GUIDANCE NOTES

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INTERNATIONAL SHIP CLASSIFICATION

Guidelines for Analysis of Transportation and Floatover of Large Offshore Structures

2020

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CONTENTS

Chapter 1 General

Section 1 General Provisions

1.1.1 The Guidelines refer to the documented guidance for International Ship Classification (hereinafter referred to as ISC) to provide technical services for the analysis of loading, transportation and float-over installations of large offshore structures (the topside component and jacket structures of large fixed units).

1.1.2 The Guidelines define the technical requirements for large offshore structures in loadout analysis, marine transportation analysis, jacket sliding launching analysis, jacket upending analysis and deck float-over installation analysis.

1.1.3 The following codes/standards are referenced or cited in the Guidelines:

(1) *Safety Rules for Fixed Offshore Platforms* by State Economic and Trade Commission, PRC

(2) *Guidelines for Towage at Sea* by ISC;

(3) *Rules for Classification of Sea-going Steel Ships — Part 2: Hull*, by ISC;

(4) *IMO Intact Stability Code*;

(5) *Marine Operation and Marine Warranty* (DNVGL-ST-N001);

(6) *Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms—Working Stress Design* (API RP 2A-WSD);

(7) *Design and Analysis of Stationkeeping Systems for Floating Structures* (API RP 2SK).

Section 2 Definition and Abbreviations

1.2.1 Definition

Unless otherwise specified, the definitions in the Guidelines are as follows:

(1) Leg mating unit (LMU) refers to the connection unit between the topside component and the jacket, as well as the key part to be concerned in the coupling analysis.

(2) Deck support units (DSU) refer to the contact unit between the topside component and the support frame. In the DSU, buffer parts or the sand tables that absorb and reduce the impact energy are generally provided. When the load transfer of the topside component is about to be completed, the buffer parts in the DSU will come into play to alleviate the collision between the topside component and the support frame;

(3) Deck support frame (DSF) refers to the support structure of the topside component on the construction site or on the barge.

(4) Fender refers to the device installed on the jacket or the barge side to retard the collision between the ship and the jacket. Meanwhile, it also restricts the transverse/longitudinal movement of the ship.

1.2.2 Abbreviation

See Table 1.2.2 for the meaning of abbreviations in the Guidelines.

Meaning of Abbreviations **Table 1.2.2**

Abbreviation	Meaning
MSL	Mean Sea Level
RAO	Response Amplitude Operator
GMT	Transverse Metacentric Height
GML	Longitudinal Metacentric Height
MPME	Most Probable Maximum Extreme

Chapter 2 Design Environmental Conditions

Section 1 General Provisions

2.1.1 This chapter provides the general criteria for the selection of design environmental conditions for marine operation (installation).

2.1.2 The design environmental conditions shall be selected according to the reference duration of marine operation, which includes the planned time and emergency time.

2.1.3 Marine operations can be divided into weather-restricted operations and weather unrestricted operations according to the different operation reference durations.

2.1.4 Environmental conditions for marine operation include but are not limited to wind, waves, currents and tides.

2.1.5 The environmental design criteria for marine transportation and float-over installation are provided in Sections 4.2 and 7.2 respectively.

Section 2 Weather Restricted Operation

2.2.1 The marine operation with the reference duration less than 72 hours may normally be defined as weather restricted operation.

2.2.2 If a suitable shelter point can be accessed within 48 hours, or the moving speed is adequate to elude the areas with severe weather forecasted, the operation with the reference duration longer than 72 hours can also be classified as a weather-restricted operation.

2.2.3 For weather-restricted operations, the selection of design environmental conditions can be independent of the statistical data of extremes on the premise of having enough climate window and reliable weather forecast.

Section 3 Weather unrestricted Operation

2.3.1 Except for the cases mentioned in Section 2.2, marine operations with the reference duration longer than 72 hours are generally defined as weather unrestricted operations.

2.3.2 For the weather unrestricted operations, the following statistical data of environmental extremes can be referred to as the design environmental conditions.

Recommended Extremes of Environmental Conditions for Weather unrestricted Operations **Table 2.3.2**

Reference duration	Wind	Wave and current
Reference duration ≤ 3 d	5-year monthly extreme	3-month monthly extreme
3 d < Reference duration ≤ 7 d	10-year monthly extreme	1-year monthly extreme
7 d < Reference duration ≤ 1 month	25-year monthly extreme	10-year monthly extreme
1 month < Reference duration ≤ 1 year	75-year monthly extreme	50-year monthly extreme
Reference duration＞ 1 year	100-year monthly extreme	100-year monthly extreme

Chapter 3 Loadout Analysis

Section 1 General Provisions

3.1.1 This chapter applies particularly to the skidded load-outs, in tidal waters.

3.1.2 Loadout analysis includes check of stability, longitudinal strength and ballast tank capacity of barges, and structure strength. If the loadout operation lasts more than 72 hours, mooring analysis is required.

3.1.3 Loadout operation is generally completed within 72 hours, which falls within weather-restricted operations. Design environmental conditions can be selected according to the reliable weather forecasts.

Section 2 Analysis Criteria

3.2.1 Stability

(1) The initial metacentric height is generally required to be greater than 1.0 m, and no less than 0.3 m under any circumstances;

(2) The minimum freeboard of the ship during load-out is 0.5 m plus 50% of the expected maximum wave height during operation.

3.2.2 Longitudinal strength

(1) As the weight distribution of the hull changes due to ballast and load transfer during the load-out, the longitudinal strength shall be checked;

(2) Generally, the vessel bending moment and shear force values in still water should be within the allowable harbour limits.

3.2.3 Ballast tank capacity for load-out

(1) The ballast tank capacity refers to the pumping capacity of the ship, with certain redundancy capacity considered according to the on-site operation, accident response measures, etc.;

(2) The ballast tank capacity is closely related to the cargo weight, tidal condition and load-out duration. Definitely, the ballast tank capacity within the load-out window can not only meet the requirements of adjusting the floating state during load-out, but also adjust the draft of the ship when the tide changes to keep the skidway on the barge flush with that on the quay.

Section 3 Structural Analysis

3.3.1 The supports between the structure 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 structure and the quay (or the ship) increases, the joints lose their support to be out of stress.

3.3.2 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 ±20–25 mm.

3.3.3 For structural analysis, the operating conditions for towing the structure to different positions, as well as the above errors, shall be considered.

3.3.4 The stress of members and joints shall be checked according to the relevant codes.

Section 4 Mooring Analysis

3.4.1 If the load-out operation lasts longer than 72 hours, the mooring system shall comply with the strength requirements in Table 7.5.2. The intact and one line damaged conditions shall be considered for mooring analysis.

3.4.2 The maximum calculated load on the bollard, bitt, fair-lead and their base structures shall not be less than the maximum mooring tension, and the safety factor shall not be less than the strength safety factor of the mooring line in an intact state. The safety factor can be calculated according to the following formula:

Safety factor = the rated safe operating load/the maximum calculated load

3.4.3 If the mooring load is to be held on a winch brake, then the winch brake capacity should exceed the maximum line tension multiplied by a minimum factor of 1.2 (including the intact and damaged conditions).

Section 5 Other Requirements

3.5.1 The skidded loadout duration of the jacket or deck is an important factor to determine the feasibility of loadout. The loadout duration of decks is generally shorter than 5 hours. Definitely, the tidal level of the quay is required to meet the requirement for the continuous operation lasts over 5 hours. The loadout duration of the jacket is related to the jacket length, which is generally less than 10 hours.

3.5.2 During load-out, the under-keel clearance is generally required to be greater than 1.0 m.

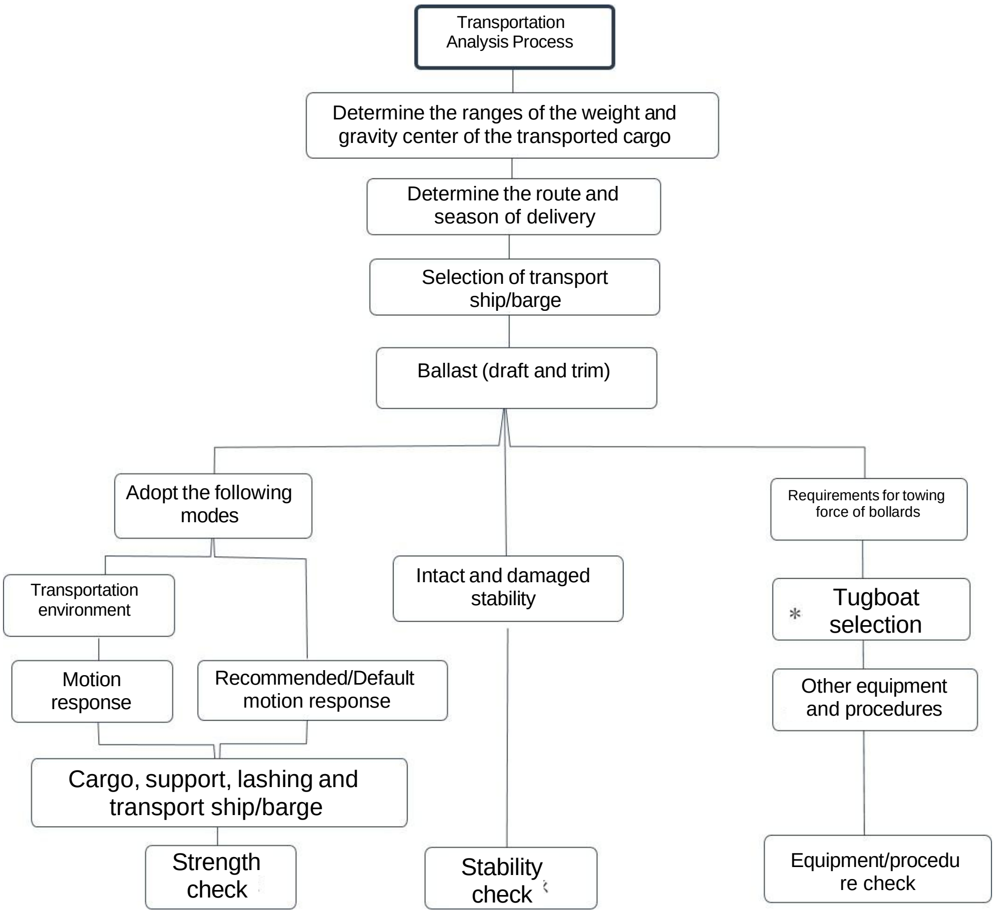
Chapter 4 Analysis of Marine Transportation

Section 1 General Provisions

4.1.1 This chapter is applicable to the transportation analysis of the jacket and the topside component. It can also be the reference for the transportation analysis of other offshore structures.

4.1.2 Analysis of marine transportation includes stability check, longitudinal strength check of transportation ships/barges, motion response analysis and structure analysis.

4.1.3 The analysis flow of the design of typical marine transportation is shown in Figure 4.1.3.



Note: * in the figure indicates that the item shall be considered for towing.

Figure 4.1.3 Analysis Process of Typical Marine Transportation

Section 2 Environmental Condition

4.2.1 The design environmental condition should be chosen non-typhoon sea state and consisting of the wave and wind.

4.2.2 The range of periods associated with the significant wave height may be calculated by the following formula:

$$\frac{\sqrt{13H_s}}{1+\frac{V\cos(\theta)}{1.56\sqrt{13H_s}}} \le T_P \le \frac{\sqrt{30H_s}}{1+\frac{V\cos(\theta)}{1.56\sqrt{30H_s}}}$$

Where: H_s — the significant wave height, m;

T_P —the spectral peak period, s;

V — the voyage speed, m/s;

θ — the voyage direction (0°means the direction of ahead sea, while 180°means the direction of following sea), deg.

4.2.3 Generally, the ship speed is very low or zero under extreme sea states, and the combination of the significant wave height and a series of spectral peak periods can be considered for the wave parameters.

4.2.4 For an ocean transportation of 30 days (or longer), the 10-year monthly extreme is generally adopted as the design environmental condition.

4.2.5 For the marine transportation lasted less than 30 days, it is conservative to adopt the 10-year monthly extreme as the design environmental condition, and it can be adjusted for reduced exposure. When the 10% risk level extremes are less than the 1-year monthly extremes, the 1-year monthly extremes are the minimum that shall be used for design.

4.2.6 Calculation method for extreme adjustment: The probability that the wind speed or significant wave height in a specific route sector does not exceed a certain value can be represented by the cumulative probability distribution, such as the Weibull distribution. For waves, the probability that the significant wave height (or the wind speed) encountered by transportation operation within about 3 hours (1 hour for wind) is less than a certain value X is represented by FX(x). If M hours (the duration of the exposure to severe sea states) are taken to cross the route sector, and the continuous wave height and wind speed events are assumed to be independent, the probability that does not exceed x can be represented by [FX(x)]N, where N=M/T, T=1 hour for wind and T=3 hours for wave. Then the probability that the wind speed or significant wave height reaches or exceeds the design extreme in this specific route sector (every 10 transports on average) is 0.1. That is, the extreme of ten voyages/towages can be calculated according to 1-[FX(x)]N=0.1. This value is also called the adjusted extreme of transportation operation, and the risk level is 10%. The extreme of a lower risk level (such as 1% or 5%) can be also obtained using such method.

