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Concept Design and Motion Analysis of A New Deep Draft Platform

Binbin Li [1] and Jinping Ou[1,2]

[1] School of Civil Engineering, Harbin Institute of Technology & Deep-water engineering research center of DLUT
90 Xidazhi Road, Harbin, China, 150001 & 2 Linggong Road, Dalian, China, 116024
E-mail: **bbinzaghi@163.com**

[2] School of Civil and Hydraulic Engineering, Dalian University of Technology
2 Linggong Road, Dalian, China, 116024

Abstract

This paper is primarily concerned with a new deep draft platform suitable for deep-water. The DDMS (deep draft Multi-spars) platform composed with five circular columns, four of which provide the buoyancy and the other one used for a closed moonpool to protect the top tension risers. A huge volume soft tank filled with high density liquid or metal is set at the bottom of the platform in order to make the CG below the CB. The heave plates are used to connect the 5columns and increase the global lateral stiffness, meanwhile provide lots of added mass and viscous damping to reduce the heave motion when the platform vertically oscillates. The small displacement of heave motion allows the installation of dry tree system which significantly reduces the cost compared the wet tree.

The process of the DDMS concept design including dimensions estimated, general arrangement, weight estimated and distribution, stability analysis, etc will be describes in the paper. Base on diffraction and radiation theory, the HBM method and Modified Morison Equation are adopted to predict the exciting force, hydrodynamic coefficients and viscous effects. The 1st order amplitude response Operators *RAO* are captured. Through the JONSWAP spectrum for 3 different extreme ocean environments，anti-wave behavior is analyzed and the simulated results show the favorable motion for all the freedom degrees.

Introduction of deep water platforms

With the rapid development of deep-water oil industry，some types of deep-water platform are widely used around the world e.g. SEMI，TLP，Spar platform and FPSO which are shown in Figure 1. Recently some new conceptual deepwater platforms are brought forward due to the keen competition of market. The new platform concepts pay more attention to the platform motion behavior，whether it supports the dry or wet drilling tree，whether it suits for various ocean environment，the less cost on design and construction，the more flexibility of the design, and the less difficulty of fabrication and installation[1].

The technologies of design and fabrication have been mature for the conventional SEMI platform, so it's widely used for drilling in deep-water region. The draft of SEMI platform is shallow, wave exciting forces especially the heave loading due to the large area from horizontal pontoons is high. Therefore the motion behavior is worse than deep draft platforms e.g. Spar and TLP. The CG (center of gravity) of SEMI is usually higher than the CB (the center of buoyancy). The problem of stability may cause some danger under harsh weather. Another reason for bad motion behavior of SEMI is the natural periods of SEMI are close to the wave frequencies range, resonance may cause larger response under extreme environment. TLP platform uses tensioned tendon to connect the platform and the fundament of seabed to control the vertical motion, the heave natural period is lower than the range of wave energy centralized range due to the huge stiffness provided by tendon vertically. The typical

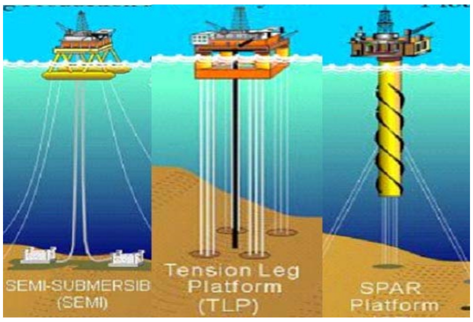

Figure 1: Sketch of SEMI, TLP and Spar

heave natural period of TLP is around 2s. One of the main advantages of TLP compared Spar is larger topside operational area and more flexible of design. But the cost of TLP platform is sensitive with water depth. With the increase of water depth, the cost of TLP platform fleetly increases. So the water depth record of TLP is 1200m now. The spar is a preferable alternative platform for deeper water region. The first classic spar Neptune installed in the Gulf of Mexico at 1996. Now there are more than 15 spar platforms in the world. After 3 classic spar platforms, the second generation spar i.e. truss spar which is more welcomed by the oil company was brought out to replace the classic spar. The most different aspect between the classic and truss spar is length of hard tank. The typical length of hard tank for classic spar is around 200m but about 70m for truss spar. The truss spar concept discharges the function of oil storage and adopts truss space frame to replace the middle section. Due to the decrease of steel using, the cost of truss spar is reduced obviously and brings more benefits to oil companies. But one problem comes out

