Deep Water Pipeline and Riser Installation by the Combined Tow Method

a report by

Alf Roger Hellestø, **Daniel Karunakaran** *and* **Ove T Gudmestad**

Subsea 7, Statoil and University of Stavanger, Norway

Introduction

Pipelines may be installed by the towing techniques where long sections of the line are made up onshore and towed with tug boats to the field. The design procedures for towed or pulled lines are very dependent on the type of tow method chosen. It is also important to control the submerged weight of a towed line to minimise towing forces and at the same time have sufficient weight for stability on the seabed in cross-currents.

The combined tow concept reported in this paper incorporates the following tow methods for deepwater pipelines and risers:

- the off-bottom tow method (with buoyancy tanks and chains) from the fabrication site to approximately 5km offshore;
- the controlled depth tow method (CDTM) from 5km offshore to a temporary location where the buoyancy tanks are removed; and
- the catenary tow method for the deepwater tow to the installation site (without buoyancy tanks and chains).

For the off-bottom and controlled depth tow methods, buoyancy steel tanks are mounted at selected intervals. Chains are also mounted at frequent intervals along the pipeline to overcome the excess buoyancy and keep the system stable. During the catenary tow method the buoyancy modules and chains are removed and the submerged weight of the system increases.

Tow Methods

In order to use the tow methods, the pipeline is normally constructed at an onshore site with access to the sea. Once the pipeline sections are welded together to a determined length and hydro-tested, the pipe is de-watered and launched into the water by a tow vessel attached to the lead. Onsite winches are attached to the trail end to ensure back tension and control the launch speed. (For more details, see Hellestø et al., 2007.)

For pipelines that are to be towed into deep water, pressurised nitrogen can be introduced into the buoyancy tanks to prevent collapse or buckling of the tanks under high external hydrostatic pressure.

Pipeline installation by towing can be divided into three main methods:

- off-bottom tow;
- mid-depth tow – CDTM; and
- catenary tow.

The choice of method is dependent on the following factors:

- the submerged weight of the pipeline;
- length of the pipeline; and
- the seabed environment and presence of existing pipelines along the selected tow route.

The combined tow concept reported in this paper looks into a combination of the three methods presented above, i.e. off-bottom tow method from the shore to a suitable depth, CDTM method from this point to entering deeper waters and catenary tow for the deepwater tow to the installation site. In the off-bottom and controlled depth tow phases, the pipeline is supported by external buoys and chains, which are removed by a remotely operated vehicle (ROV) before the catenary tow phase.

Off-bottom Tow Method

During the off-bottom tow, the submerged weight of the pipeline, together with the buoyancy modules and chains, are equal to the weight of chain links resting on the seabed. By controlling these weights the pipeline can be located above the seabed at a predetermined height during the tow (see *Figure 1*). Off-bottom tow is only feasible up to a certain depth because the buoyancy becomes more expensive as the water depth increases. Off-bottom tow is used at locations where the bottom conditions on the tow route are known and smaller towing loads and fatigue damage are required.

CDTM

In CDTM (see *Figure 2*), the pipeline is kept between the lead and trailing tug. The total submerged weight of the pipeline, floats and chains is negative. During tow, the drag on the chain creates a 'lift force', which reduces the system's submerged weight. An increasing flow velocity is consistent with an increasing angle between the drag chains and the vertical. The submerged weight is hence also determined by the relative water velocity past the chain.

At the design tow speed, the pipeline will lift off from the seabed and adopt the desired mid-depth CDTM configuration. The lift is dependent on:

- speed;
- type of chain; and
- number of links.

By controlling the tow speed and tow wire length, the pipeline configuration is maintained within acceptable limits, as defined by

Figure 1: Off-bottom Tow Method

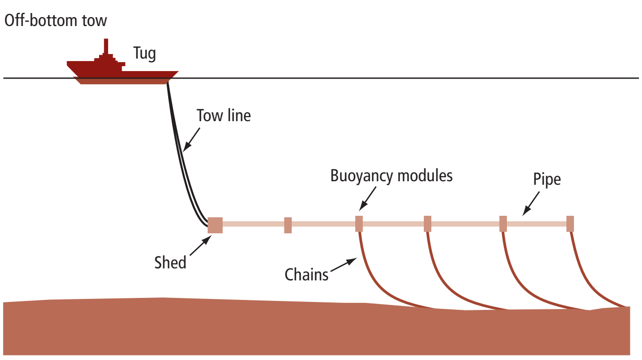

Figure 2: CDTM

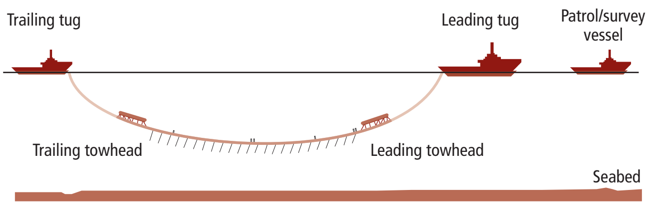

Figure 3: Catenary Tow Method

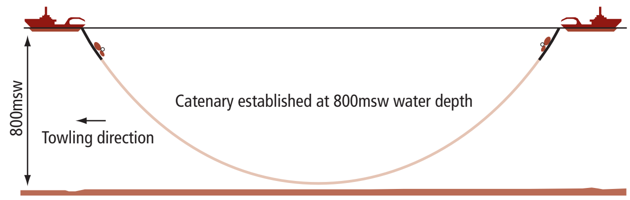

Table 1: Riser/Pipeline Data

	Pipeline	Riser/pipeline string
Length [m]	3,000	625/1375
Wt [mm]	25	28.6
OD [mm]	609.6	666.8
Material	API 5L X65	ASTM Grade 23/API 5L X65

Table 2: Design Parameters for the Deepwater Tow Operation

Deepwater Pipeline tow	Off-bottom	Controlled-depth	Catenary
Tow velocity [m/s]	0.7	2.5	2.5
Planned operation [hrs]	4	59	34

Table 3: Design Parameters for the Medium Tow Operation

Medium water depth riser/pipeline tow	Off-bottom	Controlled-depth
Tow velocity [m/s]	0.7	2.5
Planned operation [hrs]	4	55

static and dynamic tow analyses.

