A PROJECT REPORT

ON

"RISER DESIGN STRESS ANALYSIS"

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RISER DESIGN STRESS ANALYSIS

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ACKNOWLEDGEMENT

I take this opportunity to express my profound gratitude and respect to the persons who helped me in every manner to make major project at University of Petroleum and Energy Studies successful.

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CHAPTER 1

1. PROJECT BACKGROUND

To assess whether bending or riser tension dominates, the following non-dimensional number

$$\lambda_{\text{tens}} = \frac{T_0 L^2}{\pi^2 n^2 EI}$$

may be used. For λ_{tens} equal to 1, the stiffness contribution from the bending and tension stiffness will be about the same, while for larger values the tension stiffness will dominate. Here To represents the average tension, L the riser length, El is the bending stiffness and yl the number of half waves. The effects of tension and bending stiffness are both typically included in the riser analysis, and in the water depth of interest, tension dominates the stiffness.

Influence of Met ocean Conditions

The selection of accurate metocean conditions for a specific site for use in the analysis of a drilling riser is usually difficult, but it can, sometimes make the difference in whether or not a well can be drilled economically. The drilling riser is analysed based on the collection of wind, waves, and the current profile conditions for a specific well site. These metocean conditions can be based on information for a general region or an area near the well site. Whatever the case, a common understanding of the basis for the metocean conditions between the metocean specialist and the riser analyst is an important part of the process. The current profile often drives the analytical results used for determining when drilling operations through a riser should be shut down. The steady current loading over the length of the riser influences the riser deflections, and the top and bottom angles that restrict drilling operations. Furthermore, high currents cause vortex-induced vibrations (VIV) of the riser, which lead to increased drag load and metal fatigue. Current profile data at a future well site can be more difficult to collect than data on winds and seastates due to the large amount of data to be gathered throughout the water depth. Furthermore, current features in many regions of the world tend to be more difficult to analyse due to a lesser understanding of what drives them, particularly in the deeper waters. Winds and waves are important when considering the management of drilling riser operations in storms. Although not as important for determining the shape of the riser, the winds and seastates have a greater bearing on when the drilling riser should be retrieved (pulled) to the surface, Le. when the mooring system will be unable to keep the vessel within an acceptable distance of the well. Drilling risers are operated in conditions all over the world. These include large seastates off the east coast of Canada and the North Sea, the combination of high seastates and high currents west of Shetlands, the high currents offshore Brazil and Trinidad, and the cyclonic events combined with high currents in the Gulf of Mexico and offshore northwestern Australia. Typical metocean conditions for the Gulf of Mexico are listed below in table.

		Riser connected/drilling						Riser connected/non-drilling				Riser pulled	
		1-yr winter storm		10-yr eddy		Sudden squall		10-yr winter storm		100-yr eddy		100-yr hurricane	
Winds		m/s	knots	m/s	knots	m/s	knots	m/s	knots	m/s	knots	m/s	knots
Vwind (1 h)		18.0	35.0	15.0	29.2	26.0	50.5	22.0	42.8	15.0	29.2	45.0	87.5
Vwind (1 min)		21.1	41.0	17.7	34.4	31.4	61.0	26.0	50.5	17.7	34.4	53.1	103.2
Seastate		m	ft	m	ft	m	ft	m	ft	m	ft	m	ft
Hs		4.9	16.0	3.5	11.5	1.5	4.9	5.8	19.0	3.5	11.5	12.5	41.0
Tp (s)		10.0		9.0		5.9		10.6		9.0		15.0	
Mean T (s)		7.7		6.9		4.6		8.2		6.9		11.6	
Current													
m	ft	m/s	knots	m/s	knots	m/s	knots	m/s	knots	m/s	knots	m/s	knots
Surface		0.30	0.59	1.40	2.72	0.30	0.59	0.30	0.59	2.00	3.89	1.00	1.94
60	197			1.40	2.72					2.00	3.89	1.00	1.94
76	249	0.30	0.59			0.30	0.59	0.30	0.59				
77	253	0.15	0.30			0.15	0.30	0.15	0.30				
100	328			1.40	2.72					2.00	3.89	0.20	0.39
150	492			1.10	2.14					1.50	2.92		
200	656			0.80	1.56					1.20	2.33		
300	984			0.60	1.17					0.80	1.56		
500	1641			0.30	0.58					0.40	0.78		
Near bottom		0.15	0.30	0.20	0.39	0.15	0.30	0.15	0.30	0.20	0.39	0.20	0.39

Typical design met ocean criteria for Gulf of Mexico

2. AIM OF THE PROJECT

Drilling offshore oil and gas wells has become increasingly challenging as water and well depths have increased. In many regions, drilling hazards such as very narrow margins between collapse (pore) and fracture pressures, pore pressure uncertainty, pore pressure regression, high pressure and high temperature have resulted in significant additional cost due to the time required to rectify the problems associated with these hazards.

The aim of the project is to design a riser which undergoes many design and manufacturing challenges.
Some are as follows:

- Manufacturing high strength connector bolts
- Bolt and thread capacity design limits
- Careful consideration of riser pressure and load effects
- Loop current and VIV effects on the riser
- riser hang-off and centralizing
- Gas migration into the riser and deepwater well control issues require gas handling equipment
- Riser mass limitations during running and out-of phase heave acceleration of vessel causing riser buckling after disconnect
- Lack of adequate riser buoyancy industry design standards

As the development of offshore hydrocarbon reserves extends into greater water and well depths, riser system design and supply becomes a critical industry challenge.

3. OBJECTIVE OF PROJECT

The main objective of the project is to overview the stress analysis on the riser design taking the above challenges into consideration and the lessons learned from this project can be applied to improve future design practices. In addition, this also leads to knowledge transfer to other areas of the world with emergent deepwater developments.

4. SCOPE FOR PROJECT

This Chapter provides criteria for design review and classification of risers and some special requirements for top tension risers, which are found in Floating Production Installations (FPI), such as Spars, TLPs and column stabilized vessels. Acceptance criteria for completion and work over risers are not included. The term "classification," as used herein, indicates that a riser system has been designed, constructed, installed and surveyed in compliance with the existing Rules, Guides or other acceptable standards. Acceptance criteria are specified, but cover only the riser pipe bodies. For the flanges and other connectors used in the risers, the recognized standards such as the ASME Boiler and Pressure Vessel Code are to be used. On commencement of the detailed engineering phase, a comprehensive quality plan is to be prepared, detailing the controls that will be implemented in the course of the design. The quality plan is to set down the structure and responsibilities of the design team and outline procedures governing the assignment of design tasks, checking of work, document issues and tracking. The quality assurance process is to be audited at designated intervals throughout the design phase. The design process is to be fully documented and supported by comprehensive calculations in which all assumptions are fully justified. A Design Report is to be prepared, in which all data, calculations and recommendations are clearly laid out. Document control procedures are to ensure the tractability of all documentation, drawings, correspondence and certification.

5. PROJECT METHODOLOGY

1. STUDY THE CASE STUDY CAREFULLY:

In order to perform the designing of the riser, the first step is to go through the cast study completely in order to understand the different conditions to which the riser is subjected to otherwise the designing of the riser may not be correct. Hence the first step in project methodology is to study the case study carefully.

2. COLLECTION OF DATA:

After going through the case study, data is collected in order to perform the calculations and some of the data is assumed if given in the case study.

3. CALCULATIONS OF VARIOUS STRESSES:

After collection of the data along with the conditions given, the calculations of various stresses are done with the help of following equations and it is the first to designing a riser mathematically.

The design parameters to be calculated are:

a) Burst pressure

$$p_b = 0.90(SMYS + SMTS)\left(\frac{t}{D-t}\right)$$

b) Collapse pressure

$$p_c = \frac{p_{el}\,p_p}{\sqrt{p_{el}^2 - p_p^2}}$$

c) Buckling pressure

$$\frac{\varepsilon}{\varepsilon_h} - \frac{p_e - p_i}{p_c} \leq g(f_0)$$

d) Drag and lift forces

$$F = F_D - F_L = \frac{1}{2}\rho \cdot OD \cdot C_D \cdot (u_n - \dot{u}_n) \cdot \left|u_n - \dot{u}_n\right| - \rho \cdot \left(\frac{\pi \cdot OD^2}{4}\right) \cdot a_n - \left(\frac{c}{g}\right) \cdot \left(\frac{\pi \cdot OD^2}{4}\right) \cdot C_m \cdot (u_n - \dot{u}_n)$$

4. MONITORING THE DATA:

The data after calculation is monitored carefully whether the designing of the riser is correct or not.

