0.483 m. whereas if it is based on the speed of transit, it can be seen that the maximum slamming probability at 14 knot of speed.

Slamming intensity in transit condition with 7 knot speed is occur on 15 meter Hs with 105.99 time/hour. Whereas it is reviewed by maximum speed of drillship with 14 knot, maximum slamming intensity is obtained. It is about 124.451 times/hour.. Meanwhile, by observing the speed of transit, it can be seen that the intensity of the maximum slamming occurs at 14 knot of speed.

Slamming pressure in transit condition with 7 knot speed is occured on 15 meter Hs with 425.797kPa. Whereas it is reviewed by maximum speed of drillship with 14 knot, maximum slamming pressure is obtained. It is about 492.232 kPa. Meanwhile, by observing the speed of transit, it can be seen that the intensity of the maximum slamming occurs at 14 knot of speed.

4.0 CONCLUSION

RAO relatively vertical of bow, the maximum occurs when drillship transit with a speed of 14 knots is 4,232 m/m. By using wave spectra ITTC/ISSC , result obtained the biggest probability of slamming when drillship transit with a speed of 14 knots is 0.483 times at 5 m Hs. Whereas the intensity and slamming pressure, the maximum occurs when drillship transit with a speed of 14 knots which is 124.451 times/hour and 492.232 kPa at 15 m Hs.

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