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CHINA CLASSIFICATION SOCIETY

TECHNICAL GUIDELINES FOR STRUCTURAL ANALYSIS OF DEEPWATER JACKET

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Chapter 1 General

Section 1 General

1.1.1 General Requirements

1.1.1.1 The Guidelines are guidance notes issued by China Classification Society (hereinafter referred to as "CCS") on the structural analysis of deepwater jackets.

1.1.1.2 In the Guidelines, deepwater jacket refers to the jacket with a water depth greater than 120m or a natural period greater than 3s. For such deepwater jacket structures, the in-place analysis shall focus on the strength of complex tubular joints, strength of stiffener rings, internal wave effects (when applicable), dynamic response and fatigue effects. In transportation analysis, any non-negligible effect of coordinated deformation between barge and jacket on structural strength shall be considered.

1.1.1.3 The methods recommended in the Guidelines are non-mandatory. However, users who entrust CCS to provide relevant technical services shall accept the relevant requirements of the Guidelines. Other users who adopt the Guidelines shall bear all relevant risks.

1.1.2 Scope of Application

1.1.2.1 The Guidelines are applicable to the structural modeling, in-place analysis, and installation analysis of deepwater jackets designed using the working stress method.

1.1.2.2 The Guidelines do not include technical requirements for topside built for loading of platform equipment.

1.1.2.3 The collapse analysis required for deepwater jackets can be carried out in accordance with the specific requirements of Chapter 5 of *CCS Guidelines for Structural Reliability Analysis and Application of Fixed Jackets* (2015).

Section 2 References

1.2.1 Cited Regulations, Specifications and Guidelines

1.2.1.1 The Guidelines are compiled mainly according to the latest versions of the following regulations, specifications and standards:

(1) *Safety Regulations of Offshore Fixed Units* published by the State Economic and Trade Commission.

(2) *Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design* (SY/T 10030)

(3) *CCS Technical Guidelines for Fatigue Strength Assessment of Offshore Engineering Structures*

(4) *CCS Guidelines for Application of Environmental Conditions for Design and Assessment of Offshore Engineering Structures*

(5) *CCS Guidelines for Structural Reliability Analysis and Application of Fixed Jackets*

(6) *CCS Guidelines for Analysis of Transportation and Floatover of Large Offshore Structures*

Section 3 Definitions and Abbreviations

1.3.1 Terms and Definitions

1.3.1.1 Exposure Category

Exposure category refers to the structural classification level determined with consideration to human life safety and the consequences of failure.

1.3.1.2 Splash Zone

Splash zone refers to the area where the platform alternates between dry and wet due to the influence of tides, wind and waves.

1.3.1.3 In-place Analysis

In-place analysis refers to the structural strength analysis of the platform subjected to the combined effects of functional loads and environmental loads during service. The on-position analysis involved herein includes static analysis, dynamic response analysis, seismic analysis, fatigue analysis and collapse analysis.

1.3.1.4 Installation Analysis

The Guidelines cover static or dynamic analysis of the platform during offshore installation, including ship loading structure analysis, transportation analysis, launching and upending analysis, and on-bottom stability analysis.

1.3.1.5 Nominal Stress

Nominal stress refers to the stress derived based on the cross-sectional characteristics of the members and the forces acting on the members. The forces and moments acting on the rod ends shall be determined through overall stress analysis, taking into account the effects of the thickened or tapered sections at the ends.

1.3.1.6 Design Life

The design life refers to the effective service time of the structure during which no failure is anticipated, but targeted and planned maintenance, instead of overhaul, is needed.

1.3.1.7 Strength

Strength refers to the capability of a material to resist permanent deformation and fracture under the action of external forces.

1.3.1.8 Yield Strength

Yield strength refers to the yield limit of metal material when yielding occurs, that is, the stress resisting slight plastic deformation. For metal materials without obvious yield, the stress that produces 0.2% residual deformation is specified as the yield limit, which is called the conditional yield limit or yield strength.

1.3.1.9 Tensile Strength

Tensile strength refers to the resistance characterizing the maximum uniform plastic deformation. Before the stress reaching the maximum tensile stress, the deformation of the tensile specimen is uniform and consistent; once the stress exceeds the maximum tensile stress, the metal begins to neck down, that is, concentrated deformation occurs; For brittle materials with no (or very little) uniform plastic deformation, tensile strength reflects the material's fracture resistance.

1.3.1.10 Stress Concentration Factor

Stress concentration factor is the ratio of peak stress to stress without considering stress concentration (i.e. nominal stress), reflecting the degree of stress concentration.

1.3.1.11 Sea State

Sea state refers to the ocean wave condition representing a stationary random process at a specific time.

1.3.1.12 Significant Wave Height

Significant wave height refers to the average wave height of 1/3 of the largest waves in the sea state.

1.3.1.13 S-N Curve

S-N Curve refers to the curve between empirically determined stress range (taking into account the effects of discontinuities in weld profile and weld toe) and the number of fatigue cycles.

1.3.1.14 Main Structure

Main structure refers to the key structural members, such as legs, diagonal tie bars, horizontal tie bars, etc., that have an important impact on maintaining the overall integrity of the jacket structure.

1.3.1.15 Ancillary Structure

Ancillary structures refers to the auxiliary structural members, such as conductor guide frames, walkway supports, etc., whose damage will not weaken the overall integrity of the jacket structure.

1.3.1.16 Most Probable Maximum Response for Structural Response

Most probable maximum response (MPME) corresponds to a peak with a exceedance probability of about 63% in the response peak probability density function, that is, the 1/1000 of the peak value in the 3-hour sea states.

1.3.1.17 Leg

Legs refer to vertical large-diameter circular tube columns, which are the main load-bearing members that bear and transfer platform loads.

1.3.1.18 Deck Column

Deck column refers to the tubular member arranged horizontally or vertically within the horizontal layer of a jacket to connect the adjacent legs of the jacket.

1.3.1.19 Horizontal Tie Bar

Horizontal tie bar refers to the tubular member arranged obliquely in the horizontal layer of the jacket to enhance the structural stability, usually including K-type and X-type tie bars.

1.3.1.20 Diagonal Brace

Diagonal brace refers to the tubular member arranged obliquely in the facade of the topside to bear axial pressure.

1.3.1.21 Diagonal Tie Bar

Diagonal tie bar refers to the tubular member arranged obliquely within the vertical facade of the jacket to connect the jacket legs or horizontal layers, usually including K-type and X-type tie bars.

1.3.2 Abbreviation

1.3.2.1 The abbreviations used in the Guidelines are explained as follows:

SCF	Stress Concentration Factor
DAF	Dynamic Amplification Factor
UC	Unity Checks
WSD	Working Stress Design
HAT	Highest Astronomical Tide
LAT	Lowest Astronomical Tide
C.D.	Chart Datum
MPM	Most Probable Maximum
MPME	Most Probable Maximum Response
RAO	Response Amplitude Operator

Chapter 2 Structural Modeling

Section 1 General

2.1.1 General Requirements

2.1.1.1 The structural model of the deepwater jacket shall be established using approved general engineering software.

2.1.1.2 The structural model shall be established in a rectangular coordinate system, with the direction upwards the Z axis being the positive direction, X and Y being horizontal axes, Y axis being consistent with the north of the structure, the direction of the X axis to be determined by the right-hand rule, and the origin of the coordinate system to be located on the Chart Datum.

2.1.1.3 Structural models shall be established in metric units.

2.1.1.4 The structural model shall be able to reflect the mass, damping, stiffness and other important parameters and characteristics of the platform, as well as the interaction between the structure and the foundation.

2.1.1.5 The platform mass shall include the deadweight of the platform's main structure, the weight of the platform's ancillary structures, upper equipment and live loads, the mass of marine organisms, and the added mass of entrained water, etc.

2.1.1.6 For the pile leg structures connected by grouting, the structure and strength shall be checked according to the requirements of Section 10.4 of *Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design* (SY/T 10030).

2.1.2 Member Simulation

2.1.2.1 The structural model shall fully reflect the real characteristics of the deepwater jacket's structural type, stiffness and strength. For members with irregular cross-sections, such as launching trusses, equivalent cross-sections with the same section modulus can be used instead.

2.1.2.2 The corrosion effect of members in the splash zone shall be considered during structural modeling. The corrosion allowance shall be provided by the owner. If not provided, the corrosion allowance can be considered as 0.3mm/year during the in-place analysis, and the fatigue analysis can be conducted based on half of the corrosion allowance.

2.1.2.3 The joint numbers and member group numbers used in the structural model shall be able to reflect the location and classification of the members. See Section 5 for details.

2.1.2.4 For members subjected to axial loads, including legs, columns, diagonal tie bars, diagonal braces, deck columns, etc., the effective lengths L_Y and L_Z shall be corrected according to the constraints at both ends. The correction value of L_Y, L_Z is derived by multiplying the length between the restrained ends of the member by the effective length factor K in Table 2.1.2.4.

Effective Length Factor *K* **Table 2.1.2.4**

Structural Parts	Factor *K*
Leg or column	1.0
Main diagonal brace	0.8
K-brace	0.8
X-brace	0.9

NOTE: For K-braces and X-braces, if the joint is not supported out of plane, at least one pair of members forming the joint shall be in tension. The original length of the K-brace is the length from the leg surface to the center line of the joint, and the original length of the X-brace is the length of the longer rod segment that constitutes the joint.

2.1.2.5 The maximum slenderness ratio of primary and secondary members shall not exceed the values specified in Table 2.1.2.5.

Maximum Slenderness Ratio of Members Table 2.1.2.5

Member Type	Compression member	Tension members
Primary members	120	200
Secondary member	120	240

2.1.2.6 The diameter-thickness ratio of primary tubular members shall be in the range of 20~80. If the diameter-thickness ratio is greater than 60, the local buckling capacity of the members shall be assessed in accordance with the requirements of Section 6.2.2 of the *Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design* (SY/T 10030-2018).

2.1.2.7 The diameter-thickness ratio of the members at non-joints of the launching truss shall not exceed 120, and when the ratio exceeds 60, appropriate stiffener rings shall be provided to prevent local buckling.

2.1.3 Joint Simulation

2.1.3.1 For simple joints formed by multiple braces and the same chord, appropriate offset shall be considered for braces so as to ensure that the related braces meet the minimum clearance requirements.

2.1.3.2 If a thickened section is required for the chord, the thickened section shall extend to at least 305mm from the outer edge of the brace or 1/4 of the chord diameter, whichever is greater.

2.1.3.3 If a thickened section or special steel is to be used at the end of the brace, the length of this section shall not be less than the brace diameter or 600mm, whichever is greater.

2.1.3.4 When calculating the construction capacity of a joint, if a thickened section is provided for the brace, the effective capacity of the ordinary section of the brace shall be used for check instead of the effective capacity of the thickened section. If the thickened section of a brace is connected to other braces (as described in Section 2.1.3.5), the effective capacity of the ordinary section of the brace shall not be used to check the structural capacity of the joint.

2.1.3.5 For an atypical joint formed by first connecting two braces to form a joint and then connecting the joint to the chord due to the limitation of the spatial arrangement of braces in the plane, the local strength shall be checked to show that the joint has sufficient joint capability.

2.1.4 Load Simulation

2.1.4.1 When establishing a structural model, functional loads and environmental loads such as structural deadweight, equipment load, live load, etc., or a combination thereof shall be considered according to different analysis types. The specific principles for load combination are shown in the relevant analysis chapters.

2.1.4.2 The impact of marine organisms on structural loads, including the impact on the overall weight of the platform, environmental loads, and rod roughness shall be considered during the development of a structural model.

2.1.4.3 For jacket with different numbers of legs, the current blockage factor in each direction may be determined according to the provisions of Table 2.1.4.3.

Current Blockage Factor **Table 2.1.4.3**

Jacket structure type	Coefficients in different directions		
	End face	Diagonal	Side
4-leg	0.80	0.85	0.80
6-leg	0.75	0.85	0.80
8-leg	0.70	0.85	0.80

2.1.4.4 The wave motion coefficient may be considered as 1.0 for operating conditions and 0.95 for extreme conditions.

2.1.4.5 The hydrodynamic coefficient can be determined according to Table 2.1.4.5.

Hydrodynamic coefficients *Cd* and *Cm* **Table 2.1.4.5**

Type of analysis	Member type	Cd	Cm
Static/Seismic analysis	Smooth member	0.65	1.6
	Rough member	1.05	1.2
Fatigue analysis	Smooth member	0.50	2.0
	Rough member	0.80	2.0

2.1.4.6 Refer to Figure 4 in the *Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design* (SY/T 10030) for the shielding effect of the conductor.

Section 2 Drawings and Materials

2.2.1 General Requirements

2.2.1.1 The modeling of deepwater jacket structures shall be carried out based on basic data such as design basis reports, specifications, design drawings and re-control reports to ensure that the structural model can truly reflect the stiffness, mass, damping, load and other conditions of the structure.

2.2.2 Design Basis Report

2.2.2.1 The design basis report is an important basis for deepwater jacket structure analysis and shall be provided before structural modeling.

2.2.2.2 The design basis report shall include the environmental and seismic parameters of the sea area where the platform is located, including water depth, tide level, wind, wave and current parameters, seismic parameters, pile-soil data, etc.

2.2.2.3 The design basis report shall include basic information of the topside, including main dimensions, deck elevation, weight and center of gravity, etc.

