PIPELAY VESSEL

This invention relates to vessels for laying submarine pipeline. Although the invention will be described primarily in relation to the laying of rigid pipeline, the apparatus described is also applicable to the laying of flexible pipeline and other elongate products such as cables. Further, although the invention will be described in relation to a self-propelled, dynamically positioned ship, other forms of vessel may be used, such as a semi-submersible or a dumb barge.

As is well known, methods of laying rigid pipeline fall broadly into three types.

One is to wind pre-welded pipe onto a reel at a shore base, and deploy the pipe via a straightener and a launch assembly, typically a stinger.

A second is to weld pipe sections on the pipelay vessel in a horizontal "firing line", and deploy the welded pipe over a stinger or the like.

A problem of both of these (which are both S-lay methods) is that as the water depth increases the departure angle from the stinger must increase until in deep water it becomes 90°. This leads to a long and unwieldy stinger which is difficult to support from the stern of a vessel.

The third broad type is the use of J-lay, in which pipe sections are welded and launched in a generally vertical orientation. This avoids many restrictions of the S-lay methods, but is an inherently slower process. Moreover, the weight of the pipe between the ship and the seabed must be supported entirely by tensioning apparatus, in contrast to S-lay where the weight is partially taken by the stinger.

A wide variety of prior art proposals have sought to address these problems. See for example the 'Steep S-Lay' system represented by Allseas' vessel *Solitaire,* of the form generally shown in GB2299646A (Allseas/Kalkman). WO2007/000609 (Acergy) proposes to combine an elevated Steep S-Lay

stinger with a J-Lay tower located at the stern of the vessel, aligned with the S-Lay departure axis.

In general, therefore, it can be said that pipelaying methods can be considered as being in three categories:

1. Shallow S-lay, in which the pipe is launched over a stinger with a launch angle which has a predominantly horizontal component, this being used in relatively shallow water.

2. Steep S-lay, in which the pipe is launched over a stinger with a launch angle which has a predominantly vertical component, this being used in relatively deep water.

3. J-lay, in which the pipe is welded at and launched from a tower which has a substantially vertical orientation, this being capable of use in both shallow and deep water.

Hitherto, vessels have been designed to provide only one, or at most two, of these.

The aim of such developments is to enable the provision of a vessel which is capable of laying pipeline in a wide range of water depth in a flexible and economic manner and at a relatively economic capital cost. The system should be versatile enough to maintain these advantages while handling different types and sizes of pipe, and all the accessories, terminations etc that arise in a real project. The present invention seeks to provide a further step towards these goals.

According to a first aspect of the invention there is provided a pipelay vessel having a stinger extending along and outboard of one side of the vessel, the stinger having an input end and a launch end, the launch end being operable at a desired angle to the horizontal, and a diverter arranged to lead pipe onto

the stinger input end through a predominantly horizontal diversion angle from pipeline source having a substantially horizontal orientation.

The diversion angle may have both horizontal and vertical components, so that, for example, the pipeline rises from the source to an elevated position for entry to the stinger. The vertical diversion is the minor component, however, so that the centre of gravity of the pipe and the apparatus can be kept near to deck level without restricting the radius of bending of the pipe.

The vessel may include straightening and tensioning apparatus located on a section of the pipeline path, between the diverter and the input end of the stinger. The straightening and tensioning apparatus may comprise at least one straightener and at least one tensioner, sequentially arranged alongside section of pipeline path. Said section may be fixed or moveable. In a preferred embodiment, the straightening and tensioning apparatus extends along a curved path. The pipeline path may already have a downward component on entry to the stinger. The straightening and tensioning apparatus may be located substantially above deck level.

In a preferred form, the stinger input end is adjacent the stern of the vessel, the stinger launch end is forward of the input end, and the diverter comprises at least one ramp extending around the stern of the vessel. The stern is mentioned for convenience, but bow and stern may be interchangeable for this purpose, especially on barge or semi-submersible vessels. The ramp may be supported outboard of the hull, to maximise available deck space.

The stinger launch end can preferably be positioned, in use, in a vertical orientation within the length of the vessel. By positioning the stinger launch end close to midships, say within the middle third of the vessel's overall length, movement of the launch point can be minimised, for a given sea state.

The vessel may include a J-lay apparatus positioned outboard of said one side of the vessel to have a J-lay axis collinear with the launch axis of the

stinger. This facilitates handover of product between the two apparatuses, as described in WO 2007/000609, mentioned above.