4.2.7 The following factors shall be considered to determine the exposure time to severe sea states:

(1) The initial 48 hours of transportation can be assumed to be covered a reliable departure weather forecast, and such period can be excluded;

(2) The speed of the transport is reduced by taking the monthly mean wave along the route. While considering the effect of the mean sea state on the transport speed in each route sector, the speed under calm weather shall be multiplied by a factor defined by:

$$F = 1 - \left(H_m / b\right)^2$$

Where: b — the wave height in which the transport will come to a dead stop, m. It is typically 5 m for barges, and 8 m for other ships;

H_m — the monthly mean wave of that route sector, m.

(3) The effect of the mean current on the transport speed in each route sector is calculated by adding the current vector (resolved with respect to the transport heading);

(4) Generally, the minimum exposure time to be considered is 3 days.

4.2.8 Relaxation of the environmental conditions

(1) Relaxation of the environmental conditions means that the appropriate reduction of the significant wave height in other directions can be considered during analysis as the barge is

capable of voyage heading or following the wave under extreme sea states. See Table 4.2.7 for the significant wave heights in each wave direction after the relaxation of the environmental conditions.

(2) Considering the relaxation of environmental conditions, the barge must be a self-propelled ship with a redundant propulsion system. Specifically, the ship shall be equipped with:

① at least two independent main engines;

② at least two independent fuel supply systems;

③ at least two independent power transmission systems;

④ at least two independent distribution boards;

⑤ at least two independent steering systems, or another mode to operate a single steering system (excluding the emergency steering system that cannot be operated from the bridge);

⑥ Assuming that any propeller fails, the barge still has the ability to maintain the expected course under the design storm conditions considering the wind load of the cargo.

Requirements for Lowering Sea states under Different Wave Directions Table 4.2.8

Wave direction (Ahead sea: 0°)	Significant wave height (percentage of design value)
0°–± 30°	100%
± (30°–60°)	Linear interpolation between 100% and 80%
± 60°	80%
± (60°–90°)	Linear interpolation between 80% and 60%
± 90°	60%
± (90°–120°)	Linear interpolation between 60% and 80%
± 120°	80%
± (120°–150°)	Linear interpolation between 80% and 100%
± (150°–180°)	100%

Section 3 Stability

4.3.1 Intact stability criteria

(1) The vanishing angle of stability shall not be less than the value given in Table 4.3.1. If the departure status varies greatly with the arrival status or any intermediate status, such as draft and ballast change, the most dangerous situation shall be considered;

Vanishing Angle of Stability Table 4.3.1

Barges or towed objects	Total length L (m)	Molded breadth B (m)	Vanishing angle of stability (°)
Large- and medium-sized self-propelled ships	L≥ 76, and B≥ 23		36
Large barge	L≥ 76, and B≥ 23		36
Small barge	L< 76, and B< 23		40
Small self-propelled ship	L< 76, and B< 23		44
Inland and sheltered waters (within the ice-covered area)	-		36

Inland and sheltered waters (outside the ice-covered area)	-	24

(2) As an alternative method, if the maximum amplitude of motion for a specific towing or voyage can be obtained through model test or motion response analysis, the vanishing angle of stability shall not be less than:

$$20+\left(15/GM\right)+\theta$$

Where: GM — the metacentric height, m;

θ — the maximum amplitude of roll or pitch caused by the design sea state, plus the static wind heel or trim caused by the design wind, deg.

(3) The initial metacentric height is generally required to be greater than 1.0 m, and in any case shall not be less than 0.3 m. The effects of free surface shall be considered in the calculation of the metacentric height;

(4) The ratio of the area surrounded by the righting arm curve and the wind overturning arm curve to the two curves at the second intercept or flooding angle shall not be less than 1.4, that is, $A+B\geq 1.4\left(B+C\right)$ (see Figure 4.3.1);

(5) The design wind speed for the calculation of the wind overturning arm curve: 100 kn within the unrestricted service, 70 kn within the greater coastal service, 60 kn within the coastal service, and 50 kn within the sheltered water service;

(6) If the buoyancy of the suspended part of the cargo is to be taken into account in the stability calculation, it is required that the suspended part cannot enter the water under the wind speed of 15 m/s.

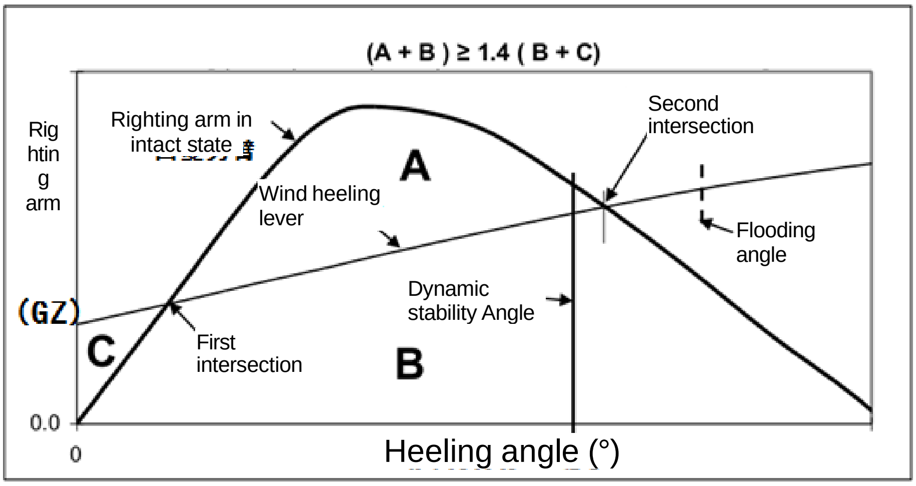


Figure 4.3.1 Typical Hydrostatic Curves in Intact Condition

4.3.2 Damaged stability criteria

(1) The metacentric height shall have positive value about any horizontal axis with damage caused by an assumed minimum penetration of 1.5 m from any external plating, between effective watertight bulkheads, with the following:

① In the damaged compartment, all piping and ventilation systems within the damaged area shall be assumed to be flooded. Measures can be provided to prevent the progressive flooding of other compartments that are intended to be intact;

② The vertical range is unlimited from the baseline upwards.

③ Within the extent of horizontal damage, the distance between two watertight bulkheads or the stepped positions near them shall not be less than 3 m. If the distance is less than 3 m, the adjacent compartment shall also be assumed to be damaged;

④If the damage smaller than the extents listed in ① or ③ causes worse results, such smaller damage extent shall be considered.

(2) Under the action of wind in any direction, the damaged hull shall still have sufficient reserve stability. Specifically, the waterline under the action of wind force after the hull is damaged shall be lower than the lower edge of any opening that may cause further water inflow (the first intersection angle is smaller than the flooding angle) (see Figure 4.3.2).

(3) To calculate the wind overturning arm, the smaller value of 50 kn or the wind speed used to calculate the intact stability shall be taken;

(4) If the buoyancy of the suspended part is considered in the intact stability, the damage of such part shall also be considered in the calculation of the damaged stability;

(5) For B-type barges and the barges with the larger freeboard, the damaged stability shall be calculated with the SOLAS probability method.

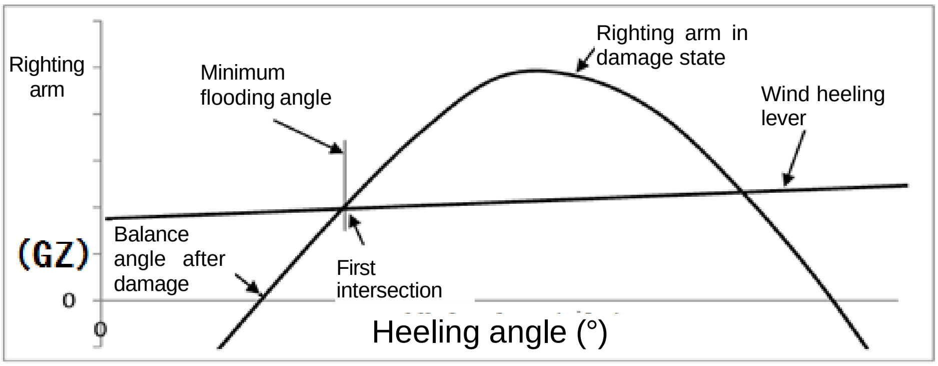


Fig. 4.3.2 Typical Hydrostatic Curves in Damage Condition

4.3.3 Draft and trim

(1) For self-propelled ships, the design draft is generally adopted. For barge towing, the draft is typically 35%-60% of the hull's molded depth, which is significantly lower than the load line. For the self-propelled ships and barges with load line certificates, the draft is not allowed to exceed the load line;

(2) For barges and large towed objects, the draft and trim shall be selected to minimize the slamming of the bow and provide good course control, with consideration to the bow tilt caused by towing tension;

(3) Trim control is required for the barge with streamlined stern and the directional stable commutating fin;

(4) See Table 4.3.3 for the recommended minimum draft and trim under towing conditions.

Recommended Values of Minimum Draft and Trim **Table 4.3.3**

Length of towed ship (m)	Minimum draft of bow (m)	Minimum trim by stern (m)
30	1.0	0.3
60	1.7	0.6
90	2.4	0.8
120	3.1	1.0
150	3.7	1.2
≥200	4.0	1.5

Section 4 Motion Response

4.4.1 The motion response is the basis of seafastening 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.

4.4.2 If the hydrodynamic analysis method is adopted to obtain the motion response, the following points shall be paid attention to:

(1) Refer to Section 4.2 for the determination of the design sea state. Specifically, consideration shall be given to the wave heights that are smaller than the design value in the natural rolling and/or pitching period of the ship. Besides, the ship motion response analysis under waves of 0°-180°at intervals of 45°shall be considered at least;

(2) Generally, it is not allowed to use free surface correction to reduce the metacentric height and then to increase the natural period of rolling. Any influence of reducing the metacentric height shall be considered in the stability calculation;

(3) In the hydrodynamic analysis method, the movement RAO can be obtained by calculating the hydrodynamic force based on the two-dimensional strip theory/three-dimensional potential flow theory. Then, the most possible extreme value can be obtained through the statistical prediction.

4.4.3 Model tests may be used to derive design motions in the case of 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.

4.4.4 If neither a motions study nor model tests are performed, then for standard configurations and subject to satisfactory marine procedures, the following motion criteria may be acceptable, as shown in Table 4.4.4.

Default Motion Response Standards **Table 4.4.4**

Transport type	Condition	L (m)	B (m)	L/B	Block coefficient	Cycle period (s)	Single amplitude (°)		Heave
							Roll	Pitch	
Weather unrestricted operation	1	>140 and >30		-	<0.9	10	20	10	0.2 g
	2	> 76 and > 23		-	Any	10	20	12.5	0.2 g
	3	≤ 76 or ≤ 23		≥2.5	<0.9	10	30	15	0.2 g
	4				≥0.9		25		
	5	≤ 76 or ≤ 23		<2.5	<0.9	10	30	30	0.2 g
	6				≥0.9		25	25	
Weather-restricted operation in non-mild sea for a duration less than 24 hours (for L/B<1.4, use weather unrestricted case)	7	Any		≥2.5	Any	10	10	5	0.1 g
	8	Any		< 2.5, ≥ 1.4	Any	10	10	10	0.1 g
Weather restricted operation in mild sea (for L/B<1.4, use weather unrestricted case)	9	Any		≥2.5	Any	10	5	2.5	0.1 g
	10	Any		< 2.5, ≥ 1.4	Any	10	5	5	0.1 g
Transportation in inland and sheltered waters (for L/B<1.4, use weather unrestricted case)	11	Any		≥1.4	Any	Static	An equivalent acceleration of 0.1 g in both		0.1 g

						directions	

Note: In the table, L indicates the waterline length, and B indicates the maximum waterline breadth.

4.4.5 Movement caused by wind load

(1) The additional motion caused by wind loads shall also be considered;

(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;

(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 motion caused by waves;

(4) In general, the motion caused by wind takes only a small proportion. 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 5 Longitudinal Strength

4.5.1 The methods for checking the longitudinal strength of barges include the specification verification method, direct calculation method, regular wave calculation method and allowable strength method.

4.5.2 The specification verification method refers to check the longitudinal strength with reference to CHAPTER 2, PART TWO, of the *Rules for Classification of Sea-Going Steel Ships*.

