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WINDFLOAT: A FLOATING FOUNDATION FOR OFFSHORE WIND TURBINES
PART III: STRUCTURAL ANALYSIS

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ABSTRACT

WindFloat is a floating foundation for large offshore wind turbines. This paper describes the structural engineering that was performed as part of the feasibility study conducted for qualification of the technology. Specifically, the preliminary scantling is described and the strength and fatigue analysis methodologies are explained, focusing on the following aspects

- the coupling between the wind turbine and the hull
- the interface between the hydrodynamic loading and the structural response.

Prior to reading this manuscript, the reader is strongly encouraged to read the related paper, which focuses on the design basis for the WindFloat, and explores the requirements that must be addressed by the design teams in this new field. An additional paper in this series describes the hydrodynamic analysis and experimental validations.

KEYWORDS

Ocean Renewable Energy, Floating Foundation for Wind Turbines, Offshore Wind, Structural Design, Fatigue, Strength.

INTRODUCTION

Interest in offshore wind energy production has increased significantly in the past 10 years. A number of solutions to install wind turbines using fixed foundations exist. However, in deep waters, which require the use of floating platforms to support the turbines, technology is still being developed and research is ongoing.

The WindFloat is a floating foundation for large wind turbines based on a small column-stabilized semi-submersible platform with one column supporting the tower for a large wind turbine. As part of the design qualification process, a global structural analysis must be performed and structural sizing and reinforcement of the components of the WindFloat achieved. The structural assessment of the design necessitates the use of a methodology and design criteria that account for the specificities of the structure. Large wind forces and hydrodynamic loading need to be accounted for accurately. In the absence of full-scale experience, the foundation is designed according to a combination of recommendations for offshore oil and gas platforms, and for fixed offshore wind turbines. To ensure the design is sufficiently conservative, an extensive numerical analysis is carried out on all novel parts of the structure, such as the truss connecting the columns together and the turbine tower and its interface with the hull. In a later phase of the project, structural optimizations of the platform will be carried out to reduce overall steel weight.

A review of the available design codes for the WindFloat is presented briefly, along with a summary of the main characteristics of the platform and preliminary scantling of the columns. The present paper focuses on the design of the truss and tower with finite-element analysis using the full description of environmental loads on the platform from hydrodynamic analysis. Strength and fatigue analysis are performed. The design of the tower is of particular interest, since it is at the interface between the floater and the wind turbine.

Space does not permit a complete description of the system, in particular wall thicknesses in various parts of the structure. The intent of this paper is not to provide specific results for a given geometry, but rather to expose practical methodologies that can be used for design, while including all significant hydrodynamic and aerodynamic loading contributions.

GENERAL DESCRIPTION OF THE WINDFLOAT STRUCTURE

The WindFloat is a small semi-submersible platform stabilized by three cylindrical columns (Figure 1). A hexagonal water-entrapment plate at the bottom of each column provides high heave added-mass and viscous damping and contributes to the control of the motions, as described in a related paper on the hydrodynamic analysis. The main elements to consider in the structural analysis of the floater consist of the columns, the water entrapment plates, the truss and the tower.

A truss made of horizontal and diagonal tubes connects the columns rigidly together. The truss is composed of six large horizontal pipes spanning the distance between columns and connected at the top and bottom of each column. These six primary members are supported by twelve diagonal bracings connected to the columns on one end and to the primary horizontal members on the other end at about a third of their length. Horizontal bracings finally connect the primary members together at a third of their length, forming three-dimensional nodes. There are three such bracings connecting the three lower primary members, and three at the top.

The tower is made of a number of sections with constant diameter and wall thickness which are welded together. At its lower end, the tower is connected to the top of a stabilizing column of the platform. The connection is located above the wave zone, with a clearance above the largest wave crests. The tower diameter is smaller than the column. A heavily stiffened top of column section is designed to carry the tower loads into the column shell. The yaw bearing is installed at the top of the tower and keeps the turbine headed into the wind. The nacelle is placed on a slew ring at the top of the tower.

