American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-8, Issue-11, pp-118-129
www.ajer.org
Research Paper Open Access

Matlab Aided Modelling of Linear Motion of an Offshore Spar Truss Platform

Chuku Promise, Olusegun Samuel Dare and Ezebuchi Akandu
Marine Engineering Department, Rivers State University, Port Harcourt, Rivers State Nigeria.
Corresponding Author: Chuku Promise

***ABSTRACT** : This research work is primarily aimed at developing a Matlab source code since the cost of acquiring or purchasing Naval Architecture and Offshore structure software today, runs into millions of Naira, Owing to this facts and many more, this research work; Linear wave effect analysis of an offshore spar truss platform using Matlab programming language was carried out to meet the need of truss spar surge and heave force which resulted in the spar truss surge and heave responses analysis design. The source code are use in calculating the wave force on entire spar truss, this wave force is either heave force or surge force, which lead to calculating the heave and surge response amplitude operator. These response amplitude operator determine the response or behavior of the spar truss. The source code when ran give a wave like pattern and the maximum surge and heave force occur at were the spar truss natural frequency is also maximum, also the maximum response amplitude operator for both case are maximum at maximum surge and heave force respectively. The work show very good agreement with other research work, these was done when the truss spar surge and heave response amplitude operator was validated with that obtained from published journal kurian, et.al., and was found that the errors between both results are less than 1% as the published work result has 0.02 and 0.0004 for surge and heave response amplitude operator at 0.0125 Hz respectively, while the Matlab result has 0.0215 and 0.00016 for surge and heave response amplitude operator at 0.0125 Hz respectively.*
As time goes interested researchers and students in this field can further developed this source code until it gets to a stage where it will be commercially approved. To achieve this objective, specific areas of interest were reviewed; Computer and software utilization in Naval Architecture and Offshore Structure with respect to wave load (wave force) and responses of the spar truss as it apply to both academics and industry, general computer programming, programming language and the reason why Matlab language is preferred, however, some recommendations were made, irregular wave approach should be applied to get the actual wave load on the offshore spar truss structure despite its difficulties because the irregular wave show the exact wave force on the structure when compared with the regular wave force and that this software should be developed further to incorporate plate truss analysis.

***KEY WORDS**: Offshore, Truss spar, Inertia force, Drag force, Spectrum, Hard tank, Soft tank, Plate, Heave, Surge, Response amplitude operator, Truss spar responses.*

Date of Submission: 07-11-2019 Date of acceptance: 27-11-2019

I. INTRODUCTION

The continuous reduction of onshore and shallow water hydrocarbon reserves have prompted the oil and gas industry to seek for solution in deep and ultra-deep water exploration and drilling.

As the water depth increases, fixed oil platforms become expensive and uneconomical. The emphasis then shifts to compliant and floating structures for deep and ultra-deep water application of exploration, drilling, production, processing, storage and offloading of crude products.

As a result of these challenges for the need for deeper offshore operations, technological innovations have been able to develop series of compliant and offshore floating structures. There are basically various kinds of offshore structures which preferential use is based on depth, environment and drilling/production/offloading operations though sometimes its a difficult decision.

Fixed Oil Platforms are class as follows

1. Jacket Platform
2. Gravity Platform

The Compliant Platforms are class as follows
1. Guyed Tower
2. Articulated Tower
3. Tension Leg Platform

The Floating Platformare class as follows
1 Semisubmersible
2 Floating Production Unit (FPU)
3 Floating Storage and Offloading (FSO)
4 Floating Production, Storage and Offloading (FPSO)
5 Drill Ship
6 Spar

The spar can be sub class as follows
1. Classic Spar
2. Truss Spar
3. Cell Spar

The interest of this thesis/research work is on offshore Spar Platform, specifically the linear motion analysis of Truss Spar being surrounded by steady state of the sea wave.

A spar is a type of cylindrical floating oil platform typically used in very deep waters, and is named for logs used as buoys in shipping that are moored in place vertically. Spar production platforms have been developed as an alternative to conventional platforms. The concept of the Spar Platform started in early sixties when the Floating Instrument Platform (FLIP) was built for oceanographic research [1].

Truss Spar Platform

Presently, there are three basic types of Spars Platform Floating Structures; Classic Spar, Truss Spar and Cell Spar [2]. They differ in designs and configurations. The Classic Spars are the earliest of the Spars Platform technology and which other spars structures were developed.

The deep draft design of Classic spars makes them less affected by wind, wave loads and currents and allows for both dry tree and subsea production.Basically the motion response of the Spar Platforms (i.e. all three Spars) is low compared to other floating structures. Classic Spars are most prevalent in the US Gulf of Mexico; however, there are also spars located offshore Malaysia and Norway.TheClassic Spar platform consists of a large-diameter, single vertical cylinder supporting a deck. The cylinder is weighted at the bottom by a chamber filled with a material that is denser than water to lower the center of gravity of the platform and provide stability because the center of buoyancy is higher than the center of gravity thereby having the capability to support large topside loads. Additionally, the Classic Spar hull is encircled by helical strakes to mitigate the effects of vortex-induced motion. All Spars are permanently anchored to the seabed by way of a spread mooring system composed of either a chain-wire-chain or chain-polyester-chain configuration ("Spar (platform)",n.d., para.1-2).Rigid risers which is less expensive than flexible risers can be used in Spar Platforms because the motion responses of the Spars Platforms are always very low. Also the dynamic motion at the mooring fairleads is very low therefore permitting the use of an array of taut or/and catenary mooring lines for station keeping of the Spars platform which the installation, operation and relocation is easy.One advantage of the Classic Spar over the Truss Spar is its oil storage ability of its cylindrical structure which can also be offloaded directly [1]. The cylindrical hull of the Spars has a moonpool which houses the riser systems throughout the depth of the Spar [3].