4.5.3 Based on the three-dimensional diffraction/radiation potential flow theory, the direct calculation method is used to calculate the hydrodynamic forces acting on the hull and obtain the transfer function of the wave-induced shear force/bending moment of the hull section. Then, the load on the barge is predicted according to the sea states using the spectral analysis method. As the transportation process generally lasts for long time, it is necessary to make a long-term statistical analysis based on the wave spread chart of the transportation sea area.

4.5.4 The regular wave calculation method refers to the calculation of the wave bending moment and shear force using the maximum design regular wave. Typically, the ship length is taken as the wavelength of the regular wave, and several positions of the regular wave can be selected along the length of the ship in order to obtain the most severe loading condition.

4.5.5 The allowable strength method only needs to check the longitudinal strength in still water. The allowable longitudinal strength includes in harbor values and voyage values.

Section 6 Structure Analysis

4.6.1 General requirements

(1) The cargo (jackets and decks) must have sufficient strength to withstand the inertial loads and wind loads, as well as the additional loads caused by overhanging the ship (see 4.7.1);

(2) The seafastener must be designed to withstand the external load during transportation and the deformation of the barge during voyage (mainly caused by longitudinal bending);

(3) In the design of seafasteners/supporting structures, the values in the table must be adopted if the calculated design load is less than the "minimum seafastening force" given in Table 4.6.1.

Minimum Seafastening Force **Table 4.6.1**

Direction	Weight of transported cargo W (ton)

	<100	100≤W <1,000	1,000≤W <5,000	5,000≤W <10,000	10,000≤W <20,000	20,000≤W <40,000	≥40,000
Minimum seafastening force required*W							
Horizontal	10%	10%	10%	10%	10%	Note①	5%
Longitudinal	5%	5%	5%	5%	Note②	Note③	1.5%

Note: ① (15-W/4,000)% would be taken if 20,000≤W<40,000 tons;

② The required minimum longitudinal seafastening force shall not be less than (7.5-W/4,000)% if 10,000≤W<20,000 tons;

③ The minimum longitudinal seafastening force required shall not be less than (3.5-W/20,000)% if 20,000≤W<40,000 tons.

4.6.2 Loading condition

(1) For the loading condition, the superposition of fluctuating and static loads caused by downwind and waves in all directions must be considered;

(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;

(3) For the fluctuating load, the inertial force caused by waves shall be mainly considered, and the acceleration of the transport structure shall be obtained by the method mentioned in Section 4.4;

(4) To obtain the six-degree-of-freedom acceleration of the ship through hydrodynamic analysis, the combination of loading conditions in various wave directions shall be considered;

(5) For calculation with the default standard value of motion response, totally 8 conditions shall be considered, including different combinations of the positive and negative values of heave, rolling and pitching.

4.6.3 Strength check

Structural stress shall be checked according to relevant codes.

Section 7 Other Requirements

4.7.1 Cargo buoyancy, slamming and shipping water

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

4.7.2 Longitudinal bending caused by waves

(1) The potential effects of longitudinal wave bending effects should be considered in the following conditions:

① The cargo is 1/3 longer than the barge;

② The cargo is longitudinally supported on more than two groups of supports;

③ The relative stiffness of the hull and cargo could cause unacceptable stresses to be induced in either;

④ The seafastening design allows little or no flexibility between cargo and barge .

(2) For consideration to the longitudinal bending caused by waves, the quasi-static hogging and sagging of the ship are calculated under regular waves with the wavelength equal to the barge length L and the wave height greater than L/20.

Chapter 5 Jacket launch

Section 1 General Provisions

5.1.1 This chapter is applicable to the launch analysis of jackets. The typical analysis processes include: the stability of the barge-jacket combination during launching, global structural strength of barge, the jacket and barge trajectories, structural integrity analysis during the jacket launch, and sensitivity analysis.

5.1.2 The key points of the launch analysis of jacket mainly include:

(1) Barge

① Whether the stability and global strength of the barge meet the requirements before and during launch;

② Whether the hydrostatic pressure on the barge at the maximum stern draft is within the design allowable value;

③ Whether the rocker arm loads are within their bearing range during the whole process.

(2) Jacket

① Whether the jacket maintains a good launching trajectory, without large rolling but with adequate bottom clearance, etc.;

② Whether the jacket members and its watertight attached members (such as the piping and valves) can withstand the still water pressure in case of diving to the maximum depth;

③ Whether the structural integrity of the jacket itself meets the requirements during launch;

④ Local members of the jacket should be verified against slam loading while launching for high speed.

5.1.3 The jacket launch that can be completed within 72 hours, as a weather-restricted operation, the design environmental conditions can be selected according to reliable weather forecasts.

5.1.4 The launch dynamic analysis for jacket is generally carried out in still water, despite the influence of wind, wave and current.

Section 2 Analysis Criteria

5.2.1 Jacket reserve buoyancy

(1) After the jacket launch, its reserve buoyancy shall not be less than 10% of the total intact buoyancy;

(2) In case of damage, the reserve buoyancy shall not be less than 5% of the total buoyancy of the jacket.

5.2.2 Stability

(1) Prior to the initiation of jacket sliding, the minimum metacentric height of the barge-jacket combination shall be greater than 1 m, and the range of stability shall be greater than 20 degrees or 15+10/GM, whichever is greater. The area ratio of the righting moment to the wind overturning moment curve shall be greater than 1.4 (see Figure 4.3.1);

(2) After initiation of jacket sliding, until the jacket starts to rotate relative to the barge, the metacentric height of barge-jacket combination shall be positive;

(3) The heeling angle caused by 1.5 times of the design wind speed for jacket launch shall to be acceptable.

5.2.3 Jacket launch trajectory

The jacket shall have a good launching trajectory. After the jacket is separated from the barge, the minimum clearance between the jacket and the seabed sludge shall be greater than 10% of the water depth or 5 m, whichever is greater. After jacket launch, no turn over will occur in the water.

5.2.4 Barge strength

(1) The longitudinal strength and the reaction of the rocker arm shall be within the allowable range;

(2) The barge and skidway shall have sufficient structural strength;

(3) The stern submergence shall be within the allowable range of the barge.

5.2.5 Jacket strength

The jacket shall have sufficient structural strength, and the jacket members shall be able to withstand the wave slamming load during its launching into the water.

5.2.6 Sensitivity analysis

The sensitivity of the tolerance of friction coefficient of the launching skidway, floating state of the ship and the weight and gravity center of jacket to the launching analysis results is analyzed. For the offset tolerance of gravity center, the combination of $X_{cg} \pm$ 0.3~0.5 m, $Y_{cg} \pm$ 0.3~0.5 m and $Z_{cg} \pm$ 0.5~1.0 m shall be generally considered (where, Z is the height direction of the jacket, and X/Y is the horizontal direction), and $\pm 3\%\sim 5\%$ is considered for the weight tolerance.

Section 3 Launch Dynamic Analysis

5.3.1 Analysis model

(1) The hydrodynamics, buoyancy and mass model of the jacket shall include all the components, i.e. the main structure, pontoon, secondary structure and "non-structural members", such as caissons and guide piles;

(2) In case of many overlapping members at the joint of jacket, appropriate offset shall be considered at such member joint to accurately simulate the weight and buoyancy of the member;

(3) 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 draft/trim during launching;

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

5.3.2 Analysis method

(1) In engineering analysis, the initial draft of barges is generally 70%-80% of the molded depth, and the initial longitudinal trim angle generally takes 3.75°-4.5°;

(2) The time-domain simulation analysis is 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 are checked according to the analysis criteria.

Section 4 Structural Analysis

5.4.1 Analysis condition

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.

5.4.2 Analysis model

(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.

(2) The jacket and barge/rocker arm are 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 5.4.2 shows the boundary conditions before and during rotation, during separation and after launching of the jacket.

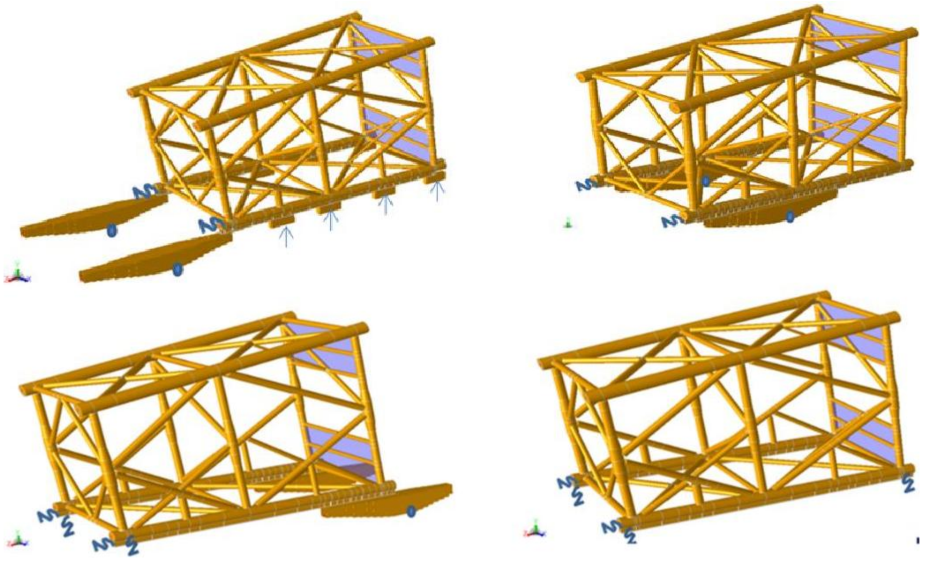


Figure 5.4.2 Analysis Model for Jacket Launch Structure

5.4.3 Strength check

(1) The stress of the members and joints shall be checked according to the relevant specifications;

(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 considered to check the slamming strength.

Chapter 6 Upending Analysis Of Jacket

Section 1 General Provisions

6.1.1 This chapter is applicable to the upending analysis of the jacket.

6.1.2 The upending analysis of jacket mainly verifies whether the metacentric height, the seabed clearance and the crane/sling capacity can meet the requirements during upending, and meanwhile, ensures the structural integrity of the jacket.

6.1.3 This chapter does not include the specific requirements for jacket compartmentation.

6.1.4 For crane-assisted upending, the uprigging platform shall be ensured to be above the water surface; if self-upending is adopted, the water inlet hole shall be ensured to be below the water surface.

6.1.5 For the jacket upending that can be completed within 72 hours, as a weather restricted operation, the design environmental conditions can be selected according to reliable weather forecasts.

Section 2 Analysis Criterion

6.2.1 Reserve buoyancy

(1) See Table 6.2.1 (1) for the requirements of reserve buoyancy without crane assistance. Specifically, the buoyancy of the jacket in the normal state shall be used, and the estimated upper limit weight of the jacket shall be adopted for gravity.

Reserve Buoyancy Requirements without Crane Assistance Table 6.2.1(1)

Condition	Intact	Damage
The jacket has been lifted, and the slings shall be reassembled before upending, if necessary *	10%	5%
During the upending through ballast, there is no need for crane assistance.	8%	4%
Absolute minimum (with the consent of all parties)	5%	2.5%

Note: * indicates that the floating state of the jacket shall be able to meet the requirements of rigging assembly. That is, one leg is kept flat on the water surface and floats horizontally; the rigging platform shall float on the water surface.

(2) See Table 6.2.1 (2) for the requirements of reserve buoyancy with crane assistance. In the calculation of reserve buoyancy:

① It is required to subtract 90% of the lifting capacity under the lifting radius of the crane from the jacket weight for the gravity;

②When two cranes are connected to the jacket, it is required to subtract 80% of the lifting capacity of the two cranes under their respective lifting radius from the jacket weight for the gravity.

Requirements for Reserve Buoyancy with Crane Assistance Table 6.2.1(2)

Condition	Intact	Damage
Lifted jacket, with static and dynamic analysis carried out and contingency procedures in place *	8%	4%
Lifted jacket, with only static analysis carried out	12%	6%

Note: * indicates that the emergency plan refers to the corrective measures taken when the static lifting force exceeds the expected static load.

6.2.2 Stability

(1) The intactness of the jacket and the floating state and metacentric height with the single compartment damaged shall be checked;

(2) See Table 6.2.2 for the minimum metacentric height of the jacket after launching and during upending.

Requirements for Minimum Metacentric Height Table 6.2.2

Condition	Intact	Damage
Horizontal and longitudinal metacentric heights after launch	0.5m	0.2m
Horizontal metacentric height during upending	0.5m	0.2m
Longitudinal metacentric height during upending	>0.0 m*	>0.0 m*
Horizontal and longitudinal metacentric heights after upending and before final positioning	0.5m	0.2m

Note: * indicates that the jacket may be in a state of longitudinal instability in a certain period of time during upending. Such short-term instability is also acceptable only if it is assessed that this situation has no adverse consequences with all the stakeholders informed.

6.2.3 Seabed clearance of jacket

In the process of upending, the minimum seabed clearance of the jacket structure and attached members shall meet the requirements in Table 6.2.3.