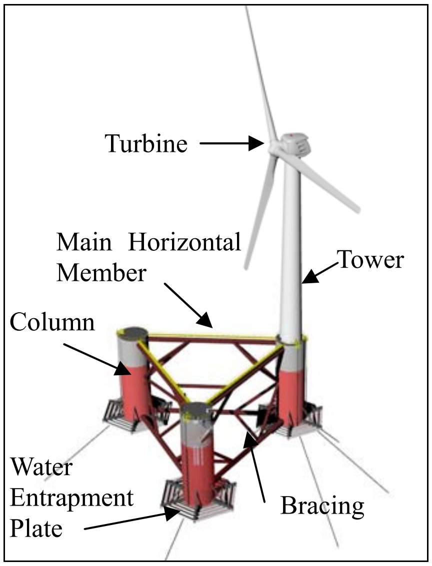

Figure 1: WindFloat Key Components

The columns are commonly used elements in floating offshore platforms and one may rely on standard industry criteria such as the ABS rules for column-stabilized units for their design. The external cylindrical shell is stiffened with regularly spaced ring girders and vertical L-shape stringers to provide sufficient local and global buckling stiffness to the column. Scantling of the structural elements of the hull aims to determine the thickness of shells, girders and webs as well as the size of their stiffeners and flanges. Since deeper shells are subject to larger pressure loads, the hull is divided horizontally into four sections which are sized according to their largest head overflow. This helps reduce the amount of steel required to build the columns. It is important to note that such rules have been designed to extremely low failure rates for structures undergoing heavy operational burden, such as Mobile Drilling Units. Constraints include the ability to withstand collisions with supply vessels, the ability to support heavy equipment including rotating machinery, and frequent moves over large distances. These will undoubtedly result in overly conservative scantlings for offshore renewable energy systems. Further studies will be aimed at minimizing structural weight while ensuring sufficient robustness, and will require extensive use of reliability analysis.

Structural design of the water entrapment plates at the keel had to be carried out numerically since design codes do not provide specific guidelines for such components. The authors have performed finite-element analysis of the heave plates for a variety of projects, including a minimal water-injection platform for deepwater marginal oil & gas fields, which is similar in payload and displacement, and whose water entrapment plates have the same edge length and surface area. The results described by Aubault et al. (2006) are used to determine the size of stiffeners and stringers on the water entrapment plate as illustrated in Figure 2.

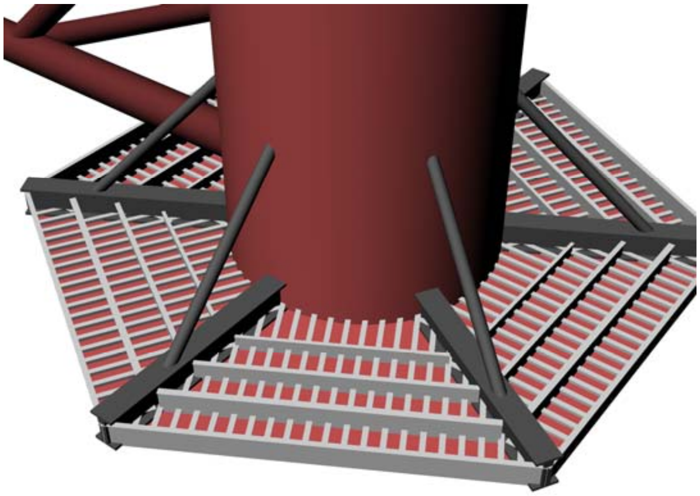

Figure 2: Detail of Structural Reinforcement of Water Entrapment Plate on WindFloat

Although structural optimizations of the heave plate will enhance project economics, the penalty for over-design of the heave plates is relatively minimal, as additional steel located at the vessel keel contributes to the platform stability, and can be compensated by ballast water, the largest weight contribution to the platform once installed.

The discussion herein focuses on the numerical analysis of the truss and tower of the WindFloat to verify their structural reliability in strength and fatigue.

DESIGN CODES AND ENVIRONMENTAL CONDITIONS

The WindFloat is a novel offshore structure which combines a wind turbine and a floater. No formal design code has been developed yet for the design of structural reinforcement and scantling. Existing standards for offshore wind turbines were developed in the last decade from knowledge of onshore wind turbines and growing experience in near-shore operations of wind energy devices. However, their scope remains limited to wind turbines in shallow waters with fixed foundations.

