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Modelling Recurrence Motion on a Large Volume Semi-Submersible

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ABSTRACT

This research described a study of recurrence motion on a volume submersible. Recurrence is the phenomenon in which a system of quasi-periodically returns to its initial conditions after undergoing some degree of evolution, this finding supports the theory of quasi determinism (QD) of sea waves. The research to determine recurrence characteristic of motion in the large volume of semisubmersible using computational methods of ANSYS® AQWA™. The motion was analyzed four types of different incident waves by using JONSWAP Spectrum and are generally regarded as a pure randomness in nature which interacts with the structure generating hydrodynamic motion. Responses of motion were performed for 3 hours, in which it was divided into 9 seed for each incident wave. Hs 7 meters Tp 12.7 sec, Hs and 7 meters Tp 13.5 sec, Hs 8 meters and Tp 12.7 sec, and Hs 8 meters and Tp 12.7 sec , recurrence occurred in the interval (to +635s, to +879) - (to+1774, +to2074), (to +1460, to+1635) - (to +5758, to +5933), (to +693, to+882) - (to+1735, to+1924) and (to +792, to+992) - (to+1938, to+2138), respectively. Recurrence motion on a large volume semisubmersible support the to support the quasi determinism (QD) theory

KEY WORDS: *Semisubmersible, Recurrence, QD Theory, Modelling.*

1.0 INTRODUCTION

As the demand for oil and gas is increasing, the need for fixed and floating structure is gaining importance in the form of offshore facilities. Semi-submersible is a very important structure in the future due to the oil and gas exploration that leads to deep water (Hagerty and Ramseur, 2010). With the caused exploration oil and gas that leads to deep water and heave suppressed deep water structures. The challenge to produce oil in deep water is more complicated, many considerations that must be estimated. As water depth increase, the safety, structural integrity, mooring, and maintenance of a system become more and more difficult and challenging (Kim, 1999).

Tendency of deep water structure is a floating structure. The important issues on floating structure is hydrodynamic. One of the reasons hydrodynamic structures due to the interaction of the motion. On the floating structure, most of the causes of motion due to the action of wave. The calculation of hydrodynamic forces on offshore structures is of great importance to designers involved in offshore engineering, the hydrodynamic force calculations for design represent a very difficult task of environmental conditions are very complex because interaction occurs between waves and structure (Soylemez. 1996).

The total hydrodynamic force produced motion due to action of wave is assumed to be equal to the sum of the drag and inertia force components. Hydrodynamic analysis is performed in the frequency domain with the Morison equation being used for calculating wave induced drag and inertia forces on the structure (Patel and Harrison. 1985). The relative importance of the two components depends on the size of the structure. Sharant (1998) have analyzed hydrodynamic loadings due to the motion of large offshore structures. The researched to develop a non- reflecting boundary condition for the analysis of fully or partly submerged offshore structures for which the effect of water compressibility may be neglected but that of surface waves is important. Hydrodynamic interaction effect between large columns can cause a substantial increase in local wave height Eatock Taylor and Sincock (1989).

The random wave motion of a floating structure that hydrodynamic moving tendency had a recurrence phenomenal. Kaihatu (2009) have studied the phenomenon of recurrence. Recurrence is the phenomenon in which a system quasi-periodically returns to its initial conditions after undergoing some degree of evolution. Recurrence phenomenon was first studied by Fermi et al. (1955) in the case of a weakly nonlinear displacement of a discretized string. Experiment recurrence of the wave carried out by Bocotti (2011), the research identical sequences of relatively large waves were found hours apart from one another. This finding supports the theory of quasi determinism of sea waves. The quasideterminism (QD) theory introduces a deterministic wave function (of both space and time) that shows what, most probably, will happen if an exceptionally large wave will occur at some point in a sea storm. QD theory has theoretical and practical significance in ocean engineering and naval architecture because it suggests that extreme wave force, far from being random, tend to be deterministic.

Boccotti (2011) continued research on the theory of quasi-determinism to determine the recurrence of large waves in wind seas and by measuring surface waves. The experiment used quasi-deterministic (QD) theory. Implies two exceptionally large waves in two sea states with the same spectrum and same configuration of the solid boundary experiment used a model and horizontal beam. It was mounted with 26 pressure transducers for measuring pressure head waves induced by wind-generated waves on the sea surface. The result from the research was concluded the QD theory it is expected that there is a time interval in which the wave profiles recorded by the gauge array in sea state A are very close to the wave profiles recorded by the gauge array in sea state B. This fact supports the validity of the QD theory quite effectively, albeit based on limited observations. The fact that the fluctuating pressure head at some given depth is the same in two distinct sea states does not simply that the free surface displacement is the same in these sea states.

The research discussed on experiment recurrence phenomena on floating structure introduced by Priyanto. A (2012). The experiment to find recurrence phenomena on semi-submersible structure. The research addresses the problems of estimating the waves run up for a large semi-submersible production platform. Significant run-up evaluations on its squared-section columns were observed for the waves in loading design condition. Some seed numbers generated JONSWAP waves in tank were used, and are generally regarded as a pure randomness in nature. Some identical sequence of relatively wave run-up was founded apart from one another for different seed. This finding supports the occurrence of waves run up for the largest semi-submersible platform

1.1 Motion on Semisubmersible

According to Molland T. (2008). A floating body has six degrees of freedom. To completely define the floating body motion it is necessary to consider movements in all these modes as illustrated in Fig. 1. The motions are defined as movements of the center of gravity of the ship and rotations about a set of orthogonal axes through the center of gravity. These are space axes moving with the mean forward speed of the floating body but otherwise fixed in space. It will be noted that roll and pitch are the dynamic equivalents of heel and trim. Translations along the x-and y-axis and rotation about the z-axis lead to no residual force or moment, provided displacement remains constant, as the ship is in neutral equilibrium.

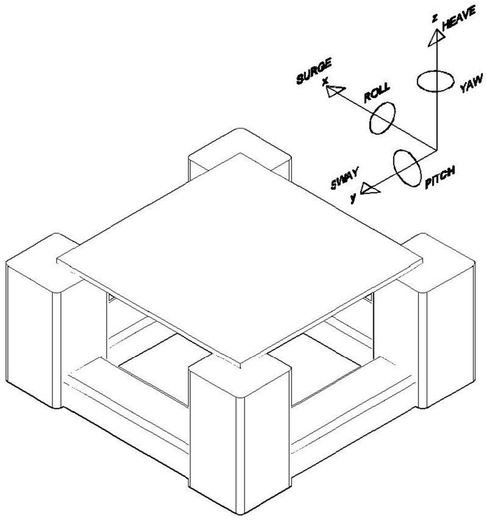


Figure 1: Semi-submersible Motion

Table 1: 6DOF motion of semi-submersible structure

Translation or rotation	Axis	Description	Positive Sense
	Along x	Surge	Forwards
Translation	Along y	Sway	To starboard
	Along z	Heave	Downwards
	About x	Roll	Starboard side down
Rotation	About y	Pitch	Bow up
	About z	Yaw	Bow to starboard

For the other translation and rotations, movement is opposed by a force or moment provided the floating body is stable in that mode. The magnitude of the opposition increases with increasing displacement from the equilibrium position, the variation being linear for small disturbances. This is the characteristic of a simple spring system. Thus, it is to be expected that the equation governing the motion of a floating body in still water, which is subject to a disturbance in the roll, pitch or heave modes, will be similar to that governing the motion of a mass on a spring.