5. GIVING VIEWS AND CONCLUSION ON THE RESULTS:

The data achieved is monitored and views and conclusions are given on that basis along with recommendations.

6. PROJECT LIMITATIONS

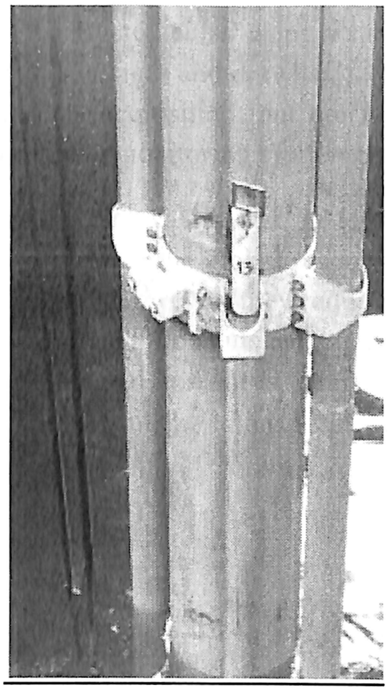


Figure 1 – Stand-alone Motion Monitoring System

Vortex-induced vibration (VIV) is responsible for majority of the fatigue damage in deepwater drilling risers. Damage from VIV is a major issue and, potentially, very dangerous. Of primary concern are the uncertainties involved in VIV prediction. These uncertainties come from various sources:

- The variation in magnitude and direction of deepwater long term currents;
- Complex multi modal characteristics of VIV in deepwater environment;
- Non-scalability of tank test results;
- Uncertainties in the design input parameters which require calibration based on measurements in the field.

Consequently, monitoring the riser response will allow comparisons between predicted and measured response for different environmental conditions. Analysis conducted can be used to calibrate VIV analysis software based on the comparison of the monitored riser response. This allows for rationalization of design methods. confirmation of long term integrity and provides riser inspection interval recommendations.

Deepwater riser monitoring can be conducted either using a stand-alone system or real time data monitoring system, each having its advantages and drawbacks. Real time monitoring systems, on the other hand, provide real time data acquisition, but are more expensive and require more complex interfaces. A typical stand-alone monitoring motion sensor attached to an auxiliary line.

Monitoring systems measure deepwater riser response in terms of motion or strain along the length. Motion monitoring systems measure the global response, are relatively inexpensive and have a proven track record in deepwater. However, they require large amount of data processing to calculate stresses and fatigue. Strain measurements can be used calculate fatigue damage with little data processing, but the monitoring equipment is, generally expensive, has more complex interfaces with the pipe, lower subsea reliability and has little track record in deepwater.

CHAPTER 2

LITERATURE REVIEW

Risers are used to contain fluids for well control (drilling risers) and to convey hydrocarbons from the seabed to the platform (production risers). Riser systems are a key component for offshore drilling and floating production operations. This chapter covers drilling risers in floating drilling operations from MODUS and production risers (as well as drilling risers) from floating production operations.

A riser is a unique common element to many floating offshore structures. Risers connect the floating drilling/production facility with subsea wells and are critical to safe field operations. For deepwater operation, design of risers is one of the biggest challenges. During use in a floating drilling operation, drilling risers are the conduits for operations from the mobile offshore drilling unit (MODU). While connected much of the time, drilling risers undergo repeated deployment and retrieval operations during their lives and are subject to contingencies for emergency disconnect and hang-off in severe weather. Production risers in application today include top tension production risers (TTRs), flexible pipes steel catenary risers (SCRs) and free-standing production risers. More than 50 different riser concepts are under development today for use in deepwater and ultra- deepwater. A few of the most common riser concepts are shown in figure.

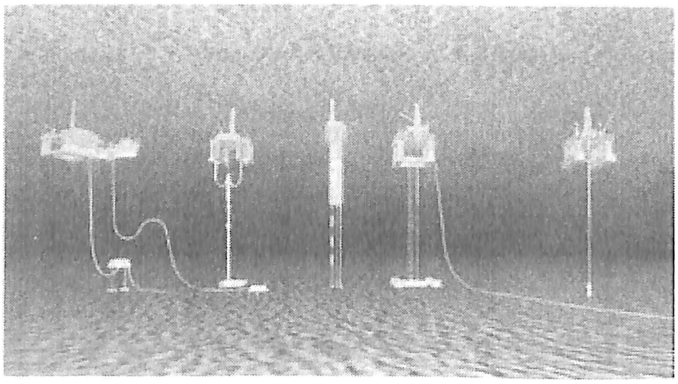


Figure 2- Schematic of riser concepts

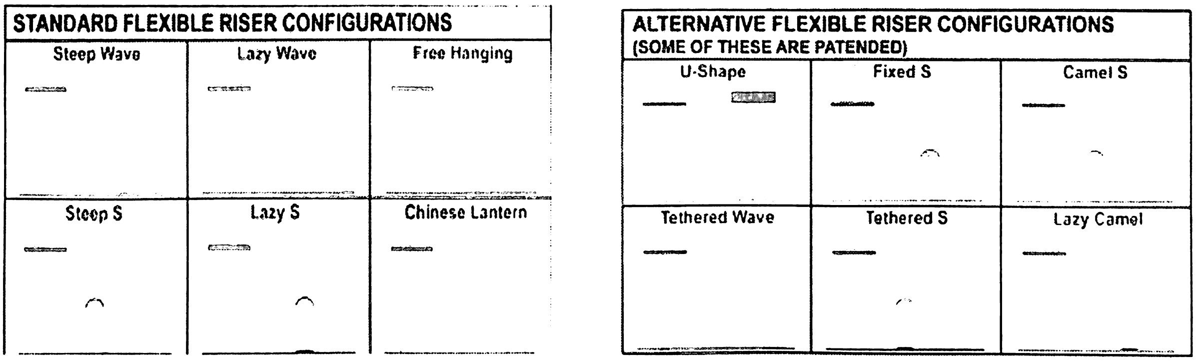


Figure 3- Different riser configurations

There are more than 1550 production risers and 150 drilling risers in use today, attached to a variety of floating platforms. About 85% of production risers are flexible. Flexible risers are applied in water depths of up to 1800 m, while a top tension riser and a steel catenary riser are used in depths as much as 1460 m. The deepest production riser in combined drilling and early production is in a water depth of 1853 m in Brazil for the Roncador Seillean FPSO. Drilling risers are in use in greater than 3000 m depth.

A top tensioned riser is a long slender vertical cylindrical pipe placed at or near the sea surface and extending to the ocean floor. These risers are, sometimes, referred to as "rigid risers" or "direct vertical access" risers.

