**Abstract**

The O-lay offshore pipe lay technique is a technique which is discussed a lot lately. The reason for this because the O-lay method can be seen as one of the future pipe laying methods that is interesting for many area’s due to the relative low costs of operation, the possibility to lay from a few meters to several thousands of meters of depth and the high speed of laying.

The main difference between the new, state of the art, O-lay technique and the existing systems is that the total length of the pipe is welded and tested onshore on a site that is near the waterfront and that after the pipeline has been coated according its specifications the pipeline will be transported as a whole, in a huge floating flat spiral to the location where it will be laid.

Although the technology is set up for laying pipe the reverse is possible as well. Retrieval of pipeline no longer in use is also possible with this technology. In some particular cases the pipeline can be reused for another oil or gas field again.

Due to its length of the pipe being laid and that it is supplied in a whole to the lay barge the lay barge has a different role in the organization. It will only act as a pipe laying vehicle and storing, welding and inspection of the pipe finds place elsewhere. Using the O-lay method pipe can be laid in very shallow as well very deep water due to the fact that the pipe is stored outside the lay barge.
Due to the fact that most operations are performed onshore the lay-out of the lay barge is focused on a better performance of laying the pipe.

For deep water operation the possibility to prepare and construct the insulated “Pipe in Pipe” on an onshore location has several advantages compared to the preparation being done offshore and gives a lot of timesaving during offshore operations.

With the O-lay method it is possible to use concrete weight coating around the pipe due to specific characteristics of concrete when using special additives.

Several tests in laboratory and under real conditions have shown that the method described is feasible for pipelines of all diameters.
The “O”-lay Method.

The method of “O”-lay pipe laying was introduced as “state of the art” technique for laying pipe of all diameters at depths of only a few meters up to several thousands of meters. The system is a combination of some already known technologies like S-lay with some new ideas. The enormous advantage of the system is that pipe is not being constructed and welded on a lay barge at the position where the pipe will be lowered on the seabed. Instead the pipe is fully prepared at predefined lengths on an onshore location which are the welded together, pulled in the water and stored in a floating “O” shaped model in front of the construction yard.

From there it will be transported to the location where the pipe is lowered to the bottom with the S-lay method using a simplified lay barge.

This paper will give you a idea of the advantages of the O-lay method compared to the existing traditional methods.

Picture 1. The O-lay Method. The floating spiral being produced with a method that is reproducible.

The method of how the spiral is constructed near the onshore pipeline construction yard defines how pipeline will perform during its transport, laying phase and sub sea operations.
Pipeline spiraling stage.

Bending steel pipe.
Considering that, within limits, everything can be deformed in an elastic way.
Steel pipe can be deformed in its elastic area and return to its original form after the applied forces are taken away.
Also concrete can be bend elastically.
The difference between the steel and the concrete is that concrete doesn’t have a yield point elongation or plastic deformation and therefore will break at its yield point.
For steel the elasticity modulus is 210.000MPa while for the concrete normally this modulus is between 20.000 and 30.000MPa. For ordinary concrete the yield point is very low.
By using additives in the concrete it is possible to achieve more the 4% of tensile strain. This severe deformation is much more then what is expected from steel.
Developments in concrete go even further.
In the laboratories of the University of Michigan, tests shows that this type of concrete is “self-healing” due to the fact that the micro cracks in the concrete are recovering and the concrete gets back its original strength after researchers subjected them to a 3 percent tensile strain. That means they stretched the specimens to 3 percent beyond their initial size.
It’s the equivalent of stretching a 100 cm piece an extra 3 cm—enough strain to severely deform and follow the deformation of the steel in the spiral and the deformations during the laying operations.
For the spiraling pipeline with concrete weight coating it is interesting to find the constraints of this elastic bending. As it looks like now the concrete is not the determining factor.

Due to the limitless tests that have been performed on steel and especially on pipeline it is easy to predict what the constraints for bend pipeline will be.
On average you can say that the diameter of the first layer of the spiral should be roughly 500 X the diameter of the pipe.
As long as the pipeline will stay within its own elastic area the pipe will not get into an oval shape. Ovalisation will occur when a pipe is bend beyond the boundaries of elastic deformation. Excessive ovalisation is not acceptable due to the fact of its incompatibility with the use of pigs and TFL tools in a later stage.

With the ‘O’-lay method it is possible to prepare any diameter of pipe to lay on the sea-bed. The advantage of this method is that pipeline will not be plastically deformed during spirailisation and the pipe will always return to its original form after the applied forces are taken away from the pipe.
Creating the spiral.