In a preferred embodiment, said pipeline source having a substantially horizontal pipe orientation comprises a pipe firing line extending parallel to and adjacent the other side of the vessel (that is the side opposite the stinger).

The vessel may further include a shallow angle stinger extending from the stern of the vessel and generally aligned with said firing line. This permits the vessel to undertake normal S-lay operations. The shallow angle stinger may also provide a path for loading on pipeline to a reel (see below).

The vessel may also further include a vertical-axis pipe reel located adjacent a pipeline path extending between the firing line and the first-mentioned stinger. In this case, the diverter may suitably comprise a first ramp for diverting pipe from the firing line to the stinger and a second ramp for diverting pipe from the firing line to the reel. Additionally, the diverter may include a third ramp for delivering pipe from the reel to the stinger. These ramps may be regarded as separate diverters, or as part of a larger diverter arrangement. The same parts may be shared between them, so as to be reconfigurable to different modes.

The vessel may include one or more cranes; a major crane may be positioned adjacent the other side of the vessel (that is the side opposite the stinger) to improve stability.

Preferably, the stinger is formed by articulated sections, and the vessel includes stinger support and handling means operable to move the stinger between a fully deployed position with a vertical departure axis and a retracted position above the vessel's waterline.

There may for example be two articulation points. In one form, the stinger has a first curved section articulated at about deck level and a second curved

section articulated to the distal end of the first section somewhere below the water line when deployed. The stinger support and handling means may comprise a flexible suspension member connected between the hull and an intermediate point on the second section and a flexible handling member connected between the hull and a point adjacent the distal end of the second section.

The launch end of the stinger is preferably flared transversely of the launch path (for example by about 5°, say 4° – 10°, in either direction) to permit limited relative motion between the pipe axis and the vessel. The heading of the vessel may be permitted to differ from the departure orientation of the pipeline or other product, which facilitates operation in a wider range of weather and wave conditions.

From another aspect, the invention provides a pipelay vessel having:

a firing line having an axis on which pipe sections are welded together to form a continuous pipeline;

shallow water launching means aligned with the firing line;

deep water launching means contained within the length of the vessel; and

a diverter arranged to selectively lead said pipeline from the firing line to the deep water launching means.

The shallow water launching means may comprise a shallow water stinger extending from the stern of the vessel for supporting pipeline as it bends to a departure angle. The deep water launching means may comprise a deep water stinger disposed along and outboard of one side of the vessel for supporting pipeline as it bends to a departure angle. The shallow water stinger may end at an angle closer to horizontal than vertical, while the deep water stinger will end at an angle closer, to vertical, and including vertical in practice.

Preferably also, the vessel further comprises a J-lay apparatus having a launch axis aligned with the in-use position of a launch end of the deep water

stinger. This facilitates handover of product between the two apparatuses, as described in WO 2007/000609, mentioned above.

The vessel may further include a vertical axis pipe reel, and the diverter (or an alternative diverter) may be selectively operable to lead pipe from the firing line to the storage reel.

A further aspect of the invention provides a pipelay vessel which is selectively operable in any one of three modes, namely (1) shallow S-lay, (2) Steep S-lay, and (3) J-lay.

The vessel preferably includes a single firing line for forming pipe for both shallow S-lay and Steep S-lay modes, and may further include a vertical axis pipe reel arranged to selectively supply pipe to the Steep S-lay stinger and/or to receive pipe from the firing line.

The invention further provides methods of operation of the vessel, as will be apparent from the description of embodiments that follow.

BRIEF DESCRIPTION OF THE DRAWINGS

An embodiment of the invention will now be described, by way of example only, with reference to the drawings, in which:

Fig. 1 is a side view of a vessel embodying the present invention, with a stinger in a deployed with a retracted position shown in outline;

Fig. 2 is a plan view, with the stinger in the retracted position;

Fig. 3 is a stern view on the line A-A of Fig. 2;

Fig. 4 is a section on the line B-B of Fig. 2 but with the stinger omitted; and

Fig. 5 is an enlarged plan view of part of the stinger.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Referring particularly to Figs. 1 and 2, a ship 10 has a hull 12 with superstructure 14 and a working deck area 16.

A firing line 18 is disposed along the starboard side of the ship 10 as a primary source of pipeline product. The firing line 18 includes means for handling pipe sections onto the firing line axis, welding the sections together, and applying any necessary treatments to the welded joints. All of these are well known in the art and are not shown or described here in detail.