Minimum Seabed Clearance Requirements for Jacket Table 6.2.3

Condition	Intact	Damage
Free floating state; and Self- upending jacket during upending	Greater of 10% of water depth or 5m	>2 m
During upending by controlled ballasting, with or without crane assistance	>5 m	>2 m

6.2.4 Lifting capacity

During upending, the lifting weight and height of the floating crane shall be within its capacity.

6.2.5 Strength

(1) The jacket, padeye, slings and other items shall have sufficient strength;

(2) To check the lifting point and the structure near the lifting point, 2.0 times the dynamic amplification factor of load shall be considered; for other structures, 1.35 times the dynamic amplification factor of load shall be considered;

(3) The tension on the sling shall be less than its rated safe working load.

6.2.6 Sensitivity analysis

For the above requirements, the weight error, the error of gravity center offset of the jacket and other conditions shall be considered, so as to ensure that the floating state and upending operability will not be affected if these parameters change slightly. For the error of gravity center offset, the combination of $X_{cg} \pm 0.3\sim0.5\ m$, $Y_{cg} \pm 0.3\sim0.5\ m$ and $Z_{cg} \pm 0.5\sim1.0\ m$ is generally considered (where, Z is the height direction of the jacket, and X/Y is the horizontal direction); 3%-5% is considered for the weight error.

Section 3 Upending Analysis

6.3.1 General requirements

This section is applicable to the upending analysis of crane assistance modes, which is divided into static analysis and dynamic analysis.

6.3.2 Static analysis of upending

(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;

(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. See Appendix 8.2 for the process and examples of static analysis.

6.3.3 Dynamic analysis of upending

(1) The purpose of dynamic analysis is to investigate the influence of wave-induced motion of the lifting ship on upending;

(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;

(3) For dynamic analysis, the frequency-domain analysis method or time-domain analysis method can be adopted.

(4) If frequency-domain analysis is carried out, it is necessary to calculate the motion RAO of the lifting ship, select the sea state of upending for spectral analysis, and predict the hook head movement and hook force under this sea state;

(5) If the time-domain analysis is carried out, the motion and stress at the hook head and padeye of the barge, as well as the movement time history of the key points of the jacket (the minimum bottom clearance position), can be obtained, and the design value can be obtained after post-processing.

Section 4 Structure Analysis

6.4.1 Analysis condition

The jacket structure is analyzed with several characteristic postures during upending as the analysis conditions, which are generally selected according to the rotation angle of the jacket (for example, the jacket rotates every 5°or 10°).

6.4.2 Analysis model

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

6.4.3 Strength check

The stress of the members and joints shall be checked according to relevant specifications.

Chapter 7 Deck Float-over Installation Analysis

Section 1 General Provisions

7.1.1 In this chapter, the criteria and methods for deck float-over installation analysis for large jacket platforms are provided.

7.1.2 The float-over installation in this chapter is applicable to the high-level float-over installation analysis of a single ship using the ballast method of transport barges to transfer load.

7.1.3 The float-over installation is mainly divided into three stages: docking, leg mating and undocking. In the float-over installation analysis, the numerical simulation is mainly conducted for these three stages.

Section 2 Environmental Condition

7.2.1 General requirements

(1) The float-over installation generally with the reference duration less than 72 hours is a weather-restricted operation, of which the design environmental conditions can be selected independent of statistical data of extremes, and the climatic conditions with sufficient probability can be adopted. If the reference duration of float-over installation is expected to be longer than 72 hours, it is suggested to consider as a weather unrestricted operation;

(2) The float-over installation is generally carried out in calm sea states, and the following points shall be paid with attention to in the selection of environmental conditions:

① The float-over installation is sensitive to the environmental conditions in different seasons (months) and directions, and the environmental conditions shall be given according to the seasons (months) and directions respectively;

② For the selected environmental conditions of the floatover, the climate window analysis shall be carried out at first to evaluate the probability of safe float-over installation under the design environmental conditions in the planned season (month);

③ The final determination of the environmental conditions of float-over installation shall be based on the following analysis results: climate window analysis; motion, clearance and collision force analysis; strength analysis of barges, structures, fittings, etc.; analysis of mooring or dynamic positioning capability; cost benefit analysis, etc.

7.2.2 Standby mooring environmental conditions

(1) Generally, the 1-year monthly extreme is selected for the standby mooring environment conditions, which can also be reduced according to actual conditions;

(2) The restrictive environmental conditions in the standby stage are generally selected according to the following conditions:

① For waves, the significant wave height 90% exceeding probability will be taken;

② The maximum flow velocity observed in the working sea area is selected;

③ The limited wind speed is determined according to the maximum allowable tension of the mooring line.

(3) The mooring environment conditions in typical standby state are shown in Table 7.2.2.

Example of Environmental Conditions for Mooring in Standby Stage Table 7.2.2

Significant wave height	Spectral peak period (s)	1-hour average wind	Flow velocity (m/s)
2.50	6.85–10.85	12.0	0.6

7.2.3 Environmental conditions of float-over installation

(1) Generally, the float-over installation is required to be carried out in relatively calm sea states. In order to improve the operability, different wave heights are generally defined under different wave directions:

① In the case of head sea and following sea, the barge has strong wave resistance, and the wave can be limited to be a higher level;

② In the case of the beam sea, barges are prone to large movements, which is extremely unfavorable to the leg mating of LMU. Therefore, it is necessary to set the wave height smaller;

③ The oblique wave situation is between the head sea and beam sea.

(2) Determining the environmental parameters such as the significant wave height that limits the operation is the key factor to ensure the successful float-over installation. For the purpose, the following methods can be adopted: the hydrodynamic analysis of each wave direction is carried out according to the wave height and periodic distribution, and the amplitude of heaving motion corresponding to the wave direction and significant wave height is obtained statistically, so as to determine the wave-limiting conditions under each wave direction, and then the wind speed and flow velocity corresponding to the distribution probability are selected according to the wave height;

(3) In engineering, the following methods can also be referenced to select the restrictive environmental conditions:

① The wind speed is generally limited to below 20–25 kn;

② Generally speaking, the significant wave height of head and following seas is 1.5 m, that of oblique waves is 1.0 m, and that of beam sea is 0.5 m；;

③ The current speed is generally limited to below 1–2 kn.

(4) The floatover can be assumed to be carried out at a low tide level; if the ballast capacity or stability at the low tide level is insufficient, the float-over installation can generally be designed according to the average tide level or average sea level.

Section 3 Climate Window Analysis

7.3.1 Climate window analysis, also known as operability analysis, aims to obtain the probability of float-over installation in a certain period of time.

7.3.2 According to the joint distribution probability of the wave height and wave direction in a month, the probability of sea state occurrence under the condition of limited wave heights in that month can be counted, in which the wind and current are calculated in a similar way.

7.3.3 After obtaining the probability that wind, wave and current appear within their respective limit ranges, the operable probability of float-over installation under limited environmental conditions can be obtained by the following formula:

$$P_{\text{Joint}} = \sum P_{Wind} \times \sum P_{Wave} \times \sum P_{Current}$$

Where: P_{joint} — the operational probability under the limited environmental conditions;

P_{wind} — the probability of occurrence under the condition of limited wind speed;

P_{wave} — the probability of occurrence under the condition of limited wave height;

$P_{current}$— the probability of occurrence under the condition of limited flow velocity.

7.3.4 The above formula for calculating the operational probability under limited environmental conditions implies the assumption that the wind, waves and currents are independent of each other, and thus the results obtained are conservative.

7.3.5 In engineering, the operability analysis of float-over installation is generally carried out in months. After the operational probability of each month is obtained, the month in which the operational days (that is, the probability) exceeds 50% shall be selected for the float-over installation. As the South China Sea is in a period of frequent typhoons in August, it is generally chosen to complete the float-over installation before August.

Section 4 Analysis of Barge Stability and Longitudinal Strength

7.4.1 Ballast analysis

(1) It is a common practice for deck float-over installation to use the ballast system to increase the draft of the ship, so as to transfer the weight of the topside component to the jacket. With the increase of the draft and load transfer, the DSU changes from full-load status to no-load status, LMU changes from no load to full load, the weight of the topside component is transferred from the barge to the jacket, and the barge is separated from the topside component, as shown in Figure 7.4.1;

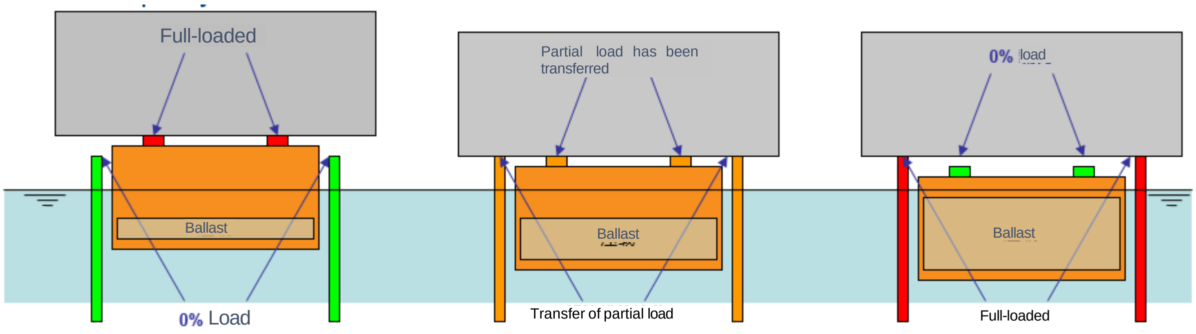


Figure 7.4.1 Ballast and Load Transfer Process

(2) The ballast analysis of float-over installation is to ensure that the barge has enough ballast capacity to complete the float-over installation;

(3) According to the different draft and load transfer state during the float-over installation, the ballast scheme for the float-over installation process is obtained, and the compartment on board shall meet the requirements of the ballast scheme;

(4) It is necessary to verify the pumping capacity of the barge according to the ballast scheme, that is, the time required to calculate the ballasting or de-ballasting shall be less than the time required for operation. Besides, certain redundancy capacity shall be considered according to the operation requirements.

7.4.2 Stability analysis

(1) The metacentric height during the float-over installation shall be greater than 0.5 m, and shall not be less than 0.3 m under any circumstances. The minimum freeboard of a pontoon is required to be 1.0 m, but the freeboard less than 1.0 m is also acceptable under the condition of sufficient measures to ensure the stability;

(2) There is generally no requirement for damaged stability.

7.4.3 Analysis of longitudinal strength

(1) During the float-over installation, it is necessary to check the longitudinal strength of the barge due to the change of hull weight distribution caused by ballast adjustment and load transfer.

(2) The allowable strength method is generally used in engineering, and the allowable value of hydrostatic longitudinal strength in the working in port is used.

Section 5 Mooring Analysis

7.5.1 General requirements

Mooring system layout and mooring line strength shall be checked in the standby stage of float-over installation.

7.5.2 Requirements of mooring line strength

(1) For the mooring system operated in the floatover, only the breaking strength of the mooring line is considered, while its fatigue strength is not considered. See Table 7.5.2 for the tension limit requirements and equivalent safety factors of different states and analysis methods;

(2) Generally, only the intact condition is considered for the mooring system operated in the floatover;

(3) Support structures such as the chain stopper, fair-lead and its base shall have the design strength equivalent to or higher than that of the anchor chain.

Tension Limit and Safety Factor of Mooring Line **Table 7.5.2**

System state	Analysis method	Maximum tension/MBL	Safety factor
Intact	Quasi-static	≤50%	2.0
Intact	Dynamic	≤60%	1.67
Damaged	Quasi-static	≤70%	1.43
Damaged	Dynamic	≤80%	1.25

7.5.3 Requirement of anchor grip

Under the design environmental conditions, the maximum horizontal tension of the towing anchor shall not exceed its bearing capacity, and the safety factor is shown in Table 7.5.3. At the same time, there shall be no uplift force at the anchor end.

Safety Factors **Table 7.5.3**

System state	Analysis method	Safety factor
Intact	Quasi-static	1.0
Intact	Dynamic	0.8

7.5.4 Spacing requirement

(1) Sufficient spacing shall be kept between the mooring system and other structures to avoid collision;

(2) Mooring line crossing the pipeline: For the mooring line crossing the high places of catenary rack of a pipeline in the intact mooring state, the vertical spacing between the mooring line and the pipeline shall be at least 10 m. Under the intact mooring state, if the pipeline is appropriately protected, the mooring line can contact the pipeline to some extent, but the contact point should not be located at the seabed;

(3) Mooring lines crossing each other: if there is a mooring line lying on the bottom at the crossing, the vertical spacing at the crossing between the two mooring lines under intact conditions shall be at least 10 m; if the mooring lines are suspended at the crossing, the vertical spacing at the crossing shall be at least 20 m;

(4) In the case with the mooring line close to the jacket leg: If the mooring line is close to the jacket platform to be installed, the horizontal distance between the mooring line and the nearest jacket leg shall be no less than 10 m;

(5) In the case with the anchor close to other structures: If the structure is located near the trajectory of anchor towing, the final position of the anchor shall be kept at least 300 m away from the structure.

