Master Thesis in Marine Technology – 2014

Snaking Behaviour of Umbilical

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Objective:

An umbilical passes through many operations in the manufacturing plant like bundling, extrusion, reeling on and off the storage drum, transfer into installation vessel. Different types of loads can appear in these stages of operation. And from these loads even before being in the operation field, umbilical can experience different type of deformation in the manufacturing plant like formation of plastic hinge, helical deformation or snaking etc. Snaking can arise from unbalanced bending moment of asymmetric arrangement of the components in cross section; residual curvature from friction effect in storage reel, creeping of outersheath, improper action of straightening machine; axial strain from the combination of squeezing and gravity load in tensioner.

To find the solutions of avoiding different deformations at the different loading conditions in the manufacturing plant and to ensure desire comfortable handling, it is necessary to predict their behaviours correctly at different loadings. Exact analytical and numerical modelling is needed to find and predict the exact behaviours of an umbilical model. In this thesis work number of modelling and simulations has done in USAP and Bflex to investigate the reason of snaking behaviour of three umbilicals, occurred in the manufacturing plant of Aker Solutions.

Introduction:

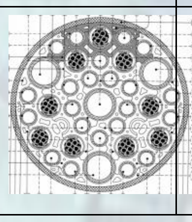
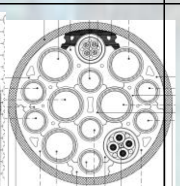
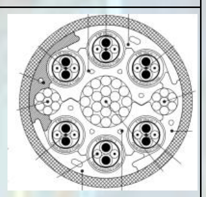
In this era of high energy demand around the world, people are exploring on subsea in search of new oil and gas resources. Many analysis, technology and instrument invention are going on to make this journey efficient and easier. Umbilical is one of those important technologies whose are helping us to reach at seabed.

Umbilical shows some regular and irregular snake like behaviour as experienced by Aker in some seldom cases either during manufacturing, main storage or installation time. When a flexible structure like umbilical behaves like snake, there could be challenges involved in handling it. Snaking cause problem in the installation and manufacturing work, it might also introduce structural deformation in the umbilical which is not desired. So it is important to know the conditions or cases of this behaviour to discover the ways of controlling.

USAP [1, 2] is a computer programme, developed by MARINTEK, for simulation of umbilical structures for determining both local and global behaviour. But USAP do static analysis only, to do the simulation in physical timing dynamic analysis need to do, which is possible in Bflex [3, 4].

The main focus of this thesis work has been on modelling the deformation pattern similar to that occurred in the Aker's manufacturing plant by doing the simulation of the actual model using different established features of software USAP and Bflex. Because then it is possible to know the reason of the deformation. It is also possible to know parameters that have effect on the deformation, intensity of their effect and also the possible solutions of not having the deformation.

Presentation of the Models:

Umbilical Name	Agbami	Droshky	Kipper
Outer radius (mm)	89	57.5	41.5
Thickness(mm)	5	5	4.5
Pitch length (m)	11.5	7	6
Lay Angle (degree)	2.8	2.96	2.5
Axial stiffness(N)	4.62E8	1.99E8	1E8
Bending stiffness (Nm^2)	2.68E4	0.858E4	0.549E4
Torsional stiffness(Nm^2)	2.06E4	0.66E4	0.1E4
Initial Symmetry of Cross Section	Symmetric	Asymmetric	Symmetric
Snaking Seen	Under installation, coming off reel	During extrusion	Turntable and installation carousal (i.e. when not in tension)
Cross Section			

Modelling:

Agbami:

Snaking found in Agbami when it was transferring from storage reel to installation vessel. So there could be three possible source of deformation, which has modelled and analysed in this work.

1. Friction effect in storage reel: when an umbilical is roll on and off in a storage reel then friction effect can come into play. Due to friction effect there will be curvature in the umbilical even on zero loading that is when the umbilical will roll out from reel it will still have curvature. So helix like shape or snaking is formed in the umbilical.

To investigate this phenomenon as the possible reason of snaking, umbilical Agbami has modelled in USAP (Figure1). The model consists of a core pipe modelled by PIPE31 element which is a straight cylindrical beam and 26 steel tubes modelled by HELIX231 element. The mechanical properties of the PVC profile and copper cables have lumped into the core pipe. The umbilical has then sent to the rolling on and off action in a reel of 2.5 meter radius.