The WindFloat is a moored platform with a complex dynamic behavior which cannot be overlooked in the structural design of critical elements such as the tower. Although offshore wind energy codes such as the Germanischer Lloyd Guidelines for the Certification of Offshore Wind Turbines (2005) provide critical information about the extent of wind loading on the structure, the design criteria may not be sufficiently conservative for a floater.

To ensure a high reliability of the design, the structural analysis of the WindFloat is largely based on standards from the oil and gas industry, including the ABS rules for Mobile Offshore Drilling Units (2001) and the API Recommended Practice for Fixed Offshore Platforms (2000). The DNV Recommended Practice C202 is used to assess shell buckling of the tower. These design criteria need to be combined with a realistic model of the wind loading effects and conservative estimation of environmental loadings on the hull.

The environmental loadings in both cases are obtained for sea-states in the wave scatter diagram encountered at the intended location of the WindFloat, off the coast of Northern California. For each peak period (Tp) in the wave scatter diagram, the sea-state with highest significant wave-height (Hs) is identified. The twelve resulting sea-states with characteristics listed in Table 1 represent the steepest wave conditions for each peak period. The strength analysis may be based on these sea-states. All peak periods are included in the strength analysis since wave loading depends on wave length. The largest wave height does not necessarily result in largest loading on the platform. The fatigue analysis requires the generation of extensive numerical data. The fatigue damage must be calculated for all sea-states in the wave scatter diagram, based on a time series of nominal stress. To avoid the production of large amounts of data and to save CPU time, the stress range is computed only for those 12 identified sea-states. For a given peak period the level of stress is assumed to be linear with significant wave height. Thus, the level of stress is scaled with significant wave height to complete the wave scatter diagram and determine the fatigue life of all structural elements.

Table 1: Sea-states for Structural Strength Analysis

Case #	Tp (sec)	Hs (m)	Hs (ft)
01	20	12.5	41.0
02	16.7	11.5	37.7
03	14.3	9.5	31.2
04	12.5	8.5	27.9
05	11.1	7.5	24.6
06	10	7.5	24.6
07	9.1	7.5	24.6
08	8.3	6.5	21.3
09	7.1	5.5	18.0
10	6.3	4.5	14.8
11	5.3	3.5	11.5
12	4.2	1.5	4.9

For each of the sea-states in Table 1, a 1-hour time-domain analysis is run using the hydrodynamic code TimeFloat v2.1. TimeFloat solves the 6-degree of freedom equations of motion of the floater using the linear radiation and diffraction coefficients and drift coefficients from WAMIT combined with the non-linear mooring forces and moment and wind loads on the turbine. A Jonswap spectrum of the irregular waves in Table 1 is combined with mooring tension from four mooring lines and a 50 knot wind speed on a 5MW turbine. Their effect on the structural response is analyzed for a number of headings between 0 and 180 degrees.

Germanischer Lloyd (GL) recommends that the wind force be applied as a function of wave conditions. Since the wind force reaches a maximum in operational conditions at a moderate wind speed and decreases with increasing wind speed, the wind force applied on the tower for large sea-states would actually be lower. Also, GL limits the scope of the analysis to operational sea-states from the scatter diagram and 50 year return period sea-states in shut down position. For this paper, results were generated for a 100 year return period, and operational condition assumed a constant wind force equal to the maximum thrust generated by a 5MW turbine. For operational conditions, further analysis is required to assess the effect of aerodynamics on the turbine. The use of a turbulent aerodynamic model is recommended. Subsequent work involves a newly coupled version of FAST and TimeFloat to generate accurate aerodynamic loading. The work described in this paper is mainly geared towards the effects of wave loading on the structure.

For the truss and the tower of WindFloat, a strength analysis and a fatigue analysis is carried out. The computation of local forces and moments is achieved with finite-element software SAP by Computer & Structures, Inc using beam theory. The structural calculations are linear. A static analysis is sufficient on the truss, since the natural period of its elements are too low to be excited by environmental loading. However, a dynamic analysis is necessary to account for the excitation of the natural period of the tower. The applied loads are obtained from TimeFloat time-series for each sea-state. External forces and moments are applied at the extremities of the tubular elements in the finite-element model or as distributed loads. For the dynamic analysis of the tower, the acceleration load calculated in TimeFloat is directly applied at the base of the tower.