2.2.2.4 The design basis report shall also include relevant information on construction, transportation and installation, such as loading method, transport vessel, floating crane and piling equipment, auxiliary righting method, positioning method, etc.

2.2.3 Specifications

2.2.3.1 The structural design shall comply with the reference specifications and standards specified in the structural design specifications.

2.2.3.2 The design loads, operating condition combinations, allowable stress magnification factors, etc. adopted in the structural model shall be consistent with those specified in the structural design specifications.

2.2.3.3 The member size, yield strength, elastic modulus and other parameters adopted in the structural model shall be consistent with those specified in the material specifications.

2.2.3.4 For tubular joints requiring special treatment such as shape control and grinding, relevant requirements of the weld inspection specification shall be considered during the calculation of local strength and fatigue life of such joints.

2.2.3.5 The adjustment of the structural model, the simulation of the lashing members, the setting of the forced displacement condition and the towing condition adopted for the loading and towing analysis shall be consistent with those specified in the loading and towing specifications.

2.2.4 Design Drawing and Weight Control Report

2.2.4.1 The structural model shall be able to fully reflect the structural characteristics expressed in the design drawings. The reference drawings mainly include:

(1) General layout of the unit

(2) Main elevation structure diagram of the jacket

(3) Launching truss structure diagram of the jacket

(4) Horizontal structure diagram of the jacket

(5) Conductor structure diagram

(6) Steel pile structure diagram

(7) Topside structure diagram

(8) Deck load of topside

(9) Drawings of auxiliary structures of the jacket, including plans of risers/support structures, plans of pump protection pipes/support structures, berthing members, boarding platform, mudmat, umbilical cable way structures and ladder railing structures, and layout of sacrificial anodes.

2.2.4.2 The structural deadweight and accessory structure weight of the jacket adopted for the structural model shall be consistent with those specified in the jacket weight control report, the load applied by the topside shall be consistent with that specified in the module weight control report (in service phase), or the module designed with the jacket shall not exceed the specified weight and center of gravity (in design phase).

Section 3 Structural Simulation of the Unit

2.3.1 Main Structure of the Jacket

2.3.1.1 The main structures of the jacket shall all be simulated in the calculation model, including the legs, deck columns, diagonal tie bar and deck columns involved in the structure plans of the main vertical face, horizontal layer and the launching truss.

2.3.1.2 The stiffness of the local connection between the jacket skirt pile and the leg structure shall be determined in advance through local finite element analysis; and the cross-sectional properties and elastic modulus of the simulated local connection members shall be modified to obtain a stiffness equivalent to the actual stiffness.

2.3.1.3 When using concentric double-layer pipe components to simulate the grouting of jacket skirt piles and steel piles, it shall be noted that the weight of the slurry in the annular space may cause the deviation of the main structure weight from the weight specified in the weight control report, and this shall be taken into account during modeling.

2.3.1.4 The bottom end point of the main pile or skirt pile of the jacket can generally be set 1m below the seabed.

2.3.1.5 The main joints of the main structure of the jacket, such as the intersection between a leg and a deck column, the intersection between a deck column and a horizontal tie bar, and the intersection between diagonal tie bars, shall be designed as mass condensation points. During modal analysis, a mass matrix will be formed according to the retained degrees of freedom.

2.3.1.6 For horizontally constructed jackets, attention shall be paid to the difference between the effective lengths LY and LZ of the members installed in the analytical structure model and those in the in-place analytical structure model.

2.3.2 Pile Foundation

2.3.2.1 The effect of the jacket pile foundation shall be simulated based on the *T-Z, Q-Z*, and *P-Y* soil data.

2.3.2.2 The pile-soil interaction document shall include the segmentation and corresponding cross-sectional dimension information reflected in the steel pile structure plan, and the end soil plug area shall be determined according to actual conditions.

2.3.2.3 When the spacing between steel piles is less than 8 times the pile diameter, the influence of pile group effect on stiffness and bearing capacity of the pile foundation shall be considered.

2.3.2.4 Scouring of pile foundation will affect the strength of steel piles and their bearing capacity; and this influence may be considered by ignoring the pile-soil effect of the foundation scour layer.

2.3.2.5 The maximum tensile strength and maximum pull-out resistance of the pile foundation shall be determined according to the bearing capacity curve.

2.3.3 Ancillary Structure of Jacket

2.3.3.1 The in-place analysis model of the jacket generally includes auxiliary structures that exist for a mid-and-long term during the service life, such as the conductor, riser, pump protection pipe, berthing members, mudmat and other structures, in order to capture the effects of wave and current loads and buoyancy.

2.3.3.2 In addition to the auxiliary structures included in the in-place analysis, the lifting tools, sea fasteners, locking facilities, temporary auxiliary structures, etc. shall also be considered in the jacket installation analysis model.

2.3.3.3 Appropriate freedom degree release shall be considered for connection unit between the conductor and its guide structure according to the actual situation, and the interaction between the conductor and the soil shall be simulated according to the T-Z, Q-Z and P-Y curves.

2.3.4 Topside

2.3.4.1 The main structures of the topside, such as the main beam, legs, main diagonal braces, etc., shall all be simulated in the calculation model to truly reflect the overall stiffness of the unit.

2.3.4.2 The main joints of the topside, such as the intersection between the main beams, the intersection between the main beam and column, and the intersection between the main beam and the diagonal brace, shall be designed as mass condensation points. During modal analysis, a mass matrix will be formed based on the retained degrees of freedom.

Section 4 Load Simulation of the Unit

2.4.1 Structural and Equipment Loads

2.4.1.1 The fixed loads under four water levels: extremely high, extremely low, operating high, and operating low water levels shall be considered as a minimum requirement during the structural analysis of the conductor. These fixed loads can be automatically obtained by the calculation program after setting different water depths through the main structure simulated by the model.

2.4.1.2 It is recommended that the density of the jacket auxiliary structure simulated in the structural model should be corrected to zero, and its deadweight should be applied through member loads or joint loads, so that the comparison by item with the jacket weight control report can be conducted. The buoyancy of the jacket auxiliary structure can be automatically obtained by the model.

2.4.1.3 Loads of auxiliary structures that are not simulated in the jacket in-place analysis shall be applied to reasonable locations in the form of member loads or joint loads, with their buoyancy considered.

2.4.1.4 During modal analysis, the buoyancy of un-simulated auxiliary structures shall be converted into added mass of entrained water for consideration.

2.4.1.5 The weight of the conductor and mud inside the riser will affect the overall weight of the unit during modal analysis. This weight shall be taken into account by modifying the density of the riser.

2.4.1.6 It is recommended that the density of the main structure of the topside should be modified to zero, and its structural weight should be applied through member loads or joint loads.

2.4.1.7 The auxiliary structures of the topside, such as flare boom, crane column, living quarter, derrick, etc., if not simulated in the structural model, shall be considered through member loads or joint loads.

2.4.1.8 The equipment load of the topside shall be applied according to professional classification, and the weight, center of gravity shall be consistent with those specified in the weight control report of the module. For large functional modules with heavy weight, their weight, center of gravity or fulcrum reaction shall be accurately simulated so that the force transferring path of the topside loads and the loads distributed to the jacket structure (especially the top members of the jacket) are consistent with the actual situation.

2.4.1.9 A couple shall be set at the top of the main axis of the topside to adjust the center of gravity. The weight of each deck shall be adjusted through the load factor to ensure that the total weight and center of gravity range of the topside are consistent with the requirements of the design basis report.

2.4.2 Environmental Load

2.4.2.1 The wind load applied onto the unit shall be calculated based on the maximum sustained wind speed for 1 minute at 10m above mean sea level.

2.4.2.2 The wind load applied onto the jacket shall be calculated based on the cross-sectional area, wind area, wind speed and other parameters of the members simulated in the model, with consideration to the wind area of the un-simulated auxiliary structures.

2.4.2.3 Ancillary structures not simulated in the structural model, such as grouting pipelines, umbilical cable ways, and conductor, may generate additional wave current load, which shall be considered by correcting the C_d and C_m of the main structure or setting the wave current area. For anode blocks and external hydrostatic pressure crushing rings, a fixed coefficient, generally in the range of generally 5%~10%, can be set for the overall wave current load to take into account additional wave load.

2.4.2.4 When calculating wave load, the Doppler effect of flow on waves shall be considered and the apparent wave period shall be used.

2.4.2.5 The two-dimensional regular wave motion shall be calculated by selecting the stream function of appropriate order of or Stokes fifth-order wave theory based on apparent wave period, wave height and water depth and according to Figure 3 in the *Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design* (SY/T 10030-2018).

2.4.3 Other Loads

2.4.3.1 For deepwater jacket platforms located in seismically active zones, the effect of seismic load shall be considered. Specific methods and processes for calculating such load are described in Chapter 5 of the Guidelines.

2.4.3.2 Since the deepwater jackets have high structural flexibility, the impact of wave dynamic response shall be analyzed in detail. Specific methods and processes for calculating such impact are described in Chapter 4 of the Guidelines.

2.4.3.3 The deepwater jackets will be subject to drag loads, forced displacements, ship motion inertia loads, etc. during the loading, transportation, launching and upending processes. Specific methods and processes for calculating such loads are described in Chapters 7, 8 and 9 of the Guidelines.

2.4.4 Load Combination

2.4.4.1 All possible most unfavorable load combinations shall be taken into account.

Section 5 Naming Rules in Modeling

2.5.1 General Requirements

2.5.1.1 Joints shall be numbered in accordance with the provisions of Section 1 of Appendix A of the Guidelines.

2.5.1.2 The grouping and numbering of members and plates can be conducted in accordance with the provisions of Section 2 of Appendix A of the Guidelines.

Chapter 3 Static Analysis

Section 1 General

3.1.1 General Requirements

3.1.1.1 Approved general engineering software shall be used for static analysis of deepwater jackets.

3.1.1.2 Static analysis generally includes analysis of structural strength of members, joints, pile foundations and the bearing capacity of pile foundations under operating conditions and extreme conditions.

3.1.1.3 For deepwater jackets, the influence of P-Delta effect and wave dynamic effect on static analysis cannot be ignored and shall be considered.

Section 2 Basic Conditions

3.2.1 Module Weight Load

3.2.1.1 The block weight load should reflect the most dangerous weight and center of gravity combination of the topside under operating conditions and extreme conditions.

3.2.1.2 During the jacket design phase, the module weight load can be simplified using the maximum allowable weight, nominal center of gravity, and center of gravity offset. Taking a fixed D&P platform as an example, the definitions of the maximum allowable weight, nominal center of gravity, and center of gravity offset are as follows:

(1) The maximum allowable weight is the maximum load of the module under operating conditions and extreme conditions;

(2) The nominal center of gravity is the center of gravity of the module load when the drilling and workover rig does not deflect under operating conditions or extreme conditions;

(3) The center of gravity offset is the maximum offset of the center of gravity caused by the movement of the workover rig.

3.2.1.3 The module load adopted during the jacket service phase shall be the load in the latest weight control report of the topside.

3.2.2 Jacket Weight Load

3.2.2.1 The jacket weight load shall include the modeled weight and the weight of un-simulated ancillary structures, and a corresponding uncertainty factor shall be applied to all weights.

3.2.2.2 For major structures that are explicitly modeled, their gravity and buoyancy shall be the value automatically generated by the engineering software; For major ancillary structures that are explicitly modeled, it is recommended to correct their density to zero.

3.2.2.3 For un-simulated ancillary structures, their gravity and buoyancy shall be considered based on custom load method.

3.2.2.4 The water filling state of the structures such as the leg, launching leg, skirt pile sleeve, pile, conductor, riser, J-tube, casing, mudmat bracket, etc. of the jacket shall be set according to the jacket filling layout diagram to take into account the offset buoyancy.

3.2.3 Environmental Load

3.2.3.1 Environmental loads applied on a deepwater jacket platform shall be calculated with reference to Section 2.4.2 of Chapter 2.

3.2.4 Inertia Load

3.2.4.1 The dynamic amplification factor (DAF), most probable maximum response (MPME) and inertial load distribution of the jacket platform shall be obtained through random dynamic time-history response analysis. For details of the calculation process, please refer to Chapter 4.

Section 3 Combined Conditions

3.3.1 General Requirements

3.3.1.1 The environmental loads generated based on the extreme environmental conditions of high/low water levels under extreme conditions (100-year return period) and operating conditions (1-year return period) shall be considered separately. The general extreme environmental conditions include: environmental conditions of maximum waves and the corresponding winds and currents, environmental conditions of maximum currents and the corresponding winds and waves, and environmental conditions of maximum winds and the corresponding waves and currents.

3.3.1.2 For internal wave conditions (if any), the combined effects of waves and wind shall be considered. Generally, a combination of maximum wave and the corresponding wind under condition of 1 year return period shall be considered.

3.3.1.3 The principles of load combination are as follows:

(1) Combine according to possible load conditions;

(2) Combining the load conditions that have the most adverse effect on the structure;

(3) The live load has different values under different conditions: under operating conditions, the live load is generally taken as 50%; under extreme conditions, the live load is generally taken as 37.5%;

(4) The equipment operating weight - dry weight varies under different conditions: under operating conditions, it is generally taken as 100%; under extreme conditions, it is generally taken as 75%.