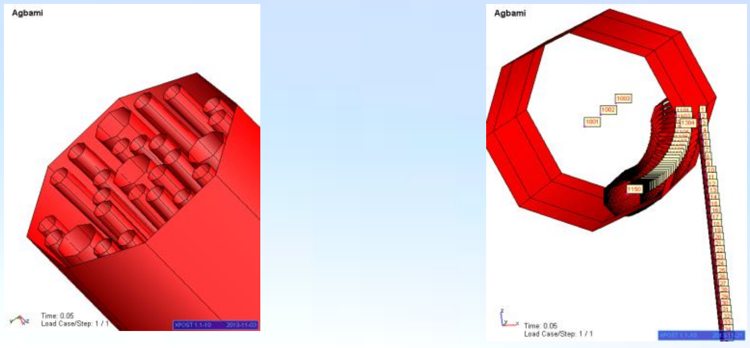


Figure1: Reeling of Agbami

2. Torsional instability in the unsupported length between storage reel and installation vessel: when an umbilical roll out from a storage reel, it could come out bearing some residual curvature on it. The source of curvature could be friction effect or creeping load from long time storage. Now due to gravity load in the unsupported portion of the umbilical which is very flexible in nature and have low bending stiffness, between storage reel and installation vessel, it could experience some curvature, which again could be in the opposite direction of its residual curvature. And when the opposite curvature amount is more than the residual one then the umbilical reaches in the criterion of having torsional instability. Due to torsional instability, umbilical will have deformation like cyclic bending. For the modelling of this snaking deformation case, the whole umbilical (Agbami) has considered as a single pipe element, PIPE31 of 12 meter length, which is the approximate distance between storage reel and installation chute taken from Figure . Simulation has run for 50 seconds. Residual curvature has activated from the first second. When it has build up in 10th second with full magnitude tension and torsion has started to apply, which means that umbilical start to move from storage reel to installation vessel. Tension of 2KN is action for the transfer operation. Gravity load is acting from twenty first second when the Agbami has start to feel unsupported in the in between portion of storage reel and installation chute.

3. Axial strain in tensioner of installation vessel: when an umbilical moves from manufacturing plant to the installation vessel, it passes through the tensioner machine. In the tensioner, umbilical is squeezes in to make it straight and it also experiences gravity load due to its vertical position in the tensioner. Any number of umbilical components can experience axial strain due to combination of gravity and squeezing load in the tensioner. When a helix component experience axial strain it transfer tension on its portion behind. So the portion of umbilical just before the tensioner which is on installation chute can experience snaking.

This phenomenon has modelled in Bflex, considering one steel tube will have axial strain. So the model consists of one steel tube and one core pipe (Figure2). The mechanical properties of all other components except the selected steel tube have lumped into the core pipe. The analysis has run for 10 second. Axial strain has applied not from the beginning since it is not residual axial strain. It has suddenly appeared in the tensioner, so axial strain has started to apply after third second.

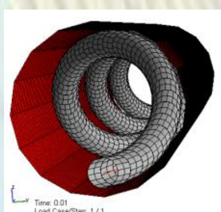


Figure 2: Agbami axial strain

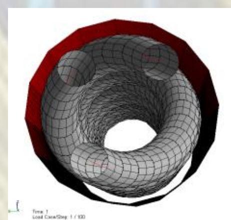


Figure 3: Droshky

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Droshky:

Droshky has unsymmetrical cross section and showed snaking when just after the extrusion. Residual curvature of component steel tubes is the probable reason in this case. Before bundling of all the components in extrusion process each component steel tube passes through the straightener machine and due to error in the straightening process steel tubes could come out with curvature from straightener machine. The deformation has pitch length of about 4.5 meter with amplitude 38 millimetres.

Droshky has modelled in Bflex with asymmetric arrangement of three steel tubes, other tubes and components have lumped into the core pipe (Figure 3). The core pipe has been modelled as a straight cylindrical beam with PIPE31 element. Steel tubes are modelled with HSHEAR353 element with tubular cross section. Three contact elements with three helixes of HCONT453 element type has included for numerical stability. Loading has applied as residual curvature both about Y and Z axis.

Kipper:

Kipper is a quite unorthodox type of umbilical having no steel tubes but some electrical wires of steel. It has showed very minor irregularities or snakelike deformation. When it was not in motion but kept on the turntable after extrusion and also when put on installation carousal. The severe form of deformation or snaking it has showed when it was spooling off from the storage reel. The modelling has done to investigate the deformation at these two stages of operation.