7.5.5 Analysis method

(1) Mooring system analysis methods include the methods of quasi-static analysis and dynamic analysis. Generally, as the floatover operation is conducted in the shallow sea area, the quasi-static analysis method can be used. If operating is in the deep sea area, and the dynamic effect of mooring lines needs to be considered, the fully-coupled dynamic analysis can be carried out for the key conditions;

(2) In the floatover mooring analysis, the time-domain analysis method is generally adopted in the dynamic simulation of the hull and mooring line to solve the general motion equation describing the average, low-frequency and wave-frequency combined response of the coupling system. The time for time-domain simulation shall be long enough to obtain the stable statistical peaks;

(3) In mooring analysis, the pre-tension of mooring lines will have obvious influence on the calculation results. In general, the pre-tension shall not be greater than 20% of its breaking force. When there are asymmetric factors in the layout of the mooring system, it is necessary to carry

out numerical simulation in all directions, and the interval between environmental directions shall not be greater than 45°.

Section 6 Leg Mating Analysis

7.6.1 Leg mating analysis criterion

(1) For preparation of leg mating, the horizontal motion amplitude at the leg mating location is generally less than 0.5 m;

(2) The offset radius (the maximum horizontal offset) in the leg mating process shall be within the capture radius (the allowable error in alignment) of the bell mouth. In engineering, the capture radius is generally less than 1.0 m;

(3) The collision or impact load of the fender shall not exceed the ultimate load of the fender and jacket;

(4) The impact load of LMU shall not exceed the design limit load of the LMU, jacket and topside component;

(5) The ballast capacity of the barge shall meet the requirements of the operation time window.

7.6.2 Analysis condition

(1) In the leg mating stage, the analysis conditions are mainly divided according to the percentage of the topside component weight transferred to the jacket in its total weight, including the 0%, 20%, 40%, 60%, 80% and 100% conditions;

(2) The capacity design of the LMU buffer shall be reflected in the above condition division. If the LMU buffer is designed to bear 70% of the weight of the topside component, the 70% weight transfer shall be considered in the analysis condition. In addition, the analysis conditions of the support capacity of the DSU buffer shall also be considered;

(3) The analysis conditions can also be subdivided according to the vertical gap between the topside component and the jacket, so as to capture the situation where the LMU may be under the maximum load. For example, when the insertion tip approaches the bottom of the bell mouth without transferring the weight, the load on the LMU may reach a large value;

(4) In general, the topside component is asymmetric, and the static load of each deck leg varies when it falls on the jacket. In the coupling analysis, the full wave directions of 0°–360° shall be considered, and the wave direction interval shall not be greater than 45°.

7.6.3 Analysis methods and models

(1) In float-over installation analysis, the coupling between the jacket, barge and deck is mainly simulated through the fender, LMU and DSU;

(2) The coupling analysis of the leg mating stage for the float-over installation is generally conducted by the time-domain numerical simulation;

(3) The leg mating analysis model is shown in Figure 7.6.3 (1), with the topside component, barge and jacket connected by a spring system;

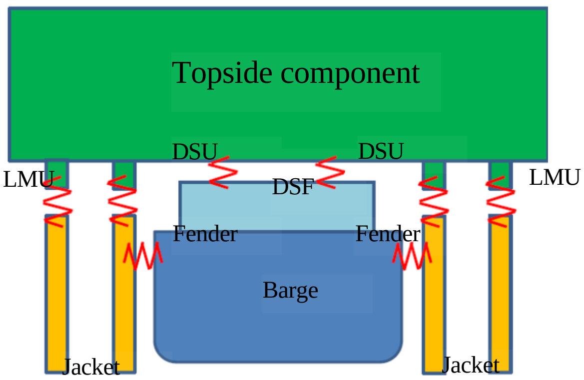


Figure 7.6.3 (1) Floatover Analysis Model

(4) Fenders can be divided into sway fenders and surge fenders. Specifically, the sway fenders can slow down the transverse collision and limit the transverse motion of the ship, while the surge fenders can limit the longitudinal motion of the ship and play a role in positioning;

(5) The load of fenders is mainly applied in the normal direction of the panel, and the relationship between load and deformation is nonlinear. The typical load-deformation curve of fenders is shown in Figure 7.6.3 (2). In the analysis model, this curve can be simulated using the nonlinear compression spring. The friction force in the tangential direction of fenders can be ignored in practical analysis;

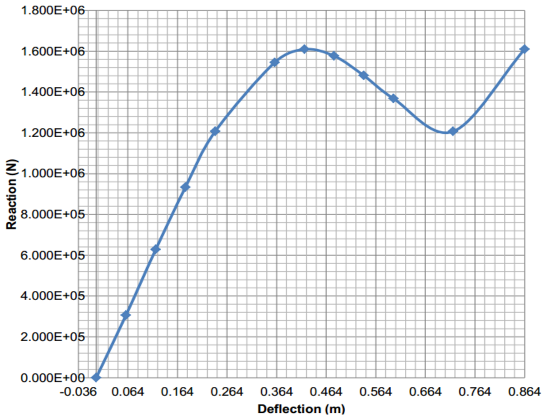
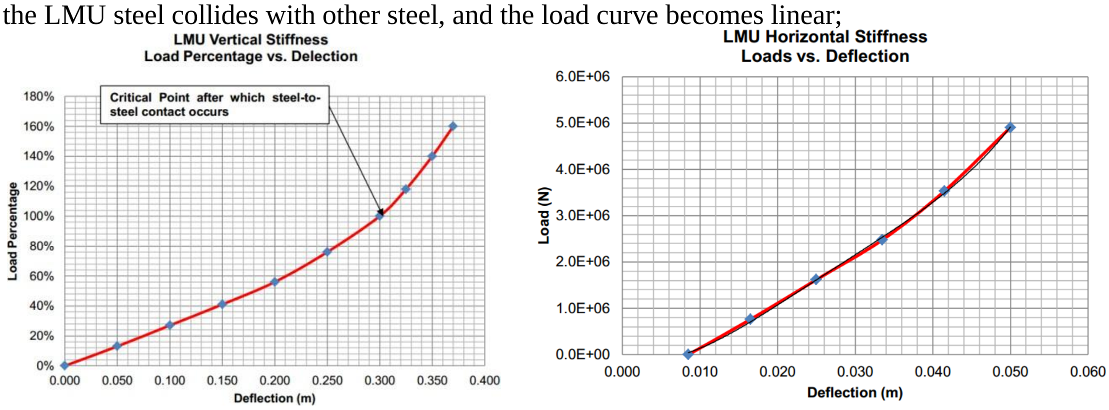


Figure 7.6.3 (2) Load-deformation Curve of Fender

(6) The buffer in the LMU is an elastic body, and the relationship between load and deformation is nonlinear, which can be simulated using a nonlinear spring in the analysis model. The typical vertical and horizontal load-deformation curves are shown in Figure 7.6.3 (3). When the stroke of the LMU buffer is maximized, the leg mating is about to be terminated. At the time, the LMU steel collides with other steel, and the load curve becomes linear;



① Vertical load-deformation curve ② Horizontal load-deformation curve

Figure 7.6.3 (3) Load-deformation Curve of LMU

(7) In the analysis model, the nonlinear compression spring can be used to simulate the nonlinear characteristics of the internal buffer of the DSU, and the vertical load-deformation curve of the typical internal buffer of the DSU is shown in Figure 7.6.3 (4). The DSU buffer is often designed to bear only a part of the weight of the topside component, e.g. 30%. That is, only when the weight of the topside component that is transferred to the jacket reaches more than 70%, the buffer in the DSU works. Before this, the buffer is completely compressed, and the contact at DSU is at the stage of steel-to-steel collision;

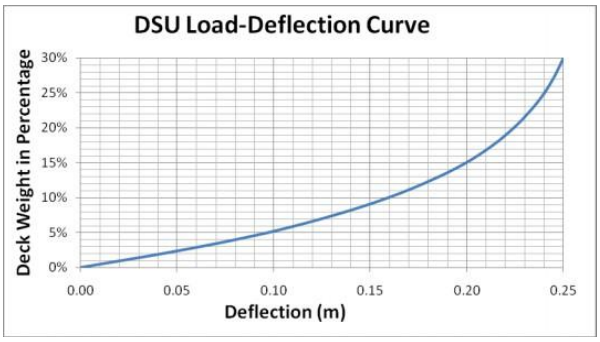


Figure 7.6.3 (4) Vertical Load-deformation Curve of DSU

(8) After the barge enters the slot, the horizontal displacement of the hull is limited by the fender, tugboat and other items, and the mooring system has little influence on the dynamic response of the fender, LMU and DSU. Therefore, the function of the mooring system can be ignored in the analysis.

Section 7 Docking and Undocking Analysis

7.7.1 Docking analysis criteria

(1) The metacentric height of the floatover barge is generally required to be greater than 1.0 m, and shall not be less than 0.3 m under any circumstances;

(2) In order to ensure that the stern (or bow) of the barge can smoothly enter the jacket slot, the transverse motion of the stern (or bow) shall not be too large, and the swing amplitude shall be less than 2.0 m generally;

(3) In the process of docking, the longitudinal and transverse motions of the barge and the yaw angle must be controlled within a certain range;

(4) To enter the slot, adequate vertical clearance between the topside component and the LMU must be ensured to avoid the collision between the topside component legs and the LMU. With consideration to the tidal level and the motion response of the barge, this vertical clearance shall be no less than 0.5 m;

(5) The collision force between the fender and jacket shall be less than the bearing limit of the jacket and fender itself.

7.7.2 Undocking analysis criteria

(1) Barges shall have sufficient freeboard, generally more than 1.0 m;

(2) The impact load still exists before sufficient clearance is obtained between the topside component and the support. The vertical impact load on the support shall not exceed the design limit load of the support and the support point of the topside component;

(3) Sufficient vertical clearance between the DSU/ support and topside component shall be ensured for ship undocking. With consideration to the tidal level and the motion response of the barge, this vertical clearance shall be not less than 0.5 m;

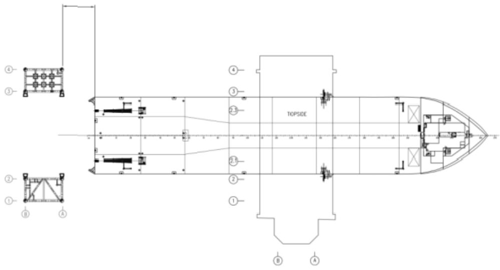
(4) The collision or impact load of the fender shall not exceed the ultimate load of the fender and jacket;

(5) After the tidal level and the motion response of the ship is considered, the vertical clearance between the barge bottom and the horizontal pipe at the bottom of the jacket installation slot shall be greater than 0.5 m.

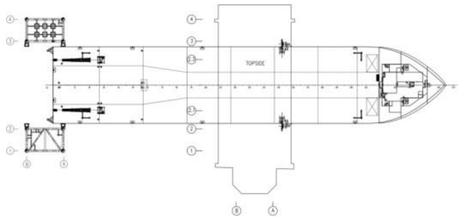
7.7.3 Analysis condition

(1) In the docking stage, analysis can be generally completed in four steps (assuming that two rows of jacket legs are set along the docking direction) according to the longitudinal relative positions of the barge and jacket; taking stern docking as an example, the steps of docking analysis are shown in Figure 7.7.3.

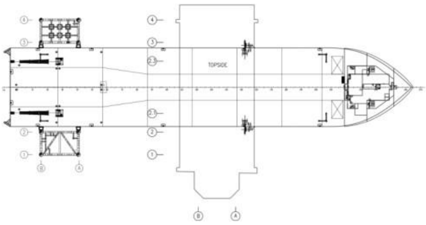
(2) In the stage of ship undocking, the division of analysis steps is similar to that of docking, and the longitudinal relative positions between the barge and jacket are opposite to that of docking.



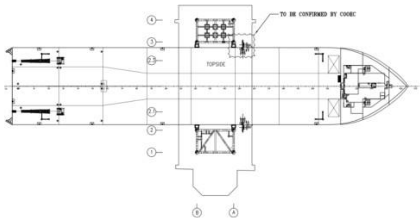
(1) The stern is still outside the jacket slot.



(2) The stern has just passed the first row of jacket legs.



(3) The stern has just passed the second row of jacket legs.



(4) The ship is in the leg mating position.

Figure 7.7.3   Example of Four Steps in Docking Stage

7.7.4 Analysis methods and models

The analysis method of ship docking and undocking is basically same as that of leg mating analysis, and the influence of the mooring system shall be considered in analysis.

