ATLANTIS PRESS
Advances in Engineering Research, volume 138
2nd International Conference on Machinery, Electronics and Control Simulation (MECS 2017)

Design on Mooring System of Proximal Shallow-sea Observation Network

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Abstract: Transport nodes of proximal shallow-sea observation network consists of buoy system, mooring system and underwater acoustic communication system, in order to make the underwater acoustic communication equipment achieve required effects, it is very important to design the structural parameters of mooring system. In this paper, the single point mooring system is studied on constructing static model of typical components in the system, furthermore, the mooring system with good working effect under the action of wind and water flow is designed.

Keywords: Single point mooring system; Static model; Anchor chain equation; Mooring system design

1. introduction

Transport nodes of proximal shallow-sea observation network require that the included angle between tangential direction of the connection of anchor end and anchor and seabed shall not exceed 16 degrees, otherwise, the anchor will be dragged, resulting in the loss of node displacement. Underwater acoustic communication system is installed in the sealed cylindrical steel drum, the steel drum is connected with fourth section steel tube on the top, and electric welded anchor cable below. When the steel drum is vertical, effect of underwater acoustic communication equipment is the best. When the tilt angle of the steel drum (the angle between the steel drums and vertical lines) exceed 5 degrees, the working efficiency of the equipment is poor. Heavy ball can be hung in the link position of steel drum and welding anchor to control the angle of inclination of the steel drum.

1.1 Problems raised

A type of transmission node uses II type 22.05m long welding anchor chain, and the weight of the selected heavy ball is 1200kg. And now, this type of transmission node is placed in the sea water depth of 18m, sea level, sea water density of 1.025 * 103kg/m3. If the sea is still, angle of inclination, shape of anchor chain, draft depth and area of buoy of each section of steel pipe and steel drum can be calculated respectively when the sea surface wind speed is 12m/s and 24m/s.

2. Model hypothesis

For the sake of mechanical analysis, it is necessary to simplify and assume the physical environment of the system and the physical properties of the mooring structure, as:

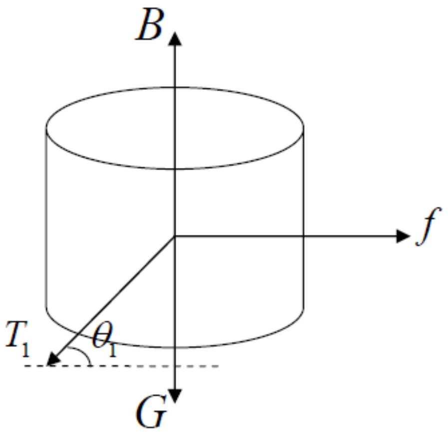
1. The sea bed is flat, ignoring the influence of the wave on the system load for static analysis;
2. Assuming that the current and wind flow are plane flow, and there is no component in the vertical direction, to simplify the analysis to a two-dimensional problem;
3. Assuming that the lower surface of the buoy is always parallel to the sea level.

3. Model establishment and solution

3.1 Model establishment [1] :

Force analysis of buoy

As shown in the coordinate system, the buoy is subject to its own gravity G_1, the offshore wind load is f_1, the buoyancy is B_1, the tension of steel pipe to buoy is T_1 , where,θ_1 is the angle of T_1 with horizontal plane. When the sea is still, the buoy is free from water resistance.



Assuming that the buoy gravity is $M_1 g$ the buoy is given as a regular cylinder of H at diameter and D at diameter. If the airflow is flowing in the horizontal plane, the projected area of the buoy in the wind direction is:

$$S = d\,(h - h_1)$$

According to the approximate formula of offshore wind load f1= 0.625Sv2, the offshore wind load can be gained as:.