The phenomenon which has modelled here is, an umbilical is rolling on in a reel (turntable E of the Aker manufacturing plant) and then rolling out from the reel. Friction effect has introduced by applying residual axial strain in the helixes. Kipper is modelled in Bflex with a core pipe having two helix tubes on it (Figure 4). The two bundles at two side of the center have modelled as helix tube having the same outer radius as wire bundle. The steel tube has modelled with the same mechanical properties as the wire bundle so that the mechanical behaviour will be same.

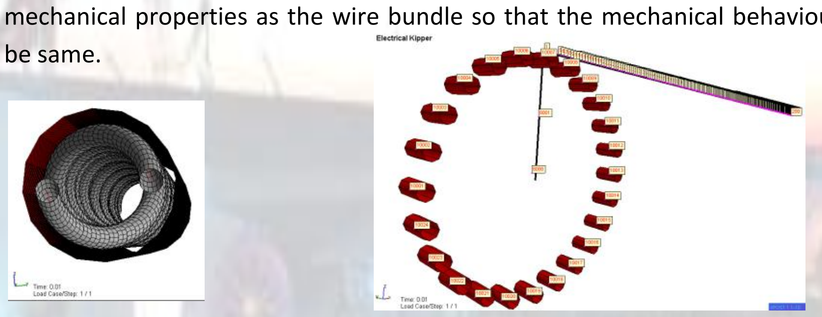

Figure 4: kipper

The reel is consists of 24 equally spaced rollers, which are modelled by CONT164 elements. To obtain the rotation of the umbilical along the reel a spring element (SPRING137) has placed at the center. To make the umbilical follow the rotation of reel center a connection has set between them by a two nodded pipe element modelled by PIPE31.

Results:

Agbami:

The effect of friction during spooling on and off can be found from the moment curvature diagram. The spooling has done through an angular amount of 90 degree and the corresponding moment curvature diagram has found as Figure 5.

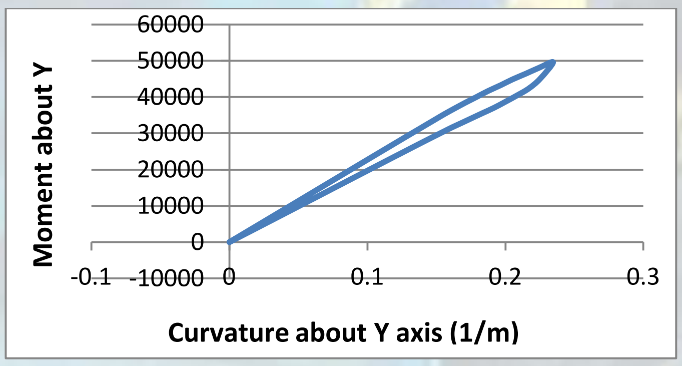

Figure 5: Moment curvature of Agbami Reeling

The curve is coming back to zero after spooling off and the area under the curve is also very small. So there is no friction effect, when Agbami spool on and off on its storage reel. That is no curvature develops in Agbami due to spooling action on the storage reel.

The snaking deformation of Agbami has amplitude of 0.4 meter and pitch length of 9 meter. Similar value of pitch length and amplitude have found from the Bflex model of 12 meter length and having residual curvature of 2.5 meter radius in torsional instability modelling. Figure 6 below

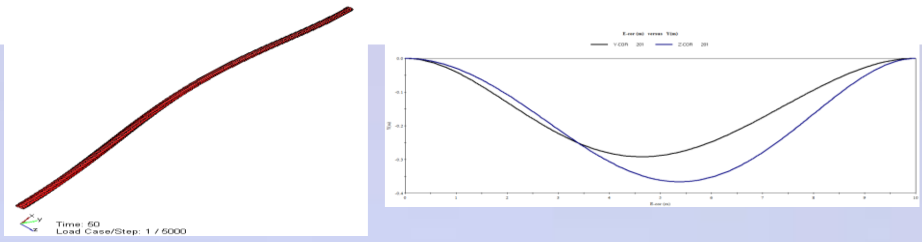

Figure 6: Torsional Instability

2.5 % axial strain of a 34.5 meter model creates the helical deformation with same pitch length and amplitude as Agbami in axial strain modelling. Deformation increases with the increase of axial strain. Figure 7 below

