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ANALYSIS FOR RUNNING AND INSTALLATION OF MARINE RISERS WITH END-ASSEMBLIES

B. Andrew Lennon*, Stewart D. Maxwell† and Jonathan M. Rawles†

*Consulting Engineer (formerly of UWG Ltd)
The Old Laundry, Marlfield Village, Clonmel, Co Tipperary, Ireland
e-mail: andrew@innealtoir.org – web page: www.innealtoir.org

†UWG Ltd
Chalk Hill House, 19 Rosary Road, Norwich NR1 1SZ, England
e-mail: stewart.maxwell@uwg.co.uk, jonathan.rawles@uwg.co.uk – web page: www.uwg.co.uk

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Abstract. *Running and installation procedures are common in the marine environment. Examples using marine risers are running a riser from a platform to the seabed for drilling, boring, extracting coring samples, or to lower equipment to the seabed. These examples all have a large assembly at the end of the riser that has a significantly larger cross-section than the riser and forms a concentrated mass. Finite element analysis can calculate the loads on the riser during installation and help determine the limiting environmental conditions. The aim of the analysis is to provide results that the installation operator can use to reduce downtime and risk during installation. Analysis procedures that meet this aim require a combination of experience, engineering judgement, and appropriate computational tools.*

1 INTRODUCTION

Example installation procedures in the marine environment include running a riser from a platform to the seabed for drilling, boring, or for extracting coring samples. Another example is using a riser to lower equipment to the seabed, such as templates, conductors, or piles. Installing equipment in the marine environment always carries an element of risk but analysis can reduce the uncertainty.

Analysis for installation and running procedures requires a combination of engineering judgment and suitable computational techniques. The analysis must capture the essential features of the riser and its support conditions. It must also reflect the loads and movements of the riser during the critical phases of installation. This type of analysis might be planned or it might be required at short notice due to changing circumstances during installation and running.

This document provides an overview of the methodology using experience from analysis projects at UWG. It describes challenges faced in the analysis, discusses the lessons learned from experience, suggests areas for improvement, and suggests extension to related areas of application.

2 DEFINING THE PROBLEM

2.1 Introduction

There are a number of ways of installing equipment on the seabed and there are established procedures using cables for wellheads, trees, and subsea blow-out preventers (BOP). This document deals with installation methods using marine risers and with running drilling risers that have large-dimension end-assemblies at the bottom such as large-diameter drillbits or subsea equipment. The important characteristic is that the equipment or drillbit has a significantly larger cross-section than the riser and that it forms a concentrated mass at the end of the riser. This larger cross-section causes significantly higher hydrodynamic load per unit length for the end-assembly than for the bare riser. Figure 1 shows a schematic of an example arrangement with a riser attached to a floating vessel and with drilling equipment at the bottom of the riser for boring large-diameter holes.