The purpose of this study is to identify the weakest points on the elements and run a preliminary structural analysis to ensure the reliability of the elements. For the strength analysis, the most extreme stresses are used to compute recommended strength ratios. When necessary, the thickness of the tubular elements was adjusted to meet the appropriate safety factors in strength. On tubular elements, fatigue assessment is especially critical at the joints. A hot spot stress approach as recommended in API is used to estimate the fatigue at the joints between bracing elements. This method entails the calculation of stress concentration factors at the joints. The fatigue life is computed based on the nominal stress as provided by a beam-column finite-element model multiplied by the stress concentration factor (SCF). The damage and fatigue life are computed with a formulation from DNV Recommended Practice RP-C203 for a short term Rayleigh distribution of stress levels.

The annual damage for all sea-states and in 3 directions is combined with Miner's rule:

$$D = \frac{T_d}{A} \times \Gamma\left(1 + \frac{m}{2}\right) \sum_{seastates} p_i \nu_i \left(2\sqrt{2}\sigma\right)^m \qquad (1)$$

where σ is the range of the nominal stress, p_i the probability of occurrence of a sea-state in any given year and ν_i the frequency of cycles which may be taken to the zero-up crossing frequency.

STRENGTH AND FATIGUE DESIGN OF THE TRUSS

The primary function of the truss is to provide the WindFloat hull with sufficient global structural stiffness to withstand environmental loads.

A three-dimensional model of the WindFloat is created (Figure 3). The columns and bracing are modeled with tubular Grade 50 steel beam-column elements. Main horizontal bracing are 150ft (45.7 m) long cylinders that support the horizontal loads between columns. Light bracing members provide reinforcement at 1/3 of their length. These bracing members are diagonal between main bracing and column for vertical stiffness and horizontal between main bracing elements to provide horizontal stiffness. The joints between the column and the bracing are modeled with an element of stiffness ten times that of the bracing element, consistent with API recommendations. The water entrapment plates are not included in this model, but the applied forces on the plates are calculated externally and transferred to the base of the columns.

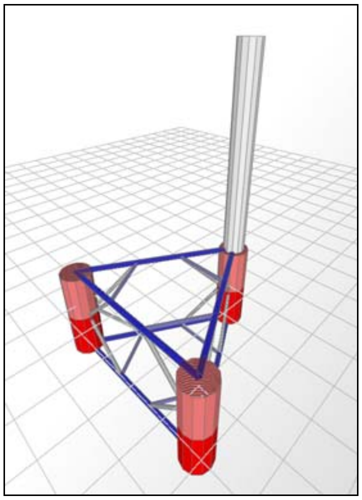

Figure 3: Truss Finite Element Model

External and inertia forces applied to each structural member are computed using a dedicated software, based on the TimeFloat program, which computes hydrodynamic loads by integration of the diffraction and radiation pressures on each part of the structure. The software also matches the hydrodynamic panels with corresponding structural elements. The force components passed to the finite-element model include weight of all elements, radiation and diffraction pressures, as well as mass inertia and hydrostatic stiffness effects. Wave exciting forces, including Froude-Krylov effects, are passed via the diffraction pressure. The viscous forces, reflecting viscous loads on heave plates, columns and truss members, are applied to the corresponding parts of the structure. The mooring forces are applied vertically to the chain stoppers at the top of column since they put the column in compression. The horizontal component of the mooring is applied to the fairlead at the keel, with a 45 degree top angle. The wind forces are applied horizontally at the top of the tower. Drift forces are neglected since they are relatively small on individual elements. It is verified that the sum of external forces and inertia forces on all parts of the structure is approximately null.

The truss consists of unstiffened tubular elements. For the analysis of tubular members, API RP2A-WSD defines allowable axial, bending shear and hoop stresses. Maximum predicted stresses on the elements in design environmental conditions are computed with finite element analysis. The overall structural reliability of a member is estimated by combination of the maximum to allowable stress ratios with appropriate safety factors. All computed ratios must be less than 1 to comply with API.

The stress on the truss is determined using a static finite-element algorithm on the model subject to all environmental loads including rigid-body dynamics contributions. To capture the highest stress level, the forces are calculated for a 1-minute snapshot of the most extreme wave of a 1-hour simulation on all relevant sea-states for three headings.