The spiral is created with the help of a central barge which has the capability to stay in a determined spot due to its dynamic positioning system. This barge acts as a center point (or central mooring system) and will act as a pivot in a later stage of creating the spiral.

![Image](image_url)

Picture 4. The “O”-lay Method. First part of the floating spiral being laid. The dynamically positioned auxiliary boats together with winches on the centre barge perform the initial bending and rotation of the spiral.

Around this central barge are several small auxiliary boats that are connected to the pipeline at intervals when the pipeline is pushed/pulled in the water.

At first the pipeline will be pulled in the water past point A in figure 4. When a sufficient part of the pipeline has been pulled past point A, (more than 2/3 of the length of the circumference of the spiral diameter) the pipe will be connected, at point A to the centre line and outer anchor line in such a way that the pipe cannot move sideways. The end of the pipe should than be pushed/pulled by a small support boat together with the auxiliary boats in the direction of the central point in such a way that the pipe will be orbiting the centre point at a predefined radius it will pass point B in figure 4. Here again the pipe will be attached to the centre and outer anchor line. This way the pipe parameters are fixed and the first circle of the spiral will not become too small and the deformation will stay in the elastic area due to the restriction of the anchor lines in the outer periphery.

The pipeline will be pushed/pulled further with the small motorboats around the centre point. At point C, D and E the pipe will be attached to the centrelines and to outer anchor lines in the outer periphery of the spiral to be.

When the pipe reaches point F only the centre line should be attached. From the moment that the small support boat has brought the length of pipe in the semi circumference and the centre lines are attached, the anchor lines in the outer
periphery at A, B en C, D and E can be released. These anchor lines form a restriction to rotate the pipe around the centre point.

While the tensioner, which is located onshore, is feeding pipe into the system the pipe will rotate around the centre point of the spiral, increasing the amount of pipe that is in the flat floating spiral. This way many layers of pipe can be produced, all floating in the plane of the surface of the water.
It is possible to create more than 100 km of pipe in one piece while the band of floating layers is still workable by the boats creating the spiral.

Transportation Stage.

Consider the pipeline has been spiralled over its complete length. In case rough sea is expected the spiral can be secured with some “transport” ropes to reduce the tension in the pipeline during its voyage.

The pipeline shall be propelled by the centre barge and the auxiliary boats (See figure 5 ) to the location where it will be lowered to the sea bottom. A tugboat could be kept available in the near vicinity to help out in case of an unexpected event occurs.
Offshore "O"-lay pipe laying by: Jan Buijvoets, Pipeline Technology Conference 2011 Hannover
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The anchor lines should be detached from the centre point and the spiral can be towed to the new location. Although the spiralled pipe can withstand rough waves (up to a certain limit the spiral can stand waves up to 4-5 meter) it is always good to consider the weather forecasts when the pipe is being transported. For logistic reasons it is recommended to choose a pipe yard that is in the vicinity of starting point of the laying location since the expected speed of travel of the spiral with maximum 8 knots is relatively low.

Unspiralislation stage and laying stage.

Due to the length of the pipe in the spiral the unwinding and the laying of the pipe will occur at the similar time. To have no constraints in laying, the part of the pipeline between the spiral and the lay barge should have a minimum length. This length depends on the pipe diameter, the number of windings in the spiral, the water currents and the speed at which the lay barge can lay the pipe. The pipeline between the barge and the spiral is important as it functions as a work buffer for the lay barge in case the spiral unwinding for some reason is delayed for a while.
Compared to the traditional methods of laying larger diameter pipe the speed of laying can be considerable higher. The basis for this is that no welding and ultrasonic inspection has to be performed on the pipe while the pipe is being transferred over the lay barge since these procedures have been done in the onshore pipeline construction yard.

The motive that the lay barge is being employed is that at the point where the pipe submerges, there is a need for guarded buoyancy so the pipe can be launched in the water in a controlled way. Depending on the positioning system, the size of the tensioners, type of stinger and floating capacity of the barge the pipes can be lowered to a certain depth. The higher the capacity of the barge the more depth can be reached.

The barge also functions as safety precaution in case a wet buckle would occur during the lay process.

The barge is relatively simply in its lay out. Due to the pipe being fed from the spiral there is no need for an enormous amount of workspace around the pipe. Instead of a stinger at the bow it is possible to lower the pipe at the centre of the barge. The weight of the pipe under the barge is better distributed and the angle of the heavy stinger can be accurately positioned. The barge consists of a lifting crane, a minimum of two tensioners (one at the stern and one at the stinger), an abandonment and recovery system, a positioning system (preferable a dynamic positioning system that can
interact with the dynamic positioning system of the centre barge), a barge stabilise and ballast system, a small workshop and living accommodations. It might be an option to have a single welding station and coating station on the barge in case the pipeline to be laid is for a project with a longer distance. As a consequence the pipeline can then be delivered in several lengths (more spirals).