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due to the reduced length of hard tank, the heave exciting force induced by wave increases significantly. So truss spar employs some heave plates between hard and soft tank to improve the performance of hydrodynamic as preamble mentioned. The main function of heave plates is providing added mass to shift the natural period of heave direction higher than the wave period in order to avoid resonance; meanwhile, due to the flow separation, the heave plates provide viscous damping to platform. Heave plates have be proved by theory and application that they can effectively reduce the motion of platform[2][3]. It should note that viscous damping plays an important role in controlling the response amplitude especially in resonant range. The third generation spar platform called cell spar was first used at year of 2004 in GOM. Cell spar utilizes some columns of smaller diameter combined together to provide buoyancy of platform needed. The less difficulty of fabrication of hard tank and less cost on transport and installation are the main advantages of cell spar. There are many shipyards all over the world can produce the small circular column, so the oil companies can freely choose the dock closer to the installation site. However the concept of cell spar limits the topside weight and payload, there is only one cell spar i.e. Red Hawk so far.

Concept introduction of DDMS

Base on the advantages and disadvantages of various types of platforms mentioned, a new deep draft platform called DDMS (Deep Draft Multi-Spars) with excellent motion characters and adaptability to the extreme ocean conditions is designed to reduce the difficulty and cost of the fabrication. Figure 2 shows the DDMS platform concept. The hard tank of DDMS is combined with four symmetrical spars with small diameter used to provide the buoyancy and one larger spar located at center of horizontal cross-section. The main functions of the large spar are creating a manmade closed moonpool and making the risers through it and meanwhile protecting the risers especially the buoyancy-cans which were widely used for spar platform. Buoyancy-cans provide tension the risers needed and effectively increase the payload of platform. Of course that the type of hydraulic-pressure riser can also be used here and the customers may decide adopt the manmade moonpool or not. There is no special component for middle section. The soft tank filled with high density liquid or metal is located at 40m below the bottom of multi-spars and connected with four small circular columns to the spars. The distance between the spars and soft tank should be adjusted for designer to guarantee the sufficient stability. DDMS platform concept makes the CG below the CB, so DDMS have good stability even under extreme condition. Though the draft of spars of DDMS is very deep even up to 146m, we also consider employing heave plates to reduce the heave response farther. The other function for heave plates is connecting the five spars and providing global lateral stiffness. Each level of heave plate is composed with four triangular sub-plates and spaced out with four horizontal beams. So the global structural configuration of DDMS is quite different from the truss spar or SEMI. We can also set horizontal bracing or K-type beams at top of spars to increase the lateral stiffness. The distance of the spars depends on the topside dimensions requirement, oil and gas output, stability requirement etc. The dimensions of spars and manmade moonpool depend on the total displacement, buoyancy requirement, the riser configuration etc. So the DDMS platform has good adaptability and flexibility of design to suit for any requirement from customer. Like the Spar or SEMI platform, DDMS employs mooring system to keep horizontal station.

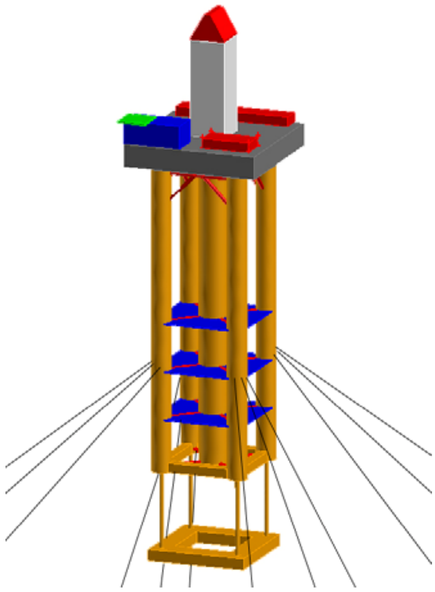

Figure 2: Sketch of DDMS Platform

Concept design of DDMS

The concept design of Deep-water platform generally follows some principles below: buoyancy must balance the total weight of platform, mooring system, risers system and any other vertical loading; available space must equal or exceed the space required for functions; motion, station-keeping and stability must meet minimum criteria[4]. Base on the mentioned principles, the steps of concept design should include: functions and design requirement of platform, hull dimension estimated, weight estimated and topside arrangement, ballast and hard tank design, displacement of void tank, mooring, risers, loading, design computation and stability etc.

The design of platform is an interactive work base on the integrated design steps[5]. When the initial design dimensions established, calculation of stability and hydrodynamic analysis should be done. If the calculational results didn't meet the minimum requirement, the main dimensions, general arrangement or weight control have to modify to meet the criteria. It should note that the checking calculations of stability and motion are two focuses in the whole design process.

Main dimensions estimated and general arrangement

In this section we will confirm the main dimensions of DDMS platform. First the most important thing is to collect

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and understand the customer's requirements such as water depth, oil and gas production every day, payload, design working lift etc. Due to the concept design, Here we simply suppose that the design water depth, design reference period and payload requirement are 1200m, 100y occurrence in GOM and 10000t respectively.