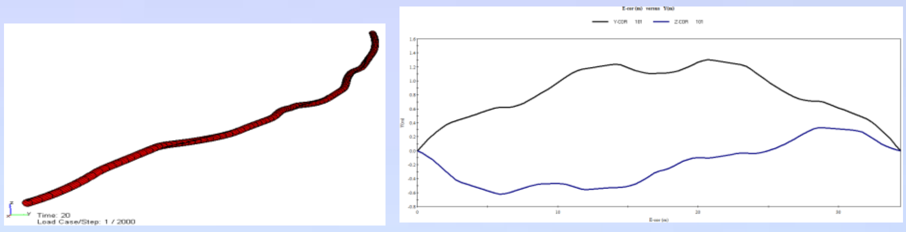

Figure 7: Axial Strain

Droshky:

For a 28 meter model similar deformation has found, when the curvature is 30% of initial applied curvature. Tension require to straighten this curvature is about 55 MN. Figure 8 below

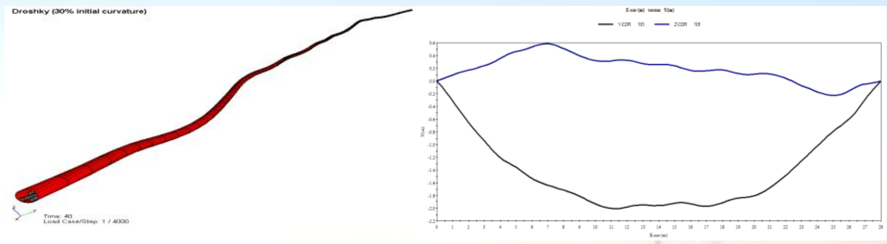

Figure 8: Droshky

Kipper:

The deformation picture after completing the spooling has found as in Figure 9 below which is quite similar to the picture of kipper on turntable. The deformation pattern is not like helix. It is like, some plastic hinges are forming after some interval of length and the umbilical is moving out from the contact with roller at that position

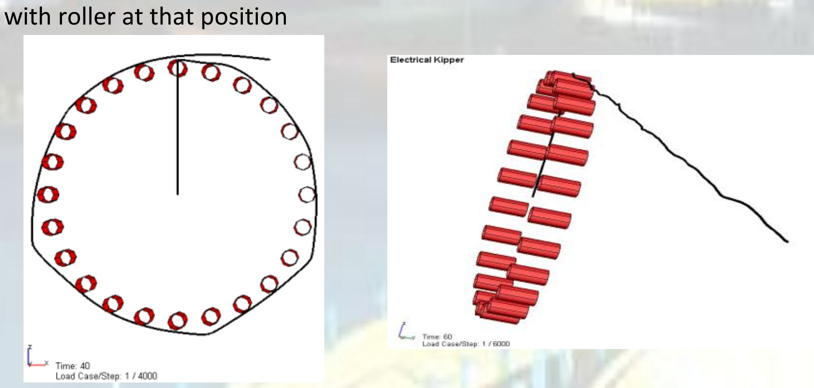

Figure 9: Kipper

The deformation formed in the model after spooling off has found as in above. Here the pattern is like helix as that found in the real case of Aker's manufacturing plant. 0.02% axial strain has applied in this case.

Conclusions:

From the modelling and simulation results, the reasons of snaking or helical deformation found for three models are:

Model	Phenomenon modelled	Result found from modelling
Agbami	Reeling on and off	No development of friction during reeling
	Axial strain in steel tubes from the tensioner	Axial strain in steel tubes from the squeezing in and gravity load in tensioner
	Transferring from storage reel to installation carousal	Torsional instability in the unsupported length
Droshky	Application of harmonic residual curvature in the steel tubes	Residual curvature in the steel tubes, appeared from individual storage reel before bundling
Kipper	Reeling on and off with residual axial strain in wires.	Development of friction

Reference:

1. Sævik, S. (2010-03-01). Usap - Theory Manual, Marintek report no. 700254.00.01. MARINTEK, Trondheim, Norway.
2. Sævik, S. (2009-01-07). Usap - Version 3.2 User Manual, Marintek report no. 700861.00.01. MARINTEK, Trondheim, Norway.
3. Sævik, S., 2009. BFLEX2010 - *Theory Manual*. MARIN-TEK, Trondheim, Norway.
4. Sævik, S., Økland, O. D., Baarholm, G. S., and Gjøsteen, J.,2009. BFLEX2010 - *Users Manual*. MARINTEK, Trondheim, Norway. Marintek Document.