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Seakeeping Analysis of Dredging Hole Initial Design of a New Tin Mining Vessel Design

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Abstract:- Tin Mining Vessel is a fairly new ship technology in Indonesia, several Tin Mining Vessel design developments have been carried out to improve performance while operating as well as safety factors for ships and crew. The design of the Tin Mining Vessel in this study is in the form of a barge with an initial hole design dimension of a 3.6 x 3.6 m which functions to insert the drill pole and suction pipe into the seabed. Tin Mining Vessel has a dimension of length (Lpp) = 72 m, width (B) = 18 m, deck height (H) = 5 m, Draught (T) = 2.5 m, and Cremona construction and drill pole and suction pipe as high as 60 m. Measurement of ship motion through seakeeping testing is used to analyze the dimensions of the hole where the tin drilling pipe is on the hull. Wave test parameters use irregular waves with significant wave heights Hs = 2.5 m, 2 m, and 1.25 m, with each of peak wave period Tp = 8.5 sec in the direction of the wave relative to the direction of the ship is 0 deg and 45 deg. The test results show that the movement of the ship when the wave condition Hs = 2.5 m shows that there is a collision between the walls of the hole box and the drilling pipe so that the initial design dimensions of the hole needs to be enlarged to 4.8 x 4.8 m by considering the ivory distance of the hull construction.

Keywords:- *Tin Mining Barge Vessel, Seakeeping Test, Hydrodynamics.*

I. INTRODUCTION

Bangka Belitung Islands in Indonesia is an area that has the largest natural resources in the world in the form of tin ore. To maximize production from marine mining, an effective strategy is to create and increase the number of tin mining vessels.

Tin Mining Vessel is a special ship that is being designed to be a ship with the latest generation of technology to be used in mining tin ore on the seabed and under the seabed. Tin Mining Vessel is an interesting research object because it is a fairly new ship technology in Indonesia, and there are various challenges that are being faced in planning, designing, and building tin-made vessels in the country starting from the early generation to the present so it is expected in the design the latest tin mining vessel design can improve ship reliability and ship safety [8]. Several Tin Mining Vessel design developments have been carried out to improve performance while operating as well as safety and safety factors for ships and crew.

Several types of tin mining vessels that have been operating or are still in the design concept for the development of previous technologies include: Bore Hole Mining Suction Production (KIP) such as Pusaka KIP Vessels and Suction Pontoon Production IX and X; Whereas the Tin Mining Vessel is currently in the stage of study are: the Semi Catamaran Tin Mining Vessel and The Tin Mining Barge Vessel as shown in Figure 1 below:

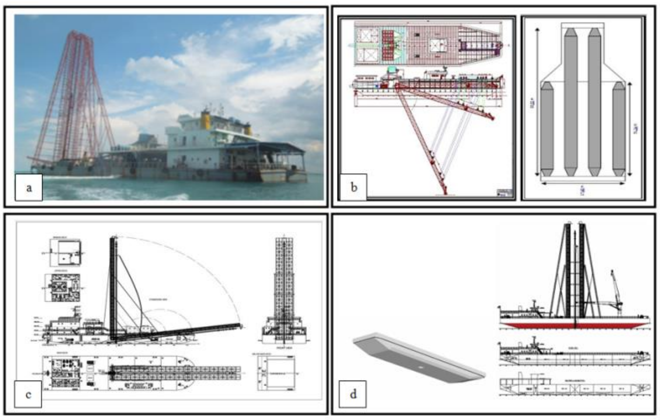

Fig 1

a. Pusaka Production Suction Vessel.
b. Pontoon Production Suction IX and X.
c. Bore Hole Mining Semi-Catamaran Vessel.
d. Tin Mining Vessel New Design.

The development of a new design of a Tin Mining Vessel is intended to correct weaknesses in the plan and design of the previous generation of tin vessels, where one of the previous generation Tin Mining Vessels, the Ponton Suction Production Ship (PIP) X, occur an incident of sinking in Prayun Waters, Kundur Barat District, Regency Karimun, Kepulauan Riau on Saturday 31 August 2019 caused by the loss of the balance of the ship while pulling another Tin Mining Vessel and worsened by the unfriendly weather and the high ocean currents as shown in Figure 2 below [5].