Hard tank

The main function of the four spars is providing sufficient buoyancy to counteract the vertical loading. Considering the total weight of DDMS, the total volume of the four spars was submitted. Generally considering the global performance and design experience of deep water platform, the four spars have the same shape and dimensions. The diameter of spars and their distance could be roughly estimated through consulting the TLP at initial stage. The exact values may be done after the weight control and stability calculation established. The length of manmade moonpool equal to the other spar's and the diameter depend on the riser configuration. Here we arranged 9 slots for risers and their buoyancy-cans getting across. Certainly you can change the pool diameter freely to satisfy the design requirement of risers.

Pontoon

The four pontoons are located at the bottom of hard tank to connect the spars. The pontoons primarily provide the global stiffness of structure and meanwhile considered as variable ballasts in order to adjust the horizontal center of gravity. According the experience of TLP platform design, the width and ratio of width and height of pontoon approximately equal to half of the spar diameter and 1.0 respectively. The length, width and height of pontoon here are $30\times5\times5$.

Heave plate

Prislin[2] and Troesch[6] researched the hydrodynamic performance of heave plates via reduced scale experiments and CFD numerical simulation, some beneficial results and conclusions are captured. In this case there heave plates were employed. Base on their conclusions and recommendations, 0.7m and 25m respectively for the thickness of heave plates and the vertical distance between the plates are adopted. The facade section and two cross-sections are shown in Figure 3 and 4.

Air gap

The air gap is an important coefficient primarily concerned with wave slamming and green water. On the other hand sufficient air gap helps to avoid flooding when DDMS inclines. As the concept design phase, according to Chou etc[7], the minimum operational air gap value:

$$h_{ag} = 0.60H_w + 1.52 + 0.2\%W_D + tide \qquad (1)$$

Where H_w and W_D denote the wave height and water depth. 1.52m accounted for a 5ft design safety margin. The calculated result here for air gap was 13.24m, finally 14m for air gap of DDMS was adopted here.

Topside dimensions and arrangement

The design values of topside dimension are $70\times70\times12$ for length, width and height. The arrangement of DDMS topside is similar with traditional TLP or SEMI platform. The accommodations, helicopter deck and control room were located at bow. Drilling tower located at center of deck, the drilling quarters defined at portside near the drilling rig. The Power supply such as turbo generators was defined at starboard. At astern side located the production plant. The cargo handing area and two cranes located at portside and starboard. It should note that the arrangement of the handing area must guarantee the safe operation.

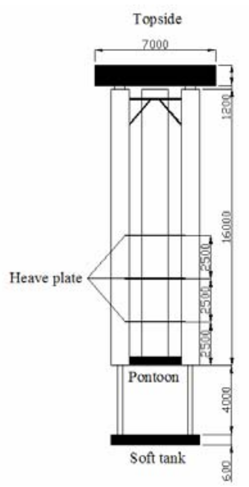

Figure 3: Sketch of facade section

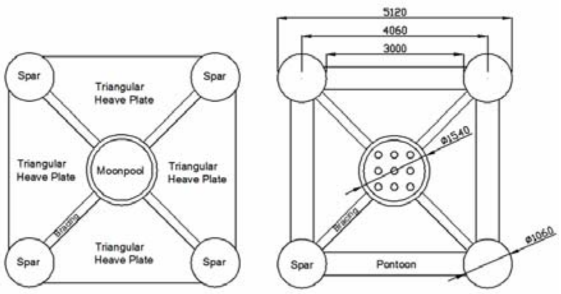

Figure 4: Sketch of Cross-sections

Weight estimated and distribution

The total weight of platform primarily comes from the topside structure, payload, weight of light ship, mooring, risers, ballasts and so on. The weight distribution must be

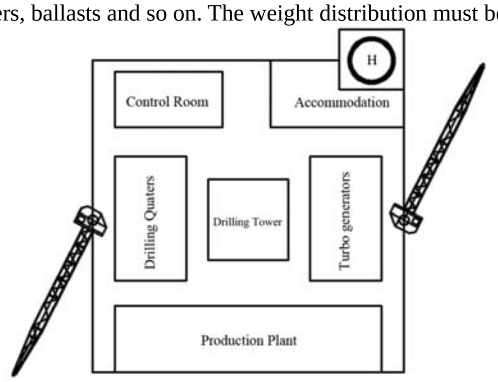

Figure 5: Topside arrangement

listed and prepare to determine the center of gravity. The generally weight arrangement should keep the longitudinal and transverse centers of gravity (LCG, TCG) at the centerline. As the concept design of DDMS, we supposed the LCG and TCG located at the centerline and then calculate the vertical center of gravity (VCG) using some most important mass contribution (weight of mooring and risers ignored) of DDMS via an EXEL spreadsheet. Table 1 represents the weight distribution and KG respectively.