A shallow angle stinger 20 is pivotally attached to the stern of the ship 10 in alignment with the firing line 18. The shallow angle stinger 20 includes tensioners indicated at 22, and is used to launch pipe at departure angles of up to about 50° in relatively shallow water. This conventional S-lay technique is well understood in the art and will not be further described.

A deep water stinger, generally indicated at 24, is disposed along the port side of the ship 10 and outboard of the hull 12. The stinger 24 comprises a first arcuate section 241 which is hinged to the hull 12 at a first articulation point 242, and a second arcuate section 243 which is hinged to the first section 241 at a second articulation point 244. The first section 241 engages a curved guide rail 245. The stinger 24 when deployed is supported primarily by suspension wires 246 extending from a winch (not shown) on the hull 12 to an intermediate point on the second section 243. In addition, a handling wire 247 extends from the outer end of the second section 243 to a winch (not shown) on the hull 12.

In Fig. 1, the stinger 24 can be seen in both a fully extended position E and a fully retracted position R in which the stinger 24 is entirely above the waterline. The stinger 24 can be moved between these positions, and set in intermediate positions if desired, by appropriate winching of the suspension wires 246 and handling wire 247. The engagement with rail 245 may be passive or driven, to assist in retraction.

As seen in Fig. 5, the distal (departure) end of the stinger 24 is laterally flared at 248 by 5° in either direction (a flare of 4° – 10° to each side may be appropriate). This is to accommodate limited relative motion between the pipe axis and the vessel which may be necessary, for example, to vary the ship's heading with respect to the pipeline axis.

A J-lay tower 26 and a pipe elevating system 38 are located at the port side of the ship 10 and extend partially outboard. The J-lay tower 26 has a pipe axis 261 aligned with the outboard end of the stinger 24 in its fully extended condition E. The J-lay tower 26 and pipe elevating system 38 are otherwise of conventional construction and need not be described in detail. In brief, tensioning apparatus is provided for supporting the weight of a suspended pipeline in line with the pipe axis, and for paying out the pipe into the water in a controlled manner. Tensioning apparatus may comprise track-type tensioners, travelling clamps or a combination of both, as well as auxiliary hang-off clamps. One or more welding stations are provided, typically above a hang-off clamp, so that a new length of pipe can be added to the top of the suspended pipeline. The weight of the suspended pipeline is then transferred to the tensioning apparatus and the hang-off clamp opened, so that the new section of pipeline can be paid out, and the process repeated to extend the pipe as desired. Particular benefits of J-lay include avoidance of bending fatigue that can be imparted to pipes undergoing S-lay processes. However, the J-lay process tends to be slower. Overall, and therefore not ideal for general pipe laying duties.

The J-lay tower 26 can be used to operate J-lay as an alternative to S-lay over either of the stingers 20 or 24. Additionally, the J-lay tower 26 can be used as a means for temporarily holding a pipe which has been launched over the deep water stinger 26, for example as part of a technique for attaching terminations or branches to the pipeline during launching. The alignment of the axes of the Steep S-lay system and the J-lay system permits the handover of a pipeline directly from one apparatus to the other. Thus, the versatility of J-lay is available for very large pipe and for fitting singular items, without

sacrificing the speed of S-lay for the major runs of pipe. In this connection, attention is drawn to our co-pending application WO2007/000609, mentioned above, which includes illustrations of various methods enabled by this alignment. Those descriptions are hereby incorporated by reference as part of the present disclosure also.

Cranes 40 and 42 are provided on the starboard side of the ship 10, above the firing line 18. Positioning the cranes to starboard helps to balance the weight of the J-lay tower 26 and pipe elevating system 38 to port.

Three ramps are provided at the stern of the ship 10 and each constitutes a diverter. A first ramp 28 extends from the firing line 18 to a straightening and tensioning assembly 30 to feed with the stinger 24. Ramp 28 is disposed so as to divert the welded pipe through 180° horizontally and also raise the welded pipe to a height suitable for launching on the stinger 24. The straightening and tensioning assembly 30 comprises a straightener 301 which removes plastic deformation of the pipe caused by diversion and/or reeling; straighteners of this nature are well known in the art. The assembly 30 further comprises one or more tensioners for applying tension to the deployed pipeline. In this example, three tensioners 302 of the known opposed-track type are shown, but any other suitable tensioning means may be used, including travelling claws. The assembly 30 may also include one or more work stations W1, W2, W3 for example for applying insulation or anti-corrosion treatments to welded joints after straightening, or for simple inspection.