The maximum API stress ratios increase with larger sea-states. Thus, sea-state #1, with the largest significant wave height, is associated with the maximum stress ratio at 90 degree heading for most frame elements. Figure 4 represents the maximum API ratios calculated in the worst case, at 90 degree heading for sea-state #1, plotted directly on the structure. The shell thickness and diameter of the truss elements were adjusted to ensure compliance with API criteria.

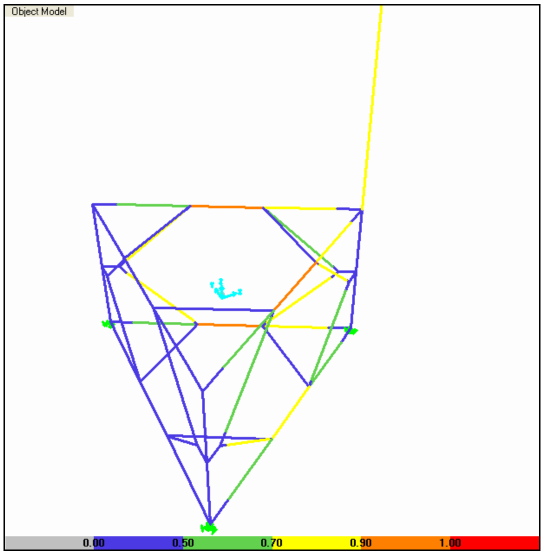

Figure 4: Maximum Design Ratios on WindFloat Platform in 90 degree heading sestate #1

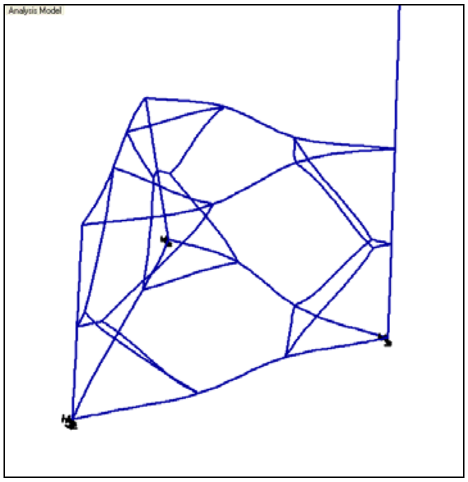

Figure 5: Deformed (50X) shape of WindFloat structure in worst loading conditions (seastate #1 at 90 degree heading).

It was determined through further analysis that the wind loads were driving the design of the truss in strength analysis. Figure 5 illustrates the effect of wave and wind loading on the shape of the truss: the main horizontal bracing elements undergo significant bending.

Next, the fatigue analysis is performed on the truss. The target design life of the WindFloat is 20 years. A safety factor of 10 is applied and a calculated fatigue life of 200 years is required.

The fatigue analysis is critical at the joints between bracing elements and the fatigue life of the connection is determined based on the stress ranges calculated by beam theory. To apply the hot-spot stress curve, the stress concentration factor needs to be determined. For a nominal stress away from the geometrical discontinuity on a simplified model of the tubular element, it is reasonable to expect the SCF to be between 4 and 6 for a well-designed connection. The Von Mises stress at the connection obtained from beam-column finite-element modeling is used as nominal stress in this case. This approach accounts for part of the stress concentration at the connection, since the rigidity of the connection is included in the beam-column model. Thus, a lower concentration factor may be assumed. A sensitivity analysis is carried out on the value of the stress concentration factor. The exact stress ratio between the maximum stress at the weld and Von Mises stress in beam theory will be determined precisely by finite-elements analysis with a 3D model of the connection in follow on studies.

It should also be noted that weld profile control is assumed at the joints of truss elements so that the API X-curve may be used to define the relationship between hot-spot stress range and number of cycles to failure.

The maximum levels of Von Mises stress in the truss are observed for peak periods between 6 and 10 sec depending on the heading. This is consistent with wave loads on the columns when the wavelength is half the distance between columns.