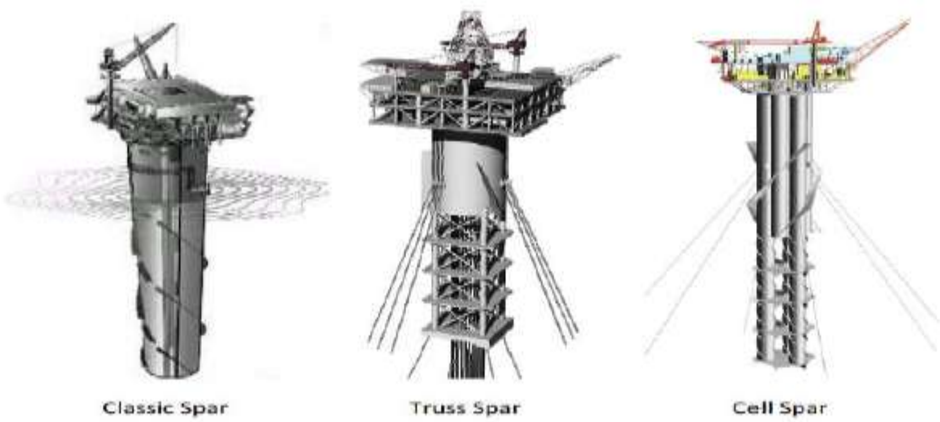


Figure 1: Classification of the Truss Spar Platform System

The classic spars was found to have insignificant low damping effect and relatively low heave natural period. A combination of these two characteristics and swell can lead to the spar having a linear excited heave resonant motion. Also if the ambient deep current becomes a major concern, then the drag force on the long cylindrical hall can be of a major and disturbing significance. In order to reduce the effect of the drag force, an alternative design concept having a midsection truss structure called truss spar was developed which was considered more cost effective, thereby receiving a considerable attention [1].

The concept of the Truss Spar Platform actually started in 1994 by Deep Offshore Technology headed by its pioneer and founder Ed Horton. The Spar Platform design development is credited to Ed Horton who also invented the TLP in the 1960s. He integrated the combination of dry tree and oil storage in Spar Platforms after considering the heave response motion of the Spar platform [4].

The truss spar consists of four major components; the topsides, hull, mooring and risers. The topsides is the top platform for offshore operations and crew members. The hull comprises of three main parts; a relatively shallow-draft cylindrical hard tank, a midsection truss like framework structure and having quite a number of heave plates and a soft tank at the bottom keel of the hull [5].

Wave Force and Motion Prediction

Wave force was found to be the most significant force that affect the dynamic responses of this structure, contribute about 70% of the total environmental force. Hence the computations of the wave force where highlighted in the design of the spar truss structures. There are three theories used to calculate the wave force for the offshore structure that is the Morison equation, Froude Krylov theory and Diffraction theory. Morison equation take the wave forces as a product of linear summation of both inertia and drag force. This method is applicable for small structures compared to the wave length. Also, Froude Krylov theory is applicable to small structures. In Froude Krylov theory, the wave force is predominant by the inertia force rather than the drag force which is relatively small. Diffraction theory is applicable for structures that are large compared to water wave length [6]. However, in many studies Morison equation was used to compute the wave force for large structures. The reason being is because of the ease use to the Morison equation compared to the diffraction theory that is more complicated. This is justifiable because for the waves of large frequency, the ratio of the size to the wave length will still fall in the Morison equation regime should the behavior of spar in deep water by time domain method. They were using Morison equation to compute the wave force by considering the second order effects and wave kinematics. In the study they as well investigated the effects of neglecting the hydrodynamic forceon the mooring line by modeling it as nonlinear spring. The behavior of the spar subjected to regular, bichromatic and random was studied. investigated the linear hydrodynamic analysis of truss spar by frequency domain. They estimated the wave force on truss section by modified Morison equation and Diffraction theory on hard tank and determined the dynamic responses due to random waves [7], performed an experimental study to investigate the accuracy of Morison equation for wave force acting on cylinders. The forces computed by using Morison equation were compared with the experimentally measured results.

Froude Krylov Theory

The Froude Krylov theory was the first available linear theory to predict wave forces and the excited motions of a slender ship, this was developed by Froude in 1861, Froude in 1896 and Krylov in 1896. Their hypothesis assumed that the existence of the body does not change the incident wave field if the beam and draft of the body are both small compared with the wave length and this resulted in the so called Froude-Krylov force due to the incident wave only. Today this simplified approach receives little research attention except its application by practical naval architect and offshore engineers for simple structures. It was [6] that applied and then proved a similar idea to predict all the three horizontal modes of motion of either a long but full shaped body or a shallow draft structure, other than the more restructure slender ship forms.

A competitor to the STF approach is the unified slender body theory [8] which is exclusive of the high frequency limitation and devoid of the head sea singularity inherent in the diffraction problem of a strip theory [9]. It seems that the unified slender body theory gives more accurate force estimate but no better motion predictions. [10] extended this approach to shallow water and found little improvement over the strip method. Another improvement was also done to this slender body theory by [11] to a twin-hull body.

Spectral Analysis and Response

A frequency domain cumulated spectral analysis method was developed by [12] to estimate the higher order statistic of the linear oscillator responses driven by Morison wave force. Besides the wave force theories, the wave propagation direction is also another issue that affects the dynamic responses of the truss spar. According to the directions of the propagations, waves are categorized as long crested and short crested. Long crested waves are defined as waves propagated from uni-direction, while the short crested waves are defined as the linear summation ofvarious long crested waves propagated from different directions. The short crested waves could be propagated from two directions i.e., the bi-directional waves or from more than two directions i.e., the multi-directional waves. For the realistic wind-generated sea state, the short crested waves would provide a better accuracy compared to the long crested waves. Furthermore, short crested wave has different properties compared to long crested wave [13] and the appearances of these waves are three dimensional, complex and short crested [6]. Even though many studies were published focusing on long crested waves, the occurrence of such waves are rare in the real sea. Research focusing on short crested waves has been performed since 1970s. However, the scopes are mainly focused on directional wave force, directional wave spectrum, wave kinematics and vertical circular cylinder. [14] presented a solution for the diffraction of short crested wave incident on a circular cylinder. It was shown that the wave loading obtained by using plane incident waves would be overestimated when the incident waves are short crested. A solution in closed form for the velocity of the nonlinear short crested waves being diffracted by vertical cylinder was presented by [15]. Zhu's theory was extended by [13] to include the effect of a uniform current for different incident angles. They derived an analytical solution for the diffraction of short crested incident wave along positive x-axis direction on a large circular cylinder with current. Discussed the safety of using the reduced 3D loads in practical offshore design. The study proved that wave loads on cylinders in 3D wave are significantly smaller than that for 2D waves with identical spectra or even identical wave elevation time series. The wave induced forces due to short crested waves on vertical cylinders with circular, elliptical and square cross sections were discussed by [16], extended the linear diffraction theory used for large structures in regular long crested waves to short crested multi-directional random waves. The extended theory was applied to a large surface-piercing cylinder numerically and the results were compared with the experimental measured results.

II. MATERIALS AND METHODS

Truss Spar Equation

The below are design equation required to compute the surge force, heave force, surge response amplitude operator and heave response amplitude operator of the spar truss.