Table 1: Weight control and KG

Item	Weight (t)	KG (m)
Topside structure	17730	210
Payload	10000	210
Hard tank	21570	126
Heave plate1	1000	121
Heave plate2	1000	96
Heave plate3	1000	71
Pontoons	750	48.5
Small Columns	246.3	26
Soft tank and ballast	24685.4	3
Total	67982	97.89

Table 2: Main dimensions and mass features

Item	Value	Units
Mass in surge/pitch	91098	t
Mass in heave	67982	t
Radius of gyration	79.8	m
KG	97.89	m
KB	106.21	m
Diameter of spars	10.6	m
Length of spars	160	m
Diameter of moonpool	15.4	m
Distance between spars	40.6	m
Length of soft tank	6	M
Mean draft	192	m

When the CG calculation accomplished, the CB point should be found using respective volume and floating center of submersed components. Finally some hydrostatic coefficients such as waterplane stiffness, pitch/Roll stiffness and some structural characteristic parameters such as radius of gyration about X/Y axis were captured. The Table 2 summarizes the main dimensions and mass features.

Stability analysis

The stability analysis was conducted here following the MODU CODE criteria from ABS[8]. The wind loading condition was for operating draft (192m) with the platform freely afloat. For the intact and damaged stability the recommended wind velocity are 51.4m/s and 25.7m/s respectively. The main purpose of stability analysis here is to validate the dimensions. The wind incidence direction was 45 degree which is generally the worst case for intact condition.

Mooring configuration

The mooring system is usually used for station keeping of floating platforms or ships such as SEMI and FPSO. The

Table 3: Intact stability

Angles	0	5	10	20	30	40
GZ(m)	0	2.60	5.23	10.7	16.7	24
WHL(m)	1.00	1.03	1.03	1.11	1.08	0.95
First intercept(degree): 1.6			Area ratio: >1.3			
All GZ values positive						
The criteria satisfied						

Table 4: Damage stability

Angles	0	5	10	20	30	40
GZ(m)	-0.4	2.41	5.01	10.3	15.5	22.4
WHL(m)	0.41	0.44	0.45	0.54	0.49	0.39
First intercept<17: 1.5			Stability range>7			
Maximum GZ/WHL>2						
The criteria satisfied						

mooring lines primarily provide a certain horizontal restoring force to restrict the surge/sway motion. The DDMS employs 12 mooring lines and mark the number from 1 to 12 respectively. All of the lines are separated into 4 groups and symmetrically arranged on the four spars.

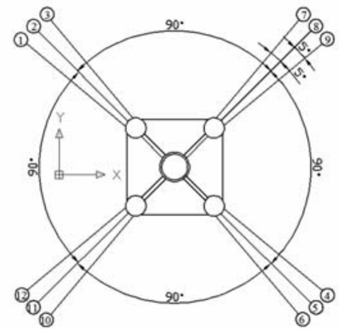

Figure 6: Mooring configuration

Each group is 90^o from another and the lines of each group were 5^o azimuth spread. The mooring configuration is shown in Figure 6. The fairleads are located near the position of VCG in order to avoid baneful moment induced by mooring lines. Each line consists of a top chain section, a cable section and a seafloor chain section. The symmetrical mooring configuration is a typical arrangement, however the unsymmetrical configuration is also suitable once for an installation site specified the commonly direction of wind or current. One important principle of mooring design is total restoring force must equal to zero at the initial equilibrium position. DDMS platform is a compliant structure with small horizontal restoring stiffness and the surge/sway natural period is usually at 150~400s. The mooring restoring force is typical nonlinear and calculated here using classical catenary theory.

Riser configuration

The riser system for DDMS includes 1 drilling riser and 8 production risers and the catenary risers are also supported. All the vertical risers are top-tensioned which provided by buoyancy cans. The cross-section of moonpool here is circularity, however the rectangular section can also be used with the dimensions depended on the number of risers. The diameter of moonpool is 13.4m with 3.5m between well slots. The riser arrangement is shown in Figure 7. The top-tensioned risers are restrained from lateral motion at keel and the buoyancy-cans are restrained by guides.

