Design check of an S-Lay offshore pipeline launching using numerical methods

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Abstract. The production of oil and gas from offshore oil fields is, nowadays, more and more important. As a result of the increasing demand of oil, and being the shallow water reserves not enough, the industry is pushed forward to develop and exploit more difficult fields in deeper waters. The purpose of this paper is to determine the optimum launching parameters of a subsea pipeline in S-Lay system using the software OffPipe. The offshore pipelines designing is an intricate enterprise following very demanding designing codes since at stake is the integrity of multi-million dollars investments in offshore oil and gas exploitation facilities. The case study of this paper is taken on purpose to show how the numeric analysis may help to detect potential problems that might occur during pipe launching with S-Lay method. In the analysed case the launching process is under control since all the launching parameters and stresses are well below the critical ones. In any event the numeric modelling of the process was demonstrated to be a valuable tool in the design engineer hands in order to assess the feasibility of any launching subsea pipe launching.

1. Introduction
The production of oil and gas from offshore oil fields is, nowadays, more and more important. As a result of the increasing demand of oil, and being the shallow water reserves not enough, the industry is pushed forward to develop and exploit more difficult fields in deeper waters [1].

Deepwater pipelines are used to carry oil and gas from wellheads and manifolds to platforms or to shore. Figure 1 shows a simple representation of a deep-water installation, with the flow lines on the seabed and the risers, a section of pipeline from the seabed to platforms or ships.

In general terms, the diameter of offshore pipelines is spanning from 75 mm up to 150 mm. In some special occasions, the limit would be 1800 mm.

The special steels deployed for pipelines has as a rule the yielding strength very high up to 500 MPA and the composition is selected to respond well for weldability.

For protection the external layer is made out of bitumastic or epoxy serving the purpose to have a good corrosion protection in place, and often the cathodic protection with sacrificial anodes is put in place [2].
For stability, the negative buoyancy is ensured by concrete coating thick enough to ensure the pipe is safely seating on the seafloor (See figure2):

The purpose of pipelines is to lie on the seafloor with continuous or discontinuous support. Where the support is not present, the span of the pipe should be carefully calculated in order to avoid bending during functioning.

More often, the pipes are buried beneath the seafloor in order to avoid any interference with external elements like ship’s anchor lines or fishing trawlers.

The launching phase of the pipeline is subjecting the pipe to the most severe stresses to be encountered in the pipe entire useful life.

There are some well known methods for offshore pipeline launching such as:
1. Conventional S-lay barge
2. Bottom-pull method
3. Reel barge
4. Surface float
5. Controlled subsurface float etc.

The size of offshore laying barges increased constantly from 1950s to become sophisticated machinery [2]. They are classified in four generations, the most known is the one given in the figure 3:

2. Materials and methods

2.1. Numeric simulation input data

The software of choice for modeling the S-Lay pipe launching is OffPipe.

The software is aiming to assist the designer for optimising the pipe launching parameters for S-Lay scheme [3].

By its intrinsic functions of OFFPIPE can get best lay-barge configuration for certain pipe laying project, which is an important reference for later design procedures.
The purpose of this paper is to determine the optimum launching parameters of a subsea pipeline in S-Lay system using the software OffPipe.

In order to start the calculation some input data for the model are necessary as follows:
- Water depth-1000 m
- Water density-100050 N/m³
- Stinger radius-200 m
- Tensioner force-2800 kN

The pipe to be launch has the following characteristics:
- Material-Steel
- Material Yielding strength-448 MPa
- Young modulus-207000 MPa
- Steel density-76970 N/m³
- Outer diameter-508 mm
- Wall thickness-23.8 mm
- Coating thickness-20 mm
- Coating density-9000 N/m³

The optimization targets are set as well as follows:
- Best radius-210 m
- Best tension-3000 kN

3. Results and discussion
The optimum radius of the pipe and tension are calculated to be the lower and the upper limits imposed above, namely 200 m for pipe radius and 3000 kN for the stinger tension.

Same analytical results are provided in order to have a broader picture of the process. In order to do that a Cartesian system of reference is established and set in the position of the first tensioner, as seen in the following figure (figure 4):
The pipe shape during launching
The results are calculated for the entire launching path of the pipe from the tensioners to the touch down point.

For the first portion comprising the path from tensioners and the stinger, the shape of the pipe is given in the figure 5. As could be seen, the angle of the curve tangent is firstly small and then progressively increasing at the departing point from the stinger.

The inflexion point for the entire shape of the pipe, is placed at coordinate \( y = -300 \) m as in the figure 6.

![Figure 5. Pipe shape on stinger.](image)

![Figure 6. Pipe shape on the entire launching path.](image)

Reaction force
The reaction force (sometime called pipe tension) exerted by the barge structure over the pipe is given in the figure 7 and figure 8.

The maximum value is recorded for the departure point of the pipe from stinger having the value of 240 kN, See figure 7.

![Figure 7. Reaction force on the stinger.](image)

![Figure 8. Reaction force of the sea bottom.](image)

Once landed the soil is exerting a reaction force of 5 kN as seen above, figure 8.

The pipe axial force
The pipe axial force developed inside the pipe during launching is decreasing from the maximum of 3000 kN exerted by tensioners at coordinate \( x = 0 \) to 2925 kN at the departing point of the pipe from the stinger, figure 9.

From this point to the touch down point the axial force is decreasing slowly at the value of 2250 kN (See figure 10).
Bending moment
As to be seen below, the bending moment is under control as the pipe is supported by the barge launching structure to a value of -350 kNm almost constant for all the rollers, figure 11.

Once the pipe is leaving the stinger the bending moment is near to zero, with a small value of -5kNm on the touchdown point, figure 12.

Axial tension inside the pipe
The axial tension of the pipe is decreasing from 81 MPa at x=0 to 75 MPa to the last roller of the stinger, figure 13.

For the rest of the launching path this tension continues to decrease at 5 MPa, figure 14.
Von Mises equivalent tension
The von Mises tension is the “moment of truth” for the launching process. The lunching process is deemed to be under control since the biggest total stress is 380 MPa, far below the yielding strength of the material of 448 MPa, See figure 15.

Once the pipe is leaving the stinger the equivalent tension is suddenly decreasing to a average value of 110 MPa, figure 16.

4. Conclusions
The offshore pipelines designing is an intricate enterprise following very demanding designing codes since at stake is the integrity of multi-million dollars investments in offshore oil and gas exploitation facilities.

The case study of this paper is taken on purpose to show how the numeric analysis may help to detect potential problems that might occur during pipe launching with S-Lay method.

In the analysed case the launching process is under control since all the launching parameters and stresses are well below the critical ones.

In any event the numeric modelling of the process was demonstrated to be a valuable tool in the design engineer hands in order to assess the feasibility of any launching subsea pipe launching.

References
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