3.3.1.4 Common load combination conditions are listed in Table 3.3.1.4.

List of Combined Conditions Table 3.3.1.4

Basic condition	Combined condition			
	Operating condition	Extreme condition	Pile pulling condition	Internal wave condition
Structural deadweight (including buoyancy)	1.0	1.0	1.0	1.0
Equipment dry weight	1.0	1.0	1.0	1.0
Equipment operating weight - dry weight	1.0	0.75	0.25	1.0
Live loads	0.5	0.375	0.00	0.5
Operating load of drilling and workover rig	1.0	-	-	1.0
Extreme load of drilling and workover machine	-	1.0	1.0	-
Operating wind, wave and current loads (extreme conditions)	1.0	-	-	-
Extreme wind, wave and current loads (extreme conditions)	-	1.0	1.0	-
Internal waves, operating waves and the related wind loads	-	-	-	1.0

Section 4 Structure Check

3.4.1 General Requirements

3.4.1.1 The strength check of members shall be conducted respectively according to Chapter 6 and Chapter 7 of the *Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design* (SY/T 10030-2018).

3.4.1.2 The main joints of the jacket shall be checked based on the nominal brace load and 50% effective strength load obtained from static analysis. For the secondary joints, only the nominal strut brace load shall be referred to during the strength check.

3.4.1.3 Joints that do not meet the requirements of the specifications can be redesigned using the joint stiffener ring method. The design method is described in Section 2 of Chapter 10.

3.4.1.4 The strength of steel piles and the bearing capacity of pile foundations shall be checked separately under extreme conditions and operating conditions.

3.4.1.5 The strength of steel piles shall be checked with reference to Chapter 6 of the *Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design* (SY/T 10030-2018).

3.4.1.6 The allowable safety factor of pile foundation bearing capacity shall be taken as 1.5 for extreme conditions and 2.0 for operating conditions.

Chapter 4 Dynamic Response Analysis

Section 1 General

4.1.1 General Requirements

4.1.1.1 The dynamic response analysis of deepwater jacket platforms shall be carried out in accordance with the requirements of this chapter.

4.1.1.2 Dynamic response analysis shall be carried out under operating conditions and extreme conditions respectively to determine the dynamic amplification factor and inertia load in different sea states and directions under operating conditions and extreme conditions.

4.1.1.3 Random linear waves with corrected peak energy shall be adopted for the dynamic response analysis of deepwater jacket platforms.

4.1.1.4 The current in the design sea state will affect the dynamic load through the nonlinear drag force in the Morison equation and shall be considered in the dynamic analysis.

4.1.1.5 The modal mass to be considered in dynamic response analysis shall include the mass of platform steel structure, all secondary structures, conductor, deck load, the mass of water in flood components, mass of marine growth expected to grow on the structure and added mass of entrained water in the underwater members, and the increase in the outer diameter of members caused by marine growth shall also to be considered.

4.1.1.6 The inertia load obtained from the dynamic response analysis shall be combined, as one of the basic loads for in-place analysis, with the platform's structural load, functional load and environmental load.

Section 2 Dynamic Amplification Factor

4.2.1 General Requirements

4.2.1.1 The dynamic amplification factor of the platform under operating conditions and extreme conditions shall be calculated respectively using the time domain method of random wave response.

4.2.1.2 The deepwater jacket has a large natural period. The DAF calculated by the single degree of freedom method will be too conservative. It is recommended that Winterstein/Jensen method should be used to calculate the DAF.

4.2.1.3 The random seeds selected for random wave response analysis shall be sufficiently representative and the mean, standard deviation, maximum wave crest, deflection and kurtosis of the generated random waves shall meet the selection criteria given in Table 4.2.1.3, so as to ensure that the sea state process has typical gaussianity with sufficient number of regular waves.

Random Wave Selection Criteria **Table 4.2.3**

Number of regular waves	≥ 200
Mean wave height	0
Maximum wave crest H_m	$0.95\frac{H_s}{4}\sqrt{2\ln N}<H_m<1.075\frac{H_s}{4}\sqrt{2\ln N}$
Standard deviation σ	$0.99\frac{H_s}{4}<\sigma<1.01\frac{H_s}{4}$
Deflection S	$-0.03 < S < 0.03$
Kurtosis K	$2.9 < K < 3.1$

Note: Hs is the significant wave height; N = simulation duration/T_z. For a simulation duration of 3 hours, N can be taken as 1000.

4.2.1.4 The structural response shall be calculated using the wavefront time history after the mean and variance have become stable. The transient time history at the beginning is usually not considered, and the duration of the transient time history shall not be less than 200s.

4.2.1.5 The time step of random wave response analysis shall be able to accurately reflect higher frequencies and shall be one twentieth of the smaller of the zero-crossing period and the platform natural period.

4.2.1.6 The DAF adopted for random wave structure response shall be calculated by the most probable maximum response (MPME) of dynamic response and static response (base shear and overturning moment) according to the Formula $(4.2.1.6-1)$.

$$DAF_{F_i} = MPME_{d,\ F_i} / MPME_{s,\ F_i} \quad (4.2.1-1)$$

Where:

F_i - Base shear force and overturning moment in *X* and *Y* directions;

d - Dynamic response;

s - Static response.

4.2.1.7 Multiple random seeds that meet the Gaussian condition may be selected to calculate the DAF, with their mean taken as the final DAF, to further eliminate the impact of randomness.

Section 3 Most Probable Maximum Response

4.3.1 General Requirements

4.3.1.1 The specific process of calculating the MPME value of deepwater jacket using the Winterstein/Jensen method is as follows:

Step 1: Calculate the statistical parameters of the structural response process: mean μ, standard deviation σ, deflection α_3 and kurtosis α_4.

Step 2: Construct a standardized response process, $Z = (R - \mu)/\sigma$, and use this process to calculate the number of occurrence of response to the zero-cross period N. For a simulation time of 3 hours, N can be assumed to be 1000.

Step 3: Calculate the parameter h_3, h_4, K according to Formulas (4.3.1.1-1)-(4.3.1.1-3), using the eigenvalues from Step 1.

$$h_3 = \frac{\alpha_3}{4 + 2\sqrt{1 + 1.5(\alpha_4 - 3)}} \quad (4.3.1-1)$$

$$h_4 = \frac{\sqrt{1 + 1.5(\alpha_4 - 3)} - 1}{18} \quad (4.3.1-2)$$

$$K = (1 + 2{h_3}^2 + 6{h_4}^2)^{-0.5} \quad (4.3.1-3)$$

If the kurtosis calculated in Step 1 is $\alpha_4 > 5$, the parameter h_3, h_4, K shall be updated using the Jensen method. The update method is as follows:

(1) The three-variable nonlinear equation system of Members C_1, C_2, C_3:

$$\begin{aligned} \sigma^2 &= {C_1}^2 + 6C_1C_3 + 2{C_2}^2 + 15{C_3}^2 \\ \sigma^3\alpha_3 &= C_2(6{C_1}^2 + 8{C_2}^2 + 72C_1C_3 + 270{C_3}^2) \\ \sigma^4\alpha_4 &= 60{C_2}^4 + 3{C_1}^4 + 10395{C_3}^4 + 60{C_1}^2{C_2}^2 + 4500{C_2}^2{C_3}^2 + \\ &\quad 630{C_1}^2{C_3}^2 + 936C_1{C_2}^2C_3 + 3780C_1{C_3}^3 + 60{C_1}^3C_3 \end{aligned} \quad (4.3.1-4)$$

(2) Set the initial value of C_1, C_2, C_3, $C_1 = \sigma K(1 - 3h_4)$, $C_2 = \sigma K h_3$, $C_3 = \sigma K h_4$;

(3) Solve the nonlinear equation system (4.3.1.1-4) and obtain the new C_1, C_2 and C_3;

(4) Update the values of parameters h_3, h_4, K, $K = \frac{C_1+3C_3}{\sigma}$, $h_3 = C_2/(\sigma K)$, $h_4 = C_3/(\sigma K)$.

Step 4: Use Formula (4.3.1.1-5) to calculate the most likely value U of the transfer process, which represents a zero-mean Gaussian process:—

$$U = \sqrt{2\ln\left(N \cdot \frac{3h}{\text{Simulation duration (h)}}\right)} \qquad (4.3.1-5)$$

Step 5: Use Formula (4.3.1.1-6) to calculate the maximum possible value converted into a standardized variable Z_{MPM}:

$$Z_{MPM} = K(U + h_3(U^2 - 1) + h_4(U^3 - 3U)) \qquad (4.3.1-6)$$

Step 6: Use Formula (4.3.1.1-7) to calculate the most probable maximum response of the process responseR_{MPME}:

$$R_{MPME} = \mu + \sigma Z_{MPM} \qquad (4.3.1-7)$$

Section 4 Distribution of Inertia Load

4.4.1 General Requirements

4.4.1.1 The distribution of inertia load on the platform shall be calculated based on the calculated DAF and MPME.

4.4.1.2 The inertial load shall be distributed to the mass condensation points of the platform according to the modal mass matrix and modal participation coefficient of the structure, so as to obtain the most realistic load distribution.

4.4.1.3 The modal mass matrix shall be a $N \times N$ order matrix obtained through modal analysis, $N = 3i$, where i is the number of mass condensation points set to retain the degree of freedom in the *x, y*, and *z* directions.

4.4.1.4 The modal participation coefficient can be calculated using Formula (4.4.1.4-1):

$$\begin{gathered}\alpha_x\phi_{x1}M + \beta_x\phi_{x2}M = (DAF_{fx} - 1)MPME_{s,fx}\\ \alpha_x\phi_{x1}MZ + \beta_x\phi_{x2}MZ = (DAF_{mx} - 1)MPME_{s,my}\\ \alpha_y\phi_{y1}M + \beta_y\phi_{y2}M = (DAF_{fy} - 1)MPME_{s,fy}\\ \alpha_y\phi_{y1}MZ + \beta_y\phi_{y2}MZ = (DAF_{my} - 1)MPME_{s,mx}\end{gathered} \qquad (4.4.1-1)$$

Where:

Z - Vertical coordinate matrix of mass points;

M - Mass matrix;

$\alpha_x, \beta_x, \alpha_y, \beta_y$ - First and second order modal participation coefficients in x and y directions;

$\phi_{x1}, \phi_{x2}, \phi_{y1}, \phi_{y2}$ - First and second order vibration modes of the platform in the x and y directions.

4.4.1.5 The distribution of inertia load can be calculated using Formula (4.4.1.5-1);

$$\begin{gathered}F_{ix} = \alpha_x\phi_{x1}M + \beta_x\phi_{x2}M\\ F_{iy} = \alpha_y\phi_{y1}M + \beta_y\phi_{y2}M\end{gathered} \qquad (4.4.1-2)$$

Where:

F_{ix}, F_{iy}——Inertial force distribution loads of the platform in x and y directions

Chapter 5 Seismic Analysis

Section 1 General

5.1.1 Definition

5.1.1.1 Strength requirements: to provide a platform with sufficient strength and stiffness to ensure that the structure does not suffer significant damage within its structural life under seismic levels that do not exceed reasonable and possible levels.

5.1.1.2 Resilience requirements: to ensure that the platform has sufficient reserve stability to prevent it from collapsing during rare strong seismic activities, although structural damage may occur.

5.1.1.3 Effective earth acceleration: A design factor used to describe the magnitude of ground acceleration that determines the size of a smooth, normalized design spectrum.

5.1.1.4 Ground motion: The vibration of the earth caused by an earthquake. The motion of any point can be uniquely described by acceleration, velocity, or displacement time history.

5.1.1.5 Response spectrum: a spectrum describing the maximum response to ground motion of a series of single-degree-of-freedom oscillators with different natural periods but the same internal damping. The response spectrum of a particular earthquake acceleration record is actually the characteristic of that ground motion expressed in terms of the maximum response of a simple (single degree of freedom) structure. When this response is represented by a set of smooth lines, it is called a smooth response spectrum.

5.1.1.6 Time history: A continuous record of ground motion or response over time.

5.1.2 Strength Level and Ductility Level

5.1.2.1 The seismic force in terms of strength level and ductility level shall be considered during seismic analysis.

5.1.2.2 For intensity level requirements, the ground motion return period is usually taken as 200 years.

5.1.2.3 For the ductility level requirement, the ground motion caused by rare strong earthquakes, the return period can be hundreds to thousands of years depending on the seismic environment, and is usually taken as 1,000 years.

Section 2 Pile Foundation Linearization

5.2.1 General Requirements

5.2.1.1 The equivalent soil stiffness can be expressed by a linear system.

5.2.1.2 A force equivalent to the seismic response shall be used to obtain the linearized equivalent soil stiffness matrix. This process requires multiple iterations until the structural natural frequencies obtained between two iteration steps are of little difference.

Section 3 Modal Analysis

5.3.1 General Requirements

5.3.1.1 For the response spectrum method, as many modes as necessary shall be considered to ensure that the response is sufficiently representative. For each of the three principal directions, at least two modes with the highest overall response as well as significant torsional modes shall be included.

5.3.1.2 The mass participation coefficient shall be no less than 90% in the X and Y directions and no less than 70% in the Z direction.

Section 4 Seismic Response Analysis

5.4.1 Analysis Basis

5.4.1.1 Dynamic analysis program such as response spectrum analysis or time history analysis shall be used.

5.4.2 Structural Model

5.4.2.1 The mass used in the dynamic analysis shall include the platform mass, the mass of the fluid inside the structure and secondary structures, and the additional mass. The additional mass can be estimated as follows: The displacement mass contributed by the lateral movement perpendicular to the longitudinal axis of the single structural frame and secondary structures. For the movement along the longitudinal axis of the structural frame and its secondary structures, the additional mass can be ignored.