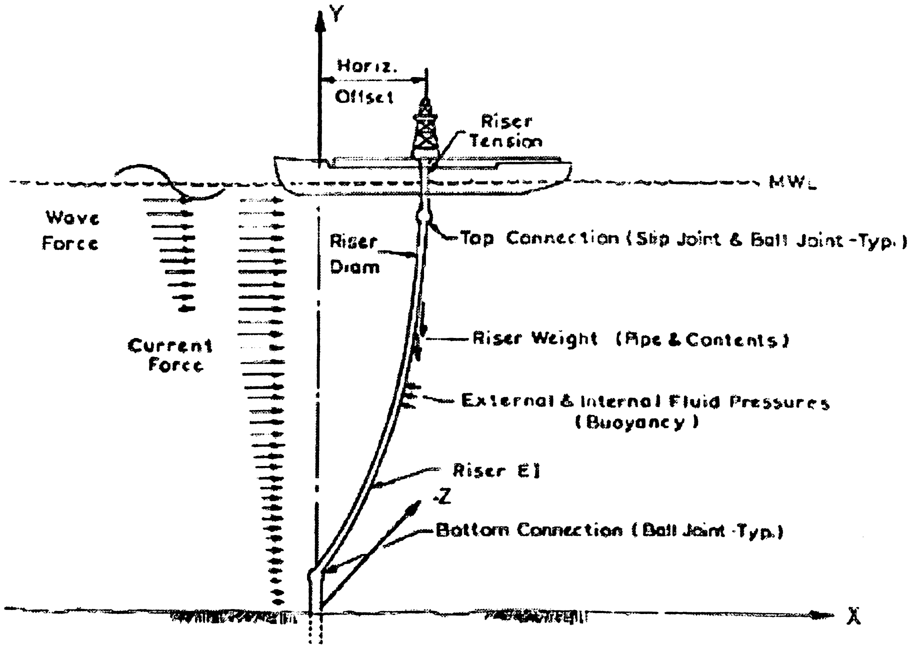
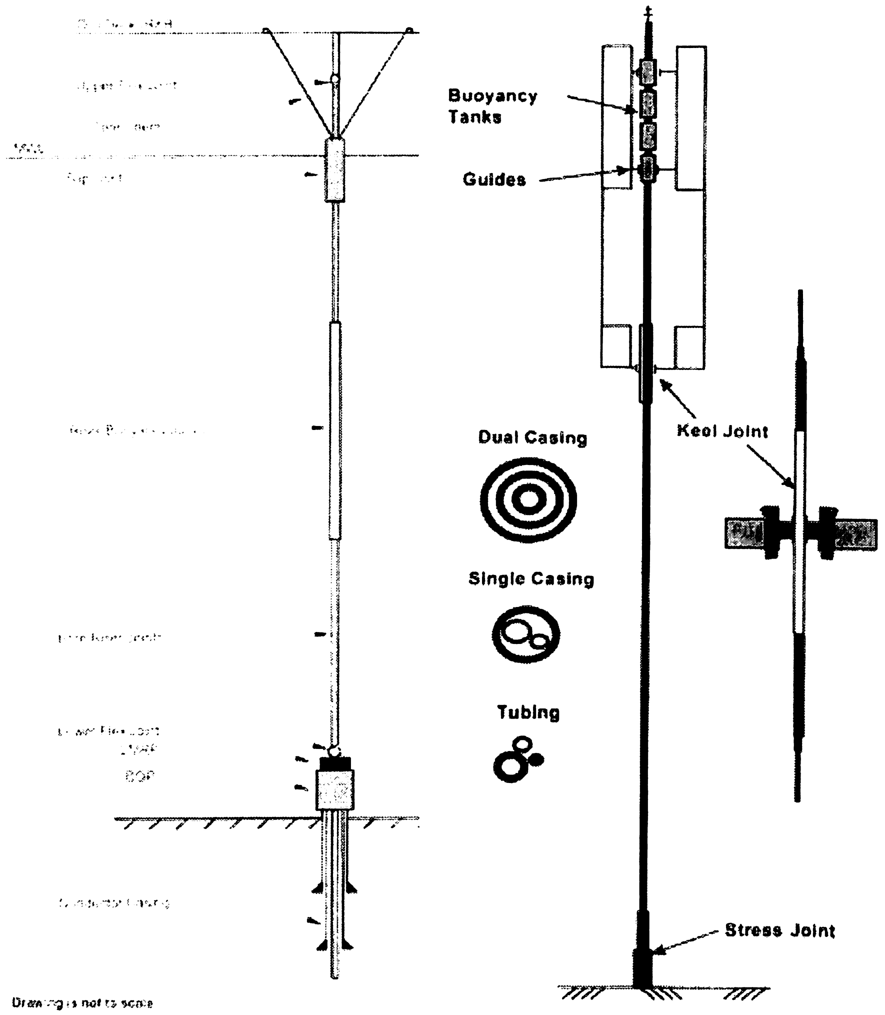


Figure 4 - Vertical tensioned drilling riser

The technical challenges and the associated costs of the riser system increase significantly with water depths. The cost of a riser system for a deepwater drilling and production platform compares with that of the hull and mooring system.



(a) drilling (b) production (on Spar)

Figure 5 - Drilling and production riser configuration

The general riser dimensions are based on the reservoir information and the anticipated drilling procedures. The size of the tubing is determined from the expected well flow rate. The wall thickness of each riser string is computed from the shut-in pressure and drilling and completion mud weights. The outside dimension of the components that must pass through the pipe, such as subsurface safety value (SSSV), drill bit, or casing connector generally determines the internal diameter of the riser. The hoop stress usually governs the wall thickness of the riser pipes. In deeper waters, the wall thickness may depend on the axial stress. The capped-end force generated by the internal pressure should also be considered in computing the axial stress. The bending stress is a determining factor at the upper and lower ball joints of the riser. In these areas thicker riser elements may be required to limit the stresses. The dimensions of the stress joint are more difficult to compute since they must be strong and flexible at the same time. Generally, a finite element program is used that determines the riser bend to the desired maximum angle at the joints. The dimensions are adjusted until the required strength is achieved. The potential for riser interference is also checked during an early determination of the riser component dimensions.

Common standards and specifications used for carbon steel riser pipe and components are listed below:

API RP 2 RD

Design of Risers for Floating Production Systems and Tension Leg Platforms

API 5L

Specification for Line Pipe

API RP 22

Recommend Practice for Preproduction Qualification for Steel Plates and Offshore Structures

ASTM A370

Methods and Definitions for Mechanical Testing of Steel Products

BS 7448

Fracture Mechanics Toughness Tests. Methods for determination of fracture resistance curves and initiation values for stable crack extension in metallic materials

DNV-OS-F10 1

Offshore Standard - Submarine Pipeline Systems

DNV-OS-F201

Standard for Dynamic Risers

NACE MR-01-75

Sulphide Stress Cracking Resistant Metallic Materials for Oilfield Equipment

Vessel Motions and Moonpool Dimensions

The vessel response amplitude operators (RAOs) used in the riser analysis can either be analytical calculations or estimates derived from the model tests. These RAOs are converted into the format required by the riser analysis program. In cases in which the vessel is not in a head seas or beam seas heading, planar riser analysis programs require that the surge and sway motions be combined. Typical vessel dimensions used for an ultradeep water drillship riser model are as follows:

Upper Flex Joint Centre above Water Line - 63 ft.

Drill floor above Water Line - 85 ft.

Vertical Centre of Gravity (VCG) above Baseline of Vessel (Keel) - 47.55 ft.

Draft of the Vessel - 29.5 ft.

Height of the BOP Stack - 63 ft.

Height of the BOP Stack from Wellhead Connector to Centre of the Bottom Flex Joint - 55 ft.

GENERAL DESIGN REQUIREMENTS

This Section pertains to the identification, definition and determination of general design requirements and loads that are to be considered in the design of risers. Loads generally acting on risers are categorized into load classes and followed by more detailed descriptions in subsequent Sections. This Subsection provides the general requirements for the design of top tension risers. More detailed descriptions of each design requirement are to be presented in the subsequent Subsections. For riser systems linked to floating installations, the installation motion due to environmental loads (wave, wind and current) will influence the riser system through the top connection. Floating installation motion response amplitude operators (RAOs) which relate wave surface elevation amplitude, floating installation response amplitude and the phase lag are to be used for wave frequency motion analyses.

Floating installation horizontal (static) offset and low frequency motion corresponding to the mean offset due to wind. wave and current acting on the installation are to be considered for normal and extreme conditions, and may be based on ABS FPI Guide or other recognized standards such as API RP 2SK and API RP 2T.

As a basis, the riser analysis is to consider the following:

- Floating installation at the neutral, far, near and transverse positions
- Loss of station-keeping ability due to mooring line or tendon failure, floating installation tilt due to damage or dynamic position failure (drive-off or drift-off), etc.
- Partial loss of riser tension or buoyancy

DESIGN BASIS

The Design Basis is the document that defines all of the data and conditions that are required for the design of a riser system. The document is to define all applied codes and standards, Owner's requirements, design criteria, environmental conditions, design loads and safety factors.