When arrived at the location where the pipe has to be laid the spiral will be unwound using the centre barge and auxiliary boats connected to the spiralled pipe. The speed of laying the pipe is independent of the diameter of the pipe or on the depth of the seabed. However a very good cooperation between the lay barge crew and the team unwinding the spiral is of high importance. Specially the unlashing of the links which keep the layers on the spiral together should keep pace with the speed of laying. Speeds of laying can be expected to reach 20 to 25 kilometres per day.

Flotation devices which are used to keep the spiral afloat during storage and transport have to be released before the pipe enters the lay-barge. They will be stored and shipped back for storage to be re-used on a following operation.

“Pipe-in-Pipe” operations
“Pipe-in-Pipe” systems claim to provide high thermal performance, due largely to insulation in between two pipes. The choice of pipe-in-pipe for projects depends on expected flow assurance and offshore installation factors. The traditional pipe lay vessels laying “Pipe in Pipe” are slowed down due to the installation of two pipes that have to be put in instead of one.
To speed up the rate of laying very smart systems have been developed so that only the inner pipe carrying the well stream needs to be welded offshore while the outer pipe which ensures thermal and mechanical continuity of the system is attached in a different manner. Nevertheless it is a time and work space consuming methodology.

The field jointing process for “Pipe in Pipe” with the O-​lay technology can be performed totally onshore and therefore reduces the time of the offshore pipe laying and thus leading to a much faster lay rate for “Pipe in Pipe” compared to any other traditional lay methods and therefore making the pipe lay window relatively small.

**Retrieving pipe from the sea bottom**

For an obvious reason the O-​lay method is also a good option if you want to retrieve a pipeline from the bottom. Specially in case the pipeline is in such a good condition that a second life for the pipe is a possibility. In case of retrieving the pipeline from the bottom a safety factor for the spiral diameter should be considered. For ecological reasons this could be the method to clean up the seafloor from pipelines which are not in use. Economical this can be interesting to retrieve the pipe and re-​use the pipe again on a different location.

This will reduce the costs even further and could be very interesting to use on very small oil or gas fields and pipelines for offshore CO2-transport.

**Economics.**

Using the “O”-​lay method has on top of some logistical and technical advantages also huge economical advantages. Physical pipe handling and logistical management is less complicated when we compare the “O”-​lay method with the traditional method of pipe laying using the S-​lay technique. The pipeline is constructed on a land base pipeline construction yard. The construction of pipeline in a pipe yard has a considerable advantage compared to construction at sea. Personnel cost due to lower transportation costs, cheaper accommodations, less expensive living cost and finally but not the least important lower wages.

Equipment is not as expensive as the traditional lay barges with complete pipe management systems, large storage places for pipes, several welding stations, inspection stations and coating stations. The “new” type of lay barge will be less
complicated and smaller, therefore they can be build for a specific project or for multiple projects in the same range of pipe or area. Transport of the spiralised pipeline only needs three or four tugboats and a rigid lashing system which is part of the central mooring system of the spiral. From literature is known that pipe lay operation with reel lay barges will lower the cost of operation 50 to 70%. The maximum diameter at this moment for reel laying is 18 inch. It is plausible that economical advantages with the “O”-lay method would be even better.

Risk.
Using new systems and procedures in any industry entail always a certain risk. Specially in the offshore industry this risk has to be calculated because there can be large consequences for not only finance but also for personnel safety and environment. With this system a large part of the procedures have been moved from offshore to land based operations, therefore we expect smaller risks at a smaller operational cost. New procedures should be looked at with great effort. Due to the reduced number of personnel required to lay the pipe, lowering the risk of accidents is an important contribution of this new method.

In this paper we have not looked specifically at the risks. Nonetheless it is well believed that this new method will have a great future. Safety, financial, ecological and possible future failure are all considered to improve with this technology.

Conclusion

The “O”-lay method is expected as a low cost and relatively high speed method of laying pipeline in water depths from several meters to several thousands of meters. Speed of laying is estimated to be up to 20 to 25 kilometres per day. Therefore offshore operations time can be limited to a minimum and advantage can be taken from a relatively small weather window with optimal conditions for the pipe lay operations.

Due to its fast operation speed at sea, the relatively low capital expenditure, the mainly land based operations and the reduced number of personnel the costs of pipeline laying will be reduced enormously.

Because of the reduced number of personnel required for the offshore operations, the lower risk of accidents is an important contribution of this new method.
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