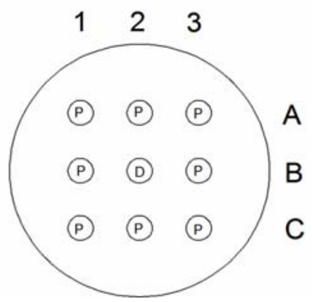

Figure 7: Riser arrangement

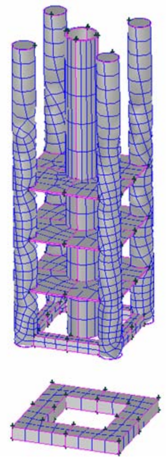

Figure 8: Diffraction panel model

Hydrodynamic analysis

Due to the large dimension components of DDMS such as spars and moonpool, High order boundary BEM for diffraction and radiation and also Morison Equation are used to predict the exciting forces and hydrodynamic coefficients. Platform Amplitude Response Operators RAO are captured.

Diffraction/radiation calculational model

The large dimensional components: spars, mooonpool, pontoons, heave plates and soft tank disturb the motion of wave, the diffraction and radiation theory were adopted to predict the hydrodynamic information. The BEM was employed to integrate the hydrodynamic pressure along the wet surface to obtain the 1st order wave exciting forces, added mass and radiation damping:

$$F_i = \mathrm{Re}[i\int_s \rho\omega(\varphi_0 + \varphi_7) n_j ds e^{-i\omega t}] = \mathrm{Re}[f_i e^{-i\omega t}]$$

$$i\omega a_{mn} + b_{mn} = i\rho\omega\int_s \varphi_n n_m ds \qquad (j,m,n = 1 \sim 6) \qquad (2)$$

Where F_i, a_{mn} and b_{mn} are the 1st order wave exciting force, added mass and radiation damping respectively. Where ρ, ω and S are sea density, frequency of incident wave and wet surface. The symbols φ_0, φ_7, φ_n, n_m denote the incident potential, diffraction potential, radiation potential for freedom n and normal vector for freedom m. computation of diffraction and radiation was solved using WAFDUT written by Dalian technology of university. The diffraction panel model in this case is shown in Figure 8.

Modified Morison Equation

The hydrodynamic coefficients of small columns connecting the spars and soft tank, vertical viscous damping of heave plates are predicted by modified Morison Equation. Viscous damping of surge/sway has been proved to influence the amplitude motion especially the resonant oscillate. Therefore the viscous damping induced by motions of spars and moonpool was accounted here using viscous item of Morison equation. The modified Morison equation for unite length below:

$$dF = C_I\rho\frac{\pi D^2}{4}\dot{u} - C_a\rho\frac{\pi D^2}{4}\ddot{x} + \frac{1}{2}\rho C_d D(u-\dot{x})\left|(u-\dot{x})\right| \qquad (3)$$

Where C_I, C_a, C_d are coefficients of inertia force, added mass and drag force respectively. The symbols u, $\dot{x}$, $\ddot{x}$ express the surge velocity of wave particle, surge velocity and acceleration of platform. The modified equation considers the relational velocity in drag item. The viscous damping of heave plate was estimated using the recommended coefficient mentioned before and vertical Morison equation for thin plate:

$$F = \frac{1}{2}\rho C_d L^2 U\left|U\right| + \rho C_a L^3\frac{\partial U}{\partial t} \qquad (4)$$

Where U is vertical relational velocity of water particle and platform. The 1st order Airy wave theory was adopted to express the velocity of water particle:

$$\eta = \frac{H}{2}\cos(kx-\omega t) \qquad (5)$$

$$u = \frac{gkH}{2\omega}\frac{\cosh k(y+d)}{\cosh kd}\cos(kx-\omega t) \qquad (6)$$

$$v = \frac{gkH}{2\omega}\frac{\sinh k(y+d)}{\cosh kd}\sin(kx-\omega t) \qquad (7)$$

Where η, u, v are function of wave surface, transverse and vertical velocities respectively. the symbols k, H, d denote wave number, wave height and water depth. The wave number was determined by dispersion equation: $\omega^2 = gk\tanh(kh)$.

Classic catenry theory

Classic Catanary theory is a simple and common method for mooring lines base on static analysis as shown in Figure 9. The theory supposes the anchor point is always free and with no uplift. Considering in-line and transverse force:

$$dT - \rho gAdz = [w\sin\varphi - F(T/EA)]ds \qquad (8)$$

$$Td\varphi - \rho gAzd\phi = [w\cos\varphi + D(1+T/EA)]ds \qquad (9)$$

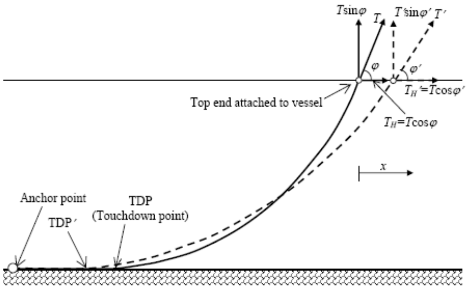

Figure 9: Diffraction panel model

Where F , D , T , w denote the mean hydrodynamic forces per unite, line tension and wet weight per unite respectively. Ignoring forces F and D together with elasticity allows simplification of the equations. The suspended line length s :