5.4.2.2 The mass of the platform shall include the fixed weight of the platform (including the weight of the structure, equipment and accessories), the live load, and 75% of the maximum supply and reserve loads.

5.4.2.3 The analytical model shall include the three-dimensional distribution of the platform stiffness and mass. Asymmetries in distribution of platform stiffness or mass may result in significant torsional response and shall be considered.

5.4.2.4 When calculating the dynamic characteristics of the braces and the dynamic characteristics of the steel structure supported by the piles, a unified model damping ratio with a critical value of 5% shall be adopted in the elastic analysis. Other damping ratios may be used provided reliable data are available.

5.4.3 Response Analysis

5.4.3.1 The spectrum analysis method is recommended for seismic response analysis of deepwater jackets. When time-history analysis is adopted, the calculation of structural response can be carried out with reference to relevant specifications.

5.4.3.2 When the response spectrum method is adopted and the same design spectrum is used equally in two horizontal directions, the modal responses of each order shall be combined by the Complete Quadratic Combination method (CQC), and the responses in each direction shall be combined by square root of the sum of squares method (SRSS).

5.4.3.3 The seismic load shall be combined in the horizontal direction (X direction, Y direction) 100% and the vertical direction (Z direction) 50% .

5.4.3.4 The mass participation factor requirements are the same as those specified in Section 5.3.1.2.

5.4.3.5 Seismic loads shall be combined with other simultaneously acting loads, such as gravity, buoyancy, hydrostatic pressure, etc. Gravity loads shall include all weights specified in Section 5.4.2.2.

5.4.3.6 For ductility analysis, the structural model and soil element model shall also include the degradation of the strength and stiffness of the structural and soil element models under extreme load reversal and the interaction of axial force and bending moment, hydrostatic pressure and local inertia force (when applicable). The P-Delta effect due to elastic or inelastic deformation of the structure and foundation shall be considered.

Section 5 Structure Check

5.5.1 Strength Requirements

5.5.1.1 In calculating component stresses, the stresses due to seismic loads shall be combined with the stresses due to gravity, hydrostatic pressure and buoyancy in a linear superposition manner. For strength requirements, the allowable stress can be increased by 70%.

5.5.2 Ductility Requirements

5.5.2.1 In areas where the horizontal ground motion acceleration is in the range of 0.05g - 0.10g (inclusive), if the structural strength analysis is performed using the ground motion intensity and characteristics of rare strong earthquakes, and the results meet the strength requirements, it can be considered that all seismic requirements for the jacket members are met. Otherwise, an analysis shall be performed to demonstrate that the structure-foundation system of the jacket has the ability to withstand rare strong earthquakes without collapse.

5.5.3 Joint Check

5.5.3.1 The allowable stress of pipe joint check can be increased by 60%.

5.5.3.2 Under the condition described in Section 5.5.2, the calculated joint loads, instead of the tensile loads or compressive buckling loads of the members, shall be adopted for the check of tubular joint.

5.5.3.3 When the ground horizontal motion acceleration of strength level is 0.1g (inclusive) or above, check of the joints of the main structural members shall be checked according to the tensile yield load or compressive buckling load of the members connected by the tubular joints.

Chapter 6 Fatigue Analysis

Section 1 General

6.1.1 General Requirements

6.1.1.1 A detailed fatigue analysis shall be conducted on deepwater jacket structures, and the spectral analysis method is recommended. Other reasonable methods may be used if they have been proven to be sufficiently representative for responses of forces and members.

6.1.1.2 Spectral analysis shall be adopted to determine the stress response for each sea state. For sea states with significant energy near the platform's natural period, dynamic effects shall be considered.

6.1.1.3 Wave conditions shall be a set of all sea states expected to occur over the long term. For the purpose of structural analysis, this set can be a collection of representative sea states expressed in terms of wave energy spectra and physical parameters with probability of occurrence, commonly seen as wave scatter diagrams.

6.1.1.4 The directionality of the wave scatter pattern as well as the platform orientation shall be considered in the fatigue analysis.

6.1.1.5 The average water depth shall usually be taken as the operating water depth.

6.1.1.6 The wave motion coefficient for fatigue analysis and the shielding factor of the riser should be 1.0. The drag force coefficient and inertia force coefficient shall be selected according to Table 2.1.4.5.

6.1.1.7 The choice of damping coefficient may have a profound effect, and based on measurements in low sea states, a critical value of 2% or lower is recommended.

Section 2 Pile Foundation Linearization

6.2.1 General Requirements

6.2.1.1 The role of pile foundations in fatigue analysis can be represented on a linear basis, usually the foundation stiffness corresponding to the "fatigue damage center" sea state may be adopted.

6.2.1.2 The "fatigue damage center" sea state refers to the wave that causes the greatest fatigue damage to the structure (accounting for the largest proportion). Most fatigue damage is caused by medium and low sea states, so the damage center wave shall refer to a medium and low sea state wave with higher probability in the wave spread chart.

6.2.2 Calculation of Central Damage Wave

6.2.2.1 The relevant data of the central damage wave can be calculated according to the following formula based on the wave spread data:

$$H_{cs} = \sum(D_i \times H_{si})/\sum(D_i) \quad (6.2.2-1)$$

$$T_{cz} = \sum(D_i \times T_{zi})/\sum(D_i) \quad (6.2.2-2)$$

$$D_i = P_i \times (H_{si})^{a \times m}/(T_{zi}) \quad (6.2.2-3)$$

$$H_{max} = b \times h_{cs} \quad (6.2.2-4)$$

$$T_{max} = c \times T_z \quad (6.2.2-5)$$

Where:

a - *C*oefficient, it is recommended to select according to Section A.16.7.2.3.2 of ISO19902;

b – The correspondence coefficient between maximum wave height and significant wave height. It is recommended to be calculated according to Section 3, Chapter 5 of CCS Guidelines for

Application of Environmental Conditions for Design and Assessment of Offshore Engineering Structures;

c - The coefficient of correspondence between maximum wave height and the zero-crossing period. It is recommended to be calculated according to Section 3, Chapter 5 of CCS Guidelines for Application of Environmental Conditions for Design and Assessment of Offshore Engineering Structures;

H_{cs} - Significant wave height of the central damage wave, m;

H_{max} - Maximum wave height of central damage wave, m;

Hsi - Significant wave height of the i^{th} wave, m;

m - slope of the first segment of the S-N curve, usually be 3.0;

P_i - probability of occurrence of the i^{th} wave;

T_{cz} - zero-crossing period of the central damage wave, s;

T_{max} - wave period corresponding to the maximum wave height of the central damage wave, s;

T_{zi} - zero-crossing period of the i^{th} wave, s. It is recommended to be calculated according to Section 3, Chapter 5 of CCS Guidelines for Application of Environmental Conditions for Design and Assessment of Offshore Engineering Structures.

Section 3 Modal Analysis

6.3.1 General Requirements

6.3.1.1 The setting of the number of vibration modes shall meet the requirements of mass participation coefficient in *X, Y* and *Z* directions. The mass participation coefficient shall be greater than 90% in the horizontal direction and greater than 70% in the vertical direction.

6.3.1.2 Since the natural period of a platform can vary significantly with design assumptions and deck operating mass, the theoretical period shall be carefully examined, especially when it falls into the trough region of the platform base shear transfer function. The period shall be shifted 5% to 10% toward a more conservative position in the transfer function, and shall be achieved within a reasonable range by adjusting the mass or stiffness in an appropriate manner.

Section 4 Wave Response Analysis

6.4.1 General Requirements

6.4.1.1 The selection of the wave frequency of the transfer function shall cover the first five order natural frequencies of the platform structure and 2% and 5% of its adjacent frequencies, so as to accurately capture the wave dynamic response of the platform.

6.4.1.2 The maximum value of the wave height of the wave sequence generating the transfer function shall be controlled within a reasonable range.

6.4.1.3 For each part around the intersecting line of each member under study, the stress response to various sea states shall be calculated, and the overall and local stress effects shall be fully considered.

6.4.1.4 For spectral fatigue analysis, the wave load per unit wave height at different frequencies can be obtained according to the Morison formula, and the transfer function under each wave direction can be analyzed by finite elements, and the stress response spectrum of different directions and different sea states can be obtained according to the following formula:

$$S_{\sigma_{i,j}}(f) = \mathrm{H}_i(f)^2 S_{i,j}(f) \qquad (6.4.1-1)$$

Where: H_i is the transfer function in the i^{th} direction, and $S_{i,j}$ is the wave spectrum of the j^{th} sea state in the i^{th} direction.

Section 5 Fatigue Life Calculation

6.5.1 Hot Spot Stress

6.5.1.1 The local stress occurring at pipe joints shall be represented by the hot spot stress in the immediately adjacent joint, taking into account the appropriate stress concentration factor.

6.5.1.2 For details on the stress concentration factors of simple tubular joints, please refer to Section 3.5.2 of Chapter 3, and Section 2 of Appendix 2 of *CCS Technical Guidelines for Fatigue Strength Assessment of Offshore Engineering Structures*.

6.5.1.3 For details on the stress concentration factors of tubular joints with internal stiffener rings, please refer to Section 3.5.4 of Chapter 3, and Section 5 of Appendix 2 of CCS *Technical Guidelines for Fatigue Strength Assessment of Offshore Engineering Structures*.

6.5.1.4 For details on the stress concentration factors of butt welds (including transition cone sections), please refer to Section 3.3.1 and 3.3.2 in Chapter 3 of *CCS Technical Guidelines for Fatigue Strength Assessment of Offshore Engineering Structures*.

6.5.1.5 For stress concentration factors of grouting tubular joints, refer to Section 3.5.5 in Chapter 3 of *CCS Technical Guidelines for Fatigue Strength Assessment of Offshore Engineering Structures*.

6.5.2 S-N Curve

6.5.2.1 The S-N curve is usually represented by the stress amplitude as the ordinate and the logarithm of the number of stress cycles lgN as the abscissa.

6.5.2.2 S-N curve shall be selected according to Section 5 in Chapter 2 of CCS *Technical Guidelines for Fatigue Strength Assessment of Offshore Engineering Structures*.

6.5.3 Wall Thickness Effect

6.5.3.1 When WJ curve is adopted, for weld joints with a thickness exceeding 16mm, the weld joint thickness correction shall be performed using the following formula.

$$S = S_0\left(t_{ref}/t\right)^{0.25} \qquad (6.5.3-1)$$

Where:

t_{ref} - Reference thickness, 16mm;

S - Allowable stress range;

S_0 - Allowable stress range obtained from S-N curve;

t - The wall thickness of the members whose fatigue life is to be predicted.

6.5.3.2 If the weld profile is trimmed in accordance with SY/T 10030-2018, the exponent in the above formula can be replaced by 0.20. For weld toe grinding, the exponent can be replaced with 0.15.

6.5.4 Weld Improvement Techniques

6.5.4.1 For welded joints, there are several methods to improve fatigue performance, including grinding the weld toe to control burrs and weld trimming to obtain a concave section with smooth transition between the parent material.

6.5.4.2 For fatigue effects after implementation of improvement measures, please refer to Sections 2 and 3 of Chapter 8 of *CCS Technical Guidelines for Fatigue Strength Assessment of Offshore Engineering Structures*.

6.5.5 Fatigue Life Safety Factor

6.5.5.1 Generally, the design fatigue life of each joint and member shall not be less than the service life of the structure after considering the safety factor. The damage ratio D adopted for the design fatigue life shall not exceed 1.0.

6.5.5.2 For in-place conditions, the fatigue safety factor of steel members shall depend on the consequences of failure (i.e. criticality) and in-service detectability. Critical members are those members whose failure would result in catastrophic consequences. If no more detailed safety analysis is performed for the deepwater jacket structure, the safety factor for detectable, non-critical connections shall be 2.0. For critical connections and/or undetectable connections, the safety factors recommended in the following table are recommended.

Fatigue Safety Factors **Table 6.5.5.2**

Fatigue critical areas	Detectable	Undetectable
No	2	5
Yes	5	10

6.5.5.3 Normally, structural fatigue during towing shall be considered. If there is no more detailed calculation, one-year fatigue damage can be considered.

6.5.6 Cumulative Fatigue Damage

6.5.6.1 The total damage of a joint can be obtained by superimposing the damage values under all sea states in all directions, and the reciprocal of the damage value is the calculated fatigue life F of the joint.

$$F = \frac{1}{D} = \frac{1}{\sum D_{i,j}} \qquad (6.5.6-1)$$

Where: $D_{i,j}$ is the damage value corresponding to each sea state in different directions.

Chapter 7 Loadout Analysis

Section 1 General

7.1.1 General Requirements

7.1.1.1 Deepwater jackets are usually loaded onto ships by means of skidded load-outs. This chapter is applicable to the strength analysis of deepwater jackets during skidded loadout.

Section 2 Jacket Strength Analysis

7.2.1 The supports between the jacket and a barge/vessel or quay can be simulated by a compressible element during load-out . When the gap between some supporting joints of the jacket and the quay (or the ship/vessel) increases, the joints lose their support to be out of stress.

7.2.2 Vertical alignment of barge and quay, including the effects of any change and any movement of the barge due to wave or tide action, can generally be within approximately ±20-25mm.