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Fig 2:- Tin Mining Vessel Sinking Incident
Source: website at [5]

In the design of the latest Tin Ship design, the concept used is to place a drill pole, suction pipe, and buffer construction as high as 60 meters above the deck of the ship placed at the midship-centerline of the ship. So that the drill and suction masts can be lowered into the sea from the deck of the ship, the midship-centerline of the ship is designed to be a square hole with an initial size of 3.6 x 3.6 meters from the main deck until the keel plate. The concern of the design of this Tin Minning Vessel is the over-motion response of the ship which can move the drill and suction mast in excess so that they can hit the pit. Surely this unexpected event will impact the value of a very large loss due to stopped operations and the cost of repairing damaged equipment. To anticipate these unwanted dangers, a seakeeping study using the hydrodynamic testing method is needed to obtain the operations response of Tin Minning Vessel New Design while operating at sea whether the movement of Tin Minning Vessel due to waves can cause a drill pole to hit the hole (size 3.6 x 3.6 m) or not? The Tin Minning Vessel New Design lines plan picture is shown in Figure 3, while the ship dimensions and model data are shown in Table 1 below:

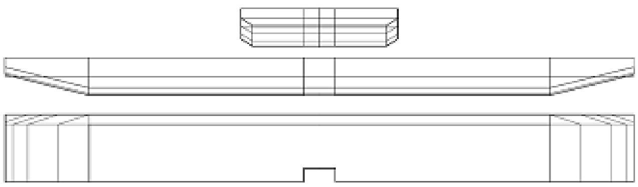
Fig 3:- Lines Plan of Tin Mining Vessel Model

Parameter	Model	Vessel
Scale	1:24	1:1
LOA (m)	3.00	72.00
LWL (m)	2.93	70.27
B (m)	0.75	18.00
H (m)	0.208	5.00
T (m)	0.104	2.50
Displacement (kg)	191.75	2,717,021
KG (m)	0.146	3.50
LCG (from AP) (m)	1.50	36.00

Table 1:- The Dimension of Tin Mining Vessel

In this study, the tin ship model was made using laminated fiber wood material, the ship model was made with a 15 x 15 cm box hole in the scale of the model located in the middle of the ship model as shown in Figure 4 below:


Fig 4:- Location of the hole where the dregding pipe is seen from the bottom of the model

Some previous studies that examined aspects of seakeeping on ships using the hydrodynamic testing method include: (Ali, 2017) in his research on Low Loaded Self Propelled Container Barge on the hydrodynamic aspects of the ship using the testing method in the hydrodynamics laboratory to obtain seakeeping performance in ship. (Mudhofar, 2015) in his research has reviewed the active skeg to reduce roll motion on fast vessels using the seakeeping test method in the hydrodynamics laboratory. The test results are then compared with the same tests on the same ship but without the use of active skegs. (Rudiyansyah, 2013) examined the seakeeping characteristics of Ro-Pax vessels in wave conditions at sea state 5 by using numerical simulation methods and testing at the Indonesian Hydrodynamics Laboratory and then comparing them using NORDFORSK 1987 standard criteria so that the seakeeping characteristics of ships are known Ro-Pax is not good because it does not meet the criteria. (Zaki, 2013) conducted preliminary research on embossed hulls and bow height corrections through seakeeping tests on the item type ship model. The results of the analysis of the response of the ship due to waves (RAO) showed that the direction of the wave from the dominant front occurred in the nodding motion and the direction of the wave from the dominant side occurred in the rotary motion. (Firdaus, 2017) has reviewed monohull and catamaran type vessels by testing seakeeping models in hydrodynamic laboratories conducted in seastate 4 conditions with waves of 45 deg, 90 deg, 135 deg and 180 deg; and the conclusion is that catamarans provide a relatively smaller motion response than monohull vessels.