LOAD COMBINATIONS AND DESIGN LOAD CASES

The risers are to be designed to satisfy the functional requirements under loading conditions corresponding to the internal environment, external environment, system requirements and service life defined by the project.

The risers are to be designed for the load combination that yields the most unfavorable conditions in terms of overall stress utilization. All potential external and internal loads are to be identified and load combinations developed to represent superpositions that may occur within defined degrees of probability. In preparing load cases, the probable duration of an event (e.g., installation) is to be taken into account in the selection of concurrent environmental conditions.

Extreme environmental events are unlikely to coincide, and therefore, the design process is to take caution to exclude unrealistic load combinations.

Load cases for the riser systems are to be defined to reflect manufacturing, storage, transportation, testing, installation, operation, retrieval and accidental events. Imposed loads are to be classified as either functional, environmental or construction and may be continuous or incidental, unidirectional or cyclic in nature. Accidental loads are to be considered separately, following review of risk factors for the particular development, and are to be applied under agreed combinations with functional and environmental loads. The design of the risers is to be based on design load cases, which are to be defined in the project-specific Design Basis documentation.

DESIGN CRITERIA

It is to be verified that the each riser is capable of withstanding all loads that are reasonably anticipated over its specified design life. The risers are to be designed to meet all applicable design criteria with the following failure modes considered:

- Burst Pressure
- Collapse check
- Drag forces
- Lift forces
- Fatigue analysis
- Global buckling
- Local buckling
- Tensile strength
- Axial load
- Bending

Other industry-recognized criteria may also be used for the design of risers.

CHAPTER 3

OVERVIEW OF EQUATIONS AND METHODS USED IN CASE STUDY

STRESS CRITERIA

Burst pressure

For the burst check, the water depth, the highest mud weight, the fabrication tolerances and the yield strength of the pipe are used to determine the minimum wall thickness of the riser. API Bulletin 5C3 (1994) is commonly used as the basis for this calculation.

The specified minimum burst pressure for risers can be calculated as follows:

$$p_b = 0.90(SMYS + SMTS)\left(\frac{t}{D-t}\right)$$

Where

pb = specified minimum burst pressure

D = nominal outside steel diameter of pipe

t = wall thickness

SMYS = Specified Minimum Yield Strength at design temperature

SMTS = Specified Minimum Tensile Strength at design temperature

De-rating of material resistance is, where applicable, to be accounted for in the definition of Specified Minimum Yield Strength and Specified Minimum Tensile Strength at elevated design temperatures.

Hoop stress criteria

In selecting pipe wall-thickness, consideration is to be given to pipe structural integrity and stability during installation, system pressure test and operation, including pressure containment, local buckling/collapse, global buckling, on-bottom stability, protection against impact loads, as well as high temperature and uneven seabed-induced loads. The internal pressure containment requirements, often used as a basis for wall-thickness design, are given in the form of a maximum allowable hoop stress σ_h:

$$\sigma_h = \eta \ SMYS \ k_T$$

Where

SMYS = Specified Minimum Yield Strength of the material

k_T = temperature dependent material strength de-rating factor (to be based on material tests or recognized codes such as ASME B31.8 for steel pipes)

η = usage factor

= 0.72 for oil risers

= 0.60 for gas risers connected to unmanned platforms

= 0.50 for gas risers connected to manned platforms

The hoop stress σ_h for pipes is to be determined by:

$$\sigma_h = \frac{(p_i - p_e)\cdot(D - t)}{2 \cdot t}$$

Where

σ_h = hoop stress

p_i = internal design pressure

p_e = external design pressure

D = nominal outside steel diameter of pipe

t = nominal pipe wall thickness

A corrosion allowance may not be included in the design to account for corrosive fluids.

For thick walled pipes with a D/t < 20, the above hoop stress criteria may be adjusted based on BSI BS 8010-3, for example.

Other methods such as the limit state design defined in API RP 1111 may be used for the internal pressure containment requirements subject to Bureau approval.

Longitudinal Stress

To ensure structural integrity against longitudinal forces, the following longitudinal stress criteria are to be satisfied:

$$\sigma_\ell \leq \eta \quad SMYS \quad k_T$$

Where

σ_l = longitudinal stress

SMYS = Specified Minimum Yield Strength of the material

k_T = temperature dependent material strength de-rating factor (to be based on material tests or recognized codes such as ASME B31.8)

η = 0.80, usage factor

Von Mises Stress

The Von Mises stress at any point in the pipe is to satisfy the following, which follows API RP 2RD:

$$\sigma_e = \frac{1}{\sqrt{2}}\sqrt{(\sigma_r - \sigma_h)^2 + (\sigma_h - \sigma_l)^2 + (\sigma_l - \sigma_r)^2} \leq \eta \cdot SMYS$$

Where

σ_e = Von Mises stress

σ_r = radial normal stress

σ_l = longitudinal normal stress

σ_h = hoop stress (normal stress circumference direction)

η = usage factor for Von Mises stress

= 0.67 for Design Operating Condition

= 0.80 for Design Extreme Condition or Temporary Condition

= 0.90 for test condition.

For survival cases (if applicable), the usage factor for Von Mises Stress is subject to the agreement between the Owner/designer and the Bureau.

LOCAL BUCKLING/COLLAPSE UNDER EXTERNAL PRESSURE AND BENDING MOMENT

Collapse_check

The riser must have sufficient collapse resistance to meet the conditions imposed by the operator. For an ultra deep water well, typical conditions call for collapse resistance sufficient to withstand the riser being void over half its length. This requirement usually covers the case of emergency disconnect in which a column of 17-ppg mud falls out of the bottom of the riser and momentarily becomes balanced with the pressure of seawater after the pressure has been equalized. In shallower water (less than 6000 ft), larger lengths of gas-filled riser may be required based on the risk of other events such as gas in the riser or lost returns. A number of design conditions can be considered when engineering the riser to resist collapse. Among others, these can include the following:

1. A gas bubble from the formation enters the well and expands as it enters the riser. The likelihood of a gas bubble filling the riser in a modern drilling operation is remote. However, it did occur once in 1982. When this incident occurred, the subsea blowout preventer (BOP) was not shut-in when the flow was detected due to concerns about formation integrity. The surface diverter was being used to direct the flow overboard when it malfunctioned, causing loss of the mud column in the riser. In a modern drilling operation, the likelihood of riser collapse is greatly diminished because the shut-in of the BOP is a standard procedure when dealing with a kick.

2. Returns are lost to the well, leaving a void on the top of the riser. The voiding of a large portion of the riser due to lost returns is a remote possibility. A large amount of lost returns would likely be detected.

3. The contents of the riser (mud) are partially lost during an emergency disconnect of the riser. The u-tube that would occur during an emergency disconnect would typically leave no more than about 50% of the riser tube void after the pressure is equalized, if the mud weight were about 17 lb/gallon (twice that of sea water). The lesser mud weights would void less of the riser.

API Bulletin 5C3 (1994) is commonly used as the basis for selecting the wall thickness to resist collapse. The calculation depends on the voided depth of riser, the yield strength of the pipe (in some cases) and the fabrication tolerances of the pipe.

Collapse calculations using API 5C3 demonstrate that a 22-in. riser with 1-1/8-in. wall thickness resists collapse, if it is completely void in 9000 ft of water. With fabrication tolerances of 8% on wall thickness, the riser resists collapse with the top 8000 ft of riser void. Figure shows the external pressure resistance of the riser with an 8% fabrication tolerance vs. depth compared to the applied pressure from the hydrostatic head of seawater. The riser's collapse resistance varies with depth due to a dependence on pipe wall tension.