Surge and Heave Force of the Truss Spar

The velocity potential $\emptyset$

$$\emptyset = \frac{g\times H}{2\times\omega}\times\frac{\cosh k(z+d)}{\cosh(k\times d)}\times \sin(kx-\omega t) \quad (1)$$

$$\frac{\partial\emptyset}{\partial x} = u = \frac{\pi\times H}{T}\times\frac{\cosh k(z+d)}{\cosh(k\times d)}\times \cos(kx-\omega t) \quad (2)$$

$$\frac{\partial\emptyset}{\partial z} = v = \frac{\pi\times H}{T}\times\frac{\sinh k(z+d)}{\cosh(k\times d)}\times \sin(kx-\omega t) \quad (3)$$

Also the acceleration is gotten by further differentiated of the velocities equations with respect to time

$$\frac{\partial u}{\partial t} = a_x = \frac{2\times\pi^2\times H}{T^2}\times\frac{\cosh k(z+d)}{\cosh(k\times d)}\times \sin(kx-\omega t) \quad (4)$$

$$\frac{\partial v}{\partial t} = a_z = -\frac{2\times\pi^2\times H}{T^2}\times\frac{\sinh k(z+d)}{\cosh(k\times d)}\times \cos(kx-\omega t) \quad (5)$$

$$C_x = \cos(\beta_x) \quad (6)$$

$$C_y = \cos(\beta_y) \quad (7)$$

$$C_z = \cos(\beta_z) \quad (8)$$

C_x and C_z are the x and z component of the unit vector C acting along the truss spar directly up or down

So, the velocity component is x-direction

$$U = u - C_x\times(C_x\times u - C_y\times v) \quad (9)$$

The velocity component is z-direction

$$V = -C_z\times(C_z\times u - C_y\times v) \quad (10)$$

The surge force on the spar truss hull [17].

$$F_{surge}^{h} = \int_{-d1}^{0}\left[C_m\times\rho\times\frac{\pi}{4}\times D_h^2\times a_x + \frac{1}{2}\times C_d\times\rho\times D_h\times|U|.U\right]dz \quad (11)$$

Where

Cm is the inertia coefficient

Cd is the drag coefficient

$\rho$is the water density

$D_h$is the spar truss hull diameter

Also

The surge force on the spar truss soft tank [17]

$$F_{surge}^{t} = \int_{-d3}^{-d2}\left[C_m\times\rho\times\frac{\pi}{4}\times D_t^2\times a_x + \frac{1}{2}\times C_d\times\rho\times D_t\times|U|.U\right]dz \quad (12)$$

Where

D_t is the soft tank diameter
The surge force on the truss spar plate

$$F_{surge}^{p} = \int_{-d3}^{-d2} \left[C_m \times \rho \times \frac{\pi}{4} \times D_p^2 \times a_x + \frac{1}{2} \times C_d \times \rho \times D_p \times |U|.U\right] dz \quad (13)$$

Also
Heave force can be computed by carrying out a double integration of the dynamic pressure on the bottom surface of the spar hull which is derived from the Bernoulli equation and the potential velocity

$$F^h{}_{heave\,1} = \frac{\rho\pi gH\, D_h{}^2}{8} \times \frac{\cos hk(d-d1)}{\cos h(kd)} \times \cos(kx-\omega t) (14)$$

$$F^h{}_{heave\,2} = -\frac{\rho\pi gH\, D_h{}^2}{8} \times \frac{\cos hk(d-d_2)}{\cos h(kd)} \times \cos(kx-\omega t) \quad (15)$$

$$F^h{}_{heave\,3} = -\frac{\rho\pi gH\, D_h{}^2}{8} \times \frac{\cos hk(d-d_3)}{\cos h(kd)} \times \cos(kx-\omega t) \quad (16)$$

$$F^h{}_{heave} = F^h{}_{heave\,1} + F^h{}_{heave\,2} + F^h{}_{heave\,3} \quad (17)$$

Also heave force for the spar soft tank

$$F^t{}_{heave1} = -\frac{\rho\pi gH\, D_t{}^2}{8} \times \frac{\cos hk(d-d_2)}{\cos h(kd)} \times \cos(kx-\omega t) (18)$$

$$F^t{}_{heave\,2} = -\frac{\rho\pi gH\, D_t{}^2}{8} \times \frac{\cos hk(d-d_3)}{\cos h(kd)} \times \cos(kx-\omega t) \quad (19)$$

Total heave force on the truss spar soft tank

$$F^t{}_{heave} = F^t{}_{heave\,1} + F^t{}_{heave\,2} \quad (20)$$

Quasi-static force for surge

The quasi-static surge force is the dynamic load that causes the truss spar to vibrate without regards to time and inertial force.

$$F_{qsurge} = \frac{F_{FKsurge}}{\varsigma_a \times C_{surge}} \quad (21)$$

Stiffness Constant

$$C_{surge} = \frac{\rho g\pi\, D^2}{4} \quad (22)$$

Frequency ratio R

The frequency ratio is the ratio of the wave frequencies to that of natural frequency

$$R_{surge} = \frac{W}{W_n} \quad (23)$$

Where W_n is the wave natural frequency

$$W_n = \frac{2\lambda}{T_{n\ surge}} \quad (24)$$

T_{nsurge}; is the natural period

Where $W_n = \frac{2\lambda}{T_{nsurge}} = \sqrt{\frac{C_{surge}}{m + A_{33}}} = \sqrt{\frac{\rho gBL}{m + A_{33}}}$ (25)

Where m is the mass of the spar truss

$$m = \rho BL \times D \quad (26)$$

Magnification factor Q

The magnification factor is the amplitude of forced vibration motion with respect to the magnification of the static deflection as a function of the frequency ratio.

$$Q_{surge} = \frac{1}{\sqrt{\left(1 - R_{surge}^2\right)^2 + \left(2d_{surge} \times R_{surge}\right)^2}} \quad (27)$$

Where d_{surge} is the damping ratio (mainly 8% - 9%)

3.3.5 Surge response amplitude operator (RAO)

The surge response amplitude operator define the way the Truss spar responded or reacted to wave surge force imparted on the truss spar.

$$RAO_{surge} = Q_{surge} \times F_{qsurge} \quad (28)$$

Wave spectrum S(w)

The wave spectrum gives the distribution of wave energy among different wave frequencies.

$$SW = \frac{124}{T_Z 4} H_S^2 W^{-5} \exp\left[-\frac{496}{T_Z^4} W^{-4}\right] \quad (29)$$

Surge response of the truss spar

The surge responses of the truss spar is the way the truss spar behave under wave surge force and spectral density as time or frequency progresses.