II. METHOD

The method that used in this research is to use the testing method in the Hydrodynamics Laboratory to obtain the motion response of the ship. Seakeeping testing of a Tin Minning Vessel model is carried out at the Maneuvering and Ocean Basin (MOB) test facility with dimensions of 60.0 x 35.0 x 2.50 meters for each length, width, and depth.

The test pool located at the Indonesian Hydrodynamics Laboratory Indonesian Institute of Hydrodynamics Technology - BPPT Surabaya is equipped with wave generator equipment with the latest generation of technology to generate both regular and irregular waves. The flowchart of this research process is shown in Figure 5 below.

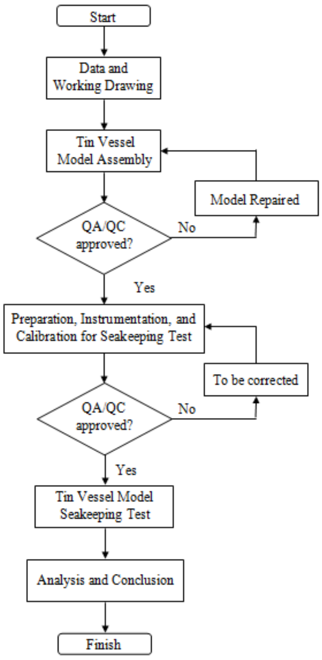

Fig 5:- Flowchart of Research

Seakeeping Test of Tin Minning Vessel is carried out under irregular wave conditions using the JONSWAP spectrum type with significant wave height variations Hs_1 = 2.5 m, Hs_2 = 2.0 m, and Hs_3 = 1.25 m; and the same peak wave period Tp = 8.5 sec in the direction of the ship relative to the direction of the arrival of the wave (heading) are: 180 degrees and 135 degrees, where the angle of the direction of the ship relative to the direction of the wave arrival is shown as in Figure 6 below.

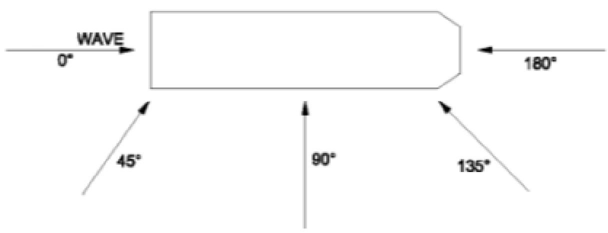

Fig 6:- Ship's Heading Angle to Waves

Seakeeping test procedures on The Tin Minning Vessel Model are based on ITTC standard No 7.5-02-07-02. The test is carried out by tethering four soft spring mooring string so that they are close to the free-floating model condition. As shown in Figure 7. The selection of spring stiffness on the mooring string is made far from the natural frequency of the waves used so that no resonance occurs. Each string is equipped with a spring with a stiffness factor k = 70.11 kN/m and each mooring string are given a pre-tension of 172.47 kN.

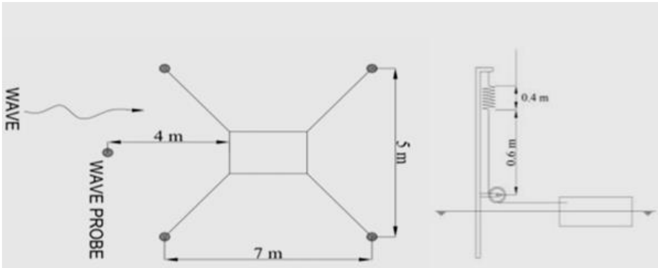

Fig 7:- Arrangement of mooring tin vessel model for seakeeping test

The motion data of the tin ship model were recorded using a wireless optical tracking system, thus illustrating the phenomenon of the ship's movement while operating. The target sensor mounted on the model will be detected by motion tracking equipment, then the model movement will be recorded using a wireless optical tracking system so that it can capture every movement of the model. All measurements made are defined in accordance with the rules of the right hand axis system as shown in Figure 8. The positive direction of the model's movement is as follows:

X : surge, forward direction
Y : sway, portside direction
Z : heave, upward direction