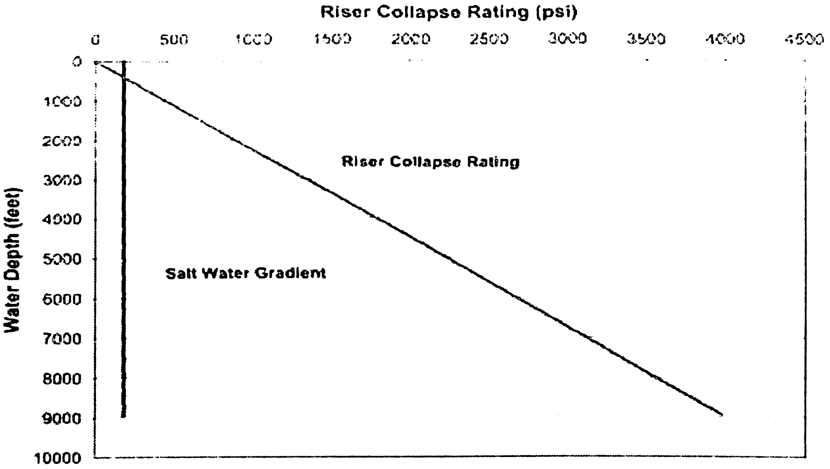


Figure 6 - Riser collapse profiles (22 in. X 1.125 in. plus 8% machine tolerance)

Collapse under External Pressure

For risers installed at water depth up to 1500 m (5000 ft), the plastic collapse pressure formula in API Bulletin 5C3 is to be used to calculate the required riser wall thickness.

For risers installed at water depth 1500 m (5000 ft) or more, the characteristic buckling pressure can be calculated based on the following formulas:

$$p_c = \frac{p_{el} p_p}{\sqrt{p_{el}^2 - p_p^2}}$$

Where

$$p_{el} = \frac{2 \cdot E}{1 - \nu^2} \cdot \left(\frac{t}{D}\right)^3$$, elastic buckling pressure

$$p_p = SMYS \cdot \frac{2 \cdot t}{D}$$, yield pressure at collapse

SMYS = Specified Minimum Yield Strength

E = Young's Modulus

ν = Poisson's ratio, 0.3 for steel risers

The riser is not considered to collapse only if the minimum differential pressure on the pipe satisfies the following:

$$(p_e - p_i) \le \eta_b p_c$$

Where

p_e = external pressure

p_i = internal pressure, should be taken as atmospheric pressure

η_b = buckling design factor

0.7 for seamless or ERW pipe

0.6 for cold expanded pipe

Local Buckling/Collapse under External Pressure and Bending Moment

For installation and temporary conditions where the pipe may be subjected to external overpressure, cross sectional instability in the form of local buckling/collapse is to be checked. For pipes with a D/t less than 50 and subjected to external overpressure combined with bending, the following strain check from API RP 1111 is to be applied:

$$\frac{\varepsilon}{\varepsilon_b} - \frac{p_e - p_i}{p_c} \le g(f_0)$$

Where

ε = bending strain in the pipe

ε_b = $\frac{t}{2D}$, buckling strain under pure bending

p_e = external pressure

p_i = internal pressure, should be taken as atmospheric pressure

f_0 = out-of-roundness, (Dmax – Dmin)/D, not to be taken less than 0.5%.

$g(f_0) = (1 + 10 f_0)^{-1}$, out-of-roundness reduction factor

An out-of-roundness higher than 3% is not allowed in the pipe without further analysis considering collapse under combined loads, propagating buckling and service ability of the pipe. Alternatively, formulas given in API RP 2RD may also be used for the analysis of collapse under combined effects of external pressure and bending moment.

PROPAGATING BUCKLES

During installation or, in rare situations, shutdown of risers, local buckles/collapse may start propagating along the pipe with extreme speed driven by the hydrostatic pressure of seawater. Buckle arrestors may be used to stop such propagating buckles by confining a buckle/collapse failure to the interval between arrestors. Buckle arrestors may be designed as devices attached to or welded to the pipe or they may be joints of thicker pipe. Buckle arrestors will normally be spaced at suitable intervals along the riser for water depths where the external pressure exceeds the propagating pressure level.

Buckle arrestors are to be used when:

$$p_e - p_i \geq 0.72 \cdot p_{pr}$$

Where

p_{pr} = buckle propagation pressure

$$= 6 \cdot SMYS \cdot \left(\frac{2 \cdot t}{D} \right)^{2.5}$$

When required, buckle arrestors are to be designed according to recognized codes, such as API RP 1111.

DRAG AND LIFT FORCES

Wind

Wind forces are exerted upon parts of risers that are above the water surface and marine structures to which risers might be attached. Statistical wind data is normally to include information on the frequency of occurrence, duration and direction of various wind speeds. For design cases where the riser is attached to a floating installation, it might also be necessary to establish the spectrum of wind speed fluctuation for comparison with the structure's natural sway periods.

Long-term and extreme-value predictions for winds are to be based on recognized techniques and clearly described. Vertical profiles of horizontal wind are to be determined based on recognized statistical or mathematical models. Published data and data from nearby land and sea stations may be used, if available. Wind data are, in general, to refer to a specified reference level and averaging time. During design, the wind data may be adjusted to any specified averaging time and elevation based on standard profiles and gust factors, such as given in API RP 2A-WSD.

Wind loads and local wind pressures are to be determined based on analytical methods or wind tunnel tests on a representative model of the riser system. In general, gust wind loads, which are loads based on wind speeds averaged over one-minute or less are to be used in the riser design combined with other simultaneous environmental loads acting on the riser and floating installation to which the riser may be attached. When appropriate, dynamic effects due to the cyclic nature of gust wind and cyclic loads due to vortex-induced vibrations, including both drag and lift components, are to be investigated. For risers with negligible dynamic response to wind, a one-hour sustained wind speed may be used to calculate the wind loads.

For wind normal to the riser axis, the following relationship may be used to calculate the wind load:

$$F_w = \frac{1}{2}\rho_a \cdot C_s \cdot V_y^2 \cdot A$$

Where

Fw = wind load

ρa = density of air

Cs = shape coefficient (dimensionless, = 0.50 for cylindrical sections)

Vy = wind speed at altitude y

A = projected area of pipe on a plane normal to the direction of the considered force

As an alternative to applying wind loads, the effect of wind can be indirectly accounted for through the modeling of floating installation offset and slow drift movement.

Current

Current may be a major contributor to both static and dynamic loading on risers installed at any depth. The current velocity and direction profile at a given location may have several contributions of which the most common are:

- Oceanic scale circulation patterns
- Lunar/astronomical tides
- Wind and pressure differential generated storm surge
- River outflow

The vector sum of all current components at specified elevations from the seafloor to the water surface describes the current velocity and direction profile for the given location. The current profile might be seasonally dependent, in which case, this is to be accounted for in the design.

For riser design, the total current profile associated with the sea state producing extreme waves is to be used in design analyses. The current velocity and direction normally do not change rapidly with time and may be treated as time invariant for each sea state.

On-site data collection may be required for previously unstudied areas and/or areas expected to have unusual or severe current conditions. If the current profile is not known from on-location measurements, but is judged not to be severe for the design, the current velocity at a given depth may be established using a velocity profile formulation. Current velocity profiles are to be based on site-specific data or recognized empirical relationships, and the worst design direction is to be assumed.

Waves

Waves are a major source of dynamic loads acting on risers located in shallow waters (normally less than 150 m), and their description is therefore of high importance. Statistical site-specific wave data, from which design parameters are to be determined, are normally to include the frequency of occurrence for various wave height groups and associated wave periods and directions. For areas where prior knowledge of oceanographic conditions is insufficient, the development of wave-dependent design parameters is to be performed in cooperation with experienced specialists in the fields of meteorology, oceanography and hydrodynamics.

For a fully-developed sea, waves may be represented using the Bretschneider spectrum while the JONSWAP spectrum normally will be applicable for less developed seas. In the calculation of spectrum moments, a proper cut-off frequency based on a project-defined confidence level is to be applied. Wave scatter diagrams can be applied to describe the joint probability of occurrence of the significant wave height and the mean zero crossing period. Where appropriate, alternative traditional regular wave approaches may be used.