A second ramp 32 extends from the firing line 18 to the periphery of a reel 34. The reel 34 is a vertical-axis reel suitable for reeling, storing and unreeling rigid pipe; reels of this nature are well known in the art and will not be further described. The second ramp 32 also acts to divert the welded pipe from the firing line 18 through 180° horizontally in order to feed it onto the reel 34.

A third ramp 36 is positioned to feed pipe from the reel 34 to the straightening and tensioning assembly 30. In order to use this facility, pipe must have

been stored on the reel 34 in the opposite rotational sense from that which would apply for reeling on from the firing line 18, for example being reeled on from a shore production facility.

As seen in Fig. 3, each ramp 28, 32, 36 has its own component of vertical inclination, as well as a general horizontal curvature forming the predominant 180° diverting curve. The inclination of ramp 28 can be fixed at an angle less than 45° but perhaps as high as 30° (α in Fig. 3), as its entry and exit points are fixed. The ramps 32 and 36 have a lesser inclination (β), which is made variable to allow level winding as product is fed or drawn on or off the reel 34.

The reel 34 may be used for example to store continuous welded pipe received from a shore base, and this can be laid in addition to pipe welded on board on the firing line 18. Alternatively, pipe can be welded on the firing line 18 and stored on the reel 34 for future use, for example while the vessel is in transit to the lay site or is waiting at the lay site for other operations to be completed.

Thus, the ship 10 can be operated in a number of modes:

- Shallow S-lay from the firing line 18 over the stinger 20.
- Steep S-lay from the firing line 18 over the stinger 24.
- Steep S-lay from the reel 34 over the stinger 24.
- J-lay from the tower 26.
- Sequential combination of Steep S-lay and J-lay with direct handover between them for handling singularities.
- Welding of pipe on the firing line 18 and storing on the reel 34.
- Loading of pipe from a shore base and storing on the reel 34 (the shallow stinger 20 can be used for this).

The same components can be used for handling and laying other elongate product, such as flexible pipe, cables and umbilicals. Flexible pipe can be used in the tensioners to serve as an abandonment winch with high tension capacity.

In terms of dimensions, the hull of vessel 10 may have an overall length around 250 – 300m (plus any outboard diverter structure). Its beam may be around 40m at deck level, perhaps 30m at the water line. The steep stinger 24 radius of curvature may be around 120m. By providing a radius over 50m, say 80 – 150m or 100 – 140m, then large diameter pipes can be handled without plastic bending. The diameter of reel 34 may be around 30 – 40m, say 34m in one example. The radius of the path defined by each of the ramps 32, 36 should be no less than that of the reel, to avoid additional plastic bending. Ramp 28 can be decidedly wider in radius, especially given its vertical component added to its horizontal curvature. Its horizontal radius may be greater than 15m, say, and its true radius (combining horizontal and vertical in the angle α) greater than 18m. This allows gentler handling of pipe compared with reeling operations.

The invention thus provides a pipelay vessel which is capable of flexible use, in being capable of operating S-lay in a wide range of water depths and also operating J-lay where circumstances require. The invention allows the necessary equipment to be disposed in a compact manner on the vessel, and without any return to base for re-configuration to the different modes. It is thus possible to use a relatively small vessel for laying in extreme depths and a range of other tasks.

Many variations and modifications are possible without departing from the spirit and scope of the invention. Some of these variations and modifications are discussed above, while others will occur to the skilled reader from a consideration of the above description and drawings.

CLAIMS

1. A pipelay vessel having a stinger extending along and outboard of one side of the vessel, the stinger having an input end and a launch end, the launch end being operable at a desired angle to the horizontal, and a diverter arranged to lead pipe onto the stinger input end through a predominantly horizontal diversion angle from pipeline source having a substantially horizontal orientation.

2. A pipelay vessel according to claim 1, in which the diversion angle has both horizontal and vertical components with the vertical diversion being the minor component.

3. A pipelay vessel according to claim 1 or claim 2, including straightening and tensioning apparatus located on a section of the pipeline path, between the diverter and the input end of the stinger.

4. A pipelay vessel according to claim 3, in which the straightening and tensioning apparatus comprises at least one straightener and at least one tensioner, sequentially arranged alongside said section of pipeline path.