$$s = (T_H / w)\sinh(wx/T_H) \qquad (10)$$

Where T_H denote the horizontal component of tension. The resultant tension T and T_H in the line at the top：

$$T = w(s^2 + d^2)/2d \ , \quad T_H = T\cos\phi_w \qquad (11)$$

Fist the offset-restoring curve as shown in Figure 10 for every mooring line was calculated, and then the platform excursion-restoring force curve was obtained as shown in Figure 11. Finally the curve of displacement and restoring force was inputted into dynamic analysis. The Figure 11 clearly reflects the nonlinear effect of platform offset and restoring force provide by mooring lines. When we need increase or decrease the horizontal stiffness, the number of mooring lines or wet weight could be adjusted.

Numerical model of motion analysis

The DDMS platform was considered as a floating rigid body of 3 characteristic freedom degrees: surge, heave and pitch. The exciting forces, hydrodynamic coefficients, hydrostatic coefficients, Mass of platform, restoring force etc were inputted into the motion equations.

The motion equation of surge:

$$M\ddot{x} + m_x\ddot{x} + m_{x\theta}\ddot{\theta} + b_{rx}\dot{x} + b_{rx\theta}\dot{\theta} + R(x) + b_{vx}U_x\left|U_x\right| = F_x \qquad (12)$$

Where M , m_x , $m_{x\theta}$, b_{rx} , $b_{rx\theta}$ and b_{vx} are mass of platform, added mass of surge, added mass of surge due to pitch, radiation damping of surge, radiation damping of surge due to pitch and surge viscous coefficient. Where x , U_x , $R(x)$ and F_x represent surge displacement, relation velocity of surge, restoring force, wave exciting force.

The motion equation of heave:

$$M\ddot{y} + m_y\ddot{y} + b_{ry}\dot{y} + C_y y + b_{vy}U_y\left|U_y\right| = F_y \qquad (13)$$

Where C_y denote waterplane stiffness of heave. The other parameters are similar with surge.

The motion equation of Pitch:

$$I\ddot{\theta} + m_\theta\ddot{\theta} + m_{\theta x}\ddot{x} + b_{r\theta}\dot{\theta} + b_{r\theta x}\dot{x} + C_\theta\theta + b_{v\theta}U_\theta\left|U_\theta\right| = M_\theta \qquad (14)$$

Where $I = Mr^2$ and C_θ denote the moment of inertia and hydrostatic restoring stiffness for pitch. The symbol r is the Radius of gyration. The other parameters are similar with surge.

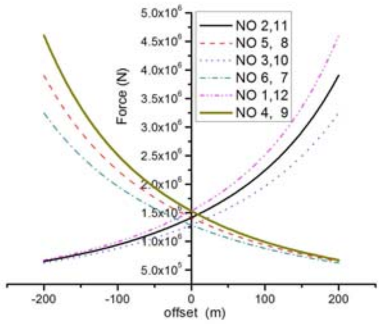

Figure 10: Offset-force curve of mooring lines

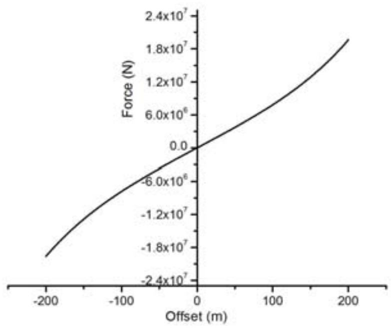

Figure 11: Excursion-force curve

Motion analysis

Due to the concept design phase of DDMS, not the professional global motion analysis, this paper primarily concerned the 1st order wave exciting. Through the numerical iteration, RAO for surge, heave and pitch were obtained and compared with a typically truss spar platform. Table 5 summarizes the main feature parameters of the truss spar. JONSWAP wave spectrum for 3 extreme environmental conditions was adopted to calculate the random response of DDMS in different sea area. In this design the storm condition time used was 3 hours. The wave incident directions for diffraction/radiation calculation were 0^o and 45^o azimuths with X axial.

Exciting force spectrums

Figure 12 and 13 show the 1st order wave exciting force spectrums. The pitch moment spectrum doesn't exhibit here because the similar trend with surge. The results reveal the smaller surge exciting force which may bring some benefits for hull structure design compared with truss spar. The main reason is the configuration of hard tank composed with 4 spars and moonpool effectively decreases the acting area. Otherwise the small diameter columns reduce the difficulty of fabrication and the cost. Since the Figure 12 showed the Surge force of wave 0° incident is larger than 45°, the *RAO* and other calculated results depend on 0° incident wave. The quite deep draft of DDMS determines the smaller heave exciting force obviously compared with truss spar. It is an important improvement compared with the platform of similar cross-section such as SEMI and TLP.