When dealing with extreme response estimations, the regular design wave heights are to be based on the maximum wave height of a given return period, e.g., 1, 10 or 100 years, found from long term wave statistics. The estimation of the corresponding extreme wave period is, in general, more uncertain due to lack of reliable data, and it is consequently recommended that the wave period be varied over a realistic interval in order to ensure that all extreme wave cases have been considered. For systems with obvious unfavorable wavelengths and periods due to geometry or Eigen-frequencies, the design wave period can be identified based on such criteria while the wave height follows from breaking wave criteria or statistical considerations.

Long-term response statistics are to be applied in fatigue damage assessment, whereby a scatter diagram of the joint probability of the sea state vector and the wave spectrum represents the wave climate defined by significant wave height, peak period and main wave direction. A simplified representation of the long-term distribution for the response may be based on the frequency domain method consisting of:

- Establishing an approximate long-term response distribution based on stochastic dynamic analyses
- Calculation of an approximate lifetime extreme response
- Identification of the design storm
- Estimation of lifetime maximum response based on time domain simulations

In analysis, a sufficient range of realistic wave periods and wave crest positions relative to risers are to be investigated to ensure an accurate determination of the maximum wave loads. Consideration is also to be given to other wave-induced effects such as wave impact loads, dynamic amplification and fatigue. The need for analysis of these effects is to be assessed on the basis of the configuration and behavioral characteristics of risers, the wave climate and past experience.

Combinations of Wind, Current and Waves

The worst combinations of wind, current and waves are to be addressed in the design. When current and waves are superimposed, the current velocity and direction are to be added as vectors to the wave-induced particle velocity and direction prior to computation of the total force, and where appropriate, flutter and dynamic amplification due to vortex shedding are to be taken into account.

Because risers have small diameters compared to the wavelengths being considered, semi-empirical formulations such as Morison's equation are considered to be an acceptable basis for determining the hydrodynamic force acting on a riser:

$$F = F_D + F_i$$

Where

F = hydrodynamic force per unit length along pipes

F_D = hydrodynamic drag force per unit length

F_i = hydrodynamic inertia force per unit length

The drag force for a stationary pipe is given by:

$$F_D = \frac{1}{2}\rho \cdot OD \cdot C_D \cdot u_n \cdot |u_n|$$

Where

ρ = density of water

OD = total external diameter of pipe, including coating, etc.

C_D = drag coefficient (dimensionless)

u_n = component of the total fluid velocity vector normal to the axis of pipes

The inertia force for a stationary pipe is given by:

$$F_i = \rho \cdot \left(\frac{\pi \cdot OD^2}{4} \right) \cdot C_M \cdot a_n$$

Where

C_M = inertia coefficient based on the displaced mass of fluid per unit length (Dimensionless)

a_n = component of the total fluid acceleration vector normal to the axis of pipes

The lift force for a stationary pipe located on or close to the seabed is given by:

$$F_L = C_L \cdot \frac{1}{2}\rho \cdot u_e^2 \cdot A_l$$

Where

F_L = lift force per unit length

C_L = lift coefficient (dimensionless)

A_l = projected area per unit length in a plane normal to the direction of the force

For risers that exhibit substantial rigid body oscillations due to the wave action, the modified form of Morison's equation, given below, may be used to determine the hydrodynamic force:

$$F = F_D + F_I = \frac{1}{2}\rho \cdot OD \cdot C_D \cdot (u_n - \dot{u}_n) \cdot |u_n - \dot{u}_n| + \rho \cdot \left(\frac{\pi \cdot OD^2}{4}\right) \cdot a_n + \left(\frac{c}{g}\right) \cdot \left(\frac{\pi \cdot OD^2}{4}\right) \cdot C_m \cdot (a_n - \dot{a}_n)$$

Where

$\dot{u}_n$ = component of the velocity vector of riser normal to its axis

C_m = added mass coefficient, i.e., Cm = CM – 1

$\dot{a}_n$ = component of the acceleration vector of the riser normal to its axis

The values of $\dot{u}_n$ and $\dot{a}_n$ are to be determined using recognized wave theory appropriate to the wave heights, wave periods and water depth at the installation location, as well as the elevation at which the load is calculated.

Tides

Tides, when relevant, are to be considered in the design of risers. Tides may be classified as lunar or astronomical tides, wind tides and pressure differential tides. The combination of the latter two is defined as "storm surge" and the combination of all three as "storm tide". The water depth at any location consists of the mean depth, defined as the vertical distance between the seabed and an appropriate near-surface datum, and a fluctuating component due to astronomical tides and storm surges. The highest and the lowest astronomical tide bound the astronomical tide variation. Still-water level is to be taken as the sum of the highest astronomical level plus the storm surge. Storm surge is to be estimated from available statistics or by mathematical storm surge modeling.

Marine Growth

Marine growth may accumulate and is to be considered in the design of risers. The highest concentrations of marine growth will generally be seen near the mean water level with an upper bound given by the variation of the daily astronomical tide and a lower bound, dependent on location. Estimates of the rate and extent of marine growth may be based on past experience and available field data. Particular attention is to be paid to increases in hydrodynamic loading due to the change of:

- External pipe diameter
- Surface roughness
- Inertial mass
- Added weight

Consideration is also to be given to the fouling effects likely on corrosion protection coatings.

Subsidence

The effects of seafloor subsidence are to be considered in the overall design of the stroke of the riser system.

Seafloor Instability

Seafloor instability may be seen under negligible slope angles in areas with weak, under-consolidated sediments. Movements of the seafloor may be activated as a result of loads imposed on the soil due to riser installation, change in riser operating conditions, wave pressure, soil self weight, earthquakes or combinations of these phenomena. When applicable, such areas are to be localized by proper surveys, and precautions such as rerouting of flowlines and risers are to be taken in the design of the riser system.

Seismic

The seismic activity level for the riser installation area is to be evaluated based on previous records or detailed geological investigations. For risers located in areas that are considered seismically active, the effects of earthquakes are to be considered in the design. An earthquake of magnitude that has a reasonable likelihood of not being exceeded during the design life is to be used to determine the risk of damage, and a rare intense earthquake is to be used to evaluate the risk of structural failure. These earthquake events are referred to as the Strength Level and Ductility Level earthquakes, respectively. The magnitudes of the parameters characterizing these earthquakes, having recurrence periods appropriate to the design life of the risers, are to be determined. The effects of earthquakes are to be accounted for in design, but generally need not be taken in combination with other environmental factors such as the 100-year design wave and/or the 100-year design current.

The strength level and ductility level earthquake-induced ground motions are to be determined on the basis of seismic data applicable to the installation location. Earthquake ground motions are to be described by either applicable ground motion records or response spectra consistent with the recurrence period appropriate to the design life of pipelines and risers. Available standardized spectra applicable to the region of the installation site are acceptable, provided such spectra reflect site-specific conditions affecting frequency content, energy distribution and duration. These conditions include the type of active faults in the region, the proximity to the potential source faults, the attenuation or amplification of ground motion and the soil conditions.

The ground motion description used in design is to consist of three components corresponding to two orthogonal horizontal directions and the vertical direction. All three components are to be applied to risers simultaneously.

As appropriate, effects of soil liquefaction, shear failure of soft mud and loads due to acceleration of the hydrodynamic added mass by the earthquake, mud slide, tsunami waves and earthquake-generated acoustic shock waves are to be accounted for in the design.

Sea Ice

For arctic and sub-arctic areas, sea ice may be experienced in the form of first-year sheet ice, multi-year floes, first-year and multi-year pressure ridges and/or ice islands. The strength of sea ice depends on features such as composition, temperature, salinity and speed of load application. The effect of sea ice on risers is to consider the frozen-in condition (winter), breakout in the spring and summer pack ice invasion, as applicable.

Impact, both centric and eccentric, is to be considered where moving ice may impact risers. Impact analysis is, as applicable, to consider both that of large masses (multi-year floes and icebergs) moving under the action of current, wind and Coriolis effect, and that of smaller ice masses which are accelerated by storm waves. The impact analysis is to consider mass, hydrodynamic added mass and shape of the ice, its velocity and its direction relative to risers.