5. A pipelay vessel according to claim 3 or claim 4, in which the straightening and tensioning apparatus extends along a curved path located substantially above deck level such that the pipeline path has a downward component on entry to the stinger.

6. A pipelay vessel according to any preceding claim, in which the stinger input end is adjacent the stern of the vessel, the stinger launch end is forward of the input end, and the diverter comprises at least one ramp extending around the stern or bow of the vessel.

7. A pipelay vessel according to claim 6, in which the ramp is supported outboard of the hull.

8. A pipelay vessel according to claim 6 or claim 7, in which the stinger launch end can be positioned, in use, in a vertical orientation within the length of the vessel.

9. A pipelay vessel according to any preceding claim, including a J-lay apparatus positioned outboard of said one side of the vessel to have a J-lay axis collinear with the launch axis of the stinger.

10. A pipelay vessel according to any preceding claim, in which said pipeline source having a substantially horizontal pipe orientation comprises a pipe firing line extending parallel to and adjacent the other side of the vessel (that is the side opposite the stinger).

11. A pipelay vessel according to any preceding claim, further including a shallow angle stinger extending from the stern of the vessel and generally aligned with said firing line.

12. A pipelay vessel according to any preceding claim, further including a vertical-axis pipe reel located adjacent a pipeline path extending between the pipeline source and the stinger.

13. A pipelay vessel according to claim 12, in which the diverter comprises a first ramp for diverting pipe from the pipeline source to the stinger, a second ramp for diverting pipe from the pipeline source to the reel, and optionally a third ramp for delivering pipe from the reel to the stinger.

14. A pipelay vessel according to any preceding claim, including one or more cranes at least one of which is positioned adjacent the other side of the vessel (that is the side opposite the stinger).

15. A pipelay vessel according to any preceding claim, in which the stinger is formed by articulated sections, and the vessel includes stinger support and handling means operable to move the stinger between a fully deployed

position with a vertical departure axis and a retracted position above the vessel's waterline.

16. A pipelay vessel according to claim 15, in which there are two articulation points, the stinger having a first curved section articulated at about deck level and a second curved section articulated to the distal end of the first section somewhere below the water line when deployed.

17. A pipelay vessel according to claim 15 or claim 16, in which the stinger support and handling means comprises a flexible suspension member connected between the hull and an intermediate point on the second section and a flexible handling member connected between the hull and a point adjacent the distal end of the second section.

18. A pipelay vessel according to any preceding claim, in which the launch end of the stinger is flared transversely of the launch path (for example by about 5°, say 4° – 10°, in either direction) to permit limited relative motion between the pipe axis and the vessel.

19. A pipelay vessel having:

a firing line having an axis on which pipe sections are welded together to form a continuous pipeline;

shallow water launching means aligned with the firing line;

deep water launching means contained within the length of the vessel; and

a diverter arranged to selectively lead said pipeline from the firing line to the deep water launching means.

20. A pipelay vessel according to claim 19, in which the shallow water launching means comprises a shallow water stinger extending from the stern of the vessel for supporting pipeline as it bends to a departure angle.

21. A pipelay vessel according to claim 19 or claim 20, in which the deep water launching means comprises a deep water stinger disposed along and outboard of one side of the vessel for supporting pipeline as it bends to a departure angle.

22. A pipelay vessel according to any of claims 19 to 21, further comprising a J-lay apparatus comprising a tower which in use is disposed generally vertically, the tower being provided with pipe tensioning apparatus and one or more welding stations, wherein the J-lay apparatus has a launch axis aligned with the in-use position of a launch end of the deep water stinger.

23. A pipelay vessel according to any of claims 19 to 22, further including a vertical axis pipe reel, and the diverter (or an alternative diverter) is selectively operable to lead pipe from the firing line to the storage reel.

24. A pipelay vessel which is selectively operable in any one of three modes, namely (1) shallow S-lay, in which the pipe is launched over a stinger with a launch angle which has a predominantly horizontal component; (2) steep S-lay, in which the pipe is launched over a stinger with a launch angle which has a predominantly vertical component; and (3) J-lay, in which the

pipe is welded at and launched from a tower which has a generally vertical orientation.

25. A pipelay vessel according to claim 24, including a single firing line for forming pipe for both shallow S-lay and steep S-lay modes.

26. A pipelay vessel according to claim 25, further including a vertical axis pipe reel arranged to selectively supply pipe to the steep S-lay stinger and/or to receive pipe from the firing line.