

# Processing and pipelines coursework engineering essay

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**PROCESSING AND PIPELINES COURESEWORK**

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### **Executive Summary:**

This report shows the basic deflection and stress analysis carried out during the installation of shallow water S-lay barge pipeline. The bending stress in the overbend region is calculated using Simple Engineer's Bending stress equation. Deflection and bending stress in the sagbend region is obtained by the Cable catenary theory and the Buoyancy theory is used to find out the wall thickness of pipe. The manually calculated theoretical results of the above mentioned methods are compared with the results of the commonly used pipeline and riser design software called Orcaflex. In this report, the critical evaluation of bending stress in Overbend and Sagbend region is carried out to explain the variations between the Theoretical and Orcaflex results.

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## 1) BACKGROUND:

The S-lay configuration of shallow water pipeline installation is shown in the figure-1 below. The steel pipeline from L450 (equivalent to X65) grade material is used for construction. The pipeline lifts off the stinger 14m below the sea level. The area above the point of inflection is called as overbend region and the area below the point of inflection is called as sagbend region.

overbend region (above point of inflection)  
Sea bed  
Sagbend region (up to point of inflection)  
Stinger  
Point of Inflection  
lift off point  
Lay barges  
sea level  
Touchdown point

Fig: 1 - S-Lay Configuration. Pipeline data is given in the table-1 below. Pipeline data

Symbol	Value	Units	Material, Specified
SMYS	450	MPa (or MN/m <sup>2</sup> )	Outer diameter
DO	323.9	mm	Submerged pipeline weight/ unit length
Wa	0.944	KN/m	Stinger radius
R	135	m	Water depth (mean sea level)

-

50. 0m Modulus of Elasticity E 210 GPa (or GN/m<sup>2</sup>) Table: 1 - Pipeline Data.

## 2. Main Technical Section:

### 2. 1. Analysis of Bending stress in overbend region:

#### 2. 1. 1. Theoretical Bending Stress calculation:

Engineer's Bending Stress equation is given by: where, E = Modulus of Elasticity (Pa or N/m<sup>2</sup>) = 210 GPa  
 R = Radius of Curvature of pipe (m) = 135 m  
 M = Bending Moment (Nm)  
 I = second moment of area of pipe (m<sup>4</sup>)  
 $\sigma$  = Bending Stress (Pa or N/m<sup>2</