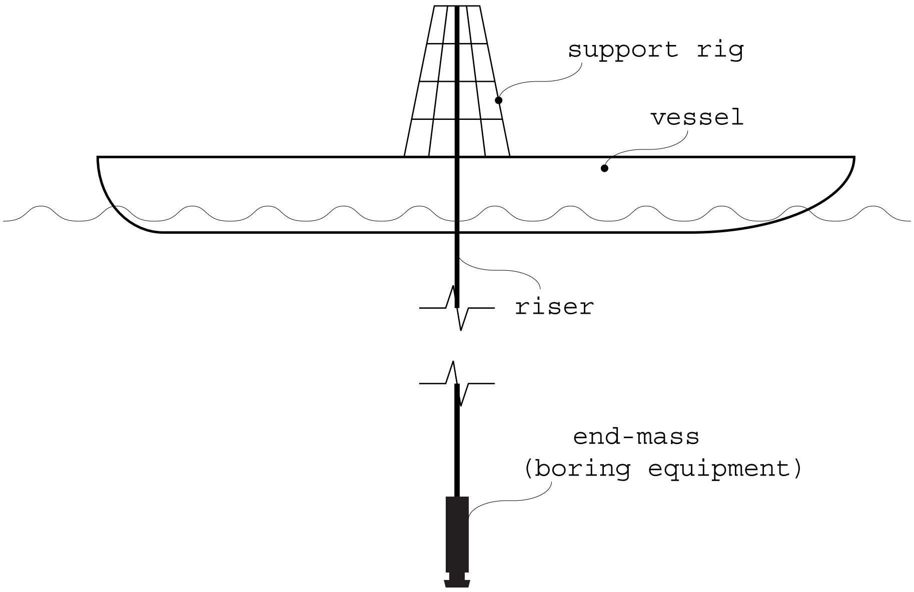

Figure 1: Schematic for running a riser from a floating vessel

2.2 Riser and end-assembly

Joints of riser are assembled into stands for running. Each stand is then lowered into the sea until the end-assembly reaches the desired depth. The riser pipe varies from small-diameter drillpipe to custom-designed sections for the marine drilling risers used for boring large-diameter holes.

Risers used for marine construction work have a large-diameter drillbit at the bottom for boring. Weights and various items of equipment are above the bit and the entire end-assembly might be two or more metres in diameter and several metres long. Example projects at UWG have used end-assemblies of approximately 2 m diameter, 10 m length, and 60 tonnes mass.

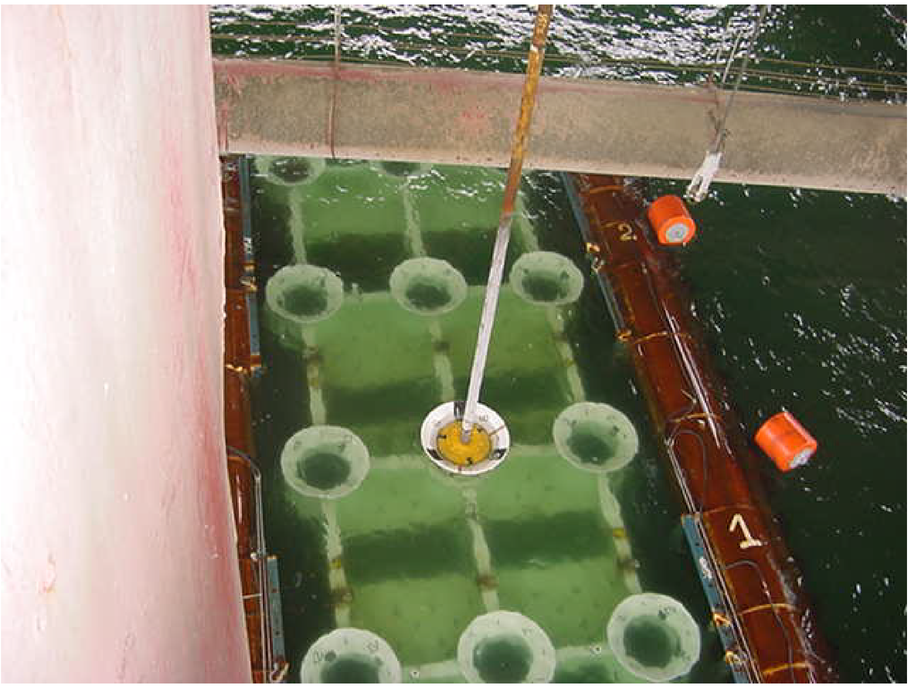

Figure 2: Drilling template being lowered into the sea using a riser

Figure 2 shows an example from a UWG installation analysis where the end-assembly is a large drilling template. The physical dimensions of this template are significantly greater than those of the riser and the mass is many times that of the riser. This template provides an example of a large structure that can be safely installed. Other examples from UWG projects include installing pre-conductors for drilling and running risers for drill-out inside piles.