The advantages of CDTM is the tow speed, which is higher than for off-bottom tow, and the absence of contact with the sea bottom, which allows passing severe slopes or rocky bottom conditions. The maximum tow speed conducted from bundle projects today is close up to 3.5m/s. Normal tow speed is in the range of 2.0–2.5m/s.

Catenary Tow

In the catenary tow, the pipeline is in a catenary configuration between the tugs (see *Figure 3*). The required bollard pull of the two tugs increases as the water depth decreases. A catenary tow is not possible in shallow depth since the required horizontal bollard pull forces to keep the pipeline sag-bend of the seabed are too high for conventional tugs. The installation on site is achieved by paying out on the tug winch wires while controlling the touch-down routing with the vessel position.

Combined Tow Method for Deepwater Installation

A main challenge with towing pipelines in deep water has been the buoyancy needed to support the pipeline. The required wall thickness in deepwater to avoid collapse makes the steel buoyancy tanks too heavy and also the use of syntactic buoyancy at these depths is expensive. Further controlled removal of buoyancy in deepwater may be a time-consuming and expensive task because the buoys may need to be recovered individually.

However, a new buoyancy tank design proposed by Subsea 7, together with making use of pressurised nitrogen to reduce the required weight, can solve the weight and handling challenges.

Installations at Location

The riser/pipeline string is gradually lowered to the seabed in the parking area subsequent to arrival on location, where it settles in an equilibrium position above the seabed with the lower portion of chain links resting on the seabed. From the parking area the riser/pipeline string will be towed in off-bottom mode until the towhead reaches the determined position. Thereafter, the riser/pipeline string will be pulled in to the platform with a wire that goes through a sheave connected to an anchor located at the platform leg and back to the lead tug.

Riser Pull-in to Production Facility

Prior to the start of the riser hang-off pull-in, the ballast chain and buoyancy tanks will be removed from the riser section after the pipeline/riser string is positioned on the seabed.

The riser will then be pulled in to the structure using a pull-in winch. During the whole operation the trail tug will adjust the hold-back tension and vessel position at the trail tow head to control the riser catenary curvature and sideways movement. ROVs will monitor the touchdown point and the lead tow head. When the riser end is at the platform deck it will be permanently fixed at hang-off flanges and the pull-in wire will be disconnected.

Design Checks

The pipeline/riser integrity during tow out and installation should be checked against DNV Submarine Pipeline Systems, OS-F101, DNV (2005).

Case Studies

Two case studies have been analysed. These are:

- deepwater pipeline installation, 800m water depth; and
- large diameter riser and pipeline installation in medium water depth, 300m.

Riser/Pipeline Data for Case Studies

The pipeline properties used for the two case studies are shown in *Table 1*.

For further details and results, see Hellesø et al., 2007.

Design and Operational Criteria

The following design criteria are governing for the tow operations:

- dynamic pipeline von Mises stress and longitudinal stress shall be within 90% of the yield stress; and
- the maximum allowable fatigue damage during installation shall be limited to 0.1.

A local buckling check based on the load controlled condition according to DNV-OS-F101 (DNV, 2005) is also performed.

Weather-restricted Operations

Uncertainties in weather forecasts are included by applying an operational limiting sea state less than the design limiting sea state. The operational versus design criteria ratio is set according to DNV Rules for planning and execution of marine operations, DNV (1996). The relevant reduction factor (alpha factor) is 0.63 for HS,D greater than 4m and an operational period less than 72 hours. Therefore, each phase of the tow operation is planned as a single marine operation within a reference period less than 72 hours, referring to the design criterion from DNV (1996). The design parameters for the tow routes are presented in *Table 2* and *3*.

Results

Two case studies were investigated; the tow of pipelines in deepwater using three combined tow methods and towing of a riser/pipeline string including pull-in to the production facility at the field. The governing criteria for these investigations are the resistance against local buckling, tow wire tension and fatigue damage during tow out/installation.

- The stresses during the tow are very low in an operational sea state of 3.5m with worst wave heading and period, and there is no risk of buckling the pipeline and riser/pipeline string.
- The maximum accumulated damage due to fatigue is 0.0003 for the riser/pipeline and 0.028 for the gas pipeline deepwater tow.
- Use of the combined tow method is therefore shown to be a robust method of transporting deepwater pipelines and risers from the fabrication site to the field.

For future, focus should be on the design and handling of the buoyancy modules. A system that can minimise the offshore time for disconnection of the buoyancy modules and recover this system back onshore should be looked into further. ■

1. Cruz I, "Towed Risers Installation Study", Towing methods evaluation report, Subsea 7 Brazil, 2005.
2. DNV, *Rules for Planning and Execution of Marine Operations*, 1996.
3. DNV-OS-F101, *Submarine pipeline systems*, 2005.
4. Hellestø AR, "Towing of deepwater pipelines and risers" MSc thesis, University of Stavanger, 2005.
5. Hellestø AR, Karunakaran D, Grytten T, Gudmestad OT, "Combined tow method for deep water pipeline and riser installation." Paper OTC 18797. To be presented at OTC 2007, Houston, Texas, 2007.