$$S_{Rsurge} = SW \times RAO_{surge}{}^2 \quad (30)$$

III. RESULT AND DISCUSSIONS

Table 1: Parameters as Input to the Matlab Source Code

Parameters	Values
Wave Period	10 sec
Wave Height	6 m
Water Depth	25 m
Significant Wave Height	8 m
Zero up crossing period	10 sec
Length of the spar truss hull	15 m
Breadth of the spar truss hull	7.5 m
Depth of the spar truss hull	3.4 m
Diameter of the spar hull	2.0 m
Diameter of the spar soft tank	1.5 m
Diameter of the spar plate	1.2 m
Sea water density	1025 kg/m^3
Kinematic Viscosity	0.00000117 m^2/s
Damping ratio	8%

Results

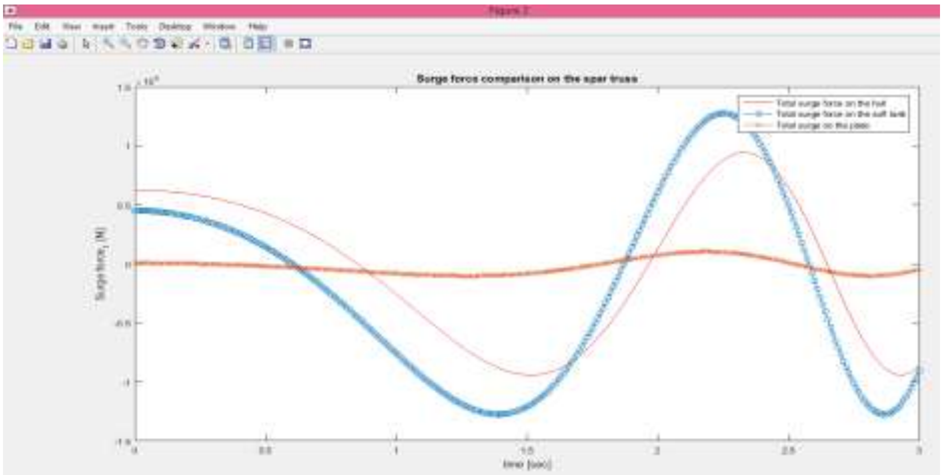


Figure 2: Comparison of the Total Surge force on the Spar Hull, Spar Soft Tank and Spar Plate

The above Figure 2 show the comparison of the total surge forces on the spar hull and spar soft tank at vary time, with red color representing the total surge force on the spar hull while the blue color represent the total surge force on the spar soft tank, it will be observed that the surge force follow a wave like pattern by moving from positive through negative and back to positive, it can also be observe that as time progresses the crest of the surge force decrease in both case under comparison, this is true because as time increases the effect of the wave load on an offshore structure decreases for a regular wave.

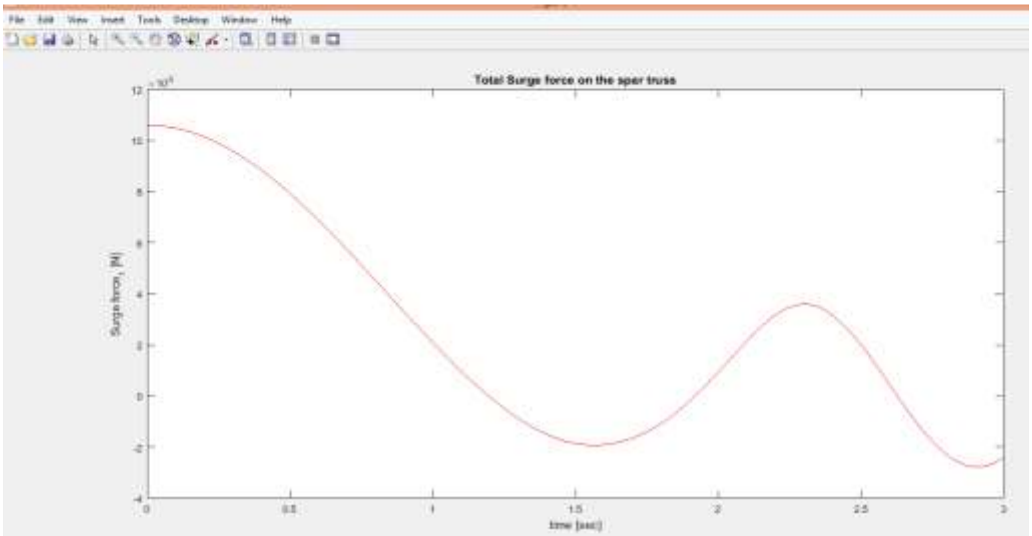


Figure 3: Total Surge Force on the Spar Truss against Time

Figure 3 show the total surge force on the entire spar truss against time and this done by summing the two comparison graph in figure 2 to a single graph as shown, the total surge force on a spar truss start from the maximum positive at time zero and decrease to the negative at time 1.5 sec, then the total surge force begin to rise again to a maximum positive at time of 2.3 sec. It was observed that as time progresses the successive crest of surge force on the spar truss graph decreases and the total surge force graph follow a typical wave graph with decrease crest because as time increases the effect of the wave load on an offshore structure decreases for a regular wave.