$$f_1 = 0.625d\,(h - h_1)\,v^2$$

To simplify the problem, assuming that the lower surface of the buoy is always parallel to the sea level, the buoyancy is:

$$B_1 = \rho g V = \rho g h_{1\pi} \left(\frac{d}{2}\right)^2$$

As the buoy is in a state of equilibrium, equations can be listed as:

$$B_1 = G_1 + T_1 \sin\theta_1$$

$$f_1 = T_1 \cos\theta_1$$

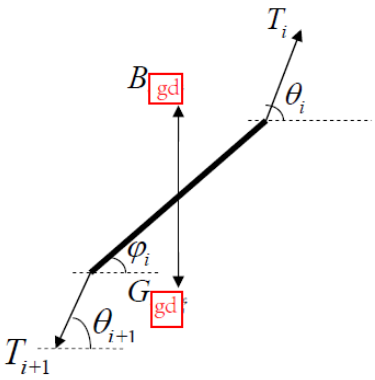
When solving the equation, the size and direction of the tension of the first steel tube to the buoy can be gained:

$$T_1 = \sqrt{(B_1 - G_1)^2 + {f_1}^2}$$

$$\theta_1 = arctan\frac{B_1 - G_1}{f_1}$$

Stress analysis of steel pipe

Stress analysis on the i steel pipe is ($i \leq 4$) conducted, as shown in figure 3, and the included angles of the steel tube under T_i and T_{i+1} with the horizontal are recorded as θ_i and θ_{i+1}



The gravity G and buoyancy B of each steel pipe are equal. The buoyancy and gravity are simplified into F_{gd}, and the steel pipe is in a state of equilibrium, equations can be listed as:

$$T_i \sin\theta_i = F_{gd} + T_{i+1} \sin\theta_{i+1}$$

$$T_i \cos\theta_i = T_{i+1} \cos\theta_{i+1}$$

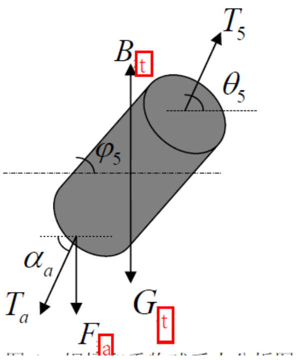
Rewrite the equation as following Iterative form:

$$T_{i+1} = \sqrt{\left(T_i sin\theta_i - F_{gd}\right)^2 + (T_i cos\theta_i)^2}$$

$$\theta_{i+1} = arctan\frac{T_i sin\theta_i - F_{gd}}{T_i cos\theta_i}$$

Force analysis on the steel drum and heavy ball

As shown, the steel drum stress analysis is similar to that of steel tube, angle steel drums at this time is ϕ_5. Because the water is still, the small ball can be omitted, directly exerting a force $Fball$ in the end of the barrel. The whole is subjected to both the force T5 and Ta, and angles between T5 and Ta and water surface are θ5 and αa.



The drum is in a state of balance, thus, equation of steel pipe can be listed as.

Establishment of anchor chain equation

As shown in figure 5, taking a micro element DL on the anchor cable with a length of L to carry out the stress analysis, because the water is still, and free from water resistance here, the cable density ρ_{ml} can be defined as the mass per unit length of chain, cable volume is negligible. Infinitesimal is affected by its own gravity ρmldl , the tilt angle of the element DL and horizontal direction is α, $d\alpha$ is the variation of inclination angle,T and $T + dT$ are respectively the tension between the two ends of the element, dT is the change of tension.

So tangent direction along the infinitesimal:

$$dT = \rho_{ml} \sin\alpha\, dl$$

And normal direction along the infinitesimal:

$$(T + dT)\sin d\alpha = \rho_{ml} \cos\alpha\, dl$$

Substituting $\sin d\alpha \approx d\alpha$ *into:*

$$Td\alpha = \rho_{ml} \cos\alpha\, dl$$

To solve the differential group:

$$dT = \rho_{ml} \sin\alpha\, dl$$
$$Td\alpha = \rho_{ml} \cos\alpha\, dl$$

We can gain:

$$T\cos\alpha = C$$

As seen from above formula, the horizontal component of the tension of the anchor cable is a certain value, which is identically equal to the horizontal component $T_a \cos\alpha_a$ of the cable tension at the hinge.