Section 8 Calculation Result Processing

7.8.1 For each coupling analysis condition (including each analysis step in the ship docking stage, leg mating stage and undocking stage), the numerical simulation results shall be output separately, and statistical analysis is conducted to verify whether the following parameters meet the requirements:

(1) Maximum values of mooring line tension, horizontal tension at the anchor end and uplift force;

(2) The motion response of the key points of the topside component, including the motion response of the center of gravity of the deck and the LMU, and the horizontal and vertical motion ranges of the LMU after docking;

(3) The motion response of the key points of the barge, including the stern and bottom of the barge and the motion response at the DSU;

(4) The load of the LMU/DSU/ fender shall not only meet its own capacity requirements, but also ensure that the collision force is within the tolerable range.

7.8.2 The simulation duration of each analysis condition generally takes 1 hour. Figure 7.8.2 (1) and Figure 7.8.2 (2) respectively give the results of the typical time history of motion and fender load.

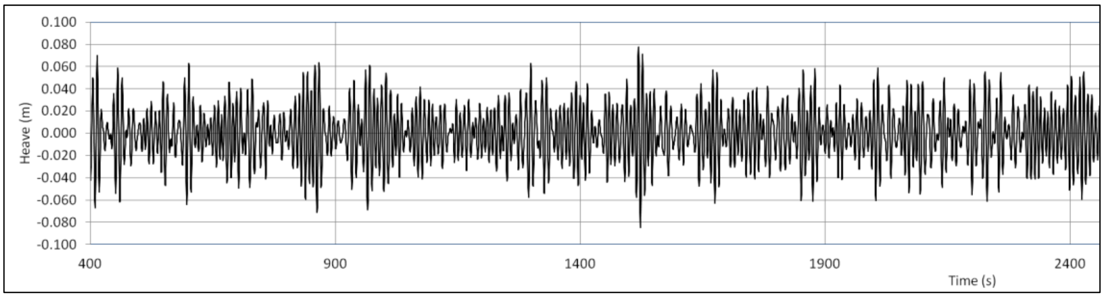


Figure 7.8.2 (1) Time History of Barge Heave Motion

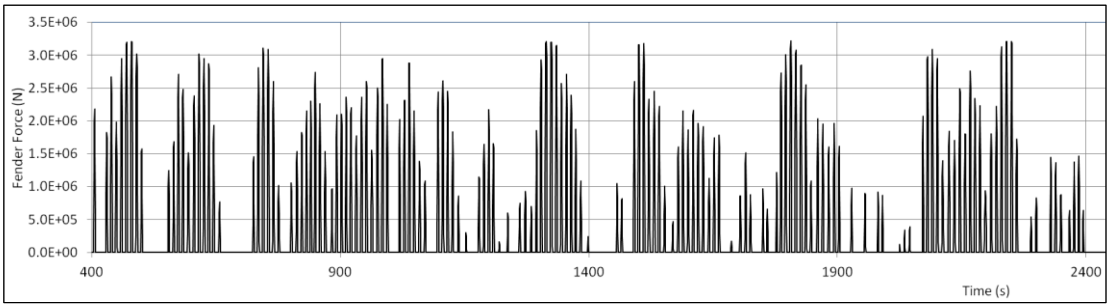


Figure 7.8.2 Time History of Fender Load

7.8.3 In general, the statistical maximum (or minimum) value of time history is taken as the analysis result. In order to avoid the sensitivity of calculation results to random numbers, several random numbers can be used for numerical simulation, and then all the statistical results are averaged to obtain the final result.

7.8.4 To calculate the capture radius of LMU, if only the maximum values of horizontal and vertical motion are counted, the results may be too conservative. It is more appropriate to directly output the time history of horizontal motion and then count its maximum values.

Section 9 Structure Analysis

7.9.1 General requirements

(1) The maximum load results of the fender, LMU and DSU shall be extracted for the strength check of jacket structure and topside component structure;

(2) The impact force on the whole system shall be within the tolerable range of the topside component, jacket and barge, with a certain margin considered.

7.9.2 Analysis condition

(1) The moment when the load on the leg (or support) of a jacket (or topside component) reaches the maximum is determined. The maximum load results need to be obtained in the analysis conditions in all environmental directions. Corresponding to the maximum stress moment, the load results of other legs (or supports) are obtained from the time history to form a loading condition;

(2) For each LMU/DSU, the maximum loading conditions in X, Y and Z directions shall be considered.

(3) For each fender, the loading condition under which it bears the maximum pressure shall be considered;

(4) In addition, structural analysis is also needed for the moment at the maximum total collision force (torque), and the loading condition with the maximum force and torque in X, Y and Z directions shall be considered.

7.9.3 Strength check

The stress of members and joints of jackets and topside components shall be checked according to the relevant specifications.

Appendix

Section 1 Jacket Launch Analysis Process and Examples

1.1 The process of jacket launch analysis mainly includes:

(1) establishing the model. Besides the models of the jacket and ship, the rocker arm and the jacket launch support also need to be simulated;

(2) checking whether the reserve buoyancy of the jacket meets the requirements;

(3) setting the floating state of the barge during launching and providing the ballast;

(4) carrying out the launching stability analysis and longitudinal strength analysis using the MOSES software;

(5) conducting the time-domain simulation and analysis during launching using the MOSES software, and checking the dynamic response;

(6) generating the loads acting on the jacket at several key time points during launching, including buoyancy, gravity, hydrodynamic force, inertia force, ship friction and supporting force, using the MOSES software;

(7) converting the load generated by MOSES into a load file in the SACS software format;

(8) reading the load file using SACS software, and checking the structural integrity of the jacket during launching;

(9) conducting the sensitivity analysis: investigating the sensitivity of the error of friction coefficient of launching skidway, floating state of the barge and the weight and gravity center of the jacket to the launching analysis results.

1.2 For the barge model, it should be noted that the hydrostatic and hydrodynamic characteristics of the ship must be accurately simulated. The hydrodynamic characteristics include the drag coefficient, additional mass and damping coefficient. The data of barge model test is the first choice to determine the hydrodynamic parameters. If no model test data is available, the hydrodynamic parameters can be determined by referring to the database data of similar barges, or calculated using the empirical formula recognized by the industry. For barges that have been simulated in previous projects, with the comparison between measured data and simulated data, the relevant parameters shall be appropriately revised if necessary.

1.3 Taking a typical deepwater jacket as an example, an example of jacket sliding launching analysis using MOSES software is given.

1.4 The barge and jacket shall be modeled. The hydrostatic model of the barges includes the compartment model in addition to the shell model. Figure 1.4 shows the barge and jacket model established using MOSES software, in which the barge has been ballasted to the required draft and trim.

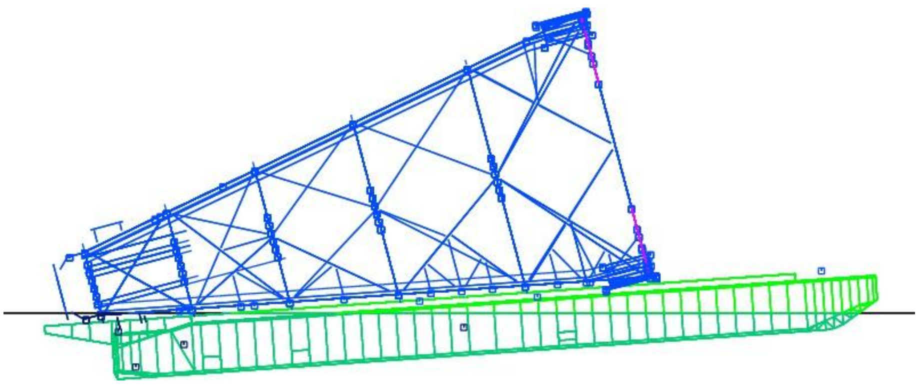


Figure 1.4 MOSES Model of Barge and Jacket

1.5 Before launching simulation calculation, it is necessary to check whether the reserve buoyancy of the jacket meets the requirements after launching. Besides, the stability and longitudinal strength of the barge during launching (including at least two conditions, i.e. the conditions before launching and at the rotating moment) shall also be checked. In this example, the reserve buoyancy of the jacket is 11.69%, which meets the requirements of 5.2.1. The stability check is shown in Figure 1.5 (1) and Figure 1.5 (2), and the results of longitudinal strength check are shown in Figure 1.5 (3) to Figure 1.5 (6).