7.2.3 For structural analysis, the typical conditions for towing the jacket to different positions during the skidded loadout, as well as the vertical alignment errors specified in Section 7.2.2 above, shall be considered.

7.2.4 The stress of members and joints shall be checked according to Chapters 6 & 7 of the *Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design* (SY/T 10030).

Chapter 8 Transportation Analysis

Section 1 General

8.1.1 General Requirements

8.1.1.1 This chapter provides recommended practices for the analysis of marine transportation of deepwater jacket. Analysis of marine transportation mainly includes the longitudinal strength check of transportation ships, the motion response analysis jacket-transportation ship combination, and the structural strength analysis of the jacket.

8.1.1.2 For principles of selecting environmental conditions for marine transportation analysis, refer to Section 4.2 of *CCS Guidelines for Analysis of Transportation and Floatover of Large Offshore Structures*.

8.1.1.3 For stability analysis methods and criteria of transportation ships, refer to Section 4.3 and 4.5 of *CCS Guidelines for Analysis of Transportation and Floatover of Large Offshore Structures.*

Section 2 Longitudinal Strength Check of Transportation Ships

8.2.1 General Requirements

8.2.1.1 Check of the longitudinal strength of a transportation ship can be conducted by allowable strength method. This method only needs to check the longitudinal strength in still water conditions.

8.2.1.2 For marine transportation of deepwater jacket, the weight distribution of the jacket on the transportation ship shall be reasonably considered when conducting the overall longitudinal strength analysis of the transportation ship.

8.2.2 Jacket Weight Distribution

8.2.2.1 The weight distribution of the jacket on the transportation ship shall be considered as follows: establish a vertical connection between the barge and the jacket, perform a structural analysis under still water conditions without considering the deformation of the connection itself, and then obtain the distribution of the jacket weight along the length of the transportation ship. Then, load the weight of the jacket onto the transportation ship in the form of point load and calculate the still water shear force and bending moment of the transportation ship.

Section 3 Motion Response Analysis

8.3.1 General Requirements

8.3.1.1 The motion response results of the jacket - transportation ship combination of the are the basis for lashing scheme design and structural integrity check. The design value of motion response can be obtained through hydrodynamic analysis, model test or calculation from the default/recommended motion values.

8.3.1.2 Model tests may be used to derive design motions provided they are reliable (verified). Scale effects should also be accounted for by increasing the design loads by a further 10% or a mutually agreed value.

8.3.1.3 If no hydrodynamic analysis and model test is conducted, the motion response recommended in Table 3.1, Appendix 1 of CCS *Guidelines for Towage* at Sea can be referred to.

8.3.2 Hydrodynamic Analysis

8.3.2.1 The ship motion response analysis under waves of 0°-180° at intervals of 45° shall be considered at least.

8.3.2.2 The sensitivity of wave period, that is, the combination of significant wave height and a series of spectral peak periods, shall be considered in the sea state for transportation analysis.

8.3.2.3 In the hydrodynamic analysis method, the movement response amplitude operator (RAO) can be obtained by calculating the hydrodynamic force based on the two-dimensional strip theory/three-dimensional potential flow theory. Then, the 3-hour MPME can be obtained through the statistical prediction.

8.3.3 Movement Caused by Wind Load

8.3.3.1 In addition to wave-induced motion, motion caused by wind loads also shall also be considered.

8.3.3.2 The contribution of wind loads to the motion is mainly reflected in the following aspects: the increase of rolling (or pitching) due to the wind inclination angle caused by wind, and the component of gravity acceleration caused by rolling (or pitching), that is, the increase of rolling (or pitching) acceleration.

8.3.3.3 One-minute gust is generally adopted to calculate the motion caused by the wind load, and it is conservatively considered that wind causes the linear superposition of the rolling (or pitching) motion caused by wind and the wave-induced motion.

8.3.3.4 In the case of good stability and a small wind area, if it is inconvenient to calculate the wind inclination angle, the maximum motion response caused by waves with 2%-3% addition shall be taken as the design motion parameter.

Section 4 Jacket Structure Analysis

8.4.1 General Requirements

8.4.1.1 The jacket must have sufficient strength to withstand the inertial loads and wind loads, as well as the additional loads caused by overhanging the ship.

8.4.1.2 The overhanging part of the jacket is sometimes submerged in water, and the load caused by wave slamming and/or shipping shall be considered in the analysis.

8.4.1.3 If the situation of external overhanging of the jacket is serious, the impact on the jacket structure shall be conducted through motion analysis or test.

8.4.2 Flexible Deformation

8.4.2.1 In the analysis of deepwater jacket transportation, if the influence of the flexible deformation between the barge and the jacket on the structural strength shall be considered.

8.4.2.2 The flexible deformation of the transportation ship shall be derived through the structural analysis of the jacket - transportation ship combination, and shall be considered as a boundary condition in the jacket structure analysis.

8.4.3 Load Case

8.4.3.1 For the load case, the superposition of fluctuating and static loads caused by downwind and waves in all directions must be considered.

8.4.3.2 The static load shall include the gravity as well as the wind load and wind inclination angle caused by the action of constant wind.

8.4.3.3 For the fluctuating load, the inertial force caused by waves shall be mainly considered, and the combination of six-degree-of-freedom acceleration under various wave directions shall be considered.

8.4.4 Strength Check

8.4.4.1 Check of the stresses of jacket joints and members shall be conducted according to Chapter 6&7 of the *Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design* (SY/T 10030).

Chapter 9 Launching and Upending Analysis

Section 1 General

9.1.1 General Requirements

9.1.1.1 This chapter applies to jacket sliding launching analysis and upending analysis of crane assistance modes.

9.1.1.2 The launching and upending analysis of the jacket is generally carried out in still water, without considering the influence of wind, wave and current.

9.1.1.3 The check of barge in the jacket sliding launching analysis is considered separately and is not covered in the Guidelines. For details of barge check, please refer to Section 5.2 of *CCS Guidelines for Analysis of Transportation and Floatover of Large Offshore Structures*.

9.1.2 Jacket Sliding Launching

9.1.2.1 The jacket launching hydrodynamic analysis (launching trajectories and force analysis), structural strength analysis and launching parameter sensitivity analysis shall be carried out.

9.1.2.2 The main points of the jacket analysis shall include:

(1) Whether the jacket maintains a good launching trajectory, without large rolling (generally less than 0.25 degrees) but with adequate bottom clearance, etc.

(2) Whether the structural strength of the jacket meets the requirements during the launch.

(3) The jacket shall have sufficient structural strength, and the jacket members shall be able to withstand the wave slamming load when launching for high speed.

9.1.2.3 For the sensitivity analysis of the launching parameters, reserve buoyancy requirements and other check criteria of the jacket, please refer to Section 5.2 of *CCS Guidelines for Analysis of Transportation and Floatover of Large Offshore Structures*.

9.1.3 Jacket Upending Analysis

9.1.3.1 The main purpose of the jacket upending analysis is to verify the stability of the jacket during the upending process, check whether the seabed clearance and crane/hanger capacity can meet the requirements, and check the structural strength of the jacket.

Section 2 Launch Dynamic Analysis

9.2.1 Analysis Model

9.2.1.1 The jacket hydrodynamic, buoyancy and mass models shall include the main structure and the ancillary structures.

9.2.1.2 For the barge model, all members that increase the mass and buoyancy of the barge, including the skidways and rocker arms, shall be considered. The buoyancy model of the barge shall be adequate for the accurate simulation according to the change of the barge during launching.

9.2.1.3 The drag coefficient, additional mass and damping coefficient of the barge and jacket shall be accurately simulated.

9.2.2 Analysis Method

The time-domain simulation analysis shall be carried out for the jacket sliding launching using professional software, thus obtaining the motion trajectory of the jacket and barge, as well as the time history of the rocker arm reaction. Thus, the key parameters can be checked according to the analysis criteria.

Section 3 Launch Structure Analysis

9.3.1 Analysis Condition

9.3.1.1 During launching, several characteristic moments shall be considered as the conditions for the structural analysis of the jacket. In terms of the characteristic moments of structural analysis, the moments before and during jacket rotation on the rocker arm, during the separation of the jacket from the barge and during diving to the maximum depth are generally selected. In addition, the moments that the tubular joints of jacket launch leg and the central position of the tubular section between adjacent joints pass through the rocker arm pin shall also be taken as the characteristic moment for structural analysis.

9.3.2 Analysis Model

9.3.2.1 The buoyancy, gravity, inertia force, friction force, supporting force and hydrodynamic force of the jacket shall be considered in the analysis of the jacket launch structure.

9.3.2.2 The jacket and barge/rocker arm shall be connected at each leg joint by a compression-only spring with large rigidity. the fixed constraint perpendicular to the rocker arm is applied at the rocker arm pin, and a horizontal spring constraint with small stiffness is applied at the end of the jacket. Figure 9.3.2.2 shows the boundary conditions before and during rotation, during separation and after launching of the jacket.

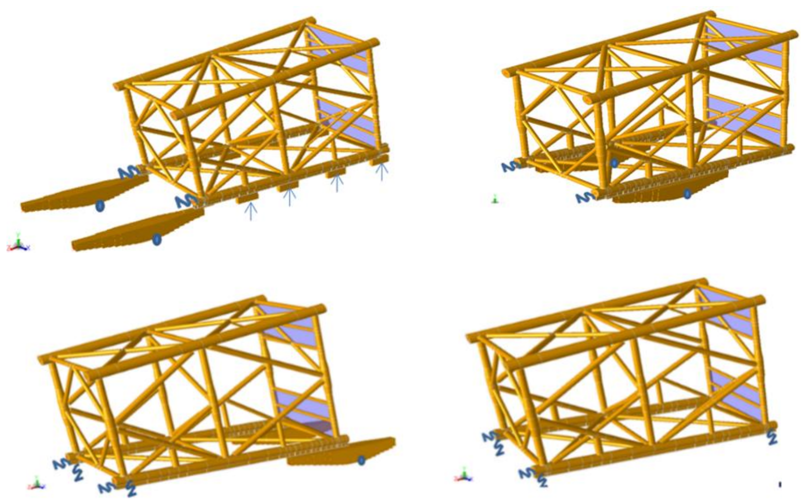

Figure 9.3.2.2 Analysis Model for Jacket Launch Structure

9.3.3 Strength Check

9.3.3.1 The stress of the members and joints shall be checked according to Chapter 6&7 of the *Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design* (SY/T 10030).

9.3.3.2 The maximum flooding speed of the jacket can be used to check the slamming strength. Besides, the flooding speed of each member on the jacket obtained from the launching dynamic analysis can also be used to check the slamming strength.

Section 4 Upending Analysis

9.4.1 General Requirements

9.4.1.1 The intact condition and the damaged compartment condition shall be considered in the jacket upending analysis.

9.4.1.2 For the check criteria of reserve buoyancy, stability, seabed clearance, etc. during the jacket upending analysis, refer to the analysis criteria in Section 6.2 of *CCS Guidelines for Analysis of Transportation and Floatover of Large Offshore Structures.*

9.4.1.3 The upending analysis of crane assistance modes is divided into static analysis and dynamic analysis.

9.4.2 Static Analysis of Upending

9.4.2.1 The purposes of static analysis are to obtain the operation flow process of upending, that is, the steps and amplitude of lifting/lowering and water filling of the crane, and to check its operability.

9.4.2.2 In fact, static analysis is to solve the equilibrium position of each crane and/or ballast operation, and determine the ballast and seabed clearance of the jacket at each step, as well as the height and lifting weight of the crane.

9.4.3 Dynamic Analysis of Upending

9.4.3.1 The purpose of dynamic analysis is to investigate the influence of wave-induced motion of the lifting ship on upending.

9.4.3.2 Analysis process: select several characteristic states from the static analysis, obtain the information such as the hook height, jacket floating state and water filling under this state, solve the equilibrium state of the system, and conduct dynamic analysis in this equilibrium state. For dynamic analysis, the frequency-domain analysis method or time-domain analysis method can be adopted.

Section 5 Upending Structure Analysis

9.5.1 Analysis Condition

9.5.1.1 The jacket structure is analyzed with several characteristic postures during upending as the analysis conditions.

9.5.2 Analysis Model

9.5.2.1 The buoyancy, gravity, inertia force, hydrodynamic force and other items of the jacket (such as dynamic analysis) shall be considered; at the same time, the pull rod unit shall be used to simulate the sling, and a small stiffness spring constraint shall be imposed on the horizontal layer at the bottom of the jacket.

9.5.3 Strength Check

9.5.3.1 The stress of the members and joints shall be checked according to Chapter 6&7 of the *Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design* (SY/T 10030).

Chapter 10 Additional Analysis

Section 1 Stability of the Submersible Unit and Mudmat Structural Analysis

10.1.1 General Requirements

10.1.1.1 The stability analysis of the submersible unit and the mudmat structural analysis of deepwater jacket mainly includes:

(1) Analysis of the stability against overturning of the jacket;

(2) Anti-sliding stability analysis of the jacket;

(3) Soil compression resistance analysis;

(4) Analysis of the structural strength of the mudmat.

10.1.1.2 The stability of the submersible unit and the structural strength of the mudmat shall withstand the environmental loads that may be encountered under all steel pile installation schemes.

10.1.1.3 The structural weight and buoyancy of the main structure and the ancillary structure shall be consistent with those specified in the weight control report.