This is indeed the case, and of the undamped case the floating body is said to move with simple harmonic motion. Disturbances in the yaw, surge and sway modes will not lead to such an oscillatory motion and these motions, when the ship is in a seaway, exhibit a different character to roll, pitch and heave. These are considered separately and it is the oscillatory motions which are dealt with in the next few sections. It is convenient to consider the motion which would follow a disturbance in still water, both without and with damping, before proceeding to the more realistic case of motions in waves.

1.2 Motion in Irregular Seas

Once the transfer functions between wave the energy and motion (component) energy are known, one can transform any wave energy spectrum to a corresponding motion energy spectrum.

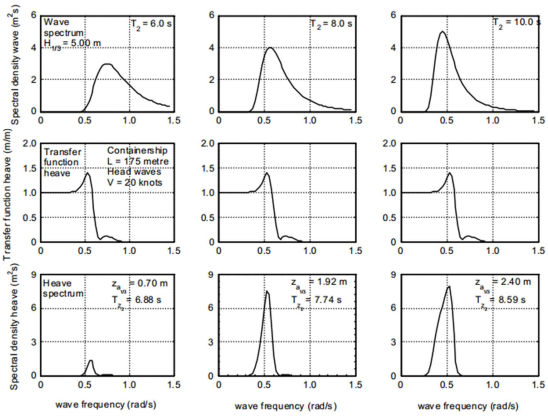
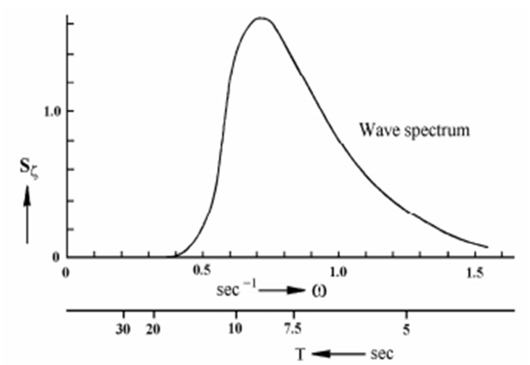


Figure 2: Effect of Wave Period on Heave

For the wave spectrum with an average period of 6.0 seconds, the transfer function has very low values in the wave frequency range. The response spectrum becomes small, only small motions result. As the average wave period gets larger and the response increases dramatically. A similar effect will be obtained for a larger range of average wave periods if the transfer function of the motion shifts in the low frequency region. A low natural frequency is required to obtain this. This principle has been used when designing semi-submersibles, which have a large volume under water and a very small spring term for heave (small water plane area). However, such a shape does not make much of a wave when it oscillates; it has little potential damping. This results in large (sometimes very large) RAO's at the natural frequency. As long as there is (almost) no wave energy at this frequency, the response spectrum will remain small (J.M J. Journee and W. W. Massie. 2001)



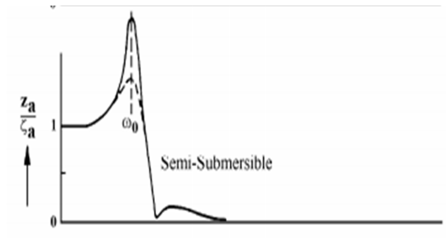


Figure 3: Effect of Natural Period in Heave Motion on Semi-submersible (J.M J. Journee and W. W. Massie. 2001)

Figure 3 shows a wave spectrum with sketches of RAO's for heave of semi-submersible structures at zero forward speed. The semi-submersible however, with a very low natural frequency (large mass and small intersection with the waterline), transfers only a very small part of the wave energy, very low first order heave motions will appear, it remains essentially stable in the waves.

1.3 Quasi Deterministic Theory of Sea Waves

According to Kaihatu (2009) the common manifestation of nonlinear wave behavior is the phenomenon of recurrence among a small number of frequency components. Loosely defined, recurrence is the phenomenon in which a system quasi-periodically returns to its initial conditions after undergoing some degree of evolution.

The latest experimental studies recurrence on wave was introduced by Boccotti (2011). The quasi-determinism (QD) theory introduces a deterministic wave function (of both space and time) that shows what, most probably, will happen if an exceptionally large wave will occur at some point in a sea storm. This deterministic wave function holds for every configuration of the solid boundary, provided that the wave motion may be regarded as irrational (Boccotti, 2008).

The most important novelty of the QD theory is that the deterministic wave-function. If a wave with a given exceptionally large height H occurs at some point x_0, y_0 at a time instant t_0 in a sea storm, there is a very great probability that the random free surface displacement around point x_0, y_0 for a span of time before and after t_0 is very close to the following deterministic wave function:

$$\eta(x_0+X, y_0+Y, t_0+T) = \frac{\Psi(X,Y,T)-\Psi(X,Y,T-T^*)}{\Psi(0,0,0)-\Psi(0,0,T^*)}\frac{H}{2} \qquad (1)$$

Here, Ψ is the covariance with both space and time lags of the random free surface displacement, that is,

$$\Psi(X,Y,T) = \langle \eta(x_0, y_0, t)\eta(x_0+X, y_0+Y, t+T)\rangle. \qquad (2)$$

Where the angle brackets denote an average with respect to time t and T^* is the lag of the absolute minimum of the auto-covariance function. See the reference scheme of Fig. 4

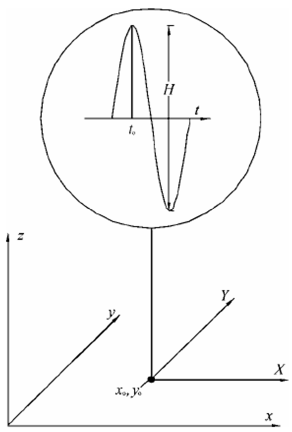


Figure 4: Reference scheme for the QD theory (Boccotti, P. 2006)

Associated with the deterministic wave function .Equation (1) is a distribution of velocity potential in the water, which to the lowest order in a Stokes expansion is given by

$$\phi(x_0 + X, y_0 + Y, z, t_0 + T) = \frac{\Phi(X,Y,z,T) - \Phi(X,Y,z,T-T^*)}{\Psi(0,0,0) - \Psi(0,0,T^*)} \frac{H}{2} \quad . \qquad (3)$$

Where Φ is the covariance of the free surface displacement and the velocity potential of the random wind-generated waves.

$$\Phi(X, Y, z, T) = \langle \eta(x_0, y_{0,} t) \eta(x_0 + X, y_0 + Y, t + T) \rangle \qquad (4)$$

This is the gist of the quasi-determinism QD theory. Specifically, the deterministic wave function (Eq.4) and the distribution of velocity potential (Eq.4) not only are valid for waves in the open sea, but also hold for waves interacting with solid bodies of arbitrary shapes and sizes. What is requested only is that the free surface displacement of the random wind-generated waves represents .As mentioned above. A stationary random *Gaussian* process of time at every point, whether or not these random processes are nonhomogeneous in space because of the presence of any solid body that induces wave diffraction. What changes from one configuration of the solid boundary to another configuration is only the relationship between the functions and directional spectrum of the incident waves.