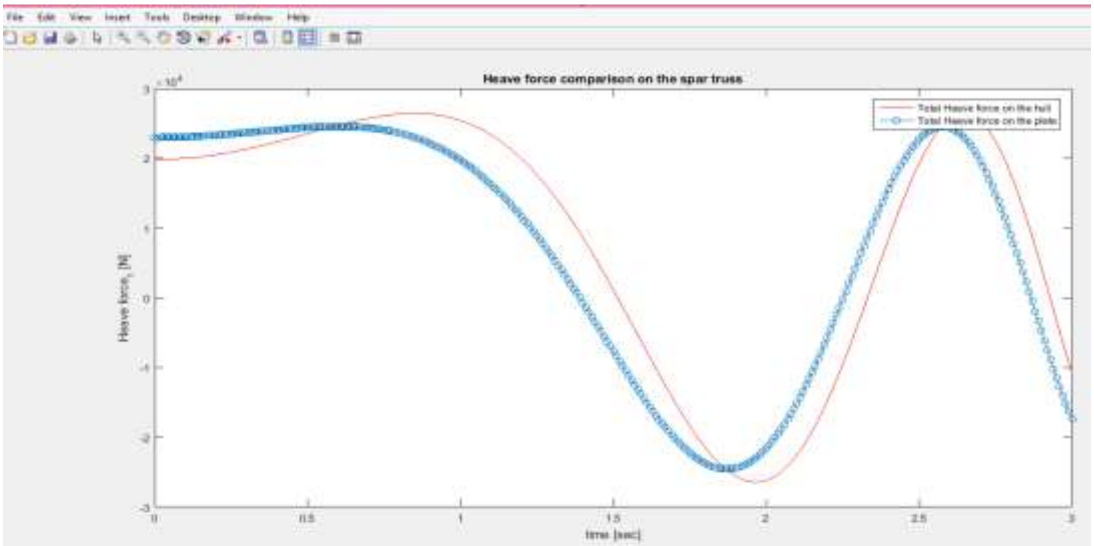


Figure 4: Heave Force Comparison on the Spar Hull and Spar Soft Tank

Figure 4 shown the heave force comparison on the spar hull, spar plate and spar soft tank against time with the red without circle representing the heave force on the spar hull while the blue line represent the heave force on the spar plate and the red line with circle represent the heave force on the spar soft tank, it was observed that the surge force on the spar plate and spar soft tank follow a similar pattern by starting at the maximum and continue reduce as time progress until it get about 1.25 sec were the heave force is at negative maximum value while the heave force on the spar hull tend to increases positively as time progresses until it get to about 1.0 sec of which the surge force on the spar hull is positive maximum, this changes in heave force on the spar hull when compared to the rest was brought about by the inclusive of the diffraction force to the incident force on the spar hull.

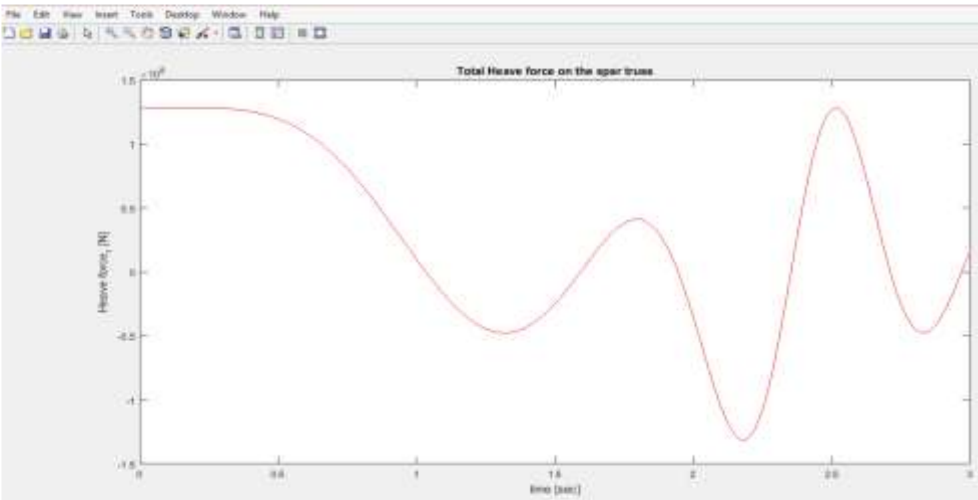


Figure 5: Total Heave Force on the Spar Truss against Time

Figure 5 show the total heave force on the spar truss against time, which was done by adding the heave force on the spar hull, the heave force on the spar plate and the heave on the spar soft tank, simply put the total heave force is the sum of the individual force shown in figure 4 to form one heave force on the spar truss, it can be observed from figure 5 that the graph is similar to that of the heave force on the spar hull this is so because the spar hull will experience the highest heave force when compared to other and it can be observed that the total heave force on the spar truss is smaller when compared to the heave force on the spar hull, this is so because the soft tank and plate are made to help reduce the effect of wave impart on the spar truss by countering the wave effect.

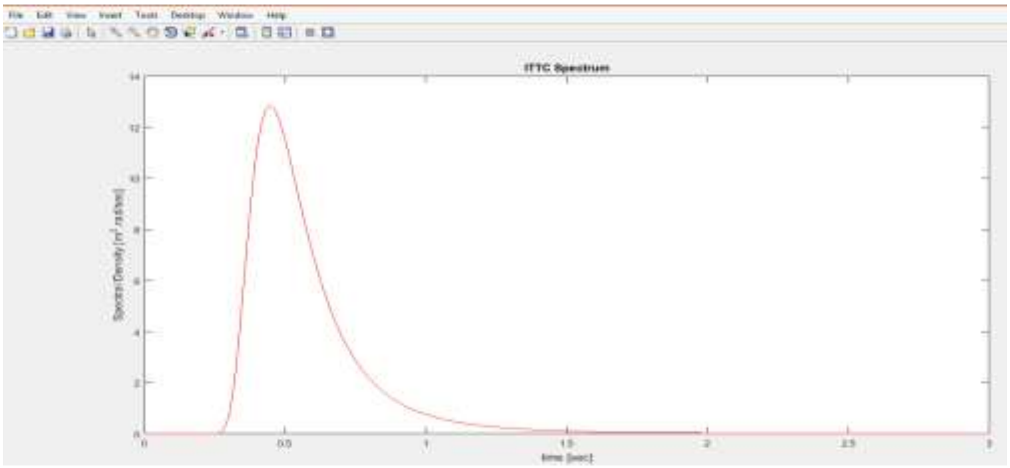


Figure 6: ITTC Spectral Density against Time

Figure 6 show the ITTC spectral density against time as it shown that as time progresses from zero to about 0.25 sec the spectral density remain at zero and a sharp progression was observed as the spectral density rise from zero to maximum as time progresses from 0.25 $sec\ to$ 0.5 sec and as time progresses from 0.5 $sec\ to$ 1.5 sec the spectral density also decreases from maximum to zero, with the progressing of time from 1.5 $sec\ to$ 3.0 sec the spectral density remain at zero. The above is the spectrum that define the wave profile of the region under investigation, though must text based there graph on ITTC spectrum on wave frequency but the difference is insignificance and time is just an inverse of wave frequency.