Substituting $T\cos\alpha$, $T_a\cos\alpha_a$, $dx = \cos\alpha\, dl$, and $dz = \sin\alpha\, dl$ *into* $Td\alpha=\rho_{ml}\cos\alpha\, dl$ *equation, and integral to chain length l on anchor as a starting point from 0 to gain a function* $l(\alpha)$ *on a, thus, the shape of the chain cable can be solved.*

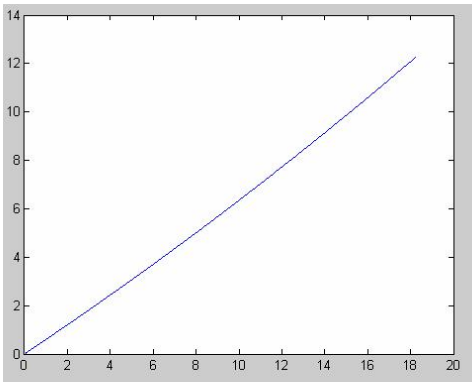
3.2 Model solution

The above equation is linked to solve by method of bisection approximation and matlab software, to gain table 1:

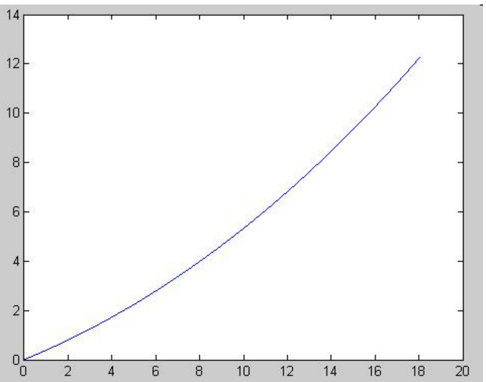
Table 1. Table of tilt angle gamma γ_i, the shape, depth and area of the anchor chain of steel drum, steel pipe under different wind speed:

Parameters / Wind spped	γ_1 (°)	γ_2 (°)	γ_3 °)	γ_4 (°)	γ_5 (°)	h_1 (m)	α_0 (°)	$A(m^2)$
12m/s	1.0612	1.0678	1.0746	1.0814	1.0969	0.7093	20.0169	1037.9
24m/s	4.0434	4.0678	4.0925	4.1175	4.1743	0.7237	30.5039	1092.5

Draw the shape curve of anchor cable with MATLAB:



when the wind speed is 12m/s, the weight of the ball is 1200kg

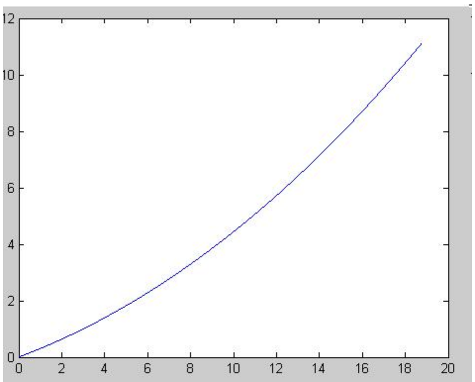


when the wind speed is 24m/s, the weight of the ball is 1200kg

4. Conclusion

From the results, it can be seen that the the working effect of underwater acoustic communication equipment is poor, and the anchor is likely to be dragged to cause nodal displacement. Therefore, it is necessary to increase the weight of the ball to ensure that the system can work properly. After the addition of different weight balls by established model, the tilt angle steel drums and anchor in the anchor and seabed angle is gained, and the tilt angle of steel drum is gained as not exceeding 5 degrees, and the angle between the anchor and the sea bed shall not exceed 16 degrees, the mass of the critical mass of these two conditions is:

At this time, the anchor curve when the wind speed is 36m/s, the weight of the ball is 4880kg Is shown on the below picture:



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