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Hydrodynamic Model Test and Simulation for the Design of Offshore Aquaculture System for Macro Algae Farming

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ABSTRACT

Marine algae biomass energy source is increasing getting approval from policy maker and community. Beside production of seaweed for biomass energy, seaweed plantation has benefit for food, cosmetic, gelatin and pharmaceutical products. Large production of biomass will require deployment of very large multibody floating structure offshore. To ensure that the system is reliable, design needs to be built, a mooring component for the mooring system, need to be properly sized to provide reliable strength for position keeping. This paper present, result of hydrodynamic test carried in UTM lab to determine coefficient required for the design and simulation of mooring system for very large floating structure for offshore aquaculture structure for ocean plantation, the paper also present safety and efficiency of the mooring system. Hydrodynamic test is traditionally used to secure coefficient require for design for environment for ship structure and offshore platform hydrodynamic interaction. The case of seaweed biomass is unique because the seaweed interacts directly and moves with the environment. The obtained the coefficient is used to model the static moorings system that assess the tension, tilt, safe mass and motion of the mooring components. Interpolated time dependent currents from the towing tank are used to estimate dynamic response of the mooring as well as the draft of the mooring components, the overall analysis is use to select required mooring components of the system. The outcome of the test presented in this paper will help for future development of offshore aquaculture system and multibody system deployment and analysis.

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Background of Study

Seaweed has become one of the economically ocean plantation that is important resource of Malaysia since 1978. The state of Sabah, Malaysia, which located in the middle of one of the 12 mega-diversity sites in the world, has numerous and varied natural resources. The fisheries sector has contributed significantly to Sabah economy. The last ten years has been tremendous with exports listing higher value each year. Real Gross Domestic Product (Sabah) in 2002 was recorded at RM10.2 billion for which the fisheries sector contributed about 2.8%. Algae farming are an alternative live hood for the fisherman in Semporna. With this project, fishing communities now can earn income by growing seaweed for sale to processing plants in Sabah. In the wet market of Semporna one can find two slims type of seaweed on sale, one type is yellowish, and the other is dark green seaweed on stalks with round buds. Both are called by the local seaweed. For the seaweed farming, it needs powerful mooring system to hold the seaweed farming, safety. Mooring systems are designed to industry standards to ensure that the mooring systems provide the holding power required to withstand expected weather and sea conditions. This research will establish the mooring system simulation using Arianne to test the suitability of mooring configuration for offshore aquaculture seaweed plantation.

Due to the decreased of the supply of seaweed, the project aims to develop local technology to mitigate shortage problem. To maintain economy of aquaculture; it is important to maintain the output of the seaweed or other ocean plantation. The researcher will explore whether the system capable to meet the several of condition.

Aquaculture industry in Malaysia having shortage of seaweed plantation system that is systematic. Government of Malaysia, NKEA demand for 1 million of seaweed every year but no proper structure to meet the demand. Deployment of offshore aquaculture system required efficient mooring arrangement for safety purpose. Comparing simulation mooring of offshore aquaculture plantation with mathematical model is required to check reliability of design and deployment.

This study discusses model test and simulation of the mooring offshore aquaculture system for ocean plantation and investigates the safety and efficiency of the mooring system. The objectives are to access the efficiency of mooring offshore aquaculture seaweed plantation. Simulate using Bureau Veritas Arriane the suitability of mooring configuration for offshore aquaculture seaweed plantation. Determine the reliability of mooring system for offshore aquaculture seaweed plantation.

Mooring System Analysis Requirement

A mooring is required to hold vessel offshore against the forces generated by wind, currents and waves, these aims are not always compatible; a mooring designer can offer moorings which will never fail or break; however, they may hold the vessel so rigidly in position that the system are not break. In sheltered waters, requirements to moor a cage safely were minimal. This situation will change dramatically with moves into coastal waters, and a potentially much higher wave climate. A mooring system for mooring a vessel offshore, which comprises a block located in the water at a depth below expected wave action and at a distance from the vessel; a mooring line extending from line pulling equipment on the vessel through the block and back, for releasable attachment to the vessel; mooring tackle attached to the block and extending away from the vessel to an anchor. A spread mooring arrangement is provided for use in deep water (greater than 200 meters) when it is advantages to maximize the clearance between shuttle tankers used for product offloading and the anchor legs associated with a spread mooring of the permanently moored tanker.

Station Keeping

The caisson can be kept in position by a dynamic positioning system. Dynamic positioning results in a very flexible system, always capable of assuming the optimal position with respect to the wave crests, and continuously adjusting for that. This means an extreme high Opex, which is not realistic so this option may not be considered any longer. The dynamic positioning of surface vessels moored to the seabed via a turret based spread mooring system, an operation referred to as the position mooring.

Mooring Components

Mooring lines are usually constructed out of one or more parts of three different materials; chain, steel wire rope or synthetic fibre rope. Chain is the most common product used for mooring lines. Two different types of chain can be recognised; studless and studlink chain. Studless chain is more suited for this problem because it is better suited for permanent moorings. Steel wire rope has a lower weight and a higher elasticity than chain, for the same breaking load. This can be an advantage in deeper water, when using longer lines. Because of the fact that offshore activities moved into deeper water, an even lighter product was developed; synthetic fibre rope. Most mooring lines consist out of several different materials; for instance, chain at the top and bottom of a line and in between synthetic fibre rope. Mooring lines can mainly be used in two different ways, namely the catenary mooring or the taut leg mooring. With a catenary mooring, the last part of the mooring line is resting on the seabed. The main advantage is that therefore the anchors only need to withstand a horizontal force; the disadvantage is that the system has a quite large footprint. In deeper water the weight of the lines starts to play a role so this type of mooring is not suited for very deep water. Now that offshore petroleum exploration moves beyond 2000 m and targets the 3000 m range, the need for efficient station keeping mooring systems increases, thus requiring solutions such as that presented in this research. In order to define optimum mooring systems, i.e. the mooring systems that lead to the minimum responses of the floating units, the following design aspects should be taken into account:

- The optimization of the platform heading, which is a function of the directional distribution of incoming environmental forces.
- The optimization of the mooring pattern based on spreading and directional variations of the environmental forces, giving due regard to the winch capacities and the fairlead layout and arrangement on the platform.
- Optimum mooring line tension or line length.
- Optimum mooring line materials and sizes.
- Automation of the design procedure in order to minimize the time required to carry it out.