As for the rotational motion, the positive direction is shown in a clockwise direction for each of the following rotary axes:
ϕ : roll following x-axis
θ : pitch following y-axis
ψ : yaw following z-axis

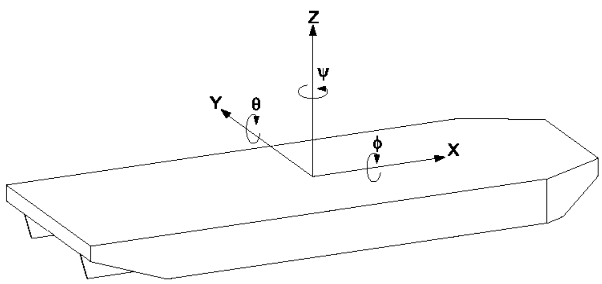

Fig 8:- Axis System in Testing Model

The Jonswap Spectrum Formula used for seakeeping testing waves is as follows [7]:

$$S_j(\omega) = \frac{\alpha g^2}{\omega^5} \exp\left[-\frac{5}{4}\left(\frac{\omega_p}{\omega}\right)^4\right]\gamma^r$$

$$r = \exp\left[-\frac{(\omega-\omega_p)^2}{2\sigma^2\omega_p^2}\right]$$

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Where:

$$\alpha = 0.076\left(\frac{U_{10}^2}{F\,g}\right)^{0.22}$$

$$\omega_p = 22\left(\frac{g^2}{U_{10}F}\right)^{1/3}$$

$$\gamma = 3.3$$

$$\sigma = \begin{cases} 0.07 & \omega \le \omega_p \\ 0.09 & \omega > \omega_p \end{cases}$$

In processing irregular signals for statistical analysis, the signal picture is displayed in Figure 9 below:

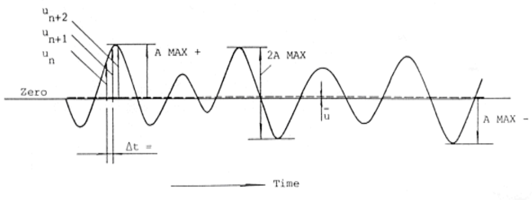

Fig 9:- Irregular Wave Signals

The results of irregular wave testing with 50Hz data frequency sampling are presented in the form of statistical analysis with several measured signal parameters. The definition of the signal parameters are as follows:

1. *Mean Value*:

$$u = \frac{1}{N}\sum_{n=1}^{n=N} u_n \tag{2}$$

Where is the number of data samples

2. *Standard Deviation*:

$$\sigma_n = \sqrt{\frac{1}{N}\sum_{n=1}^{n=N}(u_n - u)^2} \tag{3}$$

3. *Maximum Value*:

- A Max + is the highest peak value
- A Max - is the lowest valley value

4. *Maximum Double Amplitude*:

2AMAX is the highest maximum value of all signals from the valley to the crest of the wave

5. *Significant Peak Value*:

- A 1/3 + is the average value of the highest third of all wave crest signals
- A 1/3 - is the average value of the highest third of all valley wave signals

6. *Significant Double Amplitude*:

2A 1/3 is the average value of the highest third of the entire valley signal to the crest of the wave

7. *Number of Oscillations (NO)*:

NO is the amount of data oscillation during the test

III. RESULT AND DISCUSSION

In testing the Tin Mining Vessel Model seakeeping, the irregular waves generated from the wave generator at MOB laboratory are measured by the wave probe. The results of the irregular wave spectrum at the three variations in wave height show good validity values and are in accordance with the requirements of the Tin Mining Vessel Model seakeeping test procedure. Each wave spectrum generated by the wave generator is shown in Figure 10 to Figure 12 below:

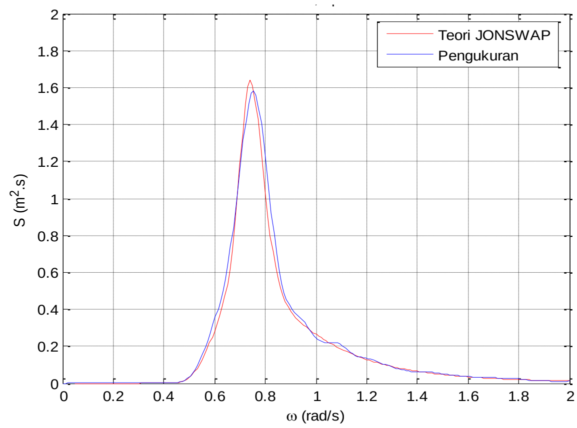

Fig 10:- Spectrum of Irregular Waves in MOB Hs = 2.5 m, Tp = 8.5 s

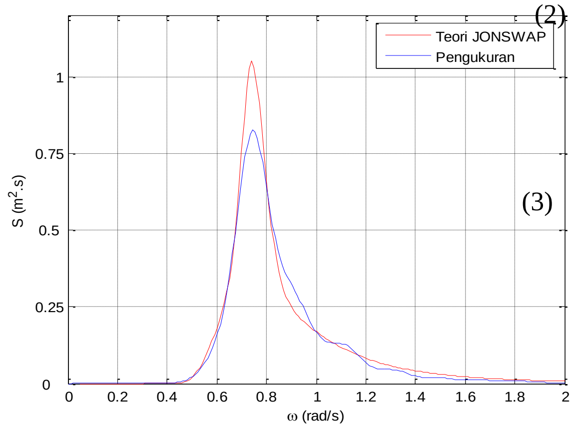

Fig 11:- Spectrum of Irregular Waves in MOB Hs = 2 m, Tp = 8.5 s

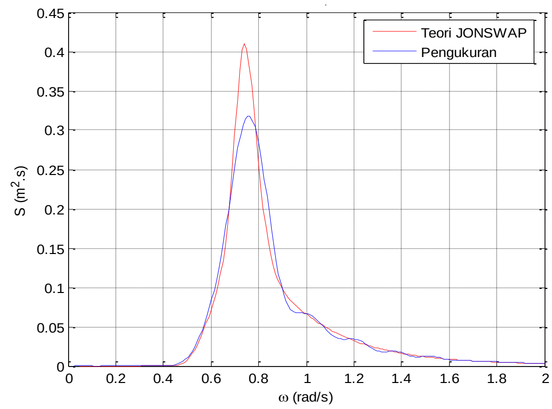

Fig 12:- Spectrum of Irregular Waves in MOB Hs = 1.25 m, Tp = 8.5 s

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To obtain the value of the natural period of roll motion (Tn) of the Tin Mining Vessel Model, the roll decay test is performed before the seakeeping test is performed. From the decay test activities, the natural period of roll motion (Tn) of the Tin Mining Vessel Model is obtained by Tn = 4,454 sec and the time trace chart of the Tin Mining Vessel Model decay test is presented in Figure 13 below.

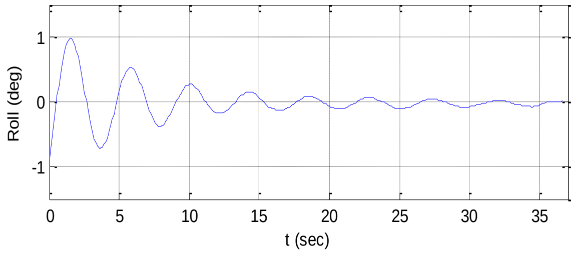

Fig 13:- Time Traces Roll Decay Test

The documentation of the seakeeping test implementation for the Tin Mining Vessel Model at an irregular wave height Hs = 2.5 m with the wave direction of 180 degrees to the ship model is shown in Figure 14, while the documentation of the seakeeping test implementation for the Tin Mining Vessel Model at an of irregular wave height Hs = 2.5 m with the wave direction of 135 degrees is shown in Figure 15.

Fig 14:- Seakeeping Test on Hs = 2.5 m, Tp = 8.5 s, Heading Angle = 180 deg

Fig 15:- Seakeeping Test on Hs = 2.5 m, Tp = 8.5 s, Heading Angle = 135 deg

Measurement of the seakeeping test of a tin mining vessel model will identify the movement at the coordinates of the drilling pipe in the center hole of the ship as shown in Figure 4. The measurement results of the test are displayed in the form of offset motion surge (X axis) and sway motion (Y axis).