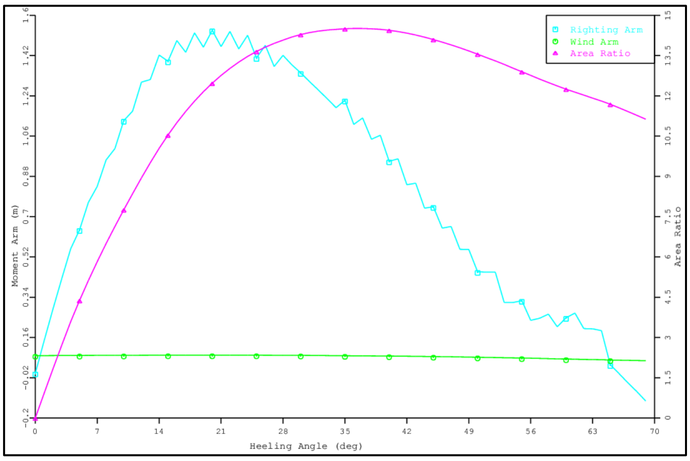


Figure 1.5(1) Stability Curve of Barge-Jacket Combination before Launching

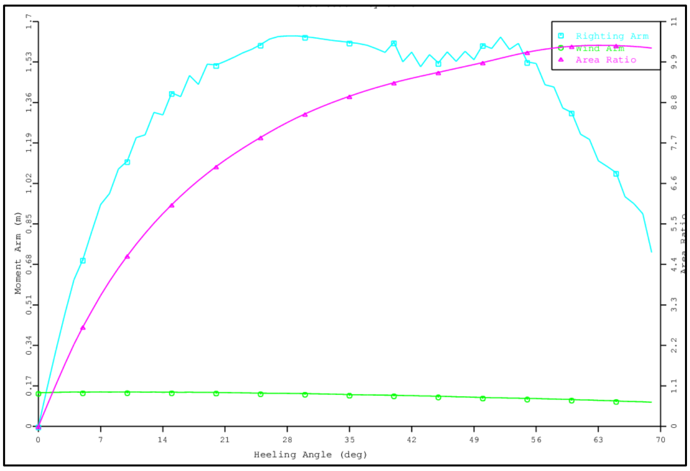


Figure 1.5 (2) Stability Curve of Barge-Jacket Combination during Rotation

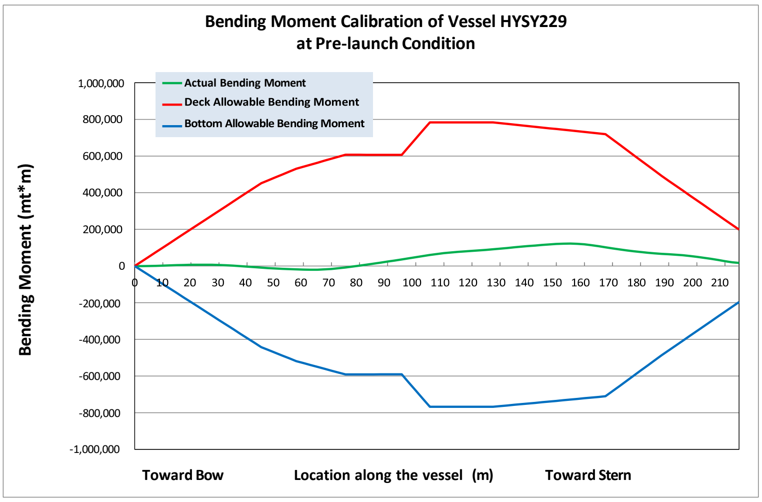


Figure 1.5 (3) Longitudinal Strength Check before Launching — Bending Moment

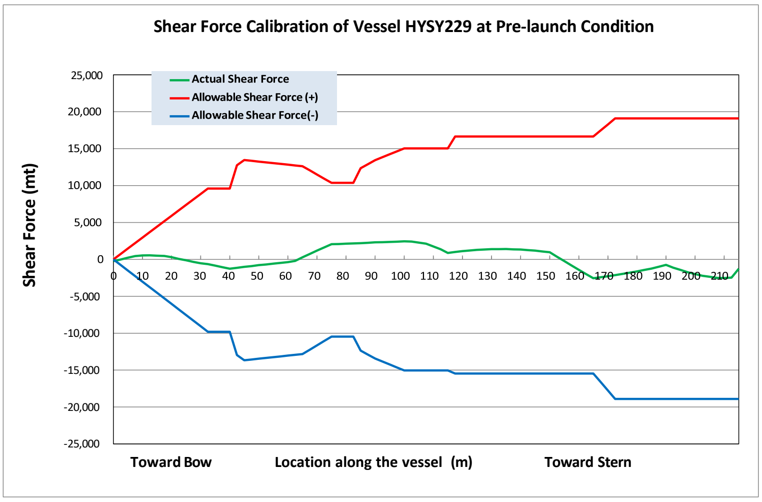


Figure 1.5 (4) Longitudinal Strength Check before Launching — Shear Force

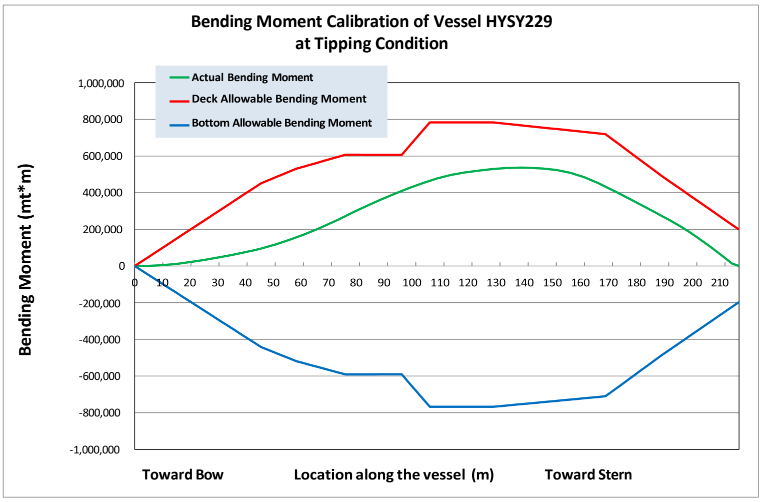


Figure 1.5 (5) Longitudinal Strength Check during Rotation — Bending Moment

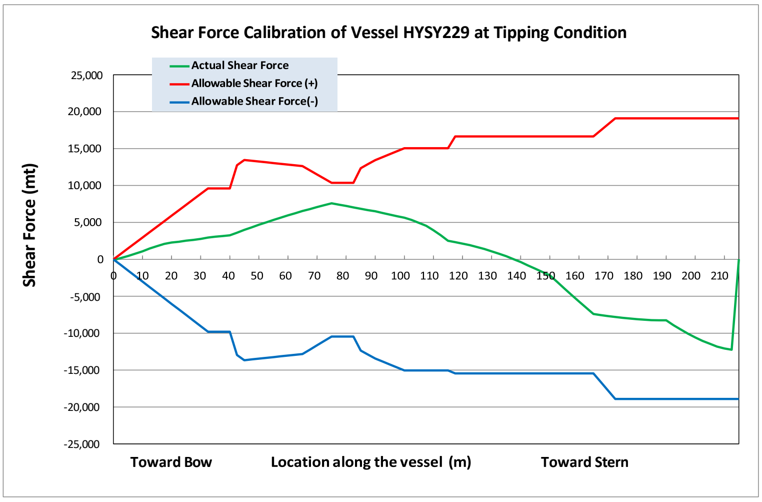


Figure 1.5 (6) Longitudinal Strength Check during Rotation — Shear Force

1.6 The sliding launching process of the jacket is simulated and analyzed in a time-domain manner using MOSES software, and the launching trajectory is shown in Figure 1.6 (1). Table 1.6 gives the key parameters of launching analysis. The analysis results of the maximum water depth and bottom clearance of the jacket, the submerged depth of the stern and the supporting reaction of the rocker arm are shown in Figure 1.6 (2) and Figure 1.6 (3), all of which can meet the requirements of Section 5.2.

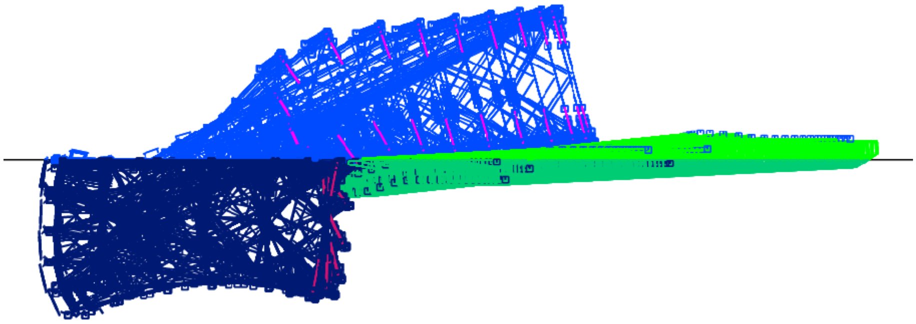


Figure 1.6 (1) Attitude in Launching Process

Examples of Launching Dynamic Analysis Results **Table 1.6**

1. Initial Conditions:	
Barge Draft at Midships (m)	11.11
Trim by Stern of Barge (deg)	4.00
Start time of Sliding (s)	0.00
Pushing Distance (m)	0.00
Jacket Weight (MT)	16264.12
2. When Jacket Tips:	
Time (sec)	31.13
Length of Leg on Deck (m)	61.16
Port Rocker Load (MT)	5716
Stbd Rocker Load (MT)	5368
Total Load on Rocker (MT)	11084
Percent of jacket Weight (%)	68
Jacket Roll Angle (deg)	-0.02
Barge Roll Angle (deg)	-0.02
Jacket Pitch Angle (deg)	5.62
Barge Pitch Angle (deg)	5.62
Max. Relative Speed (m/s)	4.45
3. When Jacket Separates:	
Time (s)	44.70
Port Rocker Load (MT)	1301
Stbd Rocker Load (MT)	1087
Total Rocker Load (MT)	2388
Percent of jacket Weight (%)	14
Jacket Roll Angle (deg)	-0.20

Barge Roll Angle (deg)	-0.10
Jacket Pitch Angle (deg)	25.02
Barge Pitch Angle (deg)	4.77
Max. Relative Speed (m/s)	6.26
4. Maxima/Minima:	
Max jacket Dive Depth @ Top (m)	89.94
Max. Barge Keel Submergence (m)	21.53
Min. Seabed clearance (m)	54.09

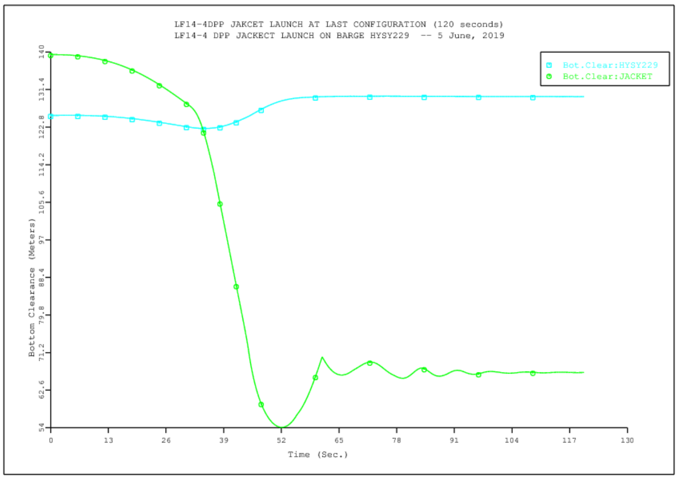


Figure 1.6 (2) Seabed Clearance during Jacket Sliding Launching

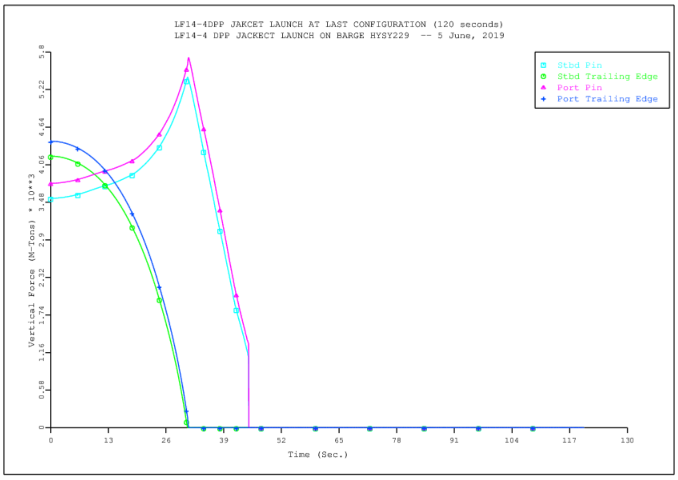


Figure 1.6 (3) Rocker Arm Supporting Reaction during Jacket Sliding Launching

1.7 The structural strength of the jacket is checked by SACS software. The buoyancy, gravity, friction, supporting force and hydrodynamic results of the jacket under the selected working conditions are all output by MOSES software.

1.8 In addition, it is necessary to analyze the sensitivity of the launching inclination, sliding friction coefficient, gravity center offset and weight error.

Section 2 Examples For Upending Analysis of Jacket

2.1 The upending process of the jacket is shown in Figure 2.1.

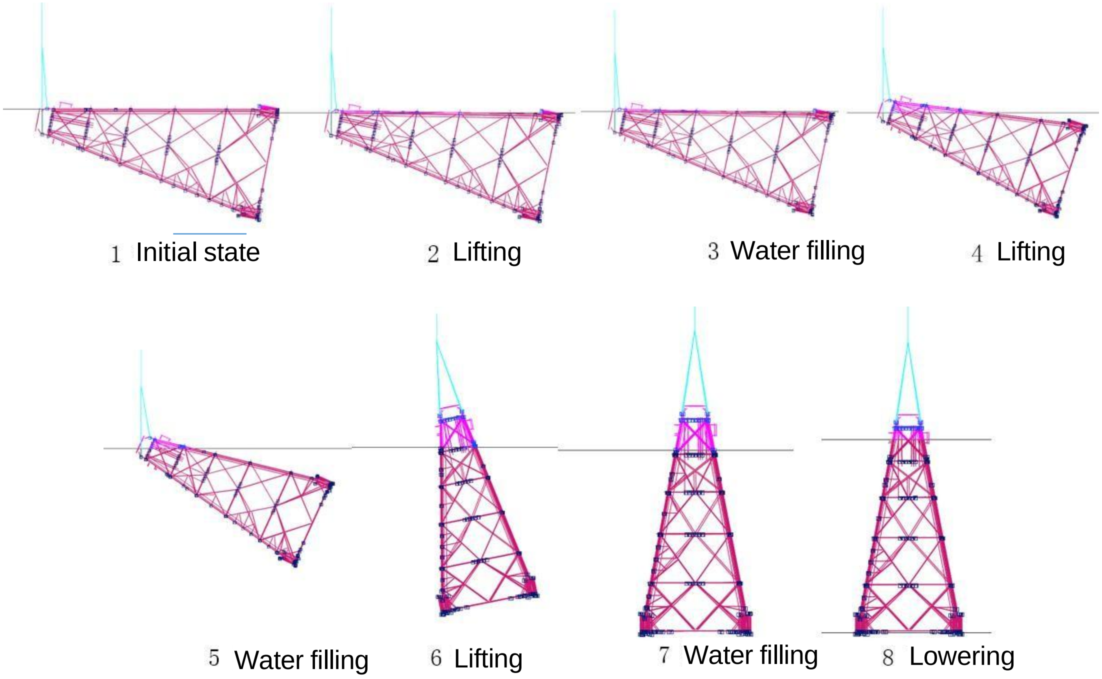


Figure 2.1 Upending Process

2.2 An example of upending analysis using MOSES software is given based on a typical deepwater jacket.

2.3 The simulation of jacket subdivision and slings is shown in Figure 2.3.

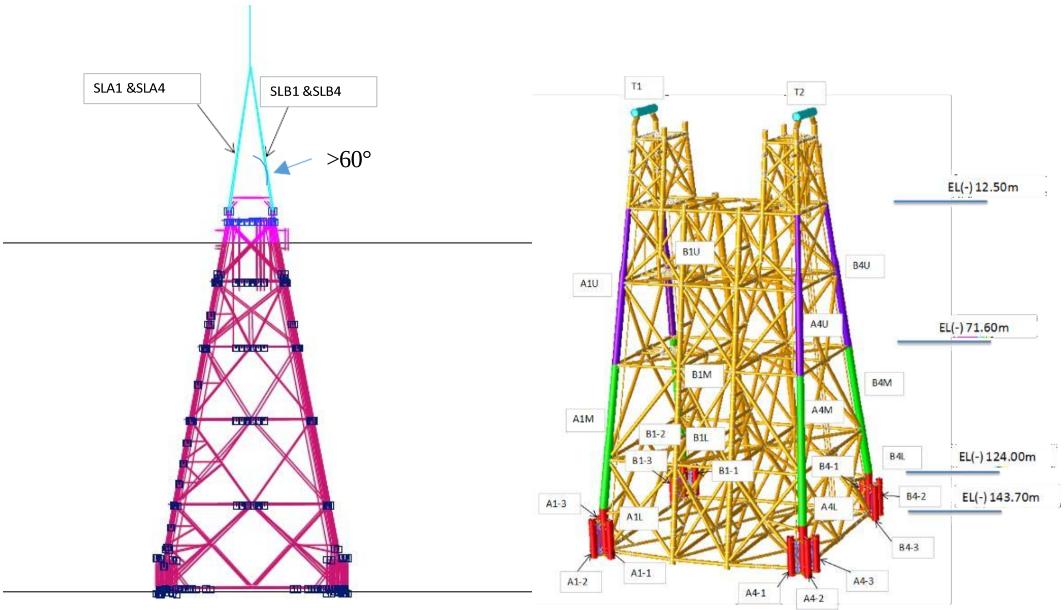


Figure 2.3 Upending Analysis Model

2.4 The simulation results of the trajectory, stability and sling force of the jacket during upending are shown in Figures 2.4 (1)–2.4 (3), and the analysis results are checked according to the analysis criteria in Section 6.2.