The mode of ice failure (tension, compression, shear, etc.) depends on the shape and roughness of the surface and the presence of frozen ice, as well as the ice character, crystallization, temperature, salinity, strain rate and contact area. The force exerted by the broken or crushed ice in moving past is to be considered. Limiting force concepts may be employed if thoroughly justified by calculations.

FATIGUE ANALYSIS

General

The fatigue damage in the risers is induced by three main sources:

- First order (wave frequency) wave loading and associated motions of floating installation
- Second order (low frequency) drift motions of floating installation
- Vortex-Induced Vibration (VIV) of risers due to current and heave motion of floating installation

Riser installation, vibrations of hull structure, riser internal fluid slugging and pressure pulses, and cyclic riser-soil interactions may also add fatigue damage to the risers. The overall fatigue life is to be determined by combining the fatigue damage from each contributing source. An appropriate weighting factor needs to be applied to individual fatigue damage prior to the combination.

1. *First and second order motion-induced fatigue analysis:*

Depending on the required level of detail and accuracy, the motion-induced fatigue analyses are to be carried out for a set of sea state windows selected from the sea state scatter diagram. For each sea state window, a representative sea state is to be selected and applied to the floating installation and risers. The random sea analysis in the time domain is to be conducted for a sufficiently long duration so that the statistical features of riser responses can be accurately captured. The fatigue damage at a specific point of riser pipe body or riser end connection is to be obtained by counting the stress cycles and using the appropriate Stress Concentration Factors (SCFs) and S-N curve defined in the Design Basis documentation. The maximum damage accumulation around the circumference of the riser body is to be considered as the fatigue damage at a specific location along the riser length. The resultant fatigue damage from each seastate is to be factored by the associated probability of occurrence and then summed according to the Palmgren-Miner's rule to determine the annual fatigue damage. Validation study needs to be conducted to verify the adequacy of finite element meshing, the convergence of statistics and the sufficiency of the number of selected critical sea state windows, loading directions and stress bins so as to produce a reliable calculation of fatigue damage. Other methods for the motion-induced fatigue analysis, such as the regular wave-based fatigue analysis or frequency domain analysis, may be used on the condition that sufficient validation studies are to be performed using the time domain random sea analysis.

2. *VIV fatigue analysis:*

The VIV fatigue analysis is to be conducted to assess the magnitude of VIV-induced fatigue damage on risers, and to determine whether VIV suppression devices are required to mitigate the vibration. Dedicated analysis software is to be used to perform the analysis.

Each of the anticipated directional current profiles with one-year return period is to be used in the long term (during the service life of the risers) VIV fatigue analysis. Responses to both uniform and sheared current profiles need to be accounted for. The VIV fatigue damage due to each current profile is to be factored by the associated occurrence probability and then summed up according to Palmgren-Miner's rule to determine the annual VIV fatigue damage.

The short term VIV fatigue analysis associated with the duration of 100-year return period current during the service life of the risers is to be considered with 100-year return period current profiles coming from different directions. The damage from the most critical current profile is to be factored by the associated occurrence probability and then added to the total VIV fatigue damage.

Whenever VIV suppressors are determined to be necessary, the VIV fatigue analysis is to be reevaluated to determine the lengths and locations of VIV suppressors and the improvement on fatigue behavior obtained.

Calculation Methods

Vortex-induced vibration can be calculated using the hand checks, computational fluid dynamics (CFD), and empirical methods. Each of these methods has their place, depending on the current profile being investigated and the level of rigor required.

I Hand Checks

Hand checks for calculating the VIV fatigue damage are most applicable when metocean conditions include currents that are constant with depth. Such conditions can exist in shallow-water locations where the current is driven by tides (e.g. the English Channel) or close to the mouths of rivers. When the current is constant with depth, VIV can be very severe. In these cases, the Strouhal equation can yield a good approximation that can be used to determine the VIV frequency. The amplitude can be estimated as being equal to say, one diameter, or some other value that could be derived from the work of Blevins (1977) or others. Using the mode shape associated with the natural frequency closest to the VIV frequency, the amplitude can be used to determine the curvature of the riser.

This curvature can then be used to calculate bending stress which, together with the VIV frequency, can be used to determine a fatigue damage rate and a predicted fatigue life.

2 Empirical Methods

High-current conditions in deep waters generally have large amounts of shear (i.e. current velocity that varies with depth). Such sheared currents are most important for the VIV riser analysis for locations in the Gulf of Mexico and offshore Brazil, Trinidad, the UK, and other high-current areas.

Although uniform currents lead to the most severe vortex-induced vibration (VIV), sheared (change of velocity with depth) currents can also lead to VIV. Analysis techniques to predict VIV frequencies and amplitudes are often considered to be a part of a drilling riser analysis procedure. Although research on riser VIV has been ongoing for decades, predictions of VIV amplitudes in real ocean currents still have uncertainties. Empirical techniques for calculating VIV and the resulting fatigue damage have been developed by Vandiver (1998) and Triantafyllou (1999). Related work has been carried out by Fumes,et al (1998).

Current profiles that cause the larger VIV amplitudes are those that have nearly uniform current speed and direction over large portions of the water column. If the current profile has a large amount of shear, the likelihood of VIV is reduced.

3 Computational Fluid Dynamics

Computational fluid dynamics (CFD) is another alternative for calculating the vortex-induced vibrations of a riser. This technique simulates the flow of fluid past the riser, models flow vortices, and predicts the riser motions. CFD techniques are under development with the objective to better model the physics, but the method requires large amounts of computer time to simulate VIV of a full length deepwater riser.

VIV SUPPRESSION/MANAGEMENT

The metocean criteria (including current profiles) specified by the operator is used to determine if vortex suppression devices such as fairings might be needed to reduce drag force on the riser and suppress VIV. Because of the uncertainties in predicting VIV, this decision is sometimes made using site-specific analysis conducted by the operator and, at times, independent analysis using different methods. Fairings are an expensive option due to the cost of the fairings themselves and the additional rig time required to install them during riser running. Less expensive alternatives include strakes, alternating bare and buoyant joints [Brooks, 1987], and simply increasing the riser tension. The less expensive alternatives are not as effective, but can be adequate in many instances.

1. Stack- Up Adjustments

The choice of where fairings are to be installed in the riser stack-up (Le. the description of joint properties along the string) has a large influence on the cost-effectiveness of well drilling operations. Fairings have been shown to be very effective. They can reduce drag force to as low as one-third of its original value and they suppress VIV almost entirely - provided they cover the portion of the riser where the high currents are predicted to be incident, This estimate of where the current is present in the water column may be highly uncertain, As a further complication, once the fairings are installed, removing or rearranging them would involve pulling (retrieving) the riser - a procedure that could take several days. Furthermore, the notion of placing fairings over the full length of a deepwater riser (i.e. greater than 3000-ft) is cost-prohibitive. Generally, at sites with severe currents, operators have chosen to put fairings over the top portion (500 ft or so) of the riser to cover the most likely high current events.

Strakes are external ribs placed on the riser string, most commonly in a helical shape. When compared to the fairings, these devices are less effective, but are still good at VIV suppression. They allow amplitudes of vibration with 10-30% of a diameter. A disadvantage of strakes is their 30-50% additional drag force when compared to an unsuppressed riser. Typically, strakes can be installed on the riser joints prior to running (installing) the riser, thus minimising the high costs associated with additional rig time. The concept of using alternating bare and buoyant joints in the riser string (staggered joints) has been documented in Brooks (1987) as a means for reducing the VIV amplitude. This technique also provides a slight reduction in drag force. This is a popular technique because it involves no preparation by rig personnel other than to have bare joints available and sequenced properly. One disadvantage is that bare joints are required, usually near the surface, where their weight cannot be used to full benefit in running the riser.

2. Operating Tension

Instead of altering the riser stack-up, VIV suppression can be achieved by increasing the operating tension. The concept of this suppression method is to excite lower modes of the riser, which have longer mode lengths. As a result, curvatures and stresses are lower and fatigue damage is reduced. An advantage of this technique is that it helps no matter where the currents are in the water column and it has virtually no effect on the well drilling operation, since the riser does not have to be pulled. However, this technique often has little effectiveness, particularly for a dynamically-positioned vessel requiring emergency disconnect. In these vessels, riser recoil considerations during emergency disconnect usually dictate that maximum riser operating tensions are not significantly higher than the minimum riser operating tensions required to conduct well drilling operations. The margin for increased tension is thus quite small.