Table 5: Feature parameters of Truss Spar

Item	Value	Unite
Diameter of hard tank	40	m
Length of hard tank	75	m
Total mass	98132	t
Topside mass	22000	t
Mean draft	231.8	m
Radius of gyration	91.7	m

Response amplitude operators

The *RAO* curves and natural periods for surge, heave and pitch are shown in Figures 14-16. Surge *RAO* is

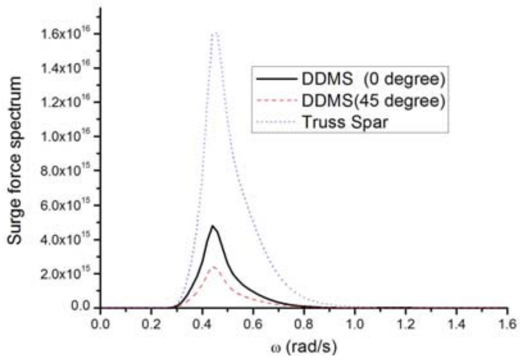

Figure 12: Surge force spectrums

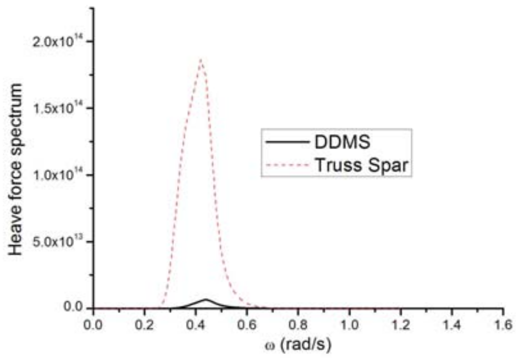

Figure 13: Heave force spectrums

smaller in the whole frequencies range due to the smaller exciting force. The curve is soft varied and low in wave frequencies range, indicates the favorable anti-wave performance. It notes that in process of computation the viscous damping doesn't affect the surge motion obviously at wave frequencies but significantly around the natural period which is very important to 2nd order wave different frequencies force. The pitch *RAO* reveals the similar conclusions with surge. It notes that the coupled effect of motion for surge and pitch is weak. The heave *RAO* of

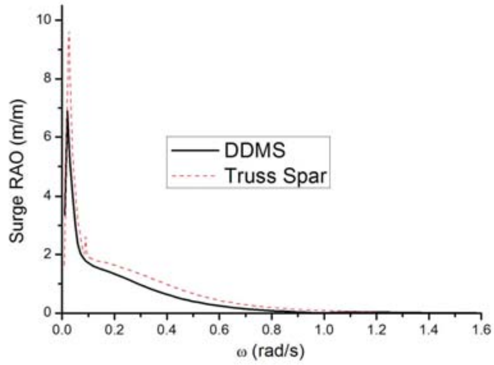

Figure 14: Surge *RAO*

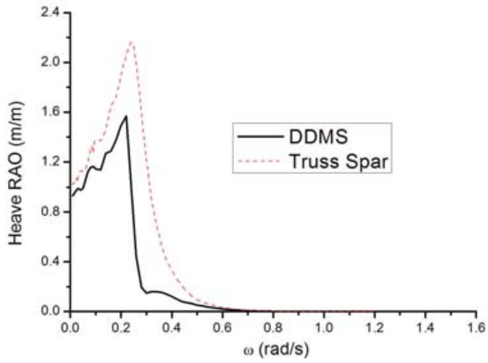

Figure 15: Heave *RAO*

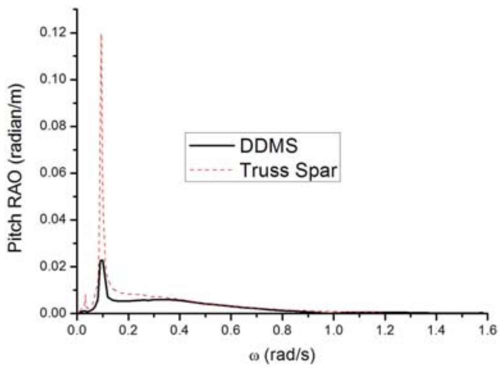

Figure 16: Pitch *RAO*

DDMS obviously shows the smaller response compared truss spar because of the associated effect of lower exciting force and heave plates. It means available for using dry tree system. As the heave natural period is higher than the wave period, the heave *RAO* curve is also soft varied. It is observed the second peak value appeared at frequency of 0.35 due to a peak exciting force at the same frequency.

The natural periods of DDMS are summarized in Tabel6.

