Flexible Riser Installation Challenges

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Abstract

The Soroosh / Nowrooz integrated field development is located in the Persian Gulf with the Nowrooz satellite field located 50km to the north of Soroosh. The processed fluids are exported to an FSU in 45m of water (LAT) for storage and off-take by shuttle tankers. The present development phase comprises the export of crude from each of the fields to a single FSU (KHALIJ-e-FARS).

Petro Barasun International Company (PBI) was selected to execute the installation of flexible riser between subsea pipeline PLEM and FSU TURRET. The client in this project is Iranian Offshore Oil Company and the project consist of installation of 4×9” oil FFRP export Pipeline to new FSU with about 200 meters length with a related PLEM (Pipeline End Manifold).

The purpose of the paper is to define the primary considerations affecting flexible riser installation and to determine further and highlight which areas of product specification may be addressed with a view to improving the economics of installation operations. The paper first defines flexible riser characteristics and identifies the necessary installation hardware prior to providing commentary on the methods of installation. A basic cost model is introduced to illustrate the major cost elements of the installation process. Areas of potential hazard and risk are briefly highlighted and a summary of conclusions is provided.

Keywords: flexible riser installation, installation methods, bending stiffness, installation economics.

Introduction

The installation of flexible risers presents a series of practical problems, some of which are of sufficient note to be of importance to the designer and to the end user. Their flexibility may easily be brought into question as soon as the installation contractor begins to handle the end product. Without the benefits of the manufacturing plant, machinery and conditions it soon becomes obvious that the material is often far from flexible and that what flexibility it possesses only creates problems for the contractor.

Whilst the contractor is in the business of overcoming these problems, it is of obvious benefit to all parties that the relevant direct experience be fed back into the design cycle. This then allows the designer, manufacturer and end user to assess and interpret any benefits that may be achievable by alteration in the specification or design parameters. To date, the manufacturers have often been left largely to their own devices and conscience with regard to specification, design and construction. They have expended finance, resources and time in large quantities on the research and development of their products.

The end products they have created are considered fit for their purpose by the relevant authorities and end users. The products fill a market requirement and have assisted in pushing forward the technical innovations of subsea developments. The majority of their R&D work is of a confidential and commercially sensitive nature.

The installation of the end product is an area in which independent installation contractors have been, and will continue to be, involved, often in association with the manufacturer. It is, however, not immediately apparent that full use is made of the accumulated experiences gained during installation operations. This is not to say that the current end product is in any way deficient or that large scale improvements are possible, only that as part of the expansion of the subject knowledge it is important to consider the products’ inherent installation problems.

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The length of the full paper must be between 6 to 10 pages. Please use the following guidelines in preparing your full papers.

CHARACTERISTICS

The detailed specifics of materials and the methods of construction of a flexible riser are not in themselves relevant to the installation operation. They do, however, determine the riser characteristics which govern the methods of installation. Some of these are so basic that the main reason to mention them here is to ensure they are not ignored.

Length

The continuous length of the riser product is a characteristic of obvious importance. The length required is an outcome of the riser system design for its specific application and will depend intrinsically on the water depth, the motion
characteristics of the permanent topside vessel and the design’s weather criteria for the site. The length required is therefore normally a physical necessity which is independent of any installation considerations.

The riser length affects the overall riser weight and the dimensions of the reels and winches necessary. There is no definable maximum limit on the length of riser that can be installed. However, it is self-evident that the shorter the length then the more easily it may be installed. Generally, there would be no anticipated difficulties with a riser length up to 1000 m. Over this length the weight may become a limiting factor, particularly if a riser system such as a Lazy- or Steep-S is being installed as these will require ancillary mid-water and gravity bases to be carried. The installation time does not increase in direct proportion to the riser length, but it does increase. If multiple riser systems are being installed then the overall installation time will increase dramatically if additional vessel trips are required because of deck loading constraints.

**Diameter**
The internal diameter of a riser is effectively a feature of the flow requirements. The external diameter is a design and manufacturing feature necessary for the specified internal diameter and flow requirement.

The external diameter is a characteristic which impacts installation in several ways. The riser diameter affects the overall riser weight and the dimensions of reels and winches: this has a bearing on vessel selection. The diameter also affects the weight/unit length, the minimum bending radius and the bending stiffness, all of which are of primary concern to the installation contractor as they dictate the handling characteristics of the riser. Generally, experience indicates that whilst a 6 in (1 in = 25.4 mm) diameter riser is relatively easy to handle, an 8 in may be difficult.

**Weight**
The weight/unit length of a flexible riser is determined by the design, materials and construction and is dependent on the diameter required and the service application. The greater the weight/unit length, the more difficult the handling problems associated with over boarding, laydown and pull-in.