The analysis results display surge-sway translational motion offset graphs from the results of testing the model in cartesian coordinates in various conditions of significant wave height and wave direction as shown in Figure 16 to Figure 21. This offset motion (blue color) is limited in the dimensions of the hole box dredging pipe / drilling pipe (red line color), wherein the initial planning of the hole box dimension is 3.6 x 3.6 m. While the location of the midpoint of the dredging pipe / drilling pipe on the graph is located at coordinates (0, 0).

From the test results shown in Figure 16 below, it can be seen that the wave variation Hs = 2.5 m and Tp = 8.5 sec on the wave direction 180 deg shows that the maximum offset graph has crossed the box, meaning that the drilling pipe has hit the hole wall at the coordinates (-1.905, -0.396).

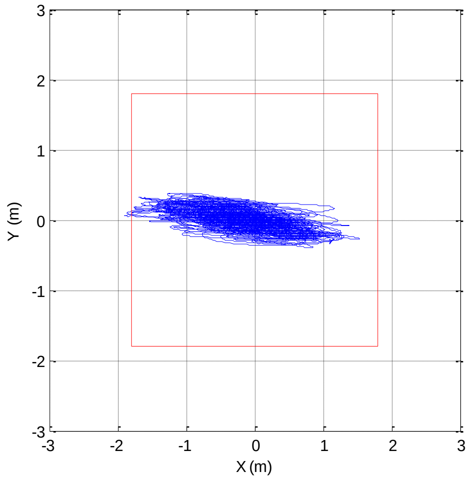

Fig 16:- Offset motion on Hs = 2.5 m, Tp = 8.5 sec, Heading angle = 180 deg

Whereas the wave variation Hs = 2.5 m and Tp = 8.5 sec on wave direction 135 deg as shown in Figure 17 below shows that the maximum offset is close to the drilling hole, if the offset graph illustrates the movement of the midpoint of the pipe then it is possible that the pipe has hit the wall of the dredging / drilling hole due to the size of the diameter of the pipe used, with a maximum coordinate offset is (-1,546, -1,432).

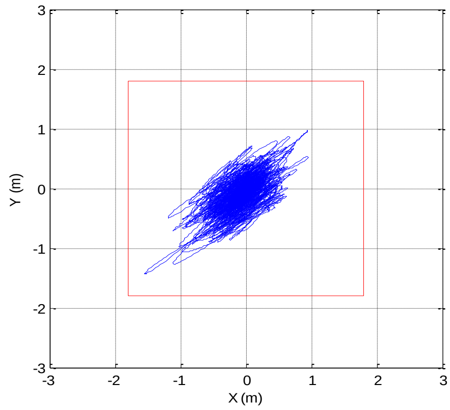

Fig 17:- Offset motion on Hs = 2.5 m, Tp = 8.5 sec, Heading angle = 135 deg

The results of the measurement of motion offset at the variation of wave height Hs = 2.0 m and Hs = 1.25 m at Tp = 8.5 sec as shown in Figure 18 up to Figure 21 shows a decrease in the value of the maximum offset compared with the variation of wave height Hs = 2.5 m. At a wave direction of 180 deg with a variation in wave height Hs = 2.0 m, the maximum offset value obtained with coordinates (-1.361, -0.312) is shown in Figure 18 below, whereas in the wave height variation Hs = 1.25m the maximum offset coordinates (-0.642) , -0.100) shown in Figure 19 below.