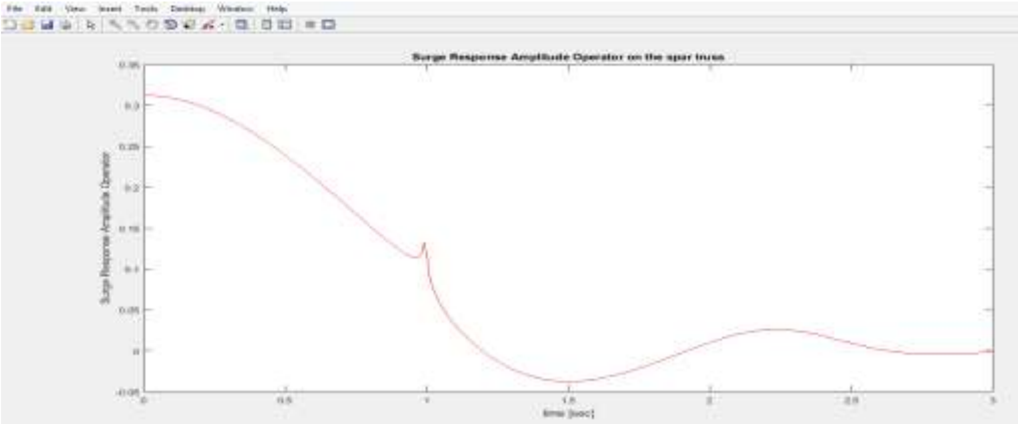


Figure 7: Surge Response Amplitude Operator against Time

Figure 7 is the surge response amplitude operator against time this define the way the spar truss will behave under surge force, it is observe that the surge response amplitude operator start at the maximum this is so because we also have the maximum surge force on the spar truss at the start as shown in figure 3 before a gradual decline as time progresses and the surge amplitude operator become minimum at time 1.5 sec this is also the time at which the surge force on the spar truss becomes minimum as shown in figure 3, it is also observe that the surge response amplitude operator tend to diminishes in crest as time progresses which means that for a larger time the surge response amplitude operator line may become constant.

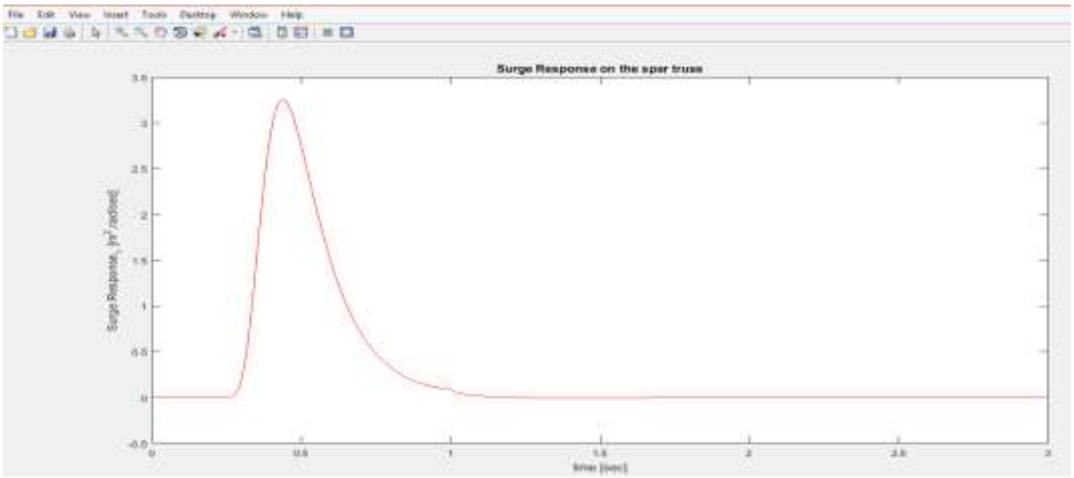


Figure 8: Surge Response of the Spar Truss against Time

Figure 8 shown the surge response of the spar truss against time, this graph show the behavior of the spar truss under surge wave force and it basically depend on the surge force, the surge response amplitude operator and the wave spectrum under consideration, it is observe that the surge response of the spar truss is similar to that of the ITTC spectrum graph as shown in figure 6 this is so because the spar truss must react exactly to the action that is acted upon it, the surge response remain at zero as time progresses from $0\ sec\ to\ 0.25\ sec$, then the surge response on the spar truss increases rapidly to maximum as time progresses from $0.25\ sec\ to\ 0.5\ sec$ and as time progresses from $0.5\ sec\ to\ 1.0\ sec$ the surge responses on the spar truss decreases rapidly from maximum to zero and remain so as time increases from $1.0\ sec\ to\ 3.0\ sec$, this so because once the spar has reacted to the surge force effect it remain steady again for a regular wave.

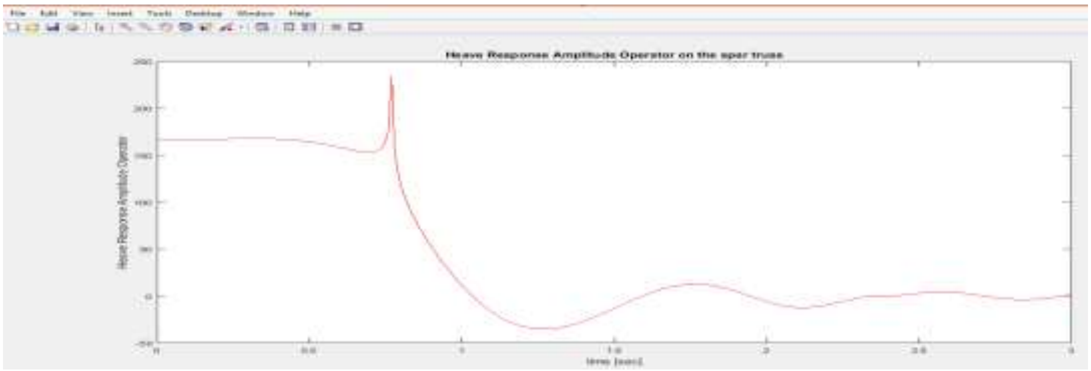


Figure 9: Heave Response Amplitude Operator against Time

Figure 9 is the heave response amplitude operator against time this define the way the spar truss will behave under heave force, it is observe that the surge response amplitude operator start and maximum at 0.75 sec this is so because we also have the maximum heave force on the spar truss at the start through to the point at which time is 0.75 sec as shown in figure 5 before a gradual decline as time progresses and the heave amplitude operator become minimum at time 1.25 sec this is also the time at which the heave force on the spar truss becomes minimum as shown in figure 5, it is also observe that the heave response amplitude operator tend to diminishes in crest as time progresses which means that for a larger time the surge response amplitude operator line may become constant.