The overall weight of the complete riser affects deck loading, sea fastening and craneage requirements. Generally, any weight-saving possible, either overall or per unit length, will have a consequent benefit towards ease of handling and vessel requirements during installation.

Table 1 presents typical weight/unit length values for various diameter risers. The values are dependent on design factors such as service conditions and operating pressures.

<table>
<thead>
<tr>
<th>External Diameter</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight/Unit length (kg/m)</td>
<td>15</td>
<td>22</td>
<td>75</td>
<td>150</td>
</tr>
<tr>
<td>Weight/Unit MBR (m)</td>
<td>0.7</td>
<td>1.0</td>
<td>1.75</td>
<td>2.10</td>
</tr>
</tbody>
</table>

**Minimum bending radius**
The minimum bending radius (MBR) is a primary characteristic of a flexible riser and it is governed by the design, materials and construction of the product. The MBR is a definitive radius to which the riser may be bent without damage. It has been suggested that safety factors should be incorporated and further that a factor of 1 -5 should be used for installation purposes except when the riser is to be bent and supported permanently. Table 1 presents typical MBR values for various diameter risers.

The MBR of a riser defines the storage drum and winch dimensions necessary. It also controls the dimensions of any gutter to feed the riser over the deck edge. It is used as a governing criterion for analysis of the catenary and its seabed touchdown point. Effectively, it is the main characteristic that must be monitored during installation operations. A large MBR in excess of 2 m must be accommodated by design, analysis and careful preparation of the installation procedures. The handling and monitoring requirements increase and the installation time increases. Note that using the suggested safety factor of 1-5 entails the installation contractor attempting to maintain the actual bend radius in excess of 3 m. During laying operations, this is simply a matter of adjusting the parameters of length paid out and/or vessel position. However, during seabed handling operations for pull-in and tie-in, it is difficult if not impossible to ensure that this is maintained.

**Maximum allowable tension**
The maximum allowable tension that can be applied to a flexible riser itself is normally so high as to be irrelevant to the installation. However, there may be a lower maximum allowable tension that should not be exceeded for the riser to end fitting connection. Effectively, if the catenary self-weight for the water depth can be applied on the end fitting then this is most unlikely to be exceeded by pull-in loads. Typical values for the actual tensile strength of various riser diameters are given in Table 2 together with their maximum allowable tensions using a safety factor of 2.
Table 2: Typical Values for Riser Tensile Strength

<table>
<thead>
<tr>
<th>Riser diameter (in)</th>
<th>Tensile strength (ton)</th>
<th>Max. allowable (ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>55</td>
<td>27.5</td>
</tr>
<tr>
<td>6</td>
<td>79</td>
<td>39.5</td>
</tr>
<tr>
<td>8</td>
<td>90</td>
<td>450</td>
</tr>
</tbody>
</table>

Tensions during installation operations need to be fully analyzed; however, typically for a 6 in riser, being installed in 120 m water depth, these would need to be maintained below 15 tones.

**Bending stiffness**

The bending stiffness of a flexible riser is a characteristic, which has a major impact during installation, particularly on handling operations subsea. It is often not included as standard datum and the information is not always made available to the installation contractor. The bending stiffness affects the lifting and manoeuvring of the riser on the seabed during laydown and during pull-in operations. Typically bending stiffnesses in excess of 90 kN m² will result in handling difficulties during laydown, pull-in and tie-in operations.

**INSTALLATION EQUIPMENT**

The equipment requirements for the installation of a flexible riser are dictated by the riser characteristics.

**Winches**

A suitable main winch is required to safely deploy a flexible riser. This may take the form of a base and motor, which engages into a separate and removable drum, thus allowing the change out of a whole drum complete with the individual riser stored on that drum. If this is not possible then it is necessary to transfer the riser from a delivery or storage drum on to the main installation winch.

A complete riser length will be a considerable weight that will be dependent on its characteristics and the weight of its ancillary end fittings. For a Lazy-S system in a 120 m water depth, this will be in the region of 40 tones for a 4 in riser and up to 80 tones for an 8 in riser.

With the MBR of a riser being of the order of 1-75 m, and this governing the drum diameter, it can be appreciated that this necessitates a dimensionally large and powerful winch.

Generally, hydraulic winches are utilized offshore and they will be capable of providing upwards of 15 tones line pull at variable speeds up to 25 m/min. Actual-laying speeds will be in the region 10-15 m/min.

As the flexible riser and pipe market is relatively small, there is a very limited element of choice in the selection of winches. Whilst there may be a requirement to optimize winch design, it is not viewed as economically justified.

For safe deployment, it is necessary that the winch be provided with a positive braking mechanism.