2.0 EXPERIMENT OF RECURRENCE

The theory is used to define recurrence wave that occurs in semi-submersible, using the Boccotti (2008) method. Where the recurrence theorem of wave derived from the quasi-determinism (QD) theory.

The QD theory suggests that the important parameters of the wave elevations spectrum are (Bocotti, 2011): the peak frequency, the dominant direction and the bandwidth. Records with some similar values of triplet are *Tp*, θ,Ψ. Where: Tp = period associated with the peak of the energy spectrum; θ = angle between the wave direction, Ψ = narrow-banddedness parameter (equal to the maximum of the auto covariance of wave run-up fluctuations).

2.1 Incident Wave Condition

Incident wave that used is irregular waves, in which to display the random nature, with incident wave parameters for significant wave height and period is shown as follows:

Table 2: Incident Wave Parameter

Hs (m)	Tp (s)	γ	Direction
7.0	12.7	1	0
7.0	12.7	1	0
8.0	13.5	1	0
8.0	13.5	1	0

2.2 Particular Dimension of Semi-submersible

The model is semi-submersible with 58.748 tones, characterized by having large displacement hulls. These platform are stabilized 4 rectangular column arrangement

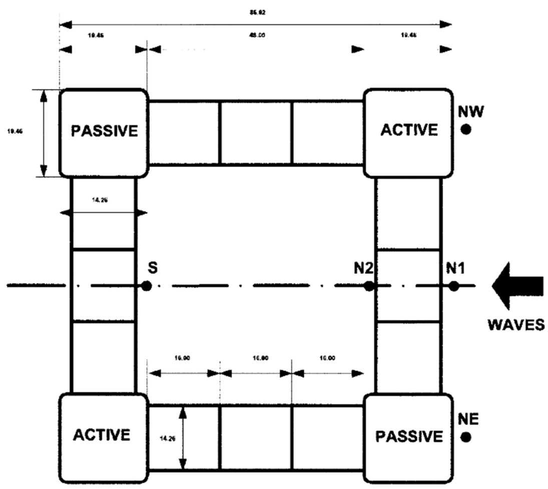


Figure 5: Dimension of Semi-submersible

Table 3: Particular dimension of Semi-submersible

Designation	Symbol	Unit	Full Scale
Overall Length	*L*	M	86.920
Overall Breadth	*B*	M	86.920
Overall Draft	*d*	M	22.000
Operating Displacement	*Δ*	MT	58.748
Centre gravity from centerline	*XCG*	M	0.00
Centre gravity above base	*KG*	M	28.59
Centre buoyancy above base	*VCB*	M	8.22
Metacentric height above base	*KM*	M	38.90
Pitch gyradius	K_{yy}	M	35.36
Roll gyradius	K_{xx}	M	36.45
Yaw gyradius	K_{zz}	M	39.83

Data analysis performed by the result of the modeling that conducted by using ANSYS AQWA^{TM}. Analyzes for research were obtained as follows:

- First, a diffraction analysis of the Semi-submersible in ANSYS AQWA, the main goal is to obtain the hydrodynamic parameters (damping, added mass coefficients) and free floating RAO's.
- Second, the results of the ANSYS AQWA hydrodynamic diffraction analysis for RAOs are reported and compared with experiment result and MOSES analysis
- Third, added mass and radiation damping describe by dimensional analysis of the force of the moment and frequency (Hz) and non-dimensional analysis
- Fourth, result in recurrence of wave run-up, describe by Structure Position based RAO response in the time domain analysis

2.2 Modelling Structure of Semi-submersible

The analysis performed using modelling with ANSYS AQWA™ software. The modeling of semi-submersible is a rectangular structure, consisting of 4 chords, and 4 braces that form a unified whole that semi-submersible that have dimensions as follows:

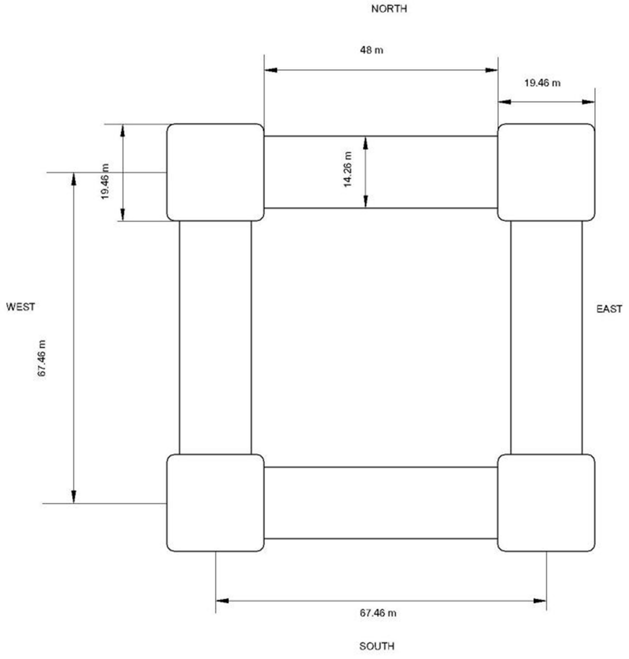


Figure.6: Dimension of Semi-submersible top view

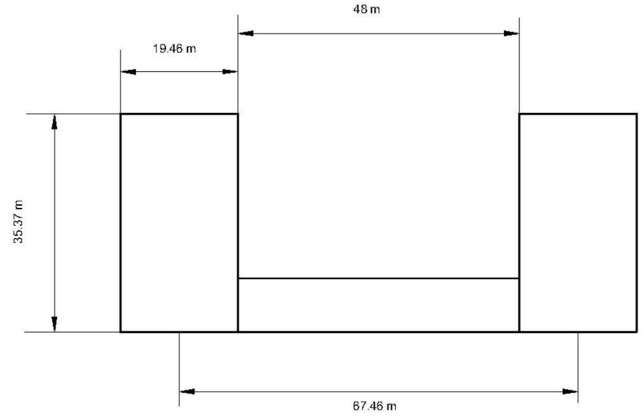


Figure 7: Dimension of Semi-submersible side view

Analysis for semi-submersible structure by having the Main particular as follows:

Description	Notation	Unit	Value
Object Name	*Semi-submersible*	*Hull*	-
State	-	-	Fully Defined
Details of Dimension			
Overall Length	Loa	[m]	86.92
Overal breadth	B	[m]	86.92
Overal Draft	d	[m]	22
Operating Displacement	Δ	[mT]	58.748
Centre Gravity from Centreline	XCG	[m]	0
Centre Gravity above Base	KG	[m]	28.59
Centre Boyancy above Base	*VCB*	[m]	8.22
Metacentric height above Base	KM	[m]	38.9
Roll Gyradius	K_{xx}	[m]	36.45
Pitch Gyradius	K_{yy}	[m]	35.36
Yaw Gyradius	K_{zz}	[m]	39.83

A point mass of semi-submersible hull analysis carried out as follows:

Table 4: Point Mass of Semi-submersible

Description	Notation	Unit	Value
Object Name	*Semi-submersible*	*Point Mass*	-
State	-	-	Fully Defined

Details of Point Mass			
Visibility			Visible
Suppressed			Not Suppressed
Point Gravity about x	X	[m]	23.9963283538818
Point Gravity about y	Y	[m]	-24.0502452850342
Point Gravity about z	Z	[m]	8.22
Mass		[kg]	58082213.5742188
Roll Gyradius	K_{xx}	[m]	36.45
Pitch Gyradius	K_{yy}	[m]	35.36
Yaw Gyradius	K_{zz}	[m]	39.83
Mass moment of inertia about x	I_{xx}	[kg.m²]	77168174160.241
	I_{xy}		0
	I_{xz}		0
Mass moment of inertia about y	I_{yy}	[kg.m²]	72621910865.3675
	I_{yz}		0
Mass moment of inertia about z	I_{zz}	[kg.m²]	92143302190.1129

The following, a 3-dimensional model of the semi-submersible ANSYS AQWA^{TM}

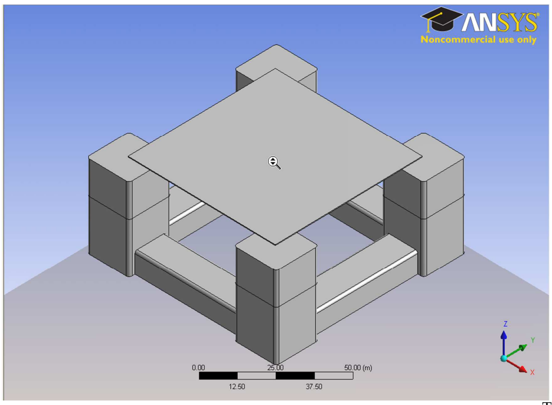


Figure.8: Modelling Semi-submersible in ANSYS AQWA^{TM}

2.3 ANSYS AQWA^{TM} Hydrostatic Result

Hydrostatic result for semi-submersible obtained by analysis using ANSYS AQWA^{TM} as follows:

Table 5: Centre of Gravity Position

Center of Gravity Position:		
X	:	23.996328 m
Y	:	-24.050245 m
Z	:	8.2200003 m

	Z	RX	RY
Heave(Z):	15032824 N/m	-42.378952 N/°	-216.56735 N/°
Roll(RX):	-2428.135 N.m/m	88676680 N.m/°	35124.684 N.m/°
Pitch(RZ):	-12408.396 N.m/m	35124.684 N.m/°	87776560 N.m/°

Table 6: Hydrostatic Displacement Properties

Hydrostatic Displacement Properties	
Actual Volumetric Displacement:	58665.59 m³
Equivalent Volumetric Displacement:	58665.578 m³

Centre of Buoyancy Position:	**X:**	23.99633 m	**Y:**	-24.050268 m	**Z:**	-13.763055 m
Out of Balance Forces/Weight:	**FX:**	-8.74E-08	**FY:**	6.45E-09	**FZ:**	7.87E-07
Out of Balance Moments/Weight:	**MX:**	-1.4181e-5 m	**MY:**	-4.5831e-6 m	**MZ:**	-8.0524e-8 m

Table 7: Cut Water Plane Properties

Cut Water Plane Properties				
Cut Water Plane Area:		1495.5331 m²		
Centre of Floatation:	**X:**	23.997154 m	**Y:**	-24.050407 m
Principal 2nd Moment of Area:	**X:**	1746005.1 m^4	**Y:**	1751151.6 m^4
Angle Principal Axis makes with X(FRA):		5028.7778 °		

Table 8: Small Angle Stability Parameters

Small Angle Stability Parameters		
C.O.G. to C.O.B.(BG):	21.983055 m	
Metacentric Heights (GMX/GMY):	8.8293858 m	8.920208 m
COB to Metacentre (BMX/BMY):	30.812441 m	30.903263 m
Restoring Moments/Degree Rotations (MX/MY):	1531966.3 N.m/°	1547724.6 N.m/°

2.4 ANSYS AQWA^{TM} Motion Result

Six degrees of freedom (6DoF) refer to the freedom of movement of a rigid body in three-dimensional space. Specifically, the body is free to move forward/backward, up/down, left/right (translation in three perpendicular axes) combined with rotation about three perpendicular axes, often termed pitch, yaw, and roll.

The 6DOF motions of a rigid body in body coordinate system are governed by the equations of linear and angular momentum referred to the center of gravity. Motion analysis of the Six degrees of freedom (6DOF) motion of the center of gravity performed to motion of the surge, heave and pitch, where the analysis is done to determine the added mass, damping and RAOs on (heading - 0 degree) and 45 degrees

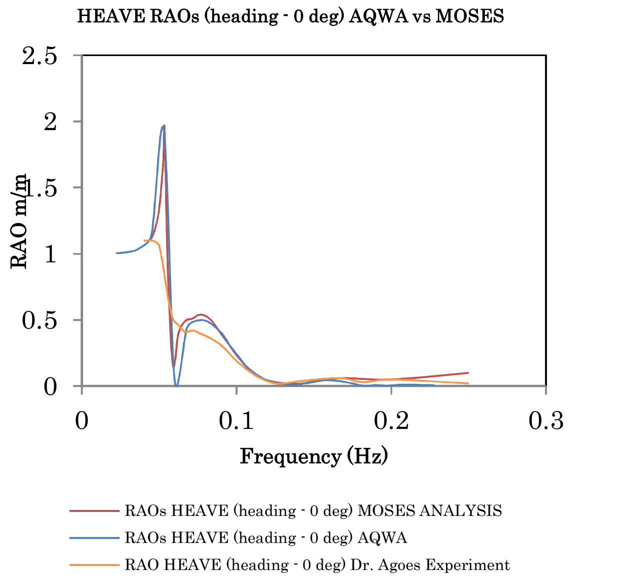


Figure 9: Heave RAOs Experiment Result vs ANSYS AQWA™ vs MOSES (heading - 0 degree)