Table 2: Fatigue Life on Connection between Bracings based on nominal wall thickness

SCF	Damage (/year)	Fatigue Life (years)
1	1.7E-03	670
1.5	8.2E-03	121
2	2.8E-02	36

The stress ranges are determined for all sea-states in the scatter diagram and combined to obtain the fatigue life. Results are summarized in Table 2. Assuming that the stress at the weld is accurately computed by the beam model, and that no increase in wall thickness is implemented at the connection, the minimum fatigue life of the nodes is 670 years. This optimistic assumption will be verified with a detailed finite-element of the connection. It is likely that increase in wall thickness over a short section near the node will be required to achieve fatigue life targets. Estimates of fatigue life based on a can with wall thickness equal to twice the nominal wall thickness of the tubular members are provided in Table 3.

Table 3: Fatigue Life with Double Wall Thickness at the Connection

SCF	Damage (/year)	Fatigue Life (years)
1	6.7E-05	14,934
1.5	3.8E-04	2,623
2	1.5E-03	670

STRUCTURAL ANALYSIS OF THE TOWER

The design of the tower must take into account wind and wave-induced motions. A dynamic analysis of the tower is required since the first lateral mode of resonance is near 3 seconds. At such periods, some wave energy may be transmitted to the tower through the platform rigid-body motions.

The tower is a slightly conical unstiffened 220ft (67m) high tube, with increasing wall thickness from top to bottom. It supports a 300 tons nacelle and rotor at the top. It is connected to the column at the bottom with a bolted or welded flange joint. The buckling strength of the tubular element is determined for extreme environmental conditions and the fatigue life of the joint at the base of the column is calculated.

The numerical model is composed of a number of beam elements with decreasing diameter and thickness from bottom to top. Beam elements are sufficient for this study since there is no external pressure distribution on the tower. A convergence analysis is carried out to determine the minimum number of elements necessary to correctly represent the dynamic characteristics of the tower. With 8 elements the mass and stiffness of the structure have converged.

One- hour time series of accelerations at the base of the tower are generated for all twelve relevant sea-states in the wave scatter diagram. Additionally, the largest possible wind force is applied horizontally at the top and the tower supports its own weight as well as the weight of the turbine. The deflections of the tower are computed using linear beam theory with a time-domain finite-element algorithm.

In Figure 6, the bending moment (top) and the sway motion at the base of the tower (bottom) are plotted during the largest wave event of the one-hour time series for sea-state 1, which corresponds to the 100 year storm. The maximum horizontal excursion at the base of the turbine tower is 60 ft (18m) crest to trough during a single wave cycle, corresponding to a 70 ft (21m) wave crest-to-trough. The bending moment time-series clearly shows the dynamic response of the tower, which includes oscillations with a period below 3 seconds superimposed to the wave induced component with a period around 20 seconds.

A 2% ratio of critical damping is applied to the numerical model. This is the level of damping expected on the tower when the turbine is parked. When the turbine rotates, the damping ratio increases on the tower due to aerodynamic drag. A sensitivity analysis is performed to evaluate the effect of damping on tower fatigue.

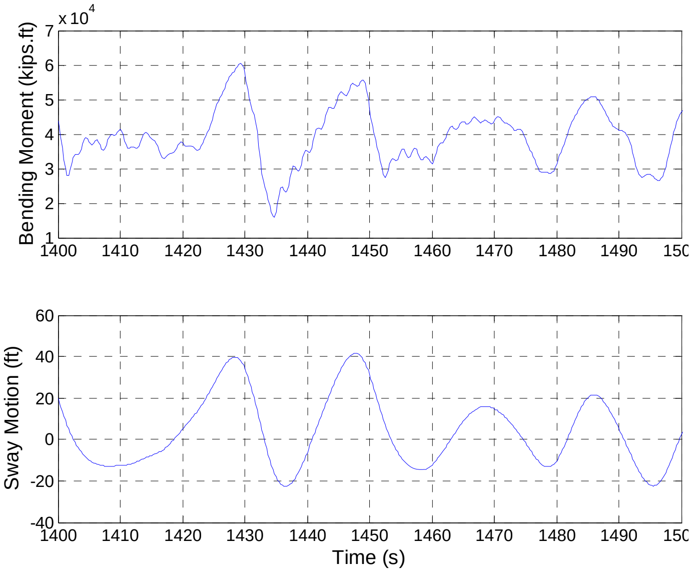

Figure 6: Bending stress (kips.ft) and sway (ft) at the base of the tower at the largest wave of sea-state #1.