2.3 Platform and top support

The boundary condition at the top support for the riser can be on a fixed platform or a floating vessel. Floating vessels move in more degrees of freedom in response to wave loading and add another factor to the analysis. Most modern working vessels have heave compensation on their cranes or elevators to eliminate vertical motion on the riser caused by platform motion. Rotational compensation for pitch and roll is also available on some vessels. The top support might be pinned or fixed depending on the compensator status and the stage of running. During assembly of stands the top of the riser is fixed and the heave compensator is disconnected. The rotation compensators do not operate during stand assembly and the top of the riser is fixed at this time.

2.4 Environmental loads

Hydrodynamic loads produced by wave and current action are the most important loads for riser installation analysis. Wave loading usually dominates in the splash zone but deceases rapidly below the waterline. Current load also decreases with depth but can remain significant down to the seabed and often has a tidal component with maximum velocity occurring twice daily. Currents in deep water can have velocity bands at different depths with variation in both speed and direction.

3 ANALYSIS CONSIDERATIONS

3.1 Introduction

Computational tools and techniques for analysing marine structures are readily available. Procedures for installation analysis of risers combine these tools with engineering judgment and with many years experience in marine riser analysis. This section discusses the software, hydrodynamics, vessel motion and seabed modelling for the analysis procedures.

3.2 Analysis software

Finite element analysis (FEA) is a powerful tool for engineering[1]. Other methods have particular applications but FEA is widely used in industry and a number of general and specialised analysis packages are readily available. The Flexcom riser analysis application from MCS is an example package for installation analysis[2]. Flexcom is a finite element analysis package with geometric non-linearity and uses special beam-column elements to represent axial force and bending moment for risers. One of its strengths is the ability to accurately represent the large rotations and deflections experienced by marine risers. It provides a range of options for adding wave and current loading to the model and has options to include wave induced vessel motions for floating vessels.

3.3 Hydrodynamics

Wave and current action produce hydrodynamic loads on the riser and on the end mass. The current velocity usually varies with depth and can also vary in direction. A number of wave theories are available to model the water particle velocity and acceleration in waves such as Stokes V theory[3].

Morison's equation provides a means of converting information on water particle velocity and acceleration into hydrodynamic loads on the structure[4]. This equation combines the water particle velocity v, acceleration v', water density ρ, diameter D, and cross-sectional area A, with drag and inertia coefficients C_d and C_m to give the force F per unit length. Morison's equation can be written as:

$$F = \frac{1}{2}\, C_d\, \rho\, D\, v|v| + C_m\, \rho\, A\, v' \tag{1}$$

The values of C_d and C_m depend on the shape and surface roughness of the riser. Values of C_d=1.2 and C_m=1.05 are typical for rough cylinders such as risers[5].

3.4 Vessel and platform motion

Floating vessels experience first-order short period motions in response to wave action. This first-order short-period motion is important for installation analysis and can be defined using Response Amplitude Operators (RAO). The RAO values define the amplitude and phase of the vessel motion relative to the wave for a particular wave frequency. RAO data usually takes the form of sets of twelve values for each wave frequency of interest. These twelve values are the amplitude and phase for heave, surge, sway, yaw, roll, and pitch. Flexcom calculates vessel motion using wave and RAO data and applies the relevant motion to the riser by means of special boundary conditions. Short-period motion of fixed is negligible compared to riser motion and deflection. Other motions occur slowly and can be modelled by applying an offset to the platform or vessel.

3.5 Seabed

Seabed support for installed end-assemblies is important. One method for including this support is to represent the soil by a series of non-linear springs. A simple alternative is to assume a point of effective fixity at a distance below the seabed[6]. This effective fixity method provides sufficient representation of the seabed support for an installation analysis.

4 ANALYSIS CASES

4.1 Introduction

This section uses engineering judgement and analysis experience to build on the information in Sections 2 and 3. The purpose of this section is to describe the loadcases that require examination for the analysis based on this information. It uses the example of a marine drilling riser that has a large-diameter drillbit at the end with various items of equipment and weights above it forming a large end-assembly. This drillbit example is typical of many of the installation analysis projects at UWG.