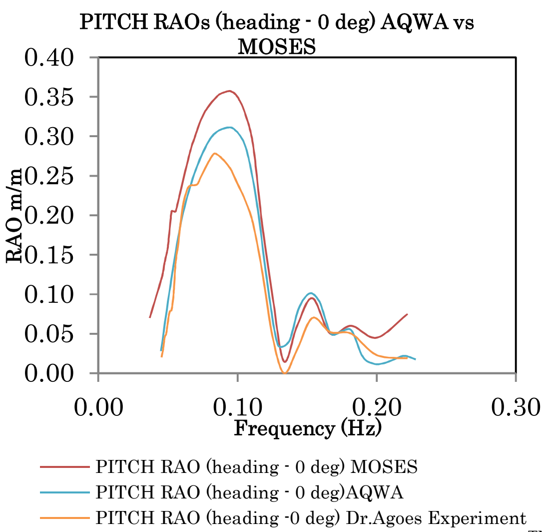


Figure 10: Heave RAOs MOSES vs ANSYS AQWA™ vs Experiment Result (heading - 0 degree)

For modelling model, it is essential to obtain evaluation natural frequency of motion (RAOs). The modelling value of RAOs were obtained through three different sets of irregular wave. In fig 9 and fig 10, the orange solid line one refers to the data obtained directly from the irregular wave moored test. The red solid line, here named MOSES, was obtained in numerical test and blue solid line obtained from ANSYS AQWA, specifically carried out to determine the RAOs heave and pitch of the semisubmersible.

The comparison show the agreeable RAOs result up to 0.25 Hz wave frequency. There are difference between MOSES, ANSYS AQWA and the moored test result. This not considered as a major concern since at higher periods the energy of the wave may be less and hence the RAOs at higher periods will not represent reasonable values.

The following is a non-dimensional added mass and damping from the modeling with ANSYS AQWA. Added mass and damping are generated based on the motion of heave and pitch based on frequency. Added mass and damping for heave motion and pitch motion, for the non-dimensional ordinate axis is different.

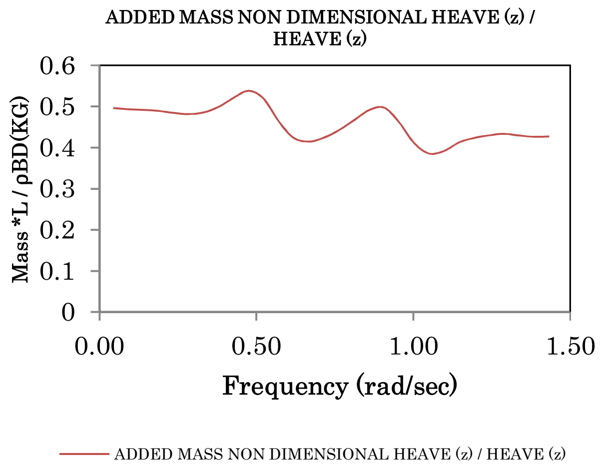


Figure 11: Added Mass non dimensional for heave (z) / heave (z)

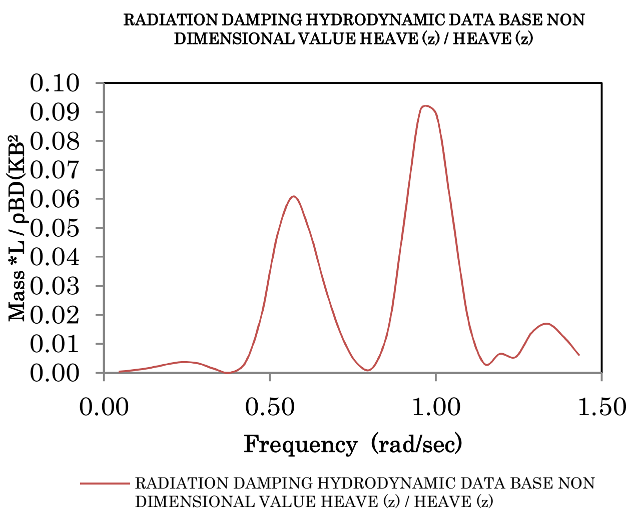


Figure 12: Radiation Damping non dimensional for heave (z) / heave (z)

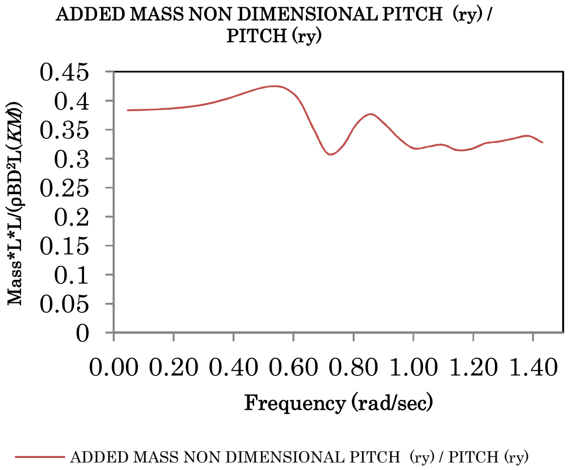


Figure 13: Added Mass non dimensional for pitch (ry) / pitch (ry)

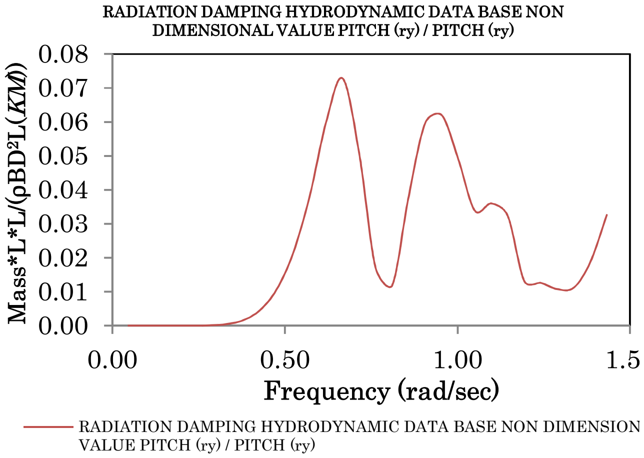


Figure 14: Radiation Damping non dimensional for pitch (ry) / pitch (ry)

JONSWAP spectrum generated by the test and moored wave generated by ANSYS AQWA, almost have the same value for irregular waves generated at each Hs 7 meters, and Hs 8 meters. Blue solid line obtained from ANSYS AQWA and the red solid line obtained from the moored wave experiment test.