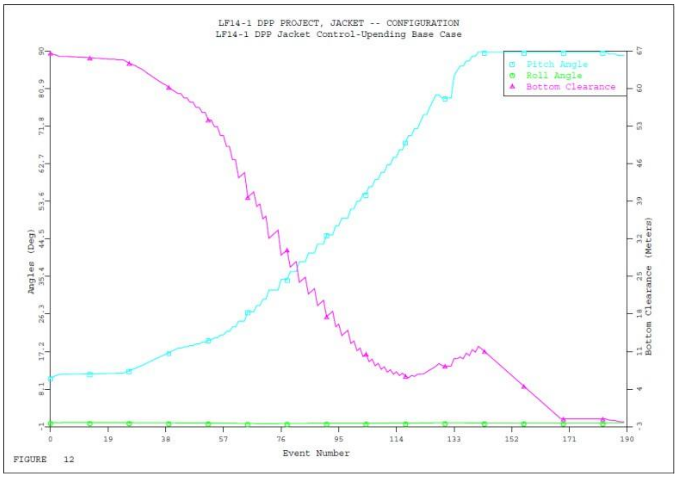


Figure 2.4 (1) Rolling/Pitching Angle and Seabed Clearance of Jacket during Upending

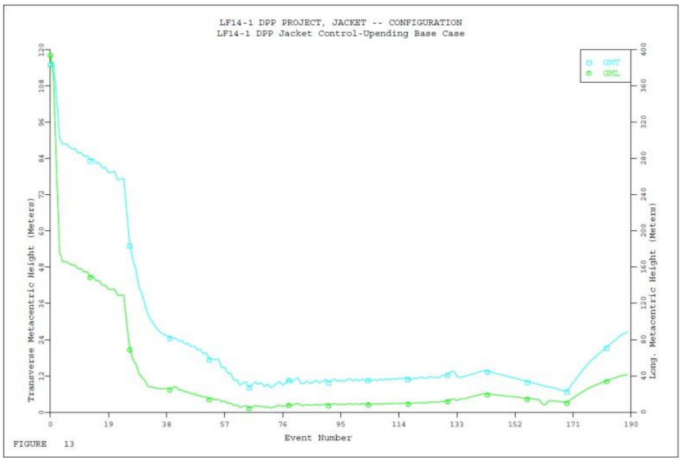


Figure 2.4 (2) Transverse/Longitudinal Metacentric Heights of Jacket during Upending

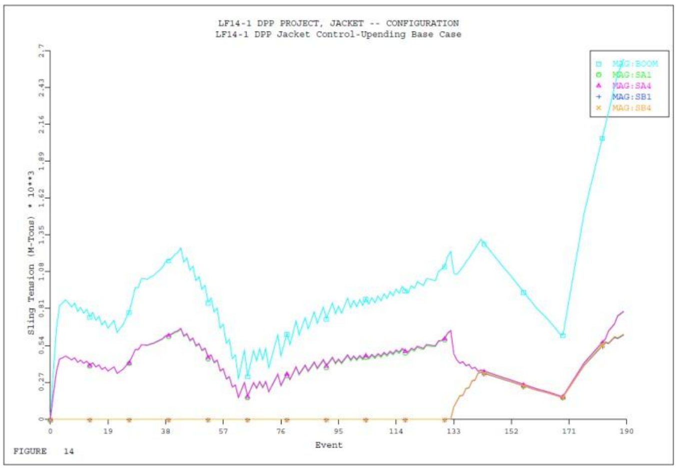


Figure 2.4 (3) Crane Lifting Point Force and Sling Tension of Crane during Upending

Section 3 Example of Climate Window Analysis for Float-over Installation

3.1 The climate window analysis of float-over installation of a deepwater jacket platform is taken as an example. See Table 3.1 for the environmental conditions of float-over installation in the oilfield in the Pearl River Estuary of South China Sea, with a water depth of 99.8 m.

Limited Environmental Conditions for Float-over Installation **Table 3.1**

Direction	Wave height **Hs**（m）	Flow velocity (m/s)	Wind speed (m/s)
Heading/Following sea	1.50	0.45	9.83
Oblique sea	1.00	0.45	9.83
Beam sea	0.50	0.45	9.83

3.2 The months with the number of operational days exceeding 50% cumulative probability shall be selected for float-over installation. As indicated in Table 3.2 (1), April, May and June are the operational months, and May is the best operational month. As the sea area is in a period of frequent typhoons in August, it should be generally chosen to complete the float-over installation before August in this Project. The joint distribution of the magnitude and direction of wind waves and currents in this sea area in May is shown in Tables 3.2 (2)–3.2 (4).

Operational Probability Calculation **Table 3.2(1)**

Month	Operational probability of wind speed (%)	Operational probability of wave (%)	Operational probability of ocean current (%)	Operational probability (%)
April	95.15	83.69	98.39	78.35
May	95.52	89.34	95.25	**81.28**
June	96.30	65.48	88.47	55.79
July	84.01	60.74	87.65	44.73

Joint Distribution of Significant Wave Height and Wave Direction (May) Table 3.2 (2)

Significant Wave Height(m)	Wave Direction																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
0.0--0.5	0	0	0.2	1.03	11.22	4.03	1.43	1.84	2.22	0.92	0.13	0	0	0	0	0	23.03
0.5--1.0	0.13	0.2	0.56	7.97	23.66	8.47	3.02	3.23	5.58	7.53	1.68	0.13	0.04	0.04	0	0.07	62.32
1.0--1.5	0.11	0.18	0.2	4.35	2.49	0.76	0.43	0.02	0.02	0.16	1.01	0	0.02	0	0	0	9.74
1.5--2.0	0	0.11	0.25	2.06	0.56	0	0	0	0.04	0	0	0	0	0	0	0	3.02
2.0--2.5	0	0	0.07	0.78	0.07	0	0	0	0.04	0	0	0	0	0	0	0	0.96
2.5--3.0	0	0	0.04	0.18	0.02	0	0	0	0.02	0.02	0	0	0	0	0	0	0.29
3.0--3.5	0	0	0.02	0	0	0	0	0	0	0.04	0	0	0	0	0	0	0.07
3.5--4.0	0	0	0.02	0	0	0	0	0	0	0.04	0	0	0	0	0	0	0.07
4.0--4.5	0	0	0	0.02	0	0	0	0	0	0.02	0	0	0	0	0	0	0.04
4.5--5.0	0	0	0	0	0.02	0	0	0	0	0.02	0	0	0	0	0	0	0.04
5.0--5.5	0	0	0	0	0	0.02	0	0	0	0.02	0	0	0	0	0	0	0.04
5.5--6.0	0	0	0	0	0	0.02	0	0	0	0.02	0	0	0	0	0	0	0.04
6.0--6.5	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0.02
6.5--7.0	0	0	0	0	0	0	0.02	0	0	0.02	0	0	0	0	0	0	0.04
7.0--7.5	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0.02
7.5--8.0	0	0	0	0	0	0	0	0.02	0	0.02	0	0	0	0	0	0	0.04
8.0--8.5	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0.02
8.5--9.0	0	0	0	0	0	0	0	0.02	0.02	0	0	0	0	0	0	0	0.04
9.0--9.5	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0.02
9.5--10.0	0	0	0	0	0	0	0	0.02	0.02	0	0	0	0	0	0	0	0.04
>10.0	0	0	0	0	0	0	0	0	0.04	0	0	0	0	0	0	0	0.04
Total	0.25	0.49	1.37	16.4	38.04	13.31	4.91	5.15	8.06	8.89	2.82	0.13	0.07	0.04	0	0.07	100
Max(m)	1.2	1.57	3.62	4.09	4.63	6	6.87	9.55	10.08	7.84	1.31	0.91	1.04	0.95	0	0.63	10.08
Mean(m)	0.91	1.11	1.15	1.09	0.66	0.63	0.6	0.66	0.77	0.89	0.88	0.64	0.79	0.75	0	0.6	0.77

Joint Distribution of Wind Speed and Wind Direction (May) Table 3.2(3)

Wind speed (m/s)	Wind Direction(coming)																Total
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
0.0-2.0	0.07	0.13	0.25	0.36	0.63	1.21	1.7	0.92	0.92	0.67	0.49	0.54	0.49	0.31	0.11	0.18	8.98
2.0-4.0	0.34	0.45	1.1	2.24	3.38	5.42	5.11	4.66	4.53	2.64	1.64	1.59	1.28	0.45	0.29	0.31	35.42
4.0-6.0	0.38	0.22	1.66	2.62	5.24	4.14	2.53	2.91	4.77	3.43	1.16	1.14	0.58	0.13	0.07	0.2	31.21
6.0-8.0	0.02	0.2	0.6	2.8	3.09	1.25	0.74	0.72	1.72	2.26	1.28	0.29	0.29	0.07	0.02	0	15.37
8.0-10.0	0.02	0.13	0.69	1.16	0.63	0.13	0.09	0.02	0.13	1.12	0.6	0.2	0.07	0.02	0	0	5.04
10.0-12.0	0	0.18	0.31	1.12	0.29	0	0	0	0.02	0.27	0.36	0.09	0	0	0	0	2.64
12.0-14.0	0	0.04	0.16	0.45	0.52	0	0	0	0	0.02	0	0	0	0	0	0	1.19
14.0-16.0	0	0.02	0	0	0.04	0	0	0	0	0	0	0	0	0	0	0	0.07
16.0-18.0	0	0	0	0.02	0.02	0	0	0	0	0	0	0	0	0	0	0	0.04
18.0-20.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20.0-22.0	0	0	0	0.02	0.02	0	0	0	0	0	0	0	0	0	0	0	0.04
22.0-24.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.0-26.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26.0-28.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28.0-30.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>30.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0.83	1.39	4.77	10.8	13.87	12.16	10.17	9.23	12.1	10.42	5.53	3.85	2.71	0.99	0.49	0.69	100
Max(m/s)	8.85	14.26	13.75	20.12	20.04	9.39	8.4	8.01	10.26	12.12	11.92	11.37	9.03	8.01	6.23	5.17	20.12
Mean(m/s)	4.12	5.62	5.81	6.39	5.47	4.04	3.58	3.68	4.29	5.35	5.28	4.13	3.62	3.03	2.73	3.03	4.72

Joint Distribution of Current Speed and Direction (May) Table 3.2(4)

curr. Speed (cm/s)	Current Direction																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
00≤10	0.83	1.25	1.01	1.16	1.03	0.85	0.81	0.81	0.81	0.63	0.29	0.52	0.78	0.69	1.12	1.1	13.69
10≤20	3.07	2.73	2.44	2.53	2.69	2.78	1.72	1.57	1.57	1.1	0.52	0.78	1.23	1.86	2.26	2.15	31
20≤30	3.07	3.65	3.49	2.51	2.28	2.2	1.61	1.3	0.87	0.52	0.56	0.74	1.1	1.59	2.26	3.05	30.8
30≤40	2.35	2.02	1.39	1.14	1.23	1.1	0.96	0.63	0.45	0.11	0.13	0.18	0.43	1.01	1.66	1.9	16.69
40≤50	0.74	0.49	0.31	0.2	0.34	0.87	0.31	0.09	0	0	0	0.04	0.22	0.52	1.08	0.94	6.16
50≤60	0.34	0.07	0	0	0.09	0.02	0.02	0	0	0	0	0	0.02	0.13	0.27	0.38	1.34
60≤70	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0.07	0.11	0.27
70≤80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0.04
80≤90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
90≤100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100≤120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120≤140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
140≤160	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
160≤180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180≤200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	10.44	10.22	8.65	7.55	7.66	7.82	5.44	4.39	3.7	2.35	1.5	2.26	3.79	5.85	8.71	9.68	100
Max (cm/s)	63.07	56.39	47.99	49.87	52.75	50.93	50.11	47.79	38.39	33.22	35.19	43.38	57.46	61.42	64.25	72.92	72.92
Mean (cm/s)	25.13	23.06	22.07	20.79	21.77	22.86	21.7	20.06	17.34	15.58	18.2	17.91	20.13	23.78	25.33	26.43	22.58