4.2 Installation from fixed platforms

Running a riser with a large-diameter drillbit from a fixed platform requires examination of three cases. The first case is the splash zone case that occurs when the end-assembly is near the splash zone. The second (seabed) case occurs when the riser is just above the seabed but does not receive any support at the bottom and the third (installed) case occurs after installation when the riser receives lateral support from the seabed. Each case examines the load on the riser for a particular stage of installation and Figure 3 shows schematics of these three stages.

The splash zone case occurs when the end-assembly passes through the zone of greatest wave loading. Assembly of riser stands is the most onerous situation as the top of the riser is fixed for this stage. Wave and current action on the large end-assembly generates significant bending moment along the riser while it is fixed. The only boundary condition for this case is a fully fixed support at the top as shown in the left image in Figure 3.

The centre image in Figure 3 shows the seabed case that occurs when the end-assembly is just above the seabed. In this case the riser has support at the top but no support elsewhere. Similar to the splash zone case, the most onerous situation occurs when the riser is fixed at the top support during assembly of a stand of riser joints. The load from wave and current action is small near the seabed and the end-assembly contributes a significantly lower portion of the riser load than for the splash zone case. This reduction in load is offset by the distribution of hydrodynamic loads on the riser that now extends over the full water depth.

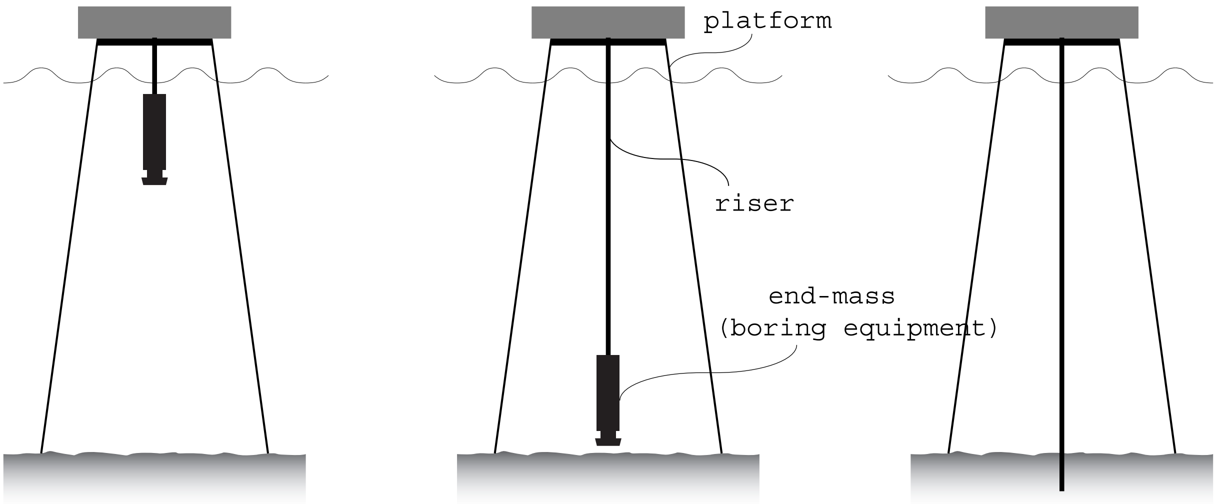

Figure 3: Installation stages (a) just below splash zone (b) just above seabed (c) installed

After the end-assembly penetrates the seabed it receives lateral support from the soil and the installed case occurs. This lateral support requires sufficient penetration to mobilise the soil support and depends on the soil stiffness. The right image in Figure 3 shows this case where the riser receives lateral support at the top and at the bottom. In this case the riser has a fixed support at the bottom to represent the soil restraint. The top support will depend on the details of the top connection and can be pinned or fixed. The riser will not be in tension for this case unless back-tension is applied from the platform.