10.1.1.4 The water filling state of the structures such as the leg, launching leg, skirt pile sleeve, riser, J-tube, casing, mudmat bracket, etc. of the jacket shall be set according to the jacket filling layout diagram with consideration to the offset buoyancy.

10.1.2 Anti-overturning Stability Analysis of the Jacket

10.1.2.1 The overturning moment generally includes the overturning moment caused by waves and currents, and the additional overturning moment caused by the inclination of the steel piles in the pile group sleeve and the weight of the steel piles and pile hammers.

10.1.2.2 The additional overturning moment shall be consistent with the direction of the overturning moment caused by waves and currents to conservatively consider the stability of the jacket against overturning.

10.1.2.3 The righting moment generally includes the righting moment generated by the deadweight of the jacket in water and the reduction of the righting moment caused by the accidental inclination of the jacket. The inclination angle can generally be 1°.

10.1.2.4 The righting arm is the horizontal distance from the center of gravity of the jacket in water to the overturning axis. The horizontal distance from the axis to the edge of the horizontal layer at the seabed of the jacket is generally B (or L) /4, where B and L refer to the width and length of the mudmat, respectively.

10.1.2.5 The allowable safety factor for anti-overturning stability is generally 1.5.

10.1.3 Anti-sliding Stability Analysis of the Jacket

10.1.3.1 The anti-sliding stability of the jacket can be calculated with reference to Article 1, Section 12, Chapter 9 of the *Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design* (SY/T 10030).

10.1.3.2 The allowable safety factor for anti-sliding stability is generally 1.5.

10.1.4 Compression Strength Analysis of Soil

10.1.4.1 The ultimate compression strength of soil shall be selected according to the engineering geological survey report.

10.1.4.2 The allowable safety factor for soil compression is 1.5 for combined conditions and 2.0 for static load conditions.

10.1.5 Structural Strength Analysis of Mudmat

10.1.5.1 A local finite element model shall be established for the strength analysis of the mudmat structure. The model shall include the main beam of the dustproof plate, the groove plate, the connecting columns between the mudmat and the horizontal layer of the jacket, the mudmat diagonal braces, and the jacket structure near the mudmat.

10.1.5.2 The strength of the main beam of the mudmat, the connecting columns between the mudmat and the horizontal layer of the jacket, the mudmat diagonal braces, and the jacket members near the mudmat shall be checked according to the criteria specified in relevant provisions of Section 4, Chapter 3.

10.1.5.3 The strength of the jacket joints near the mudmat shall be checked according to relevant provisions of Section 4, Chapter 3.

10.1.5.4 The shear and bending resistance of the grooved plate section shall be checked according to the relevant provisions of Section 4, Chapter 3.

Section 2 Joint Stiffener Ring

10.2.1 General Requirements

10.2.1.1 In case the strength of tubular joints does not meet the requirements of the specifications, joint stiffener rings can be used.

10.2.1.2 The following three methods can be used in engineering to determine the size and quantity of joint stiffener rings:

(1) Assume that the joint loads are fully resisted by the stiffener rings within the elastic range;

(2) Assume that the joint loads are completely resisted by the stiffener rings within the plastic range;

(3) Assume that the joint loads are resisted by both the simple joints and the ultimate capacity of the stiffener rings.

10.2.1.3 Method (3) determines the lower capacity limit of the stiffener rings, and Method (2) determines the upper capacity limit of the joints with stiffener rings. Method (1) is between the two methods. Therefore, if conditions permit, Method (2) is recommended for determining the size and number of joint stiffener rings.

10.2.2 Upper Limit Method

10.2.2.1 Overview

(1) Based on the position of the jacket during loading, the joint braces are defined as in-plane braces and out-of-plane braces. Figure 10.2.2.1(1) shows a typical horizontal view of an in-plane brace, and Figure 10.2.2.1(2) shows a typical top view of an out-of-plane brace. Figure 10.2.2.1(3) shows the typical cross-sectional view of a joint.

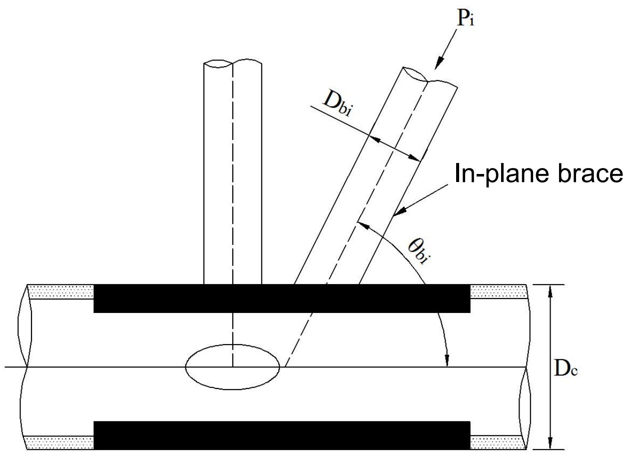

Figure 10.2.2.1(1) Typical Side View of an In-plane Brace

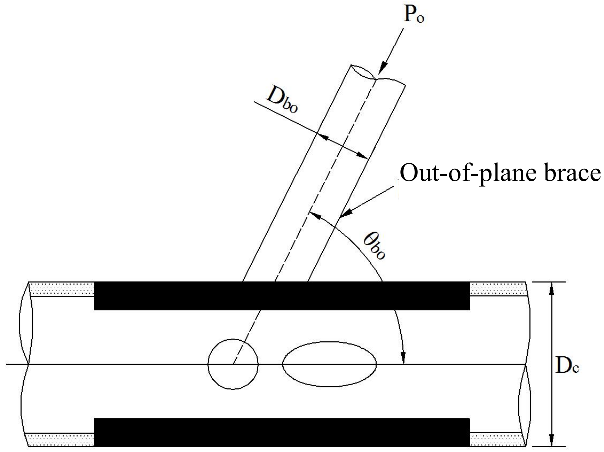

Figure 10.2.2.1(2) Typical Top View of an Out-of-plane Brace

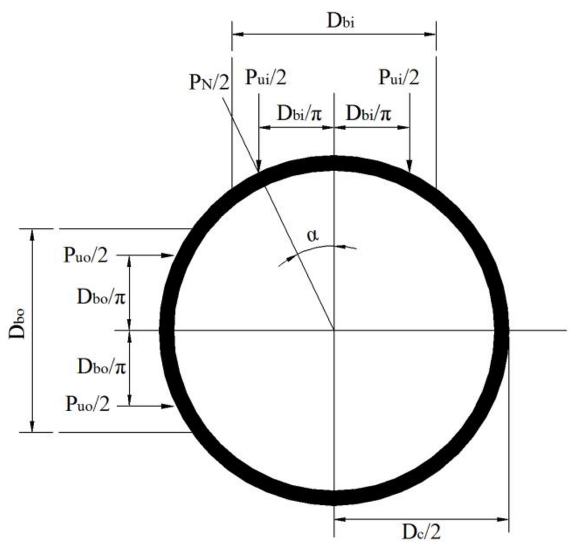

Figure 10.2.2.1(3) Typical Cross-sectional View of a Joint

(2) Vertical component of axial load

According to Figure 10.2.2.1(3), the following relationship can be obtained:

$$\alpha = sin^{-1}\left(\frac{2D_{bi}}{\pi D_c}\right) \qquad (10.2.2-1)$$

$$P_{ui} = FLsin\theta_{bi}\left(P_i + \frac{\pi M_i}{D_{bi}}\right) \qquad (10.2.2-2)$$

$$P_{uo} = FLsin\theta_{bo}\left(P_o + \frac{\pi M_o}{D_{bo}}\right) \qquad (10.2.2-3)$$

$$P_N = P_{ui}\cos\alpha \qquad (10.2.2-4)$$

Where: α - Angle to the upper plastic hinge, °;

FL - Plastic analysis load factor, 1.7;

P_N - Vertical component of the in-plane brace axial load, kN;

P_i - Axial load of the in-plane brace, kN;

D_{bi} - Diameter of the in-plane brace, mm;

M_i - Bending moment of the in-plane brace, including in-plane bending moment and out-of-plane bending moment, m-kN;

P_{ui} - Design lateral load of the in-plane brace, kN;

P_o- Axial load of the in-plane brace, kN;

D_{bo}- Diameter of the in-plane brace, mm;

M_o- Bending moment of the in-plane brace, including in-plane bending moment and out-of-plane bending moment, m-kN;

P_{uo} - Design lateral load of the in-plane brace, kN;

10.2.2.2 Shear Strength Check

The formula for check of the shear strength of the stiffener ring joints is as follows:

$$V_{allow} = V_{shell} + V_{rings} \qquad (10.2.2-5)$$

Where: V_{allow} - Shear strength of the stiffener ring joint, kN;

V_{shell} - Shear strength of the thickened section of the chord, $P_a \sin\theta$, kN;

V_{rings} - Shear strength of the stiffener ring, kN;

P_a - Weighted average shear strength of joint, kN;

$$P_a = (J_K P_{aK} + J_T P_{aT} + J_X P_{aX})/(J_K + J_T + J_X) \qquad (10.2.2-6)$$

Where: P_{aK}, P_{aT}, P_{aX} - shear strength of type K, T and X joints; the calculation formula is selected with reference to the formula in Chapter 4 of API RP 2A, and the correction of strength factor is fully considered;

J_K, J_T, J_X - Percentage of Type K, T, and X joints.

$$V_{rings} = 2N_r T_r H\left(0.4F_{yr} incr\right) \qquad (10.2.2-7)$$

Where: F_{yr} - Yield strength of the rings, MPa;

N_r - Number of rings;

T_r - Thickness of the ring, mm;

H - Height of the ring, mm;

$incr$ - Allowable stress increment, 1.0 for loading condition and 1.333 for other conditions.

The shear stress ratio is as follows:

$$SR_{shear} = \frac{P_N}{FLV_{allow}} \qquad (10.2.2-8)$$

10.2.2.3 Design Loads at Hard Points

The load transferred from the brace to the chord is assumed to be shared by the shear force and axial force along the circumference of the brace and the concentrated force at the hard points. The hard point diagram is shown in Figure 10.2.2.3.

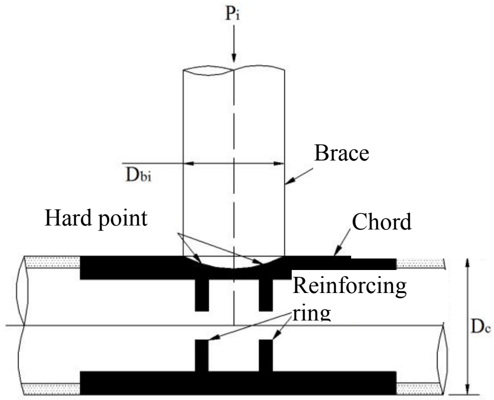

Figure 10.2.2.3 Hard Point Diagram

The design load at the hard point is determined by the following formula:

$$P_{HP} = \frac{V_{rings}}{V_{rings}+V_{shell}}\left(\frac{P_N}{2N_r}\right)\frac{1}{FL} \qquad (10.2.2-9)$$

Note: P_{HP} is used to check the yield and buckling of the web on the stiffener ring side and the brace side.

10.2.2.4 Web Yield and Buckling Check

(1) The web yield and buckling strength shall be checked on both the stiffener ring side and the brace side. Typical cross-sections of the contact surfaces of the stiffener ring, chord and brace are shown in Figure 10.2.2.4(1) and Figure 10.2.2.4(2).

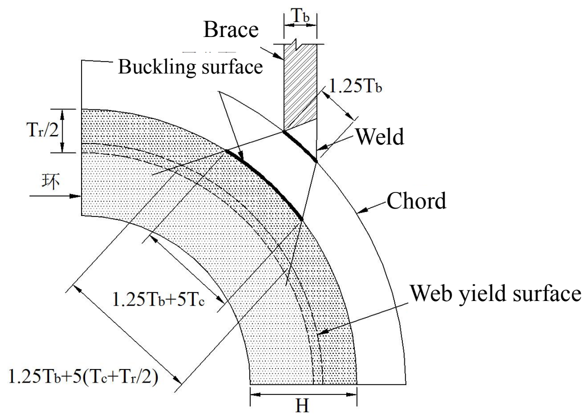

Figure 10.2.2.4(1) Buckling and Yield Surface of Web on the Stiffener Ring Side

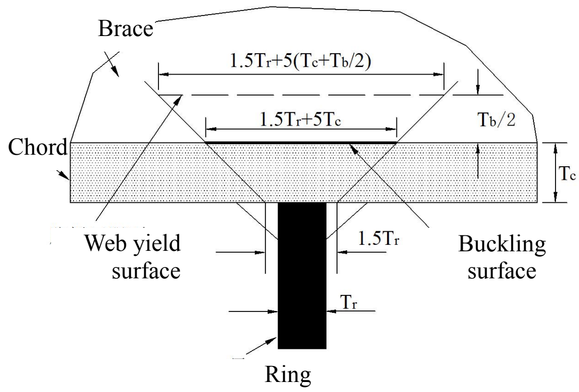

Figure 10.2.2.4(2) Buckling and Yield Surface of Web on the Brace Side

(2) Web yield check

①Stiffener ring side

$$A_{wyr} = T_r\left[1.25T_b + 5\left(T_c + \frac{T_r}{2}\right)\right] \qquad (10.2.2-10)$$

$$P_{wyr} = 0.66F_{yr}A_{wyr}Incr \qquad (10.2.2-11)$$

$$SR_{wyr} = \frac{P_{HP}}{P_{wyr}} \qquad (10.2.2-12)$$

Where: A_{wyr} - Yield area of stiffener ring side, cm^2;

P_{wyr} - Allowable load, kN;

SR_{wyr} - Yield stress ratio of stiffener ring.