In Figure 7, the bending stress at the base of the tower is plotted for 2 and 5% critical damping ratio, highlighting the variations in the dynamic response of the tower. Yet, the energy at the natural period of the tower is small compared to wave induced variations of bending stress. The structural damping does not affect the fatigue results significantly: the RMS of bending moment varies by only 1% when damping is increased from 2 to 5% of critical damping in this high sea-state.

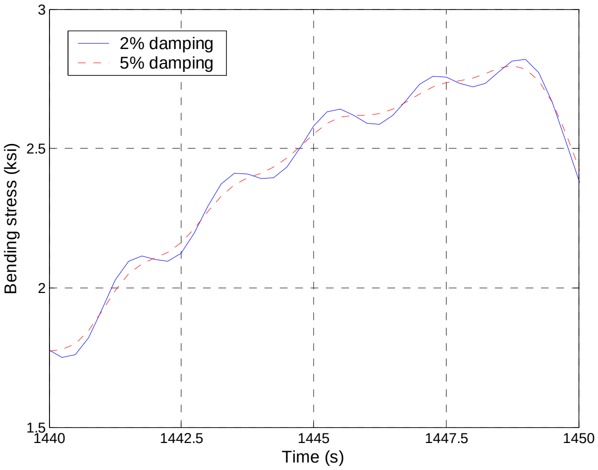

Figure 7: Sensitivity of Bending Stress with Damping Ratio in seastate 1 at 90 degree heading

The natural period of the tower is low enough to not interfere with wave induced motion of the platform. The unsupported section of the WindFloat tower is much shorter than onshore towers for the following two reasons: the hub is lower because the wind boundary layer is thinner offshore, and the platform truss provides lateral stiffness to the tower up to 33 ft (10m) elevation above the mean water line.

Bending moment at the base of the tower is also plotted in Figure 8 for seastate 12 (Tp=4.2sec). The bottom of the figure shows a time-series of the sway motion, which is a combination of linear wave dynamics with periods of 4.2 seconds and slow-drift cycles with periods of approximately 50 seconds. Only the energy from first order wave dynamics at low periods is transmitted to the tower. Excitation of the tower natural periods is not apparent due to the small magnitude of tower base motion.

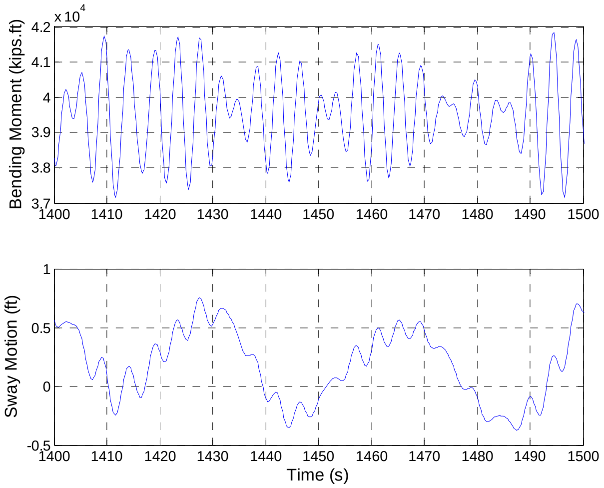

Figure 8: Bending stress (kips.ft) and sway (ft) at the base of the tower at the largest wave of sea-state #12.

For the strength analysis, the design recommendations from DNV RP C202 are used. The shell buckling assessment is based on formulas for unstiffened tubular elements. The column buckling does not need to be computed since $(kL/i)^2 < 2.5\ E/fY$ where *kL* is the effective length, *i,* the radius of gyration of the cross section and *E* the Young modulus and *fY* the yield strength of steel.

The largest events are identified over a 1-hour time series. The shell buckling ratio is calculated at the lower end of each of the 8 elements using the local wall thickness and diameter for this element. Stress is largest at these lowest ends since the axial force and bending moment increase toward the base of the tower, as illustrated at one time step in Figure 9.

It may be noted that even for extreme events of the largest sea-states, wind force on the turbine contributes up to 70% of the axial stress on the tower. The wind force is critical to the design of the tower in strength.