Table 6: Natural periods of DDMS

Item	Value	Unite
Surge	314	s
Heave	28.5	s
Pitch	66.1	s

Random response of DDMS

The random theory is commonly used in the field of engineering to represent the real condition of ocean. In order to validate the adaptability of DDMS for different sea area, 3 extreme sea conditions marked A－C were selected and Max response, standard deviation, mean period of surge, heave and pitch were captured. Table 7 shows details of Extreme environment conditions.

Table 7: Extreme environment conditions

Item	Hs	Tp	γ
A 100-y occurrence in GOM	12.3	14.2	2
B Swell wave in West Africa	1.7	25.0	6
C China southern sea(typhoon)	13.3	15.5	2.8

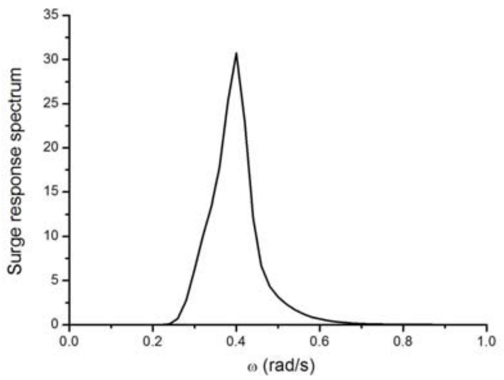

Figure 17: Surge response spectrum

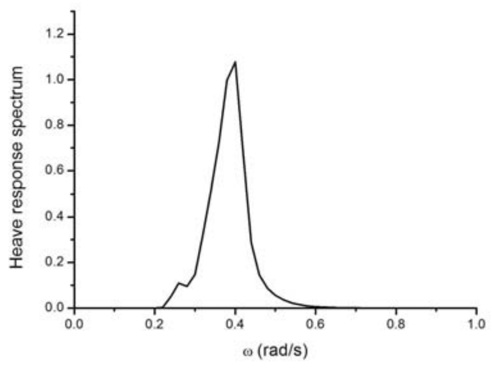

Figure 18: Heave response spectrum

The 1st order area moment, 2nd order area moment and rate of up-crossings of zero mean etc were obtained through analysis of the response spectrums. As an exhibition, the response spectrums for condition 3 are shown in Figures17-19. The correctional equation

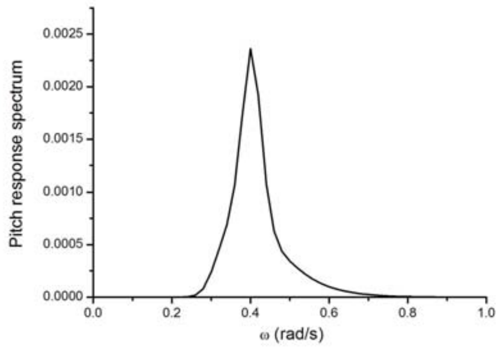

Figure 19: Pitch response spectrum

suggested by Davenport was used here to determine the peak responses. Table 4 summarizes all the results. Calculation results reveal the perfect motion performance for extreme environments of different sea areas. Especially for condition B of extreme long period exciting which is closer to heave natural period, the heave peak value is well controlled. As a comparison, the peak value of truss spar for condition B is 2.6m.

Table 4: Statistic of random response results

Cases		A	B	C
Standard Deviation	Surge	1.41	0.45	1.81
	Heave	0.24	0.31	0.33
	Pitch	0.013	0.0024	0.016
Mean Period (s)	Surge	14.5	24.0	15.6
	Heave	15.3	27.1	16.3
	Pitch	13.76	22.1	14.83
Max Response (m/degree)	Surge	5.34	1.65	6.85
	Heave	0.89	1.13	1.23
	Pitch	2.87	0.5	3.44

Conclusions

This paper brings a new deep draft platform (DDMS) integrated the advantages of Truss spar, SEMI and TLP. The concept design and hydrodynamic motion performance have been described and analyzed. The *RAO* for surge, heave and pitch have been obtained through BEM base on diffraction/radiation theory and modified Morison equation for small dimensional components and viscous effects. The conclusions are as bellow:

- The DDMS platform is perfectly optimized for less difficulty and cost on fabrication and design, larger topside area and dry tree system supported, flexible design, less loading acting induced by wave, favorable motion performance for different ocean environments.
- The comparisons of exciting force between the DDMS and truss spar indicate the benefits for structural design of DDMS due to the smaller loading resisted.
- Since the integration of hard tank of deep draft and heave plates, the peak heave response is very low.

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Otherwise the motion characters of surge and pitch are similar with truss spar but with lower peak value. The calculational results for 3 extreme sea conditions reflect the excellent adaptability of DDMS for different sea areas.

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