②Brace side

$$A_{wyb} = T_b\left[1.5T_r + 5\left(T_c + \frac{T_b}{2}\right)\right] \qquad (10.2.2-13)$$

$$P_{wyr} = 0.66F_{yb}A_{wyb}Incr \qquad (10.2.2-14)$$

$$SR_{wyb} = \frac{P_{HP}}{P_{wyb}} \qquad (10.2.2-15)$$

Where: A_{wyb} - Yield area of stiffener ring side, cm^2;

$P_{wy\mathrm{b}}$ - Allowable load, kN;

$SR_{wy\mathrm{b}}$ - brace side yield stress ratio.

(3) Web buckling check

①Stiffener ring side

$$N_{bnr} = 1.25T_b \qquad (10.2.2-16)$$

$$P_{bnr} = 0.4T_r^2\left(1 + 3\frac{N_{bnr}}{H}\left(\frac{T_r}{T_c}\right)^{1.5}\right)\sqrt{\frac{EF_{yc}T_c}{T_r}}Incr \qquad (10.2.2-17)$$

$$SR_{bnr} = \frac{P_{HP}}{P_{bnr}} \qquad (10.2.2-18)$$

Where: N_{bnr} - minimum load-bearing length of the stiffener ring side, mm, see Figure 10.2.2-5;

P_{bnr} - Allowable load, kN;

SR_{bnr} - Local buckling stress ratio of the stiffener ring side;

E - Elastic modulus of steels, MPa

②Brace side

$$N_{bnb} = 1.25T_b \qquad (10.2.2-19)$$

$$P_{bnb} = 0.4T_b^2\left(1 + 3\frac{N_{bnb}}{D_b}\left(\frac{T_b}{T_c}\right)^{1.5}\right)\sqrt{\frac{EF_{yb}T_c}{T_b}}Incr \qquad (10.2.2-20)$$

$$SR_{bnb} = \frac{P_{HP}}{P_{bnb}} \qquad (10.2.2-21)$$

Where: N_{bnb} - Minimum load-bearing length, mm, see Figure 10.2.2.4(2);

P_{bnb}- Allowable load, kN;

SR_{bnb} - Buckling stress ratio

10.2.2.5 Axial and Bending Capacity of Compound Sections

(1) After the local bearing capacity is checked according to Section 10.2.2.4, the overall bearing capacity of the stiffener ring joints shall also be checked. It is assumed that the load transferred by the brace is borne by the composite section (consisting of the effective length L_e of the chord outer wall and the stiffener ring), as shown in Figure 10.2.2.5(1).

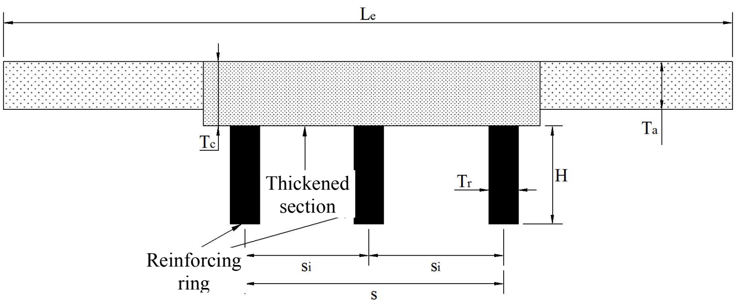

Figure10.2.2.5(1) Combined Section and Effective Length

The effective length is calculated as follows:

$$L_e = 1.1(D_cT_c) + s \qquad (10.2.2-22)$$

(2) The assumed position of the plastic hinge is shown in Figure 10.2.2.5(2).

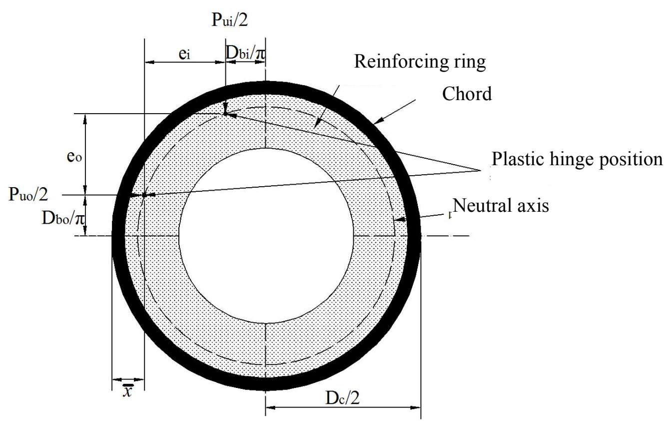

Figure 10.2.2.5(2) Assumed Location of Plastic Hinge

The free body stress conditions between plastic hinges are shown in Figure 10.2.2.5(3).

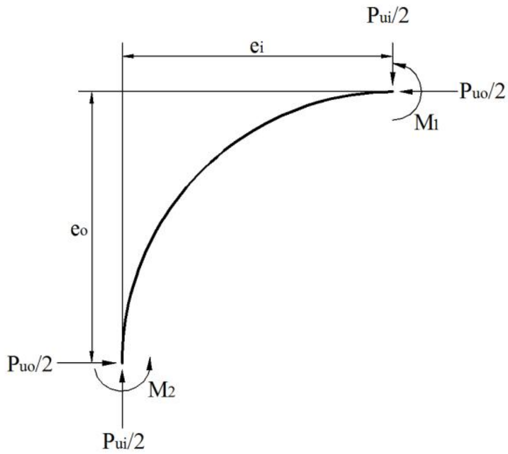

Figure 10.2.2.5(3) Free Body Stress between Plastic Hinges

The maximum axial load on a combined section is defined by the following formula:

$$P_{max} = max\left(P_{ui},\ P_{uo}\right) \qquad (10.2.2-23)$$

The ultimate axial load capacity of the chord is:

$$P_{ult} = N_r T_r F_{yr} H + L_e T_c F_{yc} \qquad (10.2.2-24)$$

Where: N_{r} - Number of stiffener rings;

T_{r} - Thickness of stiffener ring, mm;

F_{yr} - Yield strength of stiffener ring, MPa;

H- Thickness of stiffener ring, mm;

F_{yc}- Chord yield strength, MPa;

Axial load stress ratio in the chord:

$$SR_{axial} = \frac{P_{max}}{P_{ult}} \qquad (10.2.2-25)$$

The eccentricity in Figure 10.2.2.5(3) is calculated by the following formula:

$$e_i = \frac{D_C}{2} - \frac{D_{bi}}{\pi} - \overline{x} \qquad (10.2.2-26)$$

$$e_o = \frac{D_C}{2} - \frac{D_{bo}}{\pi} - \overline{x} \qquad (10.2.2-27)$$

Where: $\overline{x}$ - to be selected according to Formula (10.2.2-29) or (10.2.2-30).

The maximum bending moment is calculated by the following formula:

$$M_{max} = M_1 + M_2 = \frac{P_{ui}}{2} e_i - \frac{P_{uo}}{2} e_o \qquad (10.2.2-28)$$

Note: When P_{ui} and P_{uo} have the same symbol, the second item in the above formula can be ignored for conservative reasons.

The ultimate bending capacity of the T-section is determined by plastic analysis method. For the T-section, see Figure 10.2.2.5(4).

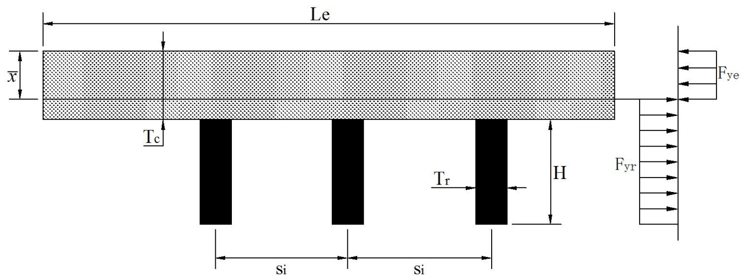

Figure 10.2.2.5(4) T-section for Plastic Analysis

$$\overline{x}_1 = \frac{HN_rT_rF_{yr} + L_eT_cF_{yc}}{2L_eF_{yc}} \qquad (10.2.2-29)$$

$$\overline{x}_2 = \frac{(2T_c + H)N_rT_rF_{yr} - L_eT_cF_{yc}}{2N_rT_rF_{yr}} \qquad (10.2.2-30)$$

When $\overline{x}_1 \leq T_c$

$$\overline{x} = \overline{x}_1 \qquad (10.2.2-31)$$

The ultimate bending capacity is calculated according to the following formula:

$$M_u = \frac{L_eF_{yc}\overline{x}^2}{2} + \frac{L_eF_{yc}}{2}(T_c - \overline{x})^2 + HN_rT_rF_{yr}\left(\frac{H}{2} + T_c - \overline{x}\right) \qquad (10.2.2-32)$$

When $\overline{x}_1 \geq T_c$

$$\overline{x} = \overline{x}_2 \qquad (10.2.2-33)$$

The ultimate bending capacity is calculated according to the following formula:

$$M_u = \left(\frac{N_rT_rF_{yr}}{2}\right)(\overline{x} - T_c)^2 + \frac{N_rT_rF_{yr}}{2}(H + T_c - \overline{x})^2 + L_eT_cF_{yc}\left(\overline{x} - \frac{T_c}{2}\right) \quad (10.2.2-34)$$

The full plasticity overall bending capacity can be determined by the following formula:

$$M_{ucap} = M_{(1)} + M_{(2)} = 2M_u \qquad (10.2.2-35)$$

$$SR_{mu} = \frac{M_{max}}{M_{ucap}incr} \qquad (10.2.2-36)$$

The combined stress ratio of axial and moment capacity is:

$$SR_{comb} = SR_{axial} + \frac{SR_{mu}}{1.18} \qquad (10.2.2-37)$$

10.2.2.6 Overall Crushing Strength Check of the Stiffener Ring Joints

In addition to meeting the requirements of Section 10.2.2.2 to 10.2.2.5, the stiffener ring joints of launching legs shall also be checked for overall crushing strength in loading, transportation and launching conditions. The check shall be conducted in accordance with Section 10.2.2.5, but also based on the following assumptions:

(1) If a joint includes more than one stiffener ring, the joint stiffener ring with the smallest moment of inertia shall be selected for overall crushing strength check, taking into account the number of stiffener rings;

(2) When the effective length L_e derived from Formula (10.2.2-22) exceeds the length of the thickened section L_c, L_e shall take the value of L_c;

(3) The design lateral load is the sum of the lateral loads of all braces on the same side;

(4) The equivalent diameter of the brace is based on the weighted average transverse load ($Psin\,\theta$) of each brace.

Section 3 Local Strength Analysis of Skirt Pile Sleeve and Connection Structure

10.3.1 General Requirements

10.3.1.1 Local strength analysis of skirt pile sleeves and connecting structures shall be conducted using approved general purpose engineering software.

10.3.2 Finite Element Model

10.3.2.1 According to the symmetry relationship of the deepwater jacket platform, typical skirt pile sleeves and connection structures, such as skirt pile sleeves and connection structures at diagonal positions, shall be selected to establish a local finite element model.

10.3.2.2 The local finite element model shall include annular plates, shear plates, skirt pile sleeves, steel piles, cement slurry between skirt pile sleeves and steel piles, stiffener rings, legs, and diagonal braces.

10.3.2.3 The local finite element model shall take the pile head point in the overall structural model as a boundary, and the local strength of the structure above the seabed shall be considered by applying the pile head load.

10.3.2.4 In the overall structural model, the legs and diagonal braces near the skirt pile sleeves shall be broke up at appropriate locations. The joint displacement at the breaking point is applied to the local finite element model as a boundary, and the breaking length shall not affect the accuracy of the local analysis.

10.3.2.5 It is advisable to use shell elements to simulate steel structures and solid elements to simulate cement slurry structures. The shell element size shall be determined based on a comprehensive consideration to the influence of factors such as wall thickness, and shall usually not exceed 4 times the wall thickness.

10.3.2.6 The conditions to be considered in the local strength analysis shall be determined based on the total load on the skirt pile heads in the overall structural analysis.

10.3.2.7 Since the skirt pile sleeve and connecting structure have great stiffness, large deformation generally does not occur, so the geometric nonlinearity can be ignored in the analysis process.

10.3.2.8 When only the local hot spot VON-MISES stress exceeds the material yield strength, the material nonlinearity can be ignored in the analysis process.

10.3.3 Strength Check Criteria

10.3.3.1 The yield strength of plate elements shall be checked with reference to Section 3.4.2.2, Chapter 3, Part 2 of *CCS Rules for Classification of Mobile Offshore Units*.

10.3.3.2 For the plate element yield strength check in the local high stress area, the allowable stress can be increased by 10% on the basis of the material yield strength, and the area of the local high stress area is recommended not to exceed 10% of the considered area.

10.3.3.3 The buckling strength of plate elements shall be checked with reference to Section 3.4.7, Chapter 3, Part 2 of CCS *Rules for Classification of Mobile Offshore Units*.