Suppression devices may not be necessary if an operator can show that the metocean conditions will not involve high current during the drilling of the well. For example, presently low activity of currents could be used to justify a forecast of low activity for the duration of a well; and this could justify use of an unsuppressed riser. However, loop currents and related or unrelated deep ocean currents are still difficult to predict. Currents that are deep in the water column, whether driven by the loop current or other mechanisms, are particularly difficult to predict (or manage VIV suppression) with any certainty.

A disconnect of the riser due to VIV in high currents is generally avoided, if at all possible. Such a disconnect event in high currents would result in the riser taking on a large angle and possibly contacting the side of the moonpool. If the bathymetry allows, the vessel could be allowed to drift toward deeper water to manage the riser angle and avoid contacting the seabed. If a disconnect does occur in high currents, it will likely be due to an emergency disconnect or a planned disconnect to protect the integrity of the wellhead connector and the conductor pipe.

3. On-Board VIV Measurements

The detection of VIV-induced alternating stresses in the riser pipe wall and the associated fatigue damage can be done using a variety of systems. The sensors that are used to measure VIV will not be discussed in this text. The two main categories of systems used to gather information on riser VIV are the so-called "real time" system and the so-called "flight recorder" system. As the name suggests, the real-time system gathers, analyses and displays VIV data virtually immediately after the riser undergoes the response. The flight recorder system gathers and stores the data until the riser is pulled, at which time the stored data can be removed for analysis.

The real-time system provides data so that, if desired, it can be used to base operational decisions on management of the riser. This system generally involves a more complex measurement system, possibly with cables that need to be installed as the riser is being run. The flight-recorder system provides data only after the riser has been pulled, so that the data cannot be used to support operational decisions; it is intended more for the support of inspection decisions or VIV research. This system involves independent canisters mounted at selected locations along the riser.

CHAPTER 4

CASE STUDY

The case study deals with the designing of the riser of Guf of Mexico whose configuration is tabulated below:

Parameter	Value
External Pressure	12200 psi
Material	X80
Minimum yield strength	80000 psi
Outer diameter	9.625 in
Wall thickness	1.06 in
Internal Pressure	11000 psi
Tensile end cap forces	15800 kN
External tensioner capacity	2678 kN
Bending strain	0.01%
out-of-roundness reduction factor	2.5%
Wind density	1.293 kg/m3
Shape factor	0.5
Wind speed	12 m/s
Depth of riser	9000 ft
Wave period	30 seconds
Drag coefficient	2
Water level	9500 ft
Density of water	1027 kg/m3

Assume the values which are not given.

Solution:

Calculation of Burst pressure

$$p_b = 0.90(SMYS + SMTS)\left(\frac{t}{D-t}\right)$$

Putting the values in the above eqation:

Pb = 0.9(80000+19260)(1.06/9.625-1.06)

= 11055.93 psi

Calculation of Collapse pressure

$$p_c = \frac{p_{el} \cdot p_p}{\sqrt{p_{el}^2 - p_p^2}}$$

Where

$p_{el} \quad = \quad \frac{2 \cdot E}{1 - \nu^2} \cdot \left(\frac{t}{D} \right)^3$, elastic buckling pressure

$p_p \quad = \quad SMYS \cdot \frac{2 \cdot t}{D}$, yield pressure at collapse

SMYS = Specified Minimum Yield Strength

E = Young’s Modulus

ν = Poisson’s ratio, 0.3 for steel risers

Pel = 2(29*10^6)/(1-0.3^2)(1.06/9.625)^3

= 85133.79 psi

Pp = 80000(2*1.06)/9.625

= 17620.78 psi

Putting values in the collapse pressure equation

Pc = 17255.05 psi

Differencial pressure = (12200-11000) psi

= 1200 psi

$$(p_e - p_i) \le \eta_b p_c$$

The above condition is satisfied

Calculation of Propagation buckling

$$\frac{\varepsilon}{\varepsilon_b} - \frac{p_e - p_i}{p_c} \le g(f_0)$$

Where

ε = bending strain in the pipe

εb = $\frac{t}{2D}$, buckling strain under pure bending

pe = external pressure

pi = internal pressure, should be taken as atmospheric pressure

f_0 = out-of-roundness, (Dmax – Dmin)/D, not to be taken less than 0.5%.

$g(f_0) = (1 + 10 f_0)^{-1}$, out-of-roundness reduction factor

ε = 0.01%

εb = 1.06/2(9.625)

= 0.055

Pe = 12200 psi

Pi = 11000 psi

Fo = 2.5%

Putting values for calculating L.H.S

= 0.07136

Putting values for calculating R.H.S

$g(f_0) = (1 + 10 f_0)^{-1}$

$= 0.8$

Calculation of Propagating buckling pressure

$$6 \cdot SMYS \cdot \left(\frac{2 \cdot t}{D}\right)^{2.5}$$

SMYS = 80000 psi

t = 1.06 in.

D = 9.625 in.

Putting values in above equation:

= 6(80000)(2*1.06/9.625)^2.5

= **10928.96 psi**

Calculation of drag and lift forces

a) **Wind load**

$$F_w = \frac{1}{2}\rho_a \cdot C_s \cdot V_z^2 \cdot A$$

Where

Fw = wind load

ρ_a = density of air

Cs = shape coefficient (dimensionless, = 0.50 for cylindrical sections)

Vy = wind speed at altitude y

A = projected area of pipe on a plane normal to the direction of the considered force

Putting the values in above equation

0.5(1.29)(0.5)(12)^2(3.3)^2(2*3.14*4.812*9000)(16.018463374)

2.2*10^9 lbf/s^2

b) Calculation of drag force

$$F_D = \frac{1}{2} C_D \rho U^2 S$$

$$S = L \times D$$

= 0.5(1)(1097)(0.08)^2(2727.27*9.25/12/3.3)(9.625)

= 876.39 N

c) Calculation of inertial force:

$$F_i = C_m \rho \pi \frac{D^2}{4} \times L \omega^2 \frac{H}{2}$$

Ratio of drag ad inertial forces

R = Fi/Fd

= 5.302 * 10^-4

CHAPTER 5

RESULTS AND DISCUSSIONS

The results and discussions are done in order to discuss the designing of the riser and along with that, the problems and conditions which must be taken under considerations.

1. To ensure structural integrity against longitudinal forces, the following longitudinal stress criteria are to be satisfied:

$$\sigma_l \leq \eta \quad SMYS \quad k_T$$

Where

σ_l = longitudinal stress

SMYS = Specified Minimum Yield Strength of the material

k_T = temperature dependent material strength de-rating factor (to be based on material tests or recognized codes such as ASME B31.8)

η = 0.80, usage factor

Therefore the above condition should be taken care of in oder to ensure structural integrity.

2. Buckle arrestors may be designed as devices attached to or welded to the pipe or they may be joints of thicker pipe. Buckle arrestors will normally be spaced at suitable intervals along the riser for water depths where the external pressure exceeds the propagating pressure level.

Buckle arrestors are to be used when the following condition occurs

$$p_e - p_i \geq 0.72 \cdot p_{pr}$$

CHAPTER 6

CONCLUSIONS

It is very essential to design risers – Drilling and Production, keeping all the necessary factors like – wind and wave loads, pressures – Burst, collapse, buckling, and vortex induced vibrations effects, etc.

These are the major factors which lead to the optimum designing of the riser. Riser is a major component in offshore environment and offshore practices are always multitime costlier than onshore exercises.

Designing of the Riser is the foundation of offshore practices (Drilling and Production).

There is a sound scope of negligence of some critical conditions which are not possible to adopt theoretically, to compensate this safety factors are taken into consideration.

On the basis of the case study, we conclude that buckle arrestors are to be installed to prevent propagation of buckling in the riser.

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