4.3 Installation from floating vessels

Floating vessels are often used in deep water where jackup platforms cannot easily operate. Small vessels are sometimes used in shallow water because of their low cost but they have the disadvantage of large vessel motions in response to waves. Larger vessels such as crane barges are also used in all water depths for construction work and have small vessel motions in response to waves for all but very large long-period waves.

The installation cases for a floating vessel are the same as those for a fixed platform but with the added complication of vessel motion. This vessel motion imparts additional loads or motion to the riser through the connection at the top of the riser. If the riser is fixed at its top during the addition of stands then the motion of the top of the riser is identical to the motion of the vessel and the effect of the large mass of the assembly at the end of the riser can cause significant bending moment at the top of the riser. If the top of the riser is free to rotate then the riser can swing as a driven pendulum. Large end-assembly masses can cause large rotations due to this pendulum action, especially when the end-assembly is near the seabed and the free-hanging section of riser is at its longest.

An important aspect of installation from a floating vessel is the probable use of motion compensators on the vessel. Motion compensators can prevent the transfer of vessel motion to the riser from heave, pitch and roll. Heave compensators are almost always present and are used to prevent transfer of axial load to the riser. The absence of a heave compensator would cause rapid changes in riser axial load due to wave-induced vessel motion. Rotational compensators for pitch and roll are often present when using large-diameter boring equipment.

If pitch and roll compensators fail or become overwhelmed by vessel motion then the boundary conditions at the top suddenly change from pinned to rotationally fixed. The bending moment distribution also changes suddenly and can lead to structural failure of the riser. If the heave compensator is overwhelmed or fails then the riser will experience significant axial load. Note that these extreme situations are different from the case where the compensators are inoperative during assembly of stands of riser as there is no sudden change in load distribution during stand assembly.

5 DISCUSSION OF KEY ISSUES

5.1 Overview

This section discusses some of the key issues for running and installation analysis with marine risers based on experience with riser analysis. It builds on Sections 2–4, which discuss the various requirements for analysis.

5.2 Environmental data

The quality of the results depends on the quality of the input. Input data must be accurate and it must be appropriate for the analysis. Analysis for offshore structures typically uses storm or extreme event data such as the 50-year or 100-year return period environmental conditions. The joint probabilities of the maximum wave and current occurring together are small for these extreme events and environmental loads. The objective for installation analysis is to find the limiting environmental condition. The working window is usually short, often less than a day, hence environmental loads with low probabilities and long return periods have little use.

Measured data is more appropriate for installation analysis and the results should provide sufficient information to determine the forecast environmental conditions that limit safe installation. Wave loading is usually the limiting condition for offshore structures but current loading can be greater for installation analysis. Maximum tidal current occurs twice per day and is a significant source of hydrodynamic load for installation. These currents can usually be forecast in advance and this information should be incorporated into the analysis.

5.3 Riser support boundary conditions

Support boundary conditions for the riser change between loadcases. The top support is fixed during addition of stands of riser but can be pinned at other times. The boundary condition can change suddenly if compensators reach their limits or if equipment problems cause the riser to stop at its top support during running. The boundary condition at the bottom changes from free to fixed depending on the stage of running.

Bending moment redistribution can be considerable due to the change in support conditions. A configuration that has a significant reserve of bending moment capacity in the nominal operating condition can change to an insufficient factor of safety in a non-design or extreme condition if the riser stops suddenly or if the compensators reach their limits.

5.4 Computational considerations

Assembling the data, building the basic model, post-processing output, and quality assurance (QA) are the most time-consuming parts of the analysis process. Solution time on a computer for a loadcase typically takes less time than preparing the input files for that case. Modelling choices should be made on the basis of the information that is available for the analysis and refinements that generate significantly more post-processing or QA should be treated with caution unless they contribute to the quality of the analysis.