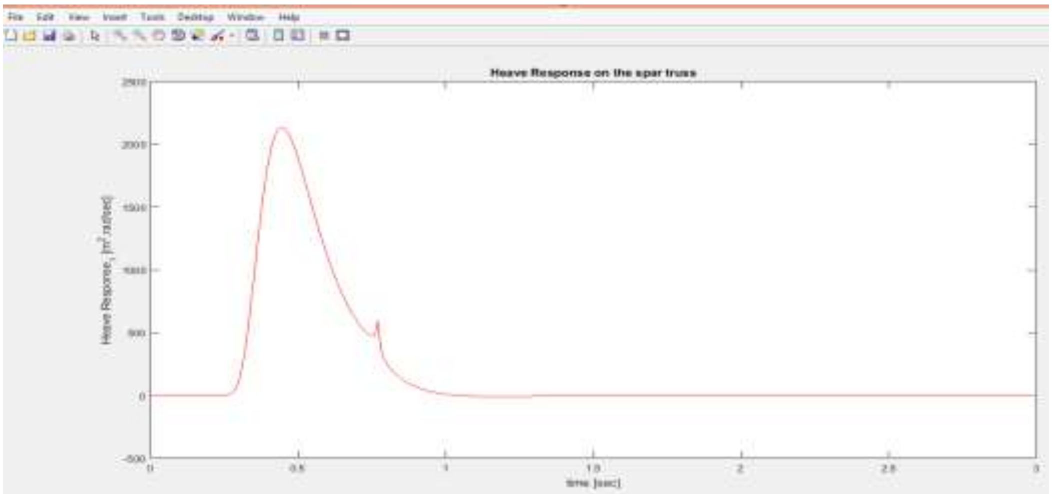


Figure 10: Heave Response of the Spar Truss against Time

Figure 10 shown the heave response of the spar truss against time, this graph show the behavior of the spar truss under heave wave force and it basically depend on the heave force, the heave response amplitude operator and the wave spectrum under consideration, it is observe that the heave response of the spar truss is similar to that of the ITTC spectrum graph as shown in figure 6 this is so because the spar truss must react exactly to the action that is acted upon it, the heave response remain at zero as time progresses from $0\ sec\ to\ 0.25\ sec$, then the heave response on the spar truss increases rapidly to maximum as time progresses from 0.25 sec to 0.5 sec and as time progresses from 0.5 sec to 1.0 sec the heave responses on the spar truss decreases rapidly from maximum to zero and remain so as time increases from 1.0 sec to 3.0 sec, this so because once the spar has reacted to the heave force effect it remain steady again for a regular wave.

Results Validations

The results from the Matlab source code will be validated using same input as use by [17] to run the Matlab source code and the results been compared to ascertain how close the source code is to other code developed for truss spar structure. This was done by inputting the values of truss spar properties and wave properties for the model case into the Matlab source code developed and the results are compared with the results of [17].

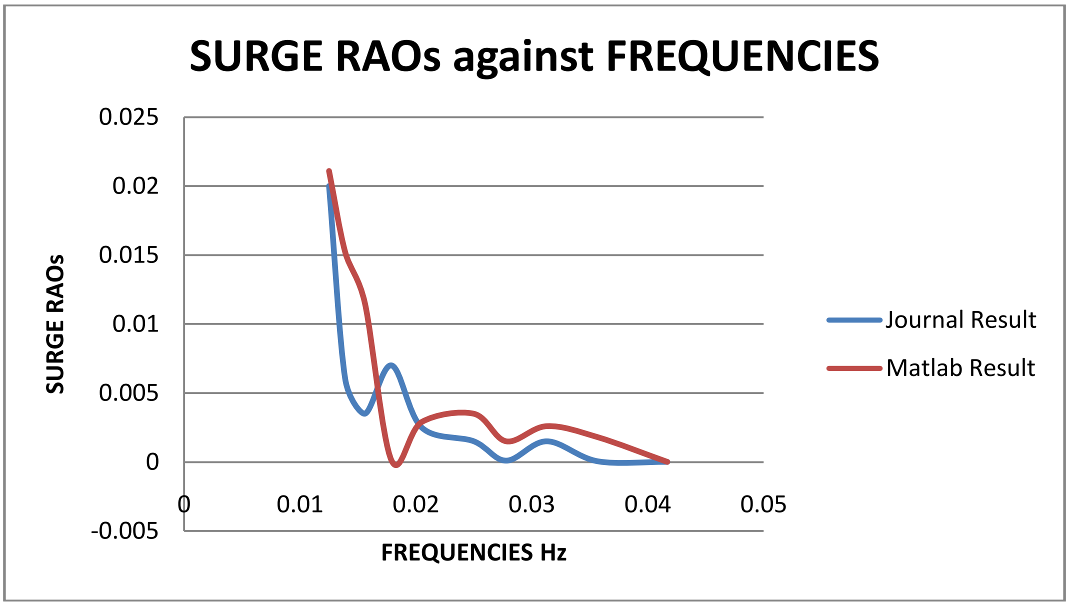
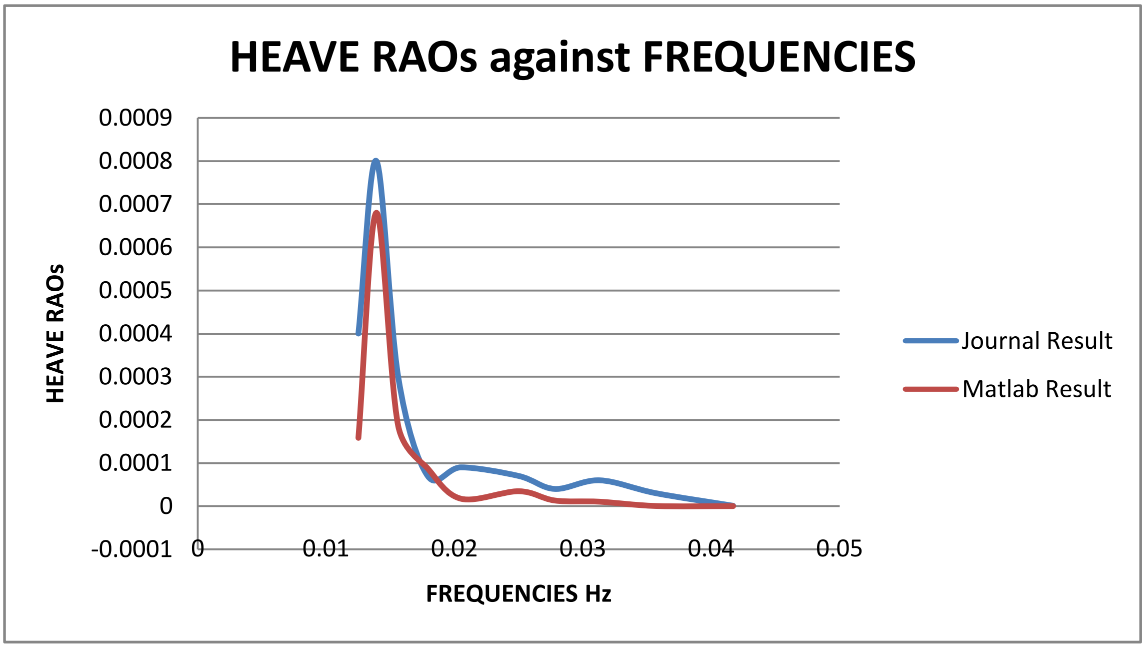