Section 4 Vortex-Induced Vibration

10.4.1 General Requirements

10.4.1.1 Wind, current, or any other fluid flowing through a structural member may cause unsteady flow patterns due to vortex shedding. This may cause the elongate element to vibrate perpendicularly to its longitudinal axis.

10.4.1.2 Effect of Vortex-induced Vibration on Slender Members:

(1) Vortex-induced vibration may cause severe fatigue damage to the system;

(2) Vortex-induced vibration may increase the average drag coefficient of the member, affecting the overall analysis of the member and affecting the analysis of other members;

(3) Vortex-induced vibration may affect wake-induced vibrations (WIO) that may affect the cylinder array (onset and amplitude);

(4) Vortex-induced vibration may have a significant effect on the relative collision velocity of two adjacent cylinders.

10.4.1.3 Conditions to be considered for the vortex-induced vibration of the jacket shall include but not limited to the following:

(1) Site construction;

(2) Towing transportation;

(3) The jacket is in position.

10.4.1.4 For underwater members, both the conditions with marine organisms and without marine organisms shall be considered.

10.4.1.5 For deepwater jackets, vortex-induced vibration of members shall be avoided as far as possible.

10.4.2 Basic Concepts and Definitions

10.4.2.1 Natural Frequency

The first-order modal natural frequency of the structure is calculated by the following formula:

$$f_n = \frac{(1.59\phi + \pi)^2}{2\pi L^2}\sqrt{\frac{EI}{m_e}} \qquad (10.4.2-1)$$

Where:

ϕ - Degree of freedom of the member end points,

$\phi = 1.0$, for fixed support - fixed support;

$\phi = 0.5$, for fixed support - hinged support;

$\phi = 0.0$, for hinged support - hinged support;

$\phi = 0.7$, for tubular joints with penetration weld at both ends;

m_e - Effective mass per unit length of the member, kg/m;

E - Elastic modulus;

L - Member length;

I - Sectional moment of inertia of the member

10.4.2.2 Effective mass

The effective mass per unit length of a member is defined as follows:

$$m_e = \frac{\int_L m[y(x)]^2 dx}{\int_L [y(x)]^2 dx} \qquad (10.4.2-2)$$

10.4.2.3 In steady flow or flow with a K_C greater than 40, the vortex shedding frequency can be calculated by the following formula:

$$f_s = S_t \frac{u}{D} \qquad (10.4.2-3)$$

Where:

f_s - Vortex shedding frequency, Hz;

St - Strouhal number;

u - Fluid velocity perpendicular to the axis of the member, m/s;

D - Member diameter, m.

For a smooth stationary cylinder, the Strouhal number (St) is a function of the Reynolds number (Re), and the relationship between the two is determined by the following figure:

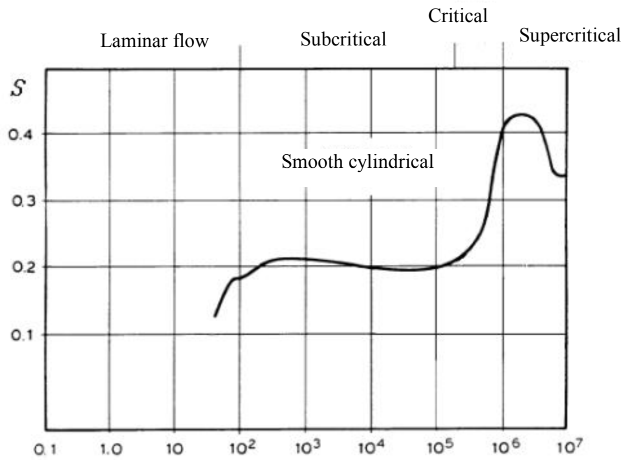

Figure 10.4.2 St-Re Relationship Curve

For a rough-surfaced cylinder or a vibrating cylinder (regardless of whether the surface is smooth or rough), the Strouhal number (St) is relatively insensitive to the Reynolds number (Re).

10.4.2.4 Cross Flow and In-line Movement

Vortex-induced vibration can be decomposed into:

(1) Cross-flow (CF) vibration, amplitude is about 1 times the diameter;

(2) Pure in-line (IL) vibration, with an amplitude of approximately 10~15% of the diameter;

(3) The cross-flow induced in-line vibration, with an amplitude of about 30~50% of the cross-flow amplitude;

(4) Pure in-line motion may occur at the lowest reduced velocities, but when the velocities are large enough to produce crossflow (and crossflow-induced in-line) responses, pure in-line motion is usually no longer concerned since its corresponding amplitude is small.

10.4.2.5 Reduction Speed

Parameter V_R (reduction velocity) shall be defined to determine the speed range where vortex shedding resonates with the natural frequency of the member:

$$V_R = \frac{u}{f_i D} \qquad (10.4.2-4)$$

Where:

u - $u(x)$, instantaneous fluid velocity perpendicular to the axial direction of the member, m/s;

f_i - i-order natural frequency of the member, Hz;

D - $D(x)$, member diameter, m;

x - Distance along the axial direction of the member, m.

10.4.2.6 Mass Ratio

The mass ratio is used to measure the relative importance of the effects of buoyancy and mass on the model and is defined as follows:

$$m^* = \frac{m}{\pi \rho D^2/4} \qquad (10.4.2-5)$$

The frequency locking range of low mass ratio is larger than that of high mass ratio, this is because the contribution of additional mass to the structural mass is relatively larger. Generally, for low mass ratio (such as risers, pipelines, etc.), vortex-induced vibration occurs in the reduction velocity of $3 < V_R < 16$, and for high mass ratio (structures exposed to wind), vortex-induced vibration occurs in the reduced velocity of $4 < V_R < 8$.

10.4.2.8 Structural Damping

Structural damping is caused by the internal friction of the member material and its magnitude is depended on the strain level and the associated deflection. For steel members exposed to wind, if no other information is available, the structural damping ratio ($\delta_S/2\pi$) can be 0.0015. For slender members in water, the structural damping under moderate deformation is usually between 0.005 (pure steel pipe) and 0.03~0.04 (flexible pipe).

10.4.3 Wind-induced Vortex Shedding

10.4.3.1 In wind-induced vibration analysis, the rules for calculation of wind speed are as follows:

(1) The calculated wind speed during towing shall be the 1-minute average wind speed at 10m above sea level on the towing path with a return period of 10 years;

(2) In the in-place analysis, the calculated wind speed shall be the 1-minute average wind speed at 10m above sea level of the site with a return period of 1 year;

(3) When calculating wind speed, the effect of height coefficient must be considered.

10.4.3.2 For circular pipes, wind-induced vibrations may occur in two planes, a plane aligned with the wind direction (in-line) or a plane perpendicular to the wind direction (cross-flow).

10.4.3.3 Wind-induced in-line vibration may occur when the reduced wind speed is within the following range:

$$\frac{0.3}{St} < V_R < \frac{0.65}{St} \qquad (10.4.3-1)$$

Where:

V_R - Reduction speed

St - Strouhal number

In-line vibrations may occur only at small stability parameters, i.e. $K_S < 2$.

10.4.3.4 Wind-induced crossflow vibration may occur when the reduced wind speed is within the following range:

$$\frac{0.8}{St} < V_R < \frac{1.6}{St} \qquad (10.4.3-2)$$

10.4.4 Flow-Induced Vortex Shedding

10.4.4.1 In-line and cross-flow vibrations are considered separately. The response model described here is mainly used in the case of single-modal locking.

10.4.4.2 Vortex-Induced In-line Vibration

In-line vortex shedding may occur in the following situations:

$$1.0 \leq V_R \leq 4.5 \qquad (10.4.4-1)$$

10.4.4.3 Vortex-induced Cross-flow Vibration

Crossflow vortex shedding may occur in the following situations:

$$3 \leq V_R \leq 16 \; for\ all\ Reynolds\ numbers \qquad (10.4.4-2)$$

Section 5 Wave Slamming

10.5.1 General Requirements

10.5.1.1 Waves passing through horizontal members in the splash zone may cause nearly vertical slamming loads. The slamming loads have very little effect on the overall base shear and overturning moment of the platform, but will have a certain impact on local members and therefore shall be considered.

10.5.1.2 The members hanging out of the edge of the barge during the towing of the platform, or the members that enter the water first when the jacket is launched, may also generate impact force. Therefore, these members shall have sufficient local strength.

10.5.1.3 For slamming loads caused by extreme wave forces, the strength requirements of the members shall be considered, and for slamming loads caused by long-term wave action, the impact on member fatigue shall be considered.

10.5.1.4 The calculated slamming loads are to be combined with the loads obtained from the analysis of the in-place extreme storm with closest wave direction. The allowable stress for member and joint check can be increased by 1/3.

10.5.2 Slamming Load

10.5.2.1 Slamming loads are caused by the relative slamming speed of water particles hitting the members. The relative slamming speed depends on the movement of the structure, wave height, wave period, wave direction and member location.

10.5.2.2 The slamming speed is derived from the wave profile and water particle velocity output by the calculation procedure. The water depth is adjusted between the maximum and minimum values to obtain the maximum slamming load acting on the member.

10.5.2.3 The angle at which the wave slamming on the member is derived from the appropriate velocity of horizontal and vertical water particles. When determining the velocity of horizontal water particles, the effect of flow velocity shall be considered.

10.5.2.4 The slamming load W_S per unit length of the tubular member is calculated by Formula (10.5.2-1).

$$W_S = C_S(w/2g)DU^2 \qquad (10.5.2-1)$$

Where:

D - member diameter, w - gravity of water, g - acceleration of gravity, U - slamming velocity of water particles;

C_S - slamming coefficient. If dynamic analysis is performed, $C_S = \pi$ shall apply. Otherwise, $C_S = 5.5$ shall apply.

Appendix A Joint Numbering and Member Grouping Rules for Structural Models

Section 1 Joint Numbering Rules

A.1.1 General requirements

A.1.1.1 The joints of the platform model shall be numbered according to the rules of this section to reflect the classification and location of the structure.

A.1.1.2 For joint number of the jacket, the first character represents the structural type, L represents the leg joint, H represents the deck column joint, X represents the diagonal tie bar, and T represents the launch frame joint. The second character represents the horizontal layer, which is numbered as 0, 1, 2, 3...in turn from the working point layer to the below.

A.1.1.3 For joint number of topside, the first character is set to D, and the second character represents the horizontal layer, the horizontal layers above the working point are numbered as 1, 2, 3...respectively. For platforms with relative large module, when the joint numbers are insufficient, the second character can be composed of multiple numbers to represent the same horizontal layer, such as D1/D2/D3 for the first layer, D4/D5/D6 for the second layer, and so on.

A.1.1.4 The joint number of the living quarter can be set according to the numbering rules of the topside, with the first character set to Q.

A.1.1.5 For joints of structures such as risers and protective tubes, the first character is set as J, and the second character is the number of the riser or protective tube. For example, J2xx is a joint of the 2# protective tube.

A.1.1.6 The first character of the joint of a conductor is set as C; the first character of WISHBONE unit joint at the riser is set as W; the first character of the joint of the flare boom is set as F; the first character of the joint of the berthing member is set as B; the first character of the joint of the mudmat is set as M; the first character of the joint of the skirt pile sleeve is set as S; and for other structure joints, the first character is set as A.

Section 2 Grouping and Numbering Rules for Members and Plates

A.2.1 General requirements

A.2.1.1 Member group shall be numbered according to the rules of this section to reflect the position, cross-section, type and other information of the members. Grouping of members shall ensure each physical member of the main structure of the jacket have an independent group as much as possible. For group numbering rules of various members, refer to Table 2.5.2.1.

A.2.1.2 Plate elements shall be used to simulate the deck plate of the topside. The group of the plate elements may be numbered as PL1, PL2, PL3, etc. according to the different plate thicknesses.

Rules for Grouping and Numbering of Jacket Structures   Table A.2.1.1 (1)

Structure type	First character	Second character	Third character
Leg	L	Sequential numbering	Sequential numbering
Inner leg pile	P	I	Sequential numbering
Skirt pile	S	K	Sequential numbering
Deck column	H	Sequential numbering	Sequential numbering
Diagonal tie bar	X	Sequential numbering	Sequential numbering
Berthing member	B	B	Sequential numbering

Riser	R	S	Sequential numbering
Riser support	R	U	Sequential numbering
J-tube	J	T	Sequential numbering
J-tube support	J	U	Sequential numbering
Pump protection tube	P	M	Sequential numbering
Pump tube support	P	U	Sequential numbering
Pump tube guide structure	P	G	Sequential numbering
Mudmat	M	D	Sequential numbering
Skirt pile sleeve	S	L	Sequential numbering

Grouping and Numbering Rules for Main Structure of Topside Table A.2.1.1 (2)

Structure type	First character	Second character	Third character
Leg	D	Sequential numbering	Sequential numbering
Main beam	M	Sequential numbering	Sequential numbering
Secondary beam	I	Sequential numbering	Sequential numbering
Diagonal brace	V	Sequential numbering	Sequential numbering
Flare boom	F	Sequential numbering	Sequential numbering
Living quarter	Q	Sequential numbering	Sequential numbering
Stairs and other accessories	A	Sequential numbering	Sequential numbering

Rules for Grouping and Numbering of Other Structures Table A.2.1.1 (3)

Structure type	First character	Second character	Third character
Conductor	C	N	Sequential numbering
Connection structure between conductor and deck column	W.B: WB1, WB2….for different sizes of conductors		
Wedge connection between pile legs	W.P		