6 FUTURE DEVELOPMENTS

6.1 Overview

Installation analysis at UWG has proved successful and has saved clients significant amounts of money through reduction of uncertainty in limiting environmental conditions and better information about riser operating envelopes. There are three key areas for continuing development in installation analysis to further improve the benefits of installation analysis for marine risers. These areas are modelling of the support boundary conditions, expanding the range of loadcases, and extending the scope of riser installation analysis into related areas.

6.2 Modelling of support boundary conditions

Sections 4 and 5 emphasise the importance of the riser support boundary conditions. One area for development is to model the lowering of riser stands by using a moving top support. Flexcom allows customisation of boundary conditions and a moving top support can be added. This boundary condition could simulate lowering of each stand of riser joints into the sea at a specified rate with wave and current loads acting on the riser and end-assembly. Implementing this feature would allow examination of the effect of various rates of lowering and the variation of riser bending moment with the depth of the riser. It would then be possible to examine the complete installation sequence by combining the analysis runs for each riser stand.

6.3 Loadcases

Section 4 describes the loadcases for finding the limiting environmental conditions for particular combinations of riser, vessel (or platform), and environmental data. Expanding the range of loadcases can provide information for advance planning.

At present the analysis phase occurs after vessel and equipment selection. Moving the analysis phase to the pre-planning stage would allow operators to compare the effect of motions of different vessels, to check the safe environmental limits of the equipment, or to examine the effect of the lowering rate mentioned in Section 6.2. A substantial increase in the number of loadcases often produces only a modest increase in time and cost if planned in advance. This economy of scale can be used to construct matrices showing the variations in various input factors relative to each other.

An example situation of the use of loadcase matrices would be assisting an operator to compare options for vessel selection. If analysis shows that the limiting environmental window is sufficiently wide then the running and installation can take place during periods when vessel and equipment hire is cheaper.

6.4 Scope of application of analysis

Riser installation analysis at UWG has covered the placing of templates on the seabed, running risers with large diameter boring equipment, risers for coring samples, and the installation of large diameter pre-conductors. This selection is only a subset of the possible uses of the procedures for installation analysis.

A candidate application is the installation of the large monopiles required for offshore renewable energy construction. These monopiles typically support wind turbine towers or tidal current turbines. Reducing lost time due to waiting on weather is important in offshore construction and detailed analysis information can help to reduce this downtime.

The information in Sections 3 to 5 concentrates on analysis of risers in shallow to medium water depths but installation analysis can be extended to deepwater situations. The software and theoretical tools are the same and the analysis procedures require only minor adaptions. The main difference between shallow/medium water depths and deepwater analysis is the effect of a longer riser hanging beneath the platform or vessel. This length of riser can attract significant hydrodynamic load and the riser deflections can be large. Results of interest from deepwater installation analysis include top rotation, riser deflections, and motion of the end-assembly such as displacement, velocity and acceleration.

7 CONCLUSIONS

Analysis can reduce risk by determining the limiting environmental conditions for installation thus providing the potential for significant cost savings through reduced downtime and reduced risk of damage to equipment. Combining existing computational procedures with judgement and experience produces analysis results of value to the marine engineering industry. Successful analysis for running and installing risers has many aspects and this document provides an overview of some of those aspects that help analysts provide clients with the required results. Experience in running and installation analysis provides the following conclusions:

1. Analysis can reduce risk by providing information on limiting environmental loads.
2. Time spent waiting on weather can be reduced by using this information.
3. The cross-section of the end-assembly is significantly larger than the cross-section of the riser and causes a significant increase in hydrodynamic loads on the riser.
4. Riser bending moment can be high when the riser is held fixed at the top.
5. Riser deflections and rotations can be high when the riser is pinned at the top.
6. Motion of floating vessels can generate high bending moment or riser motion if there is a large end-assembly on the riser.
7. Close attention to support conditions is necessary.
8. Careful selection of loadcases is required.

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