Rules and Regulation for Mooring

Offshore standard contains criteria, technical requirements and guidance on materials, design, manufacture and testing of offshore mooring chain and accessories. The standard has been written for general world-wide application. Governmental regulations may include requirements in excess of the provisions by this standard depending on the size, type, location and intended service of the offshore unit or installation. The mooring system design and simulation will requirement and safety factors set out by API RP 2SK and BV. The mooring should be design to sustain 100-year loop/eddy current. The standards give comprehensive guidance on test to be carried out on mooring system hardware includes the following:

- fluke anchors for mobile/temporary and long-term moorings,
- mooring chain and accessories,
- steel wire rope;
- windlass and winch assemblies,
- manual and automatic remote thruster system.
- Synthetic fibre ropes.

More information can be found in the standards. For example, the UK Health & Safety Executive which gives a comprehensive discussion of model r\testing technique for floating production systems and their mooring systems.

Mooring System Properties and Performance

The mooring system is analyzed and designed using the lower bound static drift stiffness to determine mean offset to static components of the load. The dynamic offsets were then added by using the lower bound dynamic stiffness curve resulting from loads that were dynamic in nature. Similarly, to determine maximum line loads, the upper bound static drift stiffness is required to determine mean offset to static components of the load. The dynamic offsets were then added by using the upper bound dynamic stiffness curve resulting from loads that were dynamic in nature.

Maintenance of Mooring System

The basic philosophy of the maintenance plan is to identify damage or unusual performance of any component of the mooring system or predict a change in material behavior before it affects the mooring system or the station keeping ability of the facility. The plan also gives specific conditions that would require a shut-in of production and what is required before production could commence again.

Mooring Design Simulation

Mooring design and dynamics can be used to assist in the design configuration of oceanographic moorings, the evaluation of mooring tension and shape under the influence of wave, wind and currents, and the simulation of mooring component positions when forced by time dependent currents. The static model predicts the tension and tilt at each mooring component, including the anchor, for which the safe mass will be evaluated in terms of the vertical and horizontal tensions. Predictions can be saved to facilitate mooring motion correction. The Main Menu of mooring simulator provides access to all the major functions available. Initially, no mooring or the necessary environmental conditions are loaded into memory, as data is entered and analysis and display options become available.

Once a complete mooring has been designed, which includes, from top to bottom, floatation, wires, fasteners and instruments, and an anchor, and appropriate environmental conditions have been entered (i.e. current profile(s) have been entered that either exceed the height of the mooring (for sub-surface) or extend to the surface (for shallow or surface moorings), then a solution can be sought. Strongly sheared current profiles may make convergence difficult. The solution is then displayed (either a surface or subsurface mooring), and the total, vertical, and horizontal tensions [measured in kg] acting on the anchor are displayed, followed by 'estimates' of the safe anchor mass necessary to hold the mooring in position, based on both the vertical and horizontal tensions which is used to incorporates drag and lift safety factors. Surface solutions, the approximate percentage (%) of the top floatation device (i.e. the amount of buoyancy) used to hold the mooring in position is displayed. In this way, both the required anchor mass and surface floatation can be evaluated to maintain a specific mooring configuration.

Material and Method

Physical model

The first principle approach involves definition of the mooring system in the simulator in order to evaluate the whole system and the environment that will be imposing on the system. Once the simulation work is concluded, the next step is to build the physical model of the whole system to make a roughly overview for system. By designing the model, it will help us to make more understanding. The physical system can be deployed and monitored before finalizing the design and full-scale deployment plan (Figure 1).

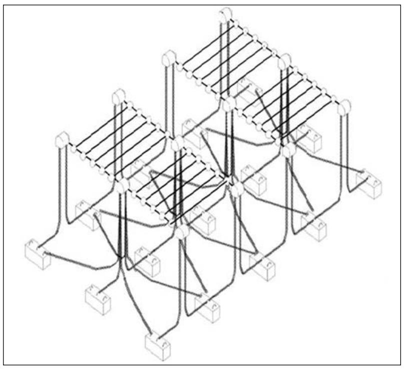


Figure 1a: System motion analysis

Theoretical Model

Each mooring element has a static vector force balance (in the x, y, and z directions), and that between time dependent solutions the mooring has time to adjust. The forces acting in the vertical direction include buoyancy (mass [kg]´g [acceleration due to gravity]) positive upwards (i.e.floatation), negative downwards (i.e. an anchor), tension from above Newtons], tension from below, drag from any vertical current and lift for an aerodynamic device. In each horizontal direction, the balance of forces is angled tension from above, angled tension from below, and drag from the horizontal velocity. Buoyancy is determined by the mass and displacement of the device and is assumed to be a constant for no compression effects and a constant sea water density. The velocity (current) and density profiles and wire/chain sections are interpolated to approximately one metre vertical resolution using linear interpolation. The drag Q in each direction acting on each mooring element is calculated. The elements immersed weight, WI is defined by:

$$WI = FB - W$$

WI is positive, the element is positively buoyant (polypropylene subsurface floats), and if it is negative, the element is negatively buoyant (wire rope and shackles) (Randall, 1997). The drag Q in each direction acting on each mooring element is calculated using:

$$Q_J = \frac{1}{2} P_W C_{Dt} A_J \mathbf{U} U_J$$

Where Qj is the drag in [N] on element 'i' in water of density rw in the direction 'j' (x, y, or z), Uj is the velocity component at the present depth of the mooring element which has a drag coefficient CDi appropriate for the shape of the element, with surface area Aj perpendicular to the direction j. At the depth of the element, the drag in all three directions [j=1(x), 2(y) and 3(z)] is estimated, including the vertical component, which in most flows is likely to be very small and negligible. Once the drag for each mooring element and each interpolated segment of mooring wire and chain have been calculated, then the tension and the vertical angles necessary to hold that element in place (in the current) can use the equation below to estimate the three [x,y,z] component of each element:

$$Q_{xi} P_f(T) = \iint dx_i dr_k$$

Static Analysis

This study allows one to predict the geometry of the line between the platform and its anchoring point and the distribution of stresses from top to bottom. The recurrence formulas for carrying out the computation process for the resultant forces applied at the end of any segment [5]. The tension, the orientation angles, the stretched length and the segment coordinates can now be formulated as

$$Rx_{(n)} = Rx_{(n-1)} + Fx_n$$

Environmental Load

For this research, currents are considered because of the dominant contribution of load compared with wave and wind. In addition, it is expected that drag loads will account for a large portion of the wave-driven loads as well. So, by studying the drag loads first, we hope to quickly arrive at an approximate model that is adequate for the design of major system components. Static current loads are discussed in detail below [4]. Static loads due to current are separated into longitudinal load, lateral load [5]. Flow mechanisms which influence these loads include main rope drag, main buoy drag, seaweed drag, and planting lines drag. The general equation used to determine lateral and longitudinal current load are.

$$F = \frac{1}{2} \rho V^2 A C_d$$

Mooring loads can be computed by means of static or dynamics analysis. Static analysis is appropriate when dynamic motions are not expected, dynamic analysis. Many successful mooring designs have been designed without a dynamic analysis. Dynamic load IS likely when mooring is exposed to ocean wave attack, large winds, rapids wind shift, large currents and current-induced eddies or macro vortices. Environmental loading additional loads on moored floating structures are considered. Static loads due to wind and current are separated into longitudinal load, lateral load, and yaw moment. Flow mechanisms which influence these loads include friction drag, form drag, circulation forces, and proximity effects. Drag coefficients are a function of Reynolds number, Re, as defined as:

$$\mathrm{Re} = UD/\nu$$

Where U is the velocity of the flow, D is the characteristic buoy dimension, and ν is the fluid kinematic viscosity. By summing the forces at the attachment point, component of the tension is given by

$$Th = Fd$$

$$Tv = Fb - W$$

Where Th and TV are the horizontal and vertical tensions in the submerged element; the forces, FD and FB are the drag and buoyant forces respectively, and W is the weight of the buoy. The resultant tension is Total tension on the mooring lines is the other important aspects that have to be considered. Concentrated loads are spread cross the length of the cable and do not be equal. As they are flexible they do not resist shear force and bending moment. It is subjected to axial tension only and it is always acting tangential to the cable at any point along the length. If the weight of the cable is negligible as compared with the externally applied loads then its self-weight is neglected in the analysis.

$$T_{HV} = \sqrt{T_H^{\,2} + T_V^{\,2}}$$

Model Test

A towing test is one method of research to determine the hydrodynamic loading coefficients (added mass and damping) in a few different configurations [6]. The samples which are seaweed are dried, but will restore to nearly nominal properties when soaked in water for a period of time. In typical practice, the rows of seaweed are held using ropes separated by about 2.6 m between rows. For the drag measurement, the seaweed was attached to towing lines and the lines were towed from the moving carriage. A frame consisting of aluminium channel sections attached to the towing carriage is used. The seaweed clumps in turn attach to a rope line. Tension load cells will be attached between the line and the frame and the measured forces recorded on the model basin's data acquisition system.

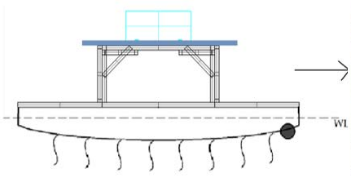


Figure 2a: model test system

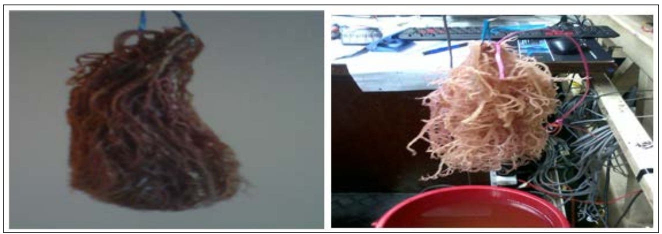
Figure 2b: Test frame construction and deployment

This research tested seaweed in a towed tank to know what the parameters we are going to calculated are. For this research, we will run two parts of testing. The first test will be using (1-meter x 0.5 meter) dimension prototype which will be conducted in Maritime Technology Laboratory. Meanwhile, the second test will be for (4-meter x 2 meter) dimension which be conducted in University of Technology Malaysia Laboratory. The first phase of the test involves:

1. Measure drag loads of seaweed samples (3configs x (3 speeds + 3 waves))
2. Dynamic test to measure added mass and damping using Planar Motion Mechanism (PMM). (3 configs X 3 speeds x 3 periods)

Tests for Seaweed Hydrodynamic Coefficients

Tests is carried out to identify hydrodynamic coefficients of an equivalent Morison model of the seaweed which will be suitable for use in typical mooring design and analysis package such as Arienne. Samples (clumps) of dried seaweed, the dried will restore to nearly nominal properties when soaked in water for a period of time. Typical size seaweed clump weighs up to 1.5kg in air, when fully grown. However, the natural buoyancy of the seaweed, make its weight in water almost insignificant. A sample clump of seaweed weight in air 4.1N and the corresponding weight in water is 0.01N in UTM lab, Figure 3.



a b

Figure 3: Seaweed

A sample row of seaweed is attached to a frame and towed from the carriage. To determine the hydrodynamic coefficient, a series of tests including towing in calm water, towing in waves and wave-only tests will be performed. As mentioned, originally, it was planned to use the PMM to perform forced oscillation tests. The resulting loads can be analysed in a straightforward manner to determine the relevant coefficients which give similar hydrodynamic loads (Figure 4).

However, the PMM system is not functioning at present. So, an alternative plan had to be developed. The main difficulty is that the available seaweed samples represent full-scale (prototype) clumps, whereas, the model basin is equipped to generate wave and current kinematics (wave height <0.4m 0.5s<Period<2.5s, and speed<5 m/s) typical of model scale conditions. Therefore, a mismatch exists between the typical body (clump) dimensions and the relative kinematics that can be generated. Some approximations and simplifying assumptions are needed to utilize the available facilities to determine the required coefficients. The solution chosen at present is to focus on certain key non-dimensional values and try to use the use different scaling factors to apply the results at fullscale. In this way, the kinematics available in the towing tank can be used. For example, it is believed that the physical behaviour of seaweed may be similar to that of cylinders in waves and currents. Therefore, the approach closely follows that of the commentary section of the API RP-2A.

Environmental Load Consideration

The weather in Malaysia is mainly influenced by two monsoon regimes, namely, the Southwest Monsoon from late May to September, and the Northeast Monsoon from November to March. However, the east coast of peninsular Malaysia is the area that exposed directly to the strong sea currents and periodic monsoon season which is prevalent off the east coast. Furthermore, with the existence of nature elements of the deep and open water environment, seaweed farming is hard to be applied in this area. Regular waves were considered and generated by the wave maker for a few tests. Random wave's spectrum was based on the Jonswap spectrum for less than 1Yr or for 1Yr or greater, respectively. Froude scaling was applied to establish the relationship between full scale wave height (Hp) and period (Tp) and the corresponding model scale wave height (Hm) and period (Tm), where $Hm = Hp/50$ and $Tm = Tp/\sqrt{50}$. Incident waves will be measured and analyzed prior to the tests. Two wave probes will be installed for calibrations: one in front of the carriage at the basin centreline and one to the side of the nominal position of the model. Wave force vector is generally expressed as the sum of linear wave force proportional to wave height and the slowly varying drift force proportional to the square of the wave height (Table 1).

Table 1: Full Scale Wave

Return Period (Year)	Full Scale Wave Height (m)	Full Scale Wave Period (s)
90%	4.599	9.711
95%	4.850	10.25
1/12th	0.6	1.295
1-Yr	5.110	10.79
10-Yr	10.7	12.82
100-Yr	7.3-13.6	11.1-15.1

Mooring design for offshore platforms makes use of software tools which have been benchmarked against model tests, computational data and full scale measurements for their given applications. Hydrodynamic loading on the platform, risers and mooring system itself due to waves and currents are calculated using a variety of tools such as potential flow, CFD and empirical data.Wave current flow reversal effects (r=ratio of current/wave orbital velocities) are expected to be similar to those for cylinders, though perhaps somewhat more complex and with different regimes for seaweed. Table 1 (a, b) below shows the nondimensional parameters for a series of seastates, typical of the Southeast Asia metocean climate. Note, it is not envisaged to design the seaweed mooring for extreme environments such as rare 100-year events, typically used for offshore platforms, because the consequences of potential failure, while still undesirable, are considered much less severe.

For the determination of coefficients, the KC number will be preserved. The KC number for all the seastates is KC>12, so, relatively large wave velocities are present. Also, the effect of flow reversal can be maintained, at least in the near surface zone where the seaweed floats, by running the same waves at similar speeds. It is remarkable that the wave kinematics are very similar for all the different seastates. Therefore it is possible to greatly simplify the tests plan by appropriate choice of the scaling factors for each seastates. In fact it is sufficient to tests a single wave to produce scaled wave kinematics for all the conditions, at least for the important parameter of wave velocity at the surface. For example, the effects on hydrodynamic loading of Keulegan-Carpenter number:

$$KC = \frac{2\pi A}{L}$$

where, A= amplitude of wave partical motion, L= typical length of a seaweed clump