Shell buckling ratios are computed for these extreme events according to DNV recommendations. At the base of the tower, the largest design equivalent Von Mises stress to design shell buckling strength ratio is 0.4, which is 40% of the maximum allowed. Thus, the tower will not be affected by buckling from dynamic wave loads and wind thrust.

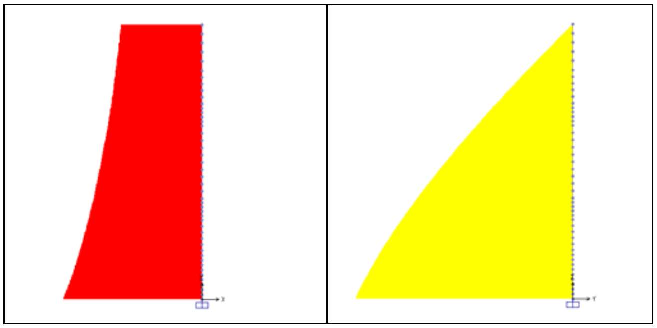

Figure 9: (left) Axial force in compression (right) Bending moment at largest event of sea-state #1 at 90 degree heading

The fatigue analysis is assessed at the joint between floater and turbine at the base of the tower. The column and the tower meet in a flange connection which is bolted or welded. The standard deviation of the Von Mises stress is determined over a one-hour simulation of the structural response to the twelve relevant sea-states. The bending moment is computed at a point at the base of the tower for a number of wave directions between 0 and 180 degrees, to account for the directionality of waves at the Northern California location. Each heading is given identical probability of occurrence for this analysis.

The hot spot stress S-N curve with a Rayleigh approximation is used to determine the damage per year on the connection. The stress concentration factor should be computed from a three-dimensional finite element analysis of the connection. However, this work will be performed in a later phase of the project once structural details of the connection are established. In a preliminary analysis, a sensitivity study is carried out on the stress concentration factor at the base of the tower.

Results are summarized in Table 4. The calculated fatigue life is 37,280 years based on nominal wave-induced stress. Damping level is conservatively assumed to be 2% of critical for all sea-states, although it will likely be higher when the turbine is spinning. The design of the connection between the tower base and top of column will have to be carefully designed to reduce Stress Concentration Factors to acceptable levels based on fatigue life targets. Fatigue due to cycling of the wind loads and tower vibrations due to the spinning rotor have not been included in this model. Detailed aerodynamic calculations will be performed to account for these additional fatigue sources. These are not expected to be significantly worse than for onshore or fixed offshore foundations.

Table 4: Summary of sensitivity of fatigue damage on SCF

Damping	SCF	Damage (/year)	Fatigue Life (years)
2%	1	2.68E-05	37,280
2%	2	5.59E-04	1,790
2%	4	1.16E-02	86
2%	6	6.87E-02	15

CONCLUSION

This paper discusses the preliminary structural assessment of a column-stabilized floating foundation supporting a large offshore wind turbine. It focuses on the methodology designed to estimate the strength and fatigue of the WindFloat's novel structural components. It is assumed that structural loading on the underwater elements of the platform, such as the columns and the water entrapment plates is mostly dependent on wave loading. Their preliminary design can be conservatively established using design guidelines developed for the offshore industry. Novel elements such as the truss or the interface between the wind turbine and the columns, i.e. the tower, must be analyzed thoroughly due to the importance of aerodynamic loading on their design. A strength and fatigue analysis is performed using a simplified beam model to assess the structural reliability of the structure under conservative environmental loading and identify the areas that will require further detailed analysis.

The work presented herein was focused on providing sufficient technical information about the system to highlight follow on design challenges. A few critical topics have been identified on the truss and tower design. The wind force is essential to the strength behavior of the WindFloat since its contribution to the bending stress of the structural members is significant. It is essential to include the effect of aerodynamics in the detailed structural analysis, but in the preliminary analysis, a large factor of safety sufficed to conclude the global structural reliability of the WindFloat. A detailed analysis of the truss node fatigue is required involving three-dimensional finite-element models.

The analysis presented herein was sufficient to verify that the general arrangement and dimensions of the main structural components of the structure are compatible with expected environmental loading. Local reinforcement of the structure will be required, but are not expected to significantly alter initial weight and cost-estimates.

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