Figure 11: Surge RAOs Validation using Kurian, et.al. Data

Figure 11 is the truss spar surge response amplitude operator validation results as obtained from (Kurian, et.al, 2013), the significant of this graph is that it help to validate the Matlab truss spar RAOs results, with the blue graph representing the truss spar surge RAOs as plotted by Kurian, et.al, while the red color graphs show the Matlab truss spar surge RAOs results at vary wave frequencies and this surge response amplitude operator results will be use to validate the truss spar surge response amplitude operator results generated from the Matlab. Though only the results generated from the Morison force equation using long crested waves will be compared and validated, since only the Morison equation approach was coded into the Matlab. But it was observed that the result obtained from journal has about 0.02 surge response amplitude operator at 0.0125 Hz while the Matlab generated results has about 0.0215 surge response amplitude operator at



0.0125 Hz.

Figure 12: Heave RAOs Validation using Kurian, et.al. Data

Figure 12 is the truss spar heave response amplitude operator validation results as obtained from [17] data, the significant of this graph is that it help to validate the Matlab truss spar RAOs results, with the blue graph representing the truss spar heave RAOs as plotted by Kurian, et.al, while the red color graphs show the Matlab truss spar heave RAOs results at vary wave frequencies and this heave response amplitude operator results will be use to validate the truss spar heave response amplitude operator results generated from the

Matlab. Though only the results generated from the Morison force equation using long crested waves will be compared and validated, since only the Morison equation approach was coded into the Matlab. But it was observed that the result obtained from journal has about 0.0004 heave response amplitude operator at 0.0125 Hz while the Matlab generated results has about 0.00016 heave response amplitude operator at 0.0125 Hz.

IV. CONCLUSIONS

From this research work I can conclude that the wave force result curves on the entire structure that is figure 2, figure 3, figure 4 and figure 5 produced by the Matlab source code are in line with what is obtainable in practice for a regular wave when compared with compared with other work.

Also since the response amplitude operator for both the surge and heave case figure 7 and figure 9 have their maximum value at the same point in time that the truss spar natural frequency has it maximum values on the spar truss, it can be said that the Matlab source code developed are in agreement with world standard practice when wave force on the spar truss is been considered and regular wave is been adopted.

I can also conclude that the work show very good agreement with other research work, these was done when the truss spar surge and heave response amplitude operator was validated with that obtained from published journal kurian, et.al., and was find that the errors between both results are less than 1% as the published work result has 0.02 and 0.0004 for surge and heave response amplitude operator at 0.0125 Hz respectively, while the Matlab result has 0.0215 and 0.00016 for surge and heave response amplitude operator at 0.0125 Hz respectively.

Lastly since both the truss spar responses figure 8 and figure 10 take same shape or pattern as the wave spectrum density figure 6 which means the truss spar motion is the same pattern as the wave induced on it, and source code developed is within agreement for practical purpose, while discussing the reason for Matlab preferable over other programming language, mathematical model for spar truss structure were given and the sort code was developed and ran to give impressive results.

ACKNOWLEDGEMENT

The Author would want to appreciate the assistance of the staff of the software laboratory of the Marine Engineering Department of Rivers State University.

REFERENCES

[1]. Sadeghi, K. (2005). Classical and approximate methods in the dynamic response analysisof a truss spar in waves (PhD Thesis, University of Newcastle upon Tyne, Newcastle).
[2]. Kurian, V.J., Tuhaijan, S.N. & Liew, M.S. (2012). Dynamic responses of spar acted upon by random wave and current.
[3]. Zou, J. (2012). Spar hull/mooring/riser coupled dynamic analysis, vim effects and Mathieu instability.M.K. Kim (Ed), Spar Platform: Technology and Analysis Method pp. 108-134.1801 Alexander Bell Drive, Reston, Virginia 20191 USA, America Society of CivilEngineers.
[4]. Halkyard, J. (2012b). Spar Floating, Production, and Storage System: History and Evolution. M.K. Kim (Ed), Spar Platform: Technology and Analysis Method pp.1-32,1801 Alexander Bell Drive, Reston, Virginia 20191 USA, America Society of Civil.
[5]. Li, C. (2012). Coupled Analysis of the motion and mooring loads of a sparconstitution'(MSc thesis) Retrieved from http://oaktrust.library.tamu. edu/bitstream /handle/ 1969. 1/ETD-TAMU-2012-08 11487/LI- THESIS.pdf.
[6]. Chakrabarti, S.K., (2001). Hydrodynamic of offshore structure. WIT press, U.K.
[7]. Boccotti, P., Arena, F., Fiamma, V. & Barbaro, G., (2012). Field experiment on random wave forces acting on vertical cylinder.
[8]. Newman, J.N., (1974). Second order slowly varying forces on vessels in irregular waves.International Symposium on Dynamic of Marine Vehicles and Structures in Waves London.
[9]. Ogilvie, T.F., (1983). Second order hydrodynamic effect on ocean platforms. International workshop on ship and platforms motions, University of California Berkeley.
[10]. Standing, R.G., Bending, W.J. & Wilson, D., (1987). Developments in the analysis of wave drift forces, low frequency damping and response. 19th Offshore Technology Conference Houston, Texas.
[11]. Bhatta, D.D. & Rahman, M., (2003). Scattering and radiation problem for a cylinder in water of finite depth. International Journal of Engineering Science 41, pp. 931-967.
[12]. Zhang, X.Y. & Liaw, C.Y., (2004). Response cumulated analysis of a linear oscillator driven by Morrison force.
[13]. Jain, Y.J., Zhan, J.M. & Zhan, Q.Y., (2008). Short crested wave current forces around a large vertical circular cylinder.
[14]. Zhu, S., (1993). Diffraction of short crested waves around a circular cylinders.
[15]. Zhu, S. & Satravaha, P., (1995). Second order wave diffraction forces on a vertical circular cylinders due to short crested waves.
[16]. Zhu, S. & Moule, G., (1994). Numerical calculation of forces induced by short crested waves on a vertical cylinder with arbitrary cross section.
[17]. Kurian, V.J., Ngand, C.Y. & Liew, M.S. (2013). Dynamic responses of truss spar due to wave actions. Research Journal of Applied Science, Engineering and Technology, 5(3), 812- 818.

Chuku Promise "Matlab Aided Modelling of Linear Motion of an Offshore Spar Truss Platform" American Journal of Engineering Research (AJER), vol. 8, no. 11, 2019, pp 118-129