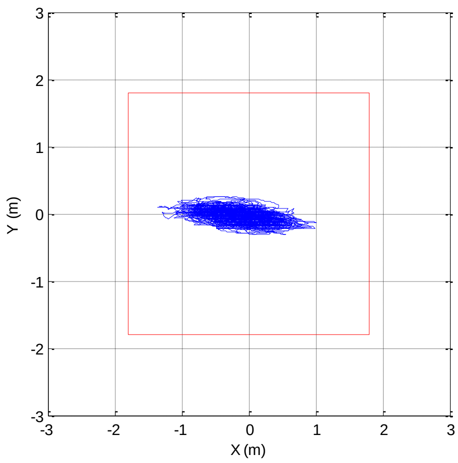

Fig 18:- Offset motion on Hs = 2.0 m, Tp = 8.5 sec, Heading angle = 180 deg

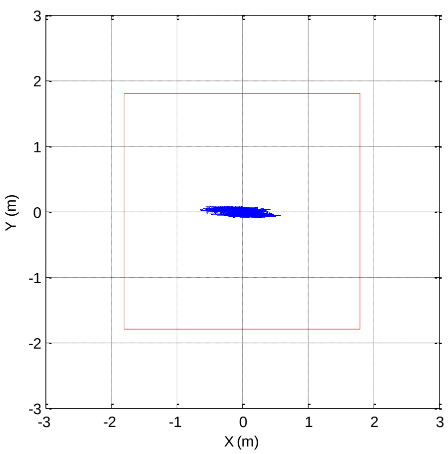

Fig 19:- Offset motion on Hs = 1.25 m, Tp = 8.5 sec, Heading angle = 180 deg

For the wave direction 135 deg with wave height variations Hs = 2.0 m, the maximum offset coordinate value (-1,041, -0,945) is shown in Figure 20 below, while in Hs = 1.25 m the maximum offset coordinates (-0.551, -0.490) are obtained shown in Figure 21 below.

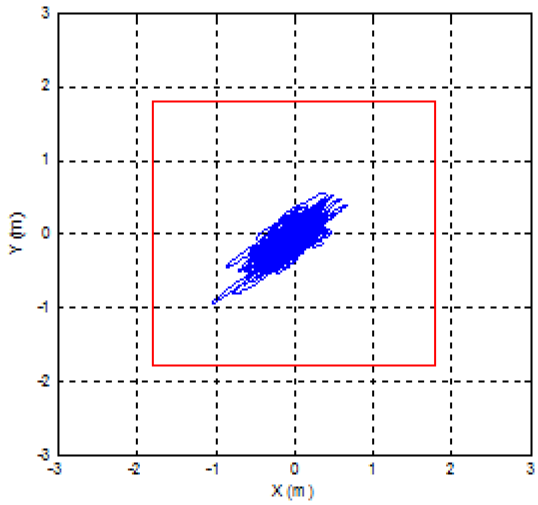

Fig 20:- Offset motion on Hs = 2.0 m, Tp = 8.5 sec, Heading angle = 135 deg

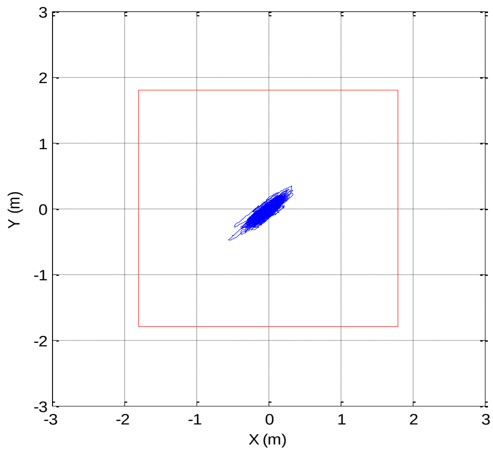

Fig 21:- Offset motion on Hs = 1.25 m, Tp = 8.5 sec, Heading angle = 135 deg

IV. CONCLUSION

- There is a collision between the hole wall of the drilling pipe and the drilling pipe at the wave condition Hs = 2.5 m which is indicated from the offset motion of the ship, so the initial design dimension of the hole where the drilling pipe must be enlarged.
- The dimensions of the deck hole where the drilling pipe is enlarged to 4.8 x 4.8 m taking into account the ivory distance of hull construction within 0.6 m.

V. SUGGESTIONS

The next researcher needs to conduct an environmental impact assessment study on the tin mining vessel development plan so that a tin mining vessel will be obtained that meets the technological feasibility and also aspects of the environmental impact.

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