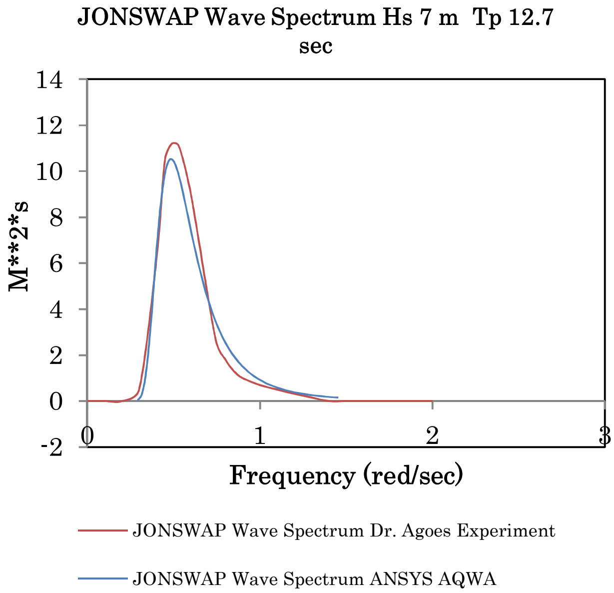


Figure 15: JONSWAP wave spectrum Hs 7 m, Tp 12.7 sec

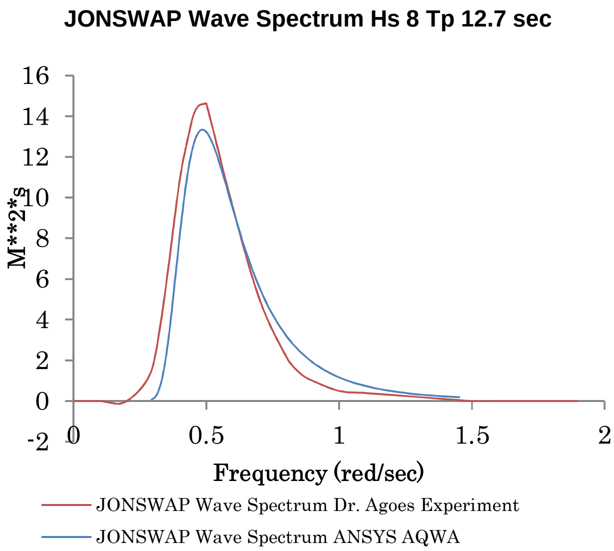


Figure 16: JONSWAP wave spectrum Hs 8 m, Tp 12.7 sec

Recurrence motion analysis using hydrodynamic response time from ANSYS AQWA based on the natural frequency of Heave motion. 3 hours analyzing natural treatment for frequency position of the model structure. Amount of data generated for 10.800 sec, with time step 0.5 sec

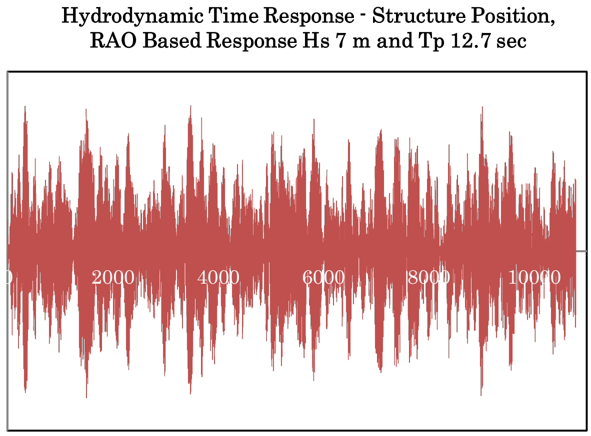


Figure 17: Response Amplitude Operator based Hydrodynamic time response for heave Hs 7m and Tp 12.7 sec

2.5 Recurrence Analysis

- Recurrence analysis Hs 7 m and Tp 12.7 sec RAO response heave Seed.01 vs Seed.02

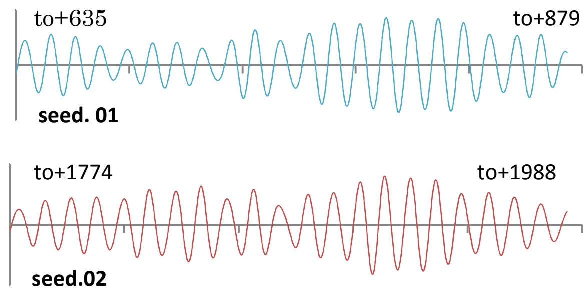


Figure 18: Recurrence phenomena RAO response on heave Seed.01 vs Seed.02 Hs 7 m and Tp 12.7 sec

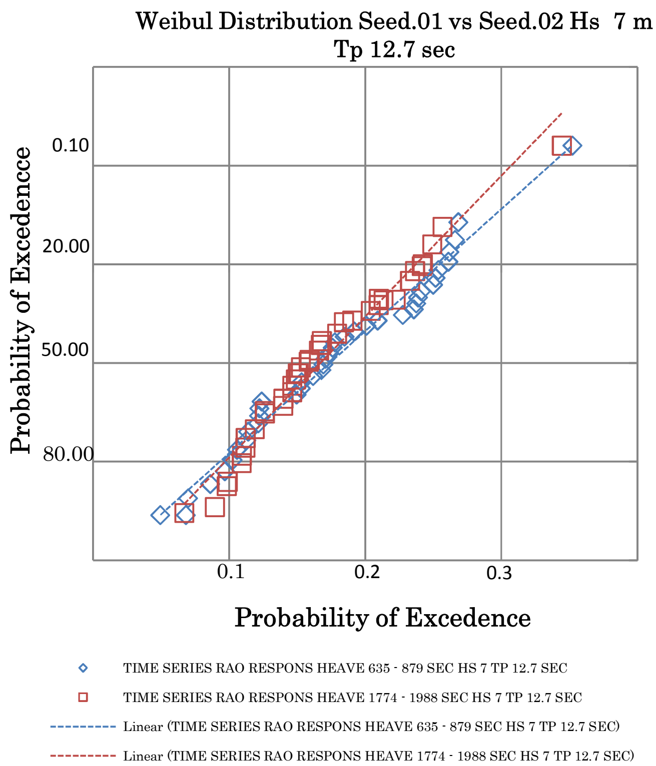
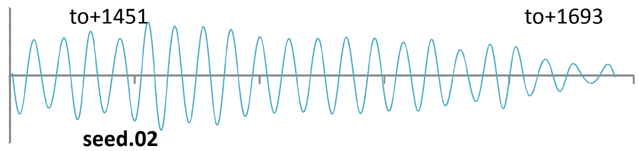


Figure 19: Weibull Distribution RAO response on heave Seed.01 vs Seed.02 Hs 7 m and Tp 12.7 sec

As the lag |*t-to*| grows also difference between the natural frequency heave motions of the two records, gradually grown. On the interval (to+635, to+879) seed. 01 the likeness between the natural frequency heave motion of measured on the interval (to+1774, to+2074) seed. 02 occurs. Respectively fig.18 that heave motion of being regular (not regular in shape and size) and from the response that determined the heave motion repeated at at least twice on the same JONSWAP spectrum interval.

The fluctuation natural frequency of heave motion for likeness is between interval (to+635, to+879) seed. 01 and (to+1774, to+2074) seed. 02 determined by a Weibull distribution on fig.19. The trend of graph showed a closed data distribution. This showed that the natural frequency of heave motion for likeness between interval (to+635, to+879) seed. 01 and (to+1774, to+2074) seed. 02 almost have the same condition of fluctuation.

- Recurrence analysis Hs 7 m and Tp 12.7 sec RAO response heave Seed.02 vs Seed.05



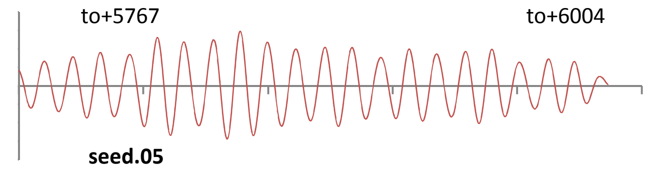


Figure 20: Recurrence phenomena RAO response on heave Seed.02 vs Seed.05 Hs 7 m and Tp 12.7 sec

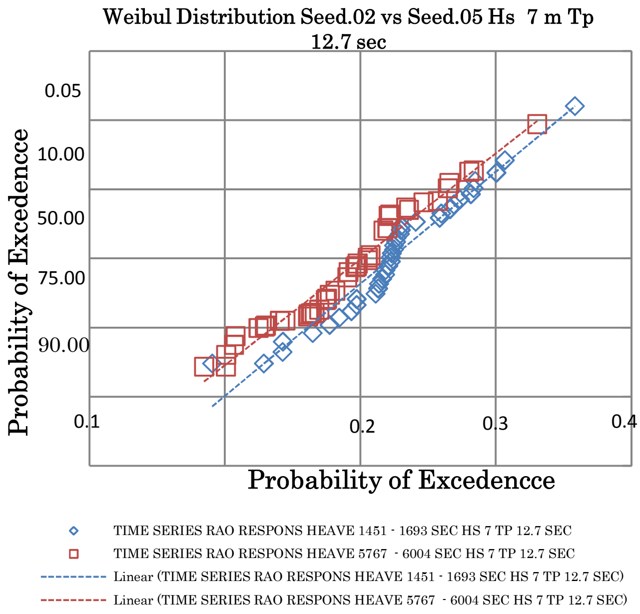


Figure 21: Weibull Distribution RAO response on heave Seed.02 vs Seed.05 Hs 7 m and Tp 12.7 sec

As the lag |*t-to*| grows also difference between the natural frequency heave motions of the two records, gradually grown. On the interval (to+1451, to+1693) seed. 02 the likeness between the natural frequency heave motion of measured on the interval (to+5767, to+6004) seed. 05 occurs. Respectively fig.20 that heave motion of being regular (not regular in shape and size) and from the response that determined the heave motion repeated at least twice on the same JONSWAP spectrum interval.

The fluctuation natural frequency of heave motion for likeness is between interval (to+1451, to+1693) seed. 02 and (to+5767, to+6004) seed. 05 determined by a Weibull distribution on fig.21 the trend of graph showed a closed data distribution. This showed that the natural frequency of heave motion for likeness between interval (to+1451, to+1693) seed. 02 and (to+5767, to+6004) seed. 05 almost have the same condition of fluctuation.

- Recurrence analysis Hs 8 m and Tp 12.7 sec RAO response heave Seed.01 vs Seed.02

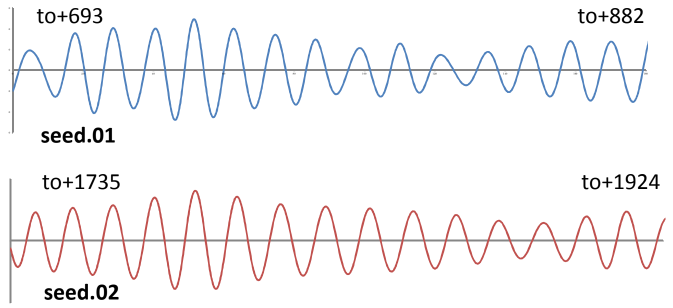


Figure 22: Recurrence phenomena RAO response on heave Seed.01 vs Seed.02 Hs 8 m and Tp 12.7 sec

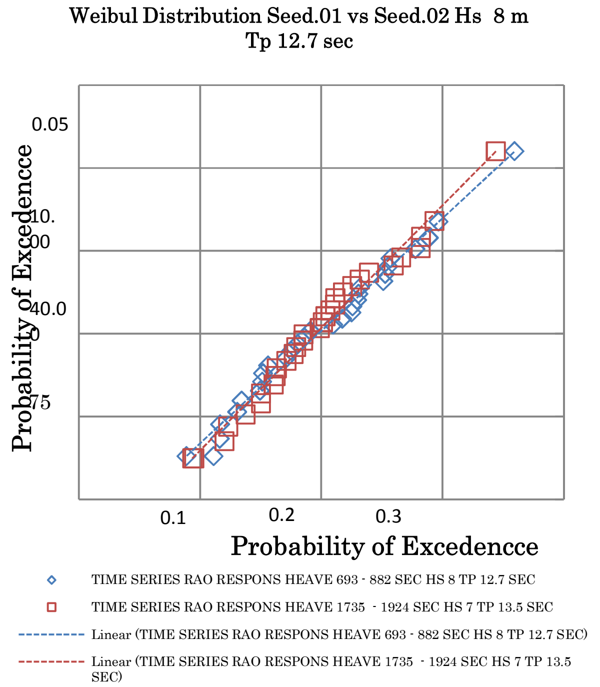


Figure 23: Weibull Distribution RAO response on heave Seed.01 vs Seed.02 Hs 8 m and Tp 12.7 sec

As the lag |*t-to*| grows also difference between the natural frequency heave motions of the two records, gradually grown. On the interval (to+693, to+882) seed. 01 the likeness between the natural frequency heave motion of measured on the interval (to+1735, to+1924) seed. 02 occurs. Respectively fig.22 that heave motion of being regular (not regular in shape and size) and from the response that determined the heave motion repeated at at least twice on the same JONSWAP spectrum interval.

The fluctuation natural frequency of heave motion for likeness is between interval (to+693, to+882) seed. 01 and (to+1735, to+1924) seed. 02 determined by a Weibull distribution on fig.23 the trend of graph showed a closed data distribution. This showed that the natural frequency of heave motion for likeness between interval (to+693, to+882) seed. 01 and (to+1735, to+1924) seed. 02 almost have the same condition of fluctuation.

- Reccurence analysis Hs 8 m and Tp 13.5 sec RAO respons heave Seed.01 vs Seed.02

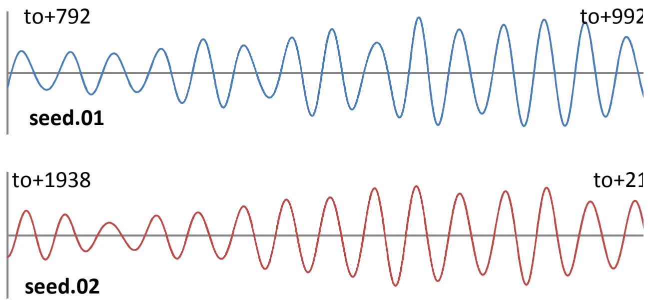


Figure 24: Recurrence phenomena RAO response on heave Seed.01 vs Seed.02 Hs 8 m and Tp 13.5 sec

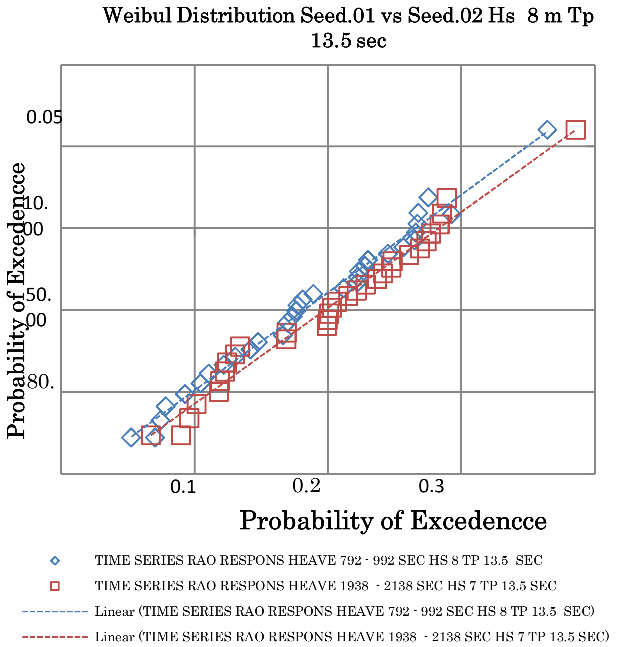


Figure 25: Weibull Distribution RAO response on heave Seed.01 vs Seed.02 Hs 8 m and Tp 13.5 sec

As the lag |*t-to*| grows also difference between the natural frequency heave motions of the two records, gradually grown. In the interval (to+792, to+992) seed. 01 the likeness between the natural frequency heave motion of measured on the interval (to+1938, to+2138) seed. 02 occurs. Respectively fig.24 that heave motion of being regular (not regular in shape and size) and from the response that determined the heave motion repeated at at least twice on the same JONSWAP spectrum interval.

The fluctuation natural frequency of heave motion for likeness is between interval (to+792, to+992) seed. 01 and (to+1938, to+2138) seed. 02 determined by a Weibull distribution on fig.25. The trend of graph showed a closed data distribution. This showed that the natural frequency of heave motion for likeness between interval (to+792, to+992) seed. 01 and (to+1938, to+2138) seed. 02 almost have the same condition of fluctuation.

- Recurrence analysis Hs 8 m and Tp 13.5 sec RAO response heave Seed.05 vs Seed.09

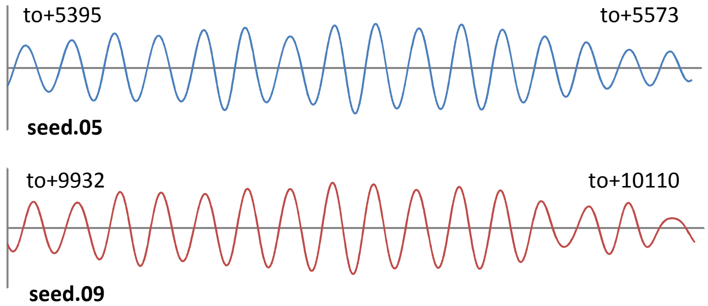


Figure 26: Recurrence phenomena RAO response on heave Seed.05 vs Seed.09 Hs 8 m and Tp 13.5 sec

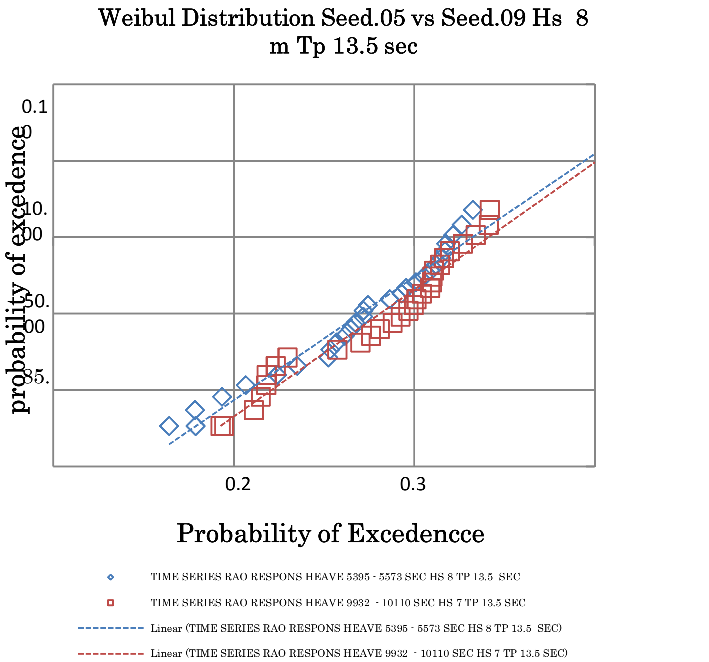


Figure 27: Weibull Distribution RAO response on heave Seed.05 vs Seed.09 Hs 8 m and Tp 13.5 sec

As the lag |*t-to*| grows also difference between the natural frequency heave motions of the two records, gradually grown. In the interval (to+5395, to+5573) seed. 05 the likeness between the natural frequency heave motion of measured on the interval (to+9932, to+10110) seed. 09 occurs. Respectively fig.26 that heave motion of being regular (not regular in shape and size) and from the response that determined the heave motion repeated at at least twice on the same JONSWAP spectrum interval.

The fluctuation natural frequency of heave motion for likeness is between interval (to+5395, to+5573) seed. 05 and (to+9932, to+10110) seed. 09 determined by a Weibull distribution on fig.27. The trend of graph showed a closed data distribution. This showed that the natural frequency of heave motion for likeness between interval (to+5395, to+5573) seed. 05 and (to+9932, to+10110) seed. 09 almost have the same condition of fluctuation.

CONCLUSION

The semi-submersible structure essentially stable in the waves, that proved with very low natural frequency (large mass and small intersection with the waterline), transfers only a very small part of the wave energy, very low first order heave motions will appear, it remains essentially stable in the waves. The semi-submersible structure the research showed the shape and size of the natural frequency of heave motion have the same character with experiment. The natural frequency of semi-submersible structure research by ANSYS$^{@}$AQWA^{TM} almost have the same criteria, shape and size with natural frequency researched by MOSES and experiment by Priyanto, A. (2012).

From the (QD) theory that there is a time interval in which the heave motion semi-submersible measured by the JONSWAP spectrum records with some similar value of fluctuation heave motion, period and angle direction. The research has proven the recurring phenomena. (QD) theory introduces a deterministic wave function (of both space and time) that shows what, most probably, will happen if an exceptionally large wave will occur at some point in a sea storm.

The research showed, the JONSWAP spectrum in incidence waves appears to be not random (irregular shape). This effect given influenced on the natural frequency of heave motion semi-submersible structure in irregular shape. From the response that determined the heave motion repeated at at least twice on the same JONSWAP interval and proved the QD theory based on Priyanto. A (2012)

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