Table 2a: Fullscale Seaweed Parameters

Model scale		6	12	16	30
Exceedence Prob/ Return Period		50%	90%	99%	1-year
Hs	m	0.15	0.15	0.18	0.17
Hmax	m	0.32	0.30	0.34	0.32
Amax	m	0.16	0.15	0.17	0.16
Tp	S	1.88	1.85	2.00	1.95
Tasso	S	1.76	1.73	1.85	1.83
Uc	m/s	0.09	0.14	0.20	0.29
Mass	g	6.94	0.87	0.37	0.06
Length, L	cm	8.00	8.00	8.00	8.00
Amax/L		1.98	1.88	2.11	2.00
Diameter, D	cm	1.00	1.00	1.00	1.00
Amax/D		15.8	15.0	16.9	16.0
Uw	m/s	0.57	0.54	0.57	0.55
U	m/s	0.65	0.68	0.77	0.84
Uc/Uw		0.15	0.25	0.34	0.53
r=Uw/Uc		6.61	4.01	2.95	1.87
KC No.= 2πA/L		12.4	11.8	13.3	12.6
Re No. = UL/v		52,195	54,385	61,450	67, 566

Table 2b: Proposed Model scale Parameters

Exceedence Prob/ Return Period		50%	90%	99%	1-year
Hs	m	0.9	1.8	2.8	5
Hmax	m	1.9	3.6	5.4	9.6
Amax	m	0.95	1.8	2.7	4.8
Tp	s	4.6	6.4	8	10.7
Tasso	s	4.3	6	7.4	10
Uc	m/s	0.21	0.47	0.78	1.61
Mass	g	1500	1500	1500	1500
Length, L	cm	50	50	50	50
Amax/L		1.9	3.6	5.4	9.6
Diameter, D	cm	1	1	1	1
Amax/D		95	180	270	480
Uw	m/s	1.39	1.88	2.29	3.02
U	m/s	1.60	2.35	3.07	4.63
Uc/Uw		0.15	0.25	0.34	0.53
r=Uw/Uc		6.61	4.01	2.94	1.87
KC No. = 2πA/L		11.9	22.6	33.9	60.3
Re No. = UL/v		799,073	1,177,478	1,536,257	2,312,964

What varies between seastates is actually the current velocity, and resulting ratio r, of wave/current velocities. For the present, tests, it is decided to focus on deterministic, regular waves, representing the worst design wave for each seastate. These waves are characterized by Hmax and associated period Tasso. Therefore, the tests can be carried out by using the same wave and changing the current velocity for each seastate. As these tests are currently ongoing, results will be presented as they become available in time for the conference.

Figure 4: UTM Towing Tank and Carriage

Scale Model Tests

The hydrodynamic loads measured will be used to build approximate scale models of the seaweed. The model seaweed will mimic the Froude-scaled properties (mass, dimensions, added mass and damping) of the seaweed measured previously. Suitable material such as plastic ribbon, rubber tubing or even young seaweed seedlings will be used to build a sufficiently quantity of scaled seaweed. The tests of floating structure in regular and irregular waves will be carried out in the towing tank 120m x 4m x 2.5m of Marine Technology Laboratory UTM. This laboratory is equipped with the hydraulic driven and computer-controlled wave generator which is capable to generate regular and irregular waves over a period range of 0.5 to 2.5 seconds. For this structural experiment, a model of 2m x 2m per block with 50 scale rations will be used. The floating structure dimension and model are shown in Table 2, Figure 5. Important variable quantities of importance are derived from the equation and dimensional analysis below.

Table 2a: Structural dimension

Linear	$l_p = \lambda\, l_m$
Speed	$u_p = \sqrt{\lambda}\, u_m$
Mass	$m_p = \lambda 3\, m_m$
Force	$F_p = (\lambda 3 / 0.975) * F_m$
Time	$t_p = \sqrt{\lambda}\, t_m$
Stress/Pressure	$S_p = \lambda\, S_m$

One of the important task in planning a model test is to investigate the modeling laws required for the system in question to be analyzed. The scaling parameters is very important in designing a model test and a few key areas of consideration in replicating a prototype structure for a physical model test. In order to achieve similitude between the model and the real structure, Froude's law is introduce as the scaling method. Froude's law is the most appropriate scaling law for the free and floating structure tests (Chakrabarti, 1998). The Froude number has a dimension corresponding to the ratio of u2/gD where u is the fluid velocity, g is the gravitational acceleration and D is a characteristic dimension of the structure. The Froude model must satisfy the relationship:

$$u^2_p / gD_p = u^2_m / gD_m$$

Figure 5: Scale model of the physical system

Table 2b: Structural dimension

Structural properties (one block)	No/Quantity	unit
length overall	100	m
breadth	100	m
main buoy	4	
main rope	4	
load line rope	30	
sea water density	1025	Kg/m^3

Physical System Analysis

Component of the full-scale platform and mooring cable characteristic first need to be clarified, a typical block has an overall length of 100 meter and the breadth is 100 meter. One block of seaweed farming contains four main ropes for the frame, four main buoy and 30 load lines on which is the seaweed will be planted. Table 1shows the structural properties of one block of seaweed farming. For station keeping each mooring element has a time static vector force balance (in the x, y, and z directions), and that between time dependent solutions the mooring has time to adjust. The forces acting in the vertical direction are buoyancy (mass [kg]´g [acceleration due to gravity]) positive upwards (i.e. floatation), negative downwards (i.e. an anchor), tension from above Newton], tension from below, and drag from any vertical current.

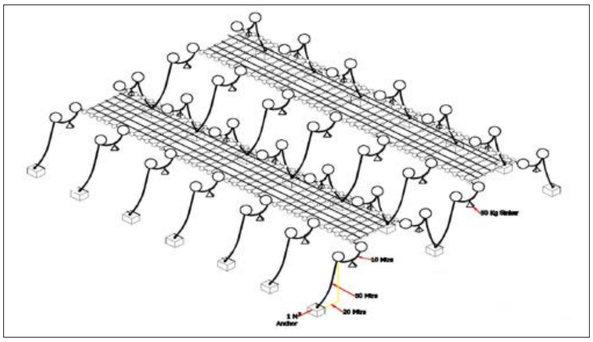


Figure 6: System to system interaction

In each horizontal direction, the balances of forces are: (1) angled tension from above, (2) angled tension from below, and (3) drag from the horizontal velocity. Buoyancy is determined by the mass and displacement of the device and is assumed to be a constant (no compression effects and a constant sea water density). Other challenges in this design are system multibody analysis in respect to analysis and keeping the whole system together and system to system interaction (Figure 6).

Simulation

At the end of this research, can determine whether this model will be able to withstand the environment conditions and suitable for "Deep Ocean" peninsular farming activities or not. Based on the result from two tests which will be running in Maritime Technology Laboratory and National Hydraulic and Instrumentation Laboratory, the final result shall be concluded to support the authenticity of this research proposal. Once a movie has been generated and/or loaded, it can be displayed. At this time the user can select the number of times the movie is to be cycled through. It may appear that the movie is always played at least twice. This is because Matlab® loads the frames first, and then plays the movie the desired number of times, at the selected fps may not play the exact fps, but this does provide relative speed control. In addition, the actual frame rate realized may depend on the memory and speed of the computer used to display the movie. The "Figure Scale Factor" is also displayed, although there should be no reason to change this value at show time, as it was set when the movie matrix was created. Re-setting the "Figure Scale Factor" here will set the figure window size, but not the size of the axes stored in the movie matrix. Note that the projection of the mooring wire/rope is plotted on all three planes. This allows one to see the extent of the displacement in the X, Y and Z directions. Clicking "Play Movie" will do exactly that.

Result

System Creation

Four samples of current speeds are taken. The current speeds start with 0.5 m/s, 1 m/s, 1.5 m/s and 2 m/s. The maximum lateral current load occurs when the structure is subject to2 m/s of current speed which has the value just over 20,000N, as shown in the figure 7. The current load increases when the current speed increases for both longitudinal and lateral load. The graph indicates that the longitudinal loads are higher than the lateral load. This is because the longitudinal current speed is moving horizontally to the x- axis of the structure (up and down in the figure) which results in the bigger load from the planting lines.

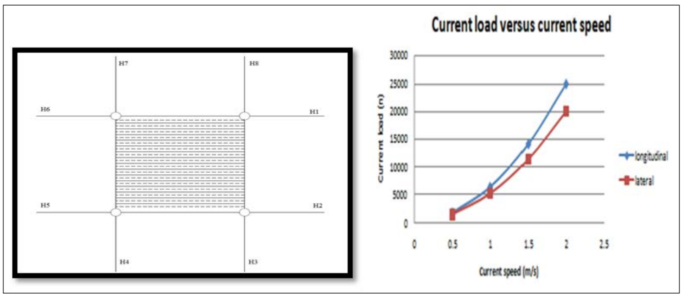


Figure 7a: Model from mathematical analysis

Figure 7a: Graph showing current load versus current speed, Figure 7b: Spread Mooring Analysis for one block showing force diagram for the mooring system. The mooring consists of H3, H4, H6, and H7 mooring lines, which resist longitudinal load, and four mooring lines, H1, H2, H4 and H5 placed perpendicularly to the longitudinal axis of the structure, which resist lateral load [7]. The maximum allowable working load, Tbreak is 39,865.6 N. Figure 7 b shows model crated and being simulated using Arianne, result will be provided in other publication.

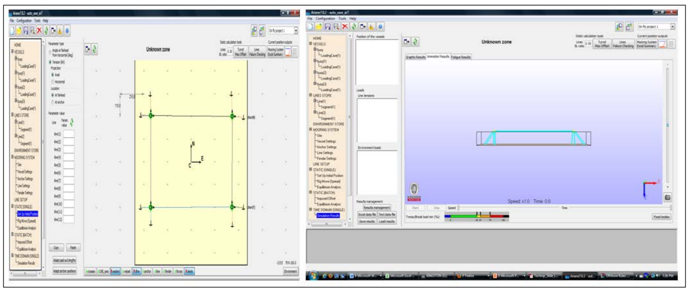


Figure 7b: Model created in Arianne simulator

Tow One Line Transverse across Basin (90 Degree) At Different Current Speed

(Figure 8) shows how the strain increases with respect to current velocity. At the slow current speed, 0.1 m/s until 0.3 m/s, the strain increases very short due to the small drag acting on the planting line and seaweed. At the medium speed 0.5 m/s, the strain begins to increase rapidly and by high speed current on 1.0 m/s and 1.2 m/s it continues to increase rapidly due to high effect of drag on the line.

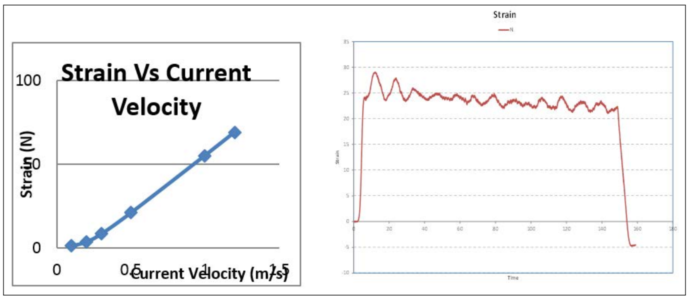


Figure 8: Current Velocity versus Strain

Meanwhile, to get the accurate result, the results of each graph need to be filtered by ignoring the unreliable data which might probably disturb the sensor during experiment. Then, select certain period from the whole graph which is in certain range and then find the average from the selected data.

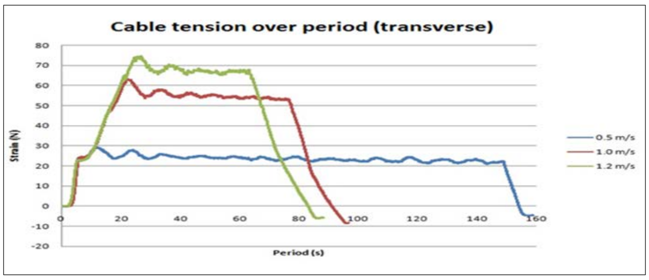


Figure 9: Cable Tension at Different Current Velocity (90 degree)

(Figure 9) above shows the comparisons of each line tension at different current speed when the line is pull over 90 meter towing tank. At 0.5m/s, 1.0m/s and 1.2m/s the average tension is 69N, 55N, and 25N. Through the comparison of each graph, it can be seen clearly that the difference of strain between each speed is not increase uniformly. This matter probably affected by the properties of cable material use for this experiment is not being considered very well.

Tow Two Line Transverse across Basin (90 Degree) At Different Current Speed

This experiment is conducted by pulling two lines with the frame along 90-meter towing tank. The aim of this experiment is to see the reduction of drag force from the first planting line to the second planting line. From the result can estimate the percentage of drag reduction after passing each planting line. The outcome can be used to estimate the total reduction for all the planting line of floating structure. (Figure 10a, 10b, 10c, and 10d) prove the differences of drag force value acting at first and second planting line. The percentage of reduction can be obtained by calculating the value of reduction from the entire graph.

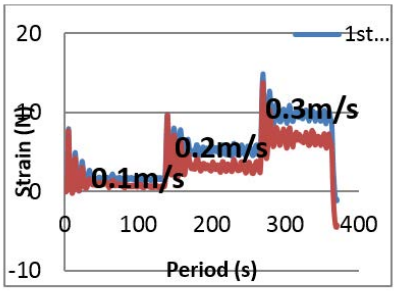


Figure 10a: Two Planting Line Strain over Period at 0.1m/s, 0.2m/s, 0.3m/s

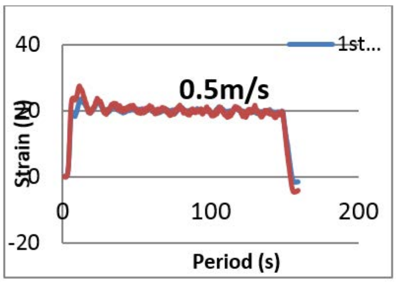


Figure 10b: Two Planting Line Strain over Period at 0.5m/s

From the (Figure 11a and 11b), the difference of tension between first and second planting line is very small due to the slow and medium current speed. The slow speed current produced low drag force to the planting lines and effect of the cable tension. From both graph the range of tension difference is only between 1 to 4 Newton.

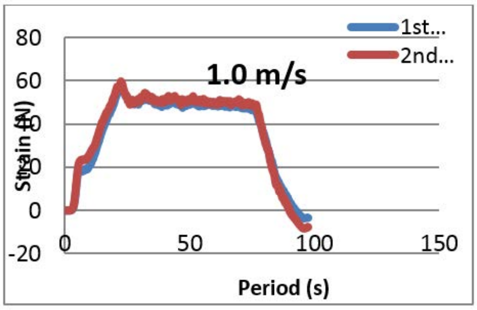


Figure 11a: Two Planting Line Strain over Period at 1.0m/s

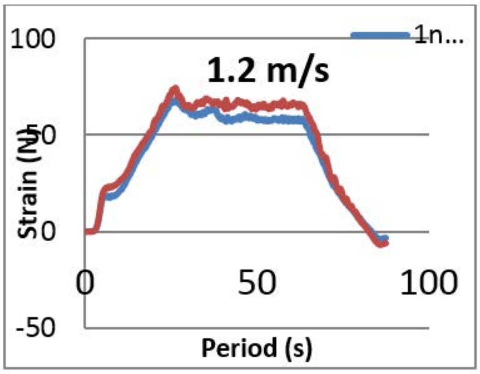


Figure 11b: Two Planting Line Strain over Period at 1.2m/s

Meanwhile, at the high-speed current (Figure 9c, 9d), the difference between first and second plating line is higher, which is about 5 to 10 Newton. From this figure value, can estimate the average reduction for planting line at the current direction of 90 degree is about 0.1 percent to 0.2 percent. Using this percentage, can calculate the total reduction of drag force for complete floating structure when the current facing the structure at 90 degree.

Tow One Line Diagonally Across Basin (45 Degree) At Different Current Speed

On the third test, the experiment is to drag the line diagonally at 45 degree. The result already estimated to be lower than the current direction of 90 degree. From Figure 10 the graph, the result show cable tension at 45 degree is less about half of the 90-degree current direction. At 0.5m/s, 1.0m/s and 1.2m/s the average tension is 12N, 27N, and 34N. This experiment proves with the different degree impact of current to the planting line, the value of drag also would be different.'

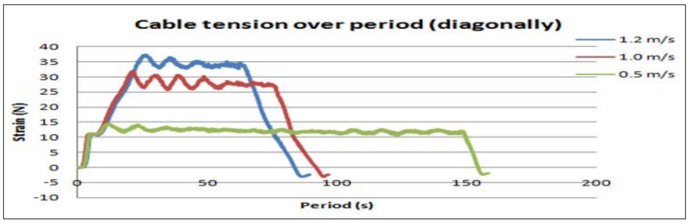


Figure 12: Cable Tension at Different Current Velocity (45 degree)

Tow Two Lines Diagonally Across Basin (45 Degree) At Different Current Speed

Tow two line at 45 degree of current speed experiment shows the comparison with the 90-degree current direction. The result obtain from the experiment is much less than the 90-degree direction. The other reason is since the first planting experience much less drag force, the second planting line can be affecting with lower drag force after reduction.

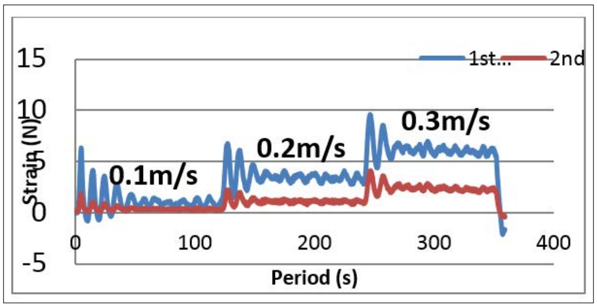


Figure 13a: Two Planting Line Strain over Period at 0.1 m/s, 0.2 m/s, 0.3 m/s

(Figure 13a, 13b, 13c), show the tension value from the current effect. The percentage of drag reduction to the second planting line is higher compared to the 90 degree drag direction. The rational is, the cable tension become less with the small drag from the current at this state. Therefore, from the average value of tension from 0.1 m/s, 0.2 m/s, 0.3 m/s, 0.5 m/s and 1.0 m/s, the reduction of drag is estimated to be within 0.1 percent to 0.3 percent which is higher than 90 degree drag direction.

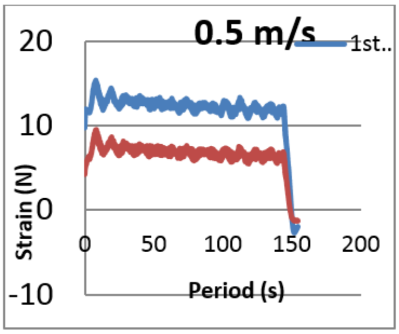


Figure 13b: Two Planting Line Strain over Period at 0.5 m/s

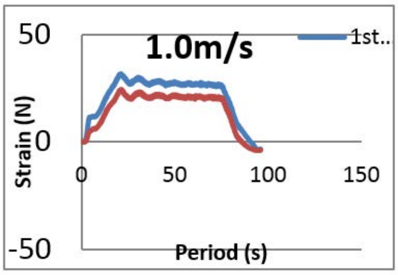


Figure 13c: Two Planting Line Strain over Period at 1.0 m/s

Tow One Line Longitudinally Along Basin (0 Degree) At Different Current Speed

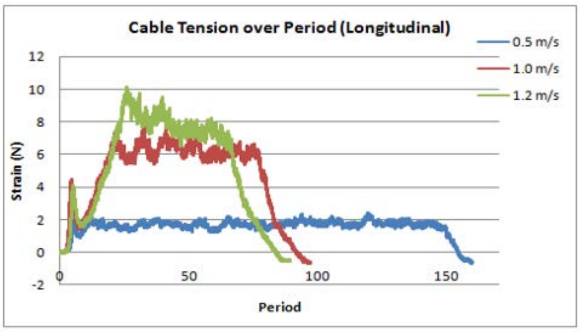
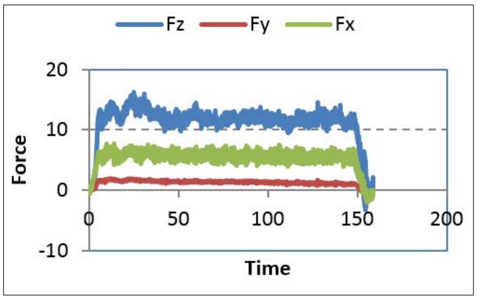
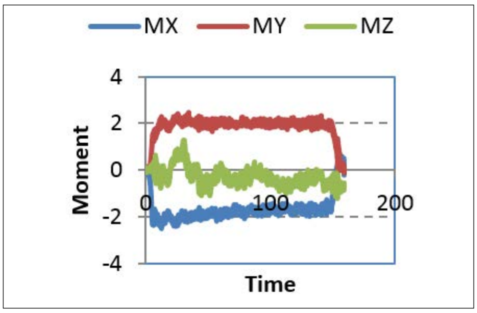


Figure 14: Cable Tension at Different Current Velocity (0 degree)

At 0 degree of current direction, the floating structure is estimated to experience the smallest drag force. It happens because from zero direction, all the components from the floating structures is having the minimum drag effect due to very small cross-sectional area of the components. The biggest contributors to this structure are seaweed and planting line. From the (Figure 15) At 0.5 m/s, 1.0 m/s and 1.2 m/s, the average tension recorded from the graph are 1.9N, 6N, and 7N. This value prove that the drag force experienced by all these lines is very small compare to the 90 degree and 45-degree current direction. All the value can be referred to the previous graph. Figure 16 shows the moment relation for the force components. Fx has more effect as expected.





Conclusion

Aquaculture farming is widely being practice onshore or near shore, due to uncertainty about the force nature of nature, lack of established design methodology, rules and guideline. The case presented represents real life solution research to solve problem facing aquaculture industry offshore. Extreme current speed is considered for the test. The result obtained represent meaningful information for the design and simulation towards reliable deployment of very large floating oceanic structure for seaweed farming and another aquaculture farming. Ocean plantation such as seaweed are very beneficial to the economy. It gains a lot of order from the world as food or cosmetics. To make it successfully to meet the demand, the system will can provide required station keeping by simulating the mooring system to know the characteristics of the mooring system [1-8].

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