**Gutters**

In order to deploy safely a flexible riser over the side of a vessel deck it is necessary to utilize a gutter or chute arrangement to lead the riser safely and ensure that a safe bending radius is maintained both over the deck edge and at either side on entry and exit. Depending on the vessel shape, an angle in excess of 90° may be required to be radiused to ensure that the riser does not contact any sharp or sudden edge in the event of the vessel backing up on the catenary.

**INSTALLATION VESSELS**

The minimum vessel requirements are dictated by the necessary installation equipment and the riser characteristics.

**Deck space**

Flexible riser installation requires a large deck space particularly as it will usually be necessary to carry the various ancillary items that make up the complete riser system, such as a mid-water arch and gravity base structures. The installation winch itself will take up a large area of deck and there must be sufficient area of deck between the winch and the gutter to allow handling and rigging of end fittings and positioning of the riser system ancillary items.

Riser systems may easily consist of three or more risers in a single group and these may be required to be installed simultaneously. The deck space requirements can easily stretch the limits of even large construction vessels. Effectively, the minimum deck space, which would be considered feasible for the majority of operations, would be 1000 m².

With deck space and loading as primary requirements, the semi-submersible construction vessels offer the most viable solution.

**Deck loading**

The basic elements of a paper are listed below in the order in which they should appear:

1. Conference header
All papers should have an abstract. The abstract should include the method of study and analysis, main results and discussion about them. Mentioning the background and importance of the subject of study is not necessary in this part. Introduction includes problem definition and scientific history of paper subject with pointing to references. Referring to references is used with mentioning reference numbers, namely [1]. In introduction, scientific and technical achievements relative to the other researches should be noted, clearly. According to the nature of paper, text & main body of paper should be divided, appropriately.

In results and discussion part, main results of paper are discussed. Moreover presentation of extended results is a part of paper. It’s necessary that the details of mentioned references in paper will be noted in references part.

Paper Preparation and Submission
Papers may be written in English or Persian (Farsi), and they will be presented in the written language in separated English or Persian sessions.

For English papers; the fonts for different parts of the paper are in Times New Roman as follows:
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- Author(s): 10 pt bold (centered)
- Affiliations: 10 pt (centered)
- Keywords: 10 pt
- Section Headings: 10 pt bold
- Subsection Headings: 10 pt
- Others: 10 pt
- Caption of tables and figures: 9 pt

The paper size for manuscripts is A4 with 20 mm margins from all sides and should be written in one-column format. Authors can use the present template for configuring their papers.

Furthermore, the section headings will start from the far left and use single spacing paragraph format with no space between the section headings and the paragraph following it. The first line of the first paragraph of each section is not indented, but the others are indented by 5 mm. Put one space between the texts of main sections. Paper must have page numbers.

- The number of accepted papers for any of first authors is limited to 4.
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SI system of units is deemed to be used. If necessary use the equivalent value in the other system of units in brackets after the SI system of units.

Equations
Equations start from the far right of the column and numbered consecutively. The equation numbers must be bracketed and placed opposite to the equation on the far right of the line in that column.
Tables, Figures and Photographs
1. Tables must be numbered and the title of the table must be placed on the top of the table with the footnotes on the bottom. Tables must appear where (or as close as to where) they are first mentioned in the text. They must be referred in the text as "Table 1".

Table 1: An example of a table

<table>
<thead>
<tr>
<th>Number</th>
<th>Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
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<tr>
<td>2</td>
<td></td>
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<td>3</td>
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<td>7</td>
<td></td>
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<tr>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

2. Figures must be numbered and the caption of the figures must be noted at the bottom of the figure. All the legends and the numerical values on the axes of the curves must be clear and readable. Figures must appear where (or as close as to where) they are first mentioned in the text. They must be referred in the text as "Figure 1".

3. Photographs must be original and are treated similar to figures. Leave one space between the Table/Figure and the text following it.

Results and Discussion
Results of the work and discussions are presented here.

Conclusions
Main conclusions of the paper must be put here.

Acknowledgment (Optional)
Acknowledgments are written here.

List of Symbols (Optional)
The list of symbols comes after the acknowledgment and before references. The English symbols come first followed by the Greek symbols. Both must be typed in alphabetical order and separated.

$E$ Modulus of elasticity
$k$ Stiffness
$p$ Acoustical pressure
$p_e$ Amplitude of the excitation plane wave
$p_b$ Blocked pressure

Greek symbols
$\sigma$ Flow resistivity
$\tau$ Tortuosity

References
References must be numbered and be listed in the list of references in the order they were referred to in the text. Their numbers must be put in squared bracket, e.g., [1]. The complete details of the references will appear in the list of references. Just mention those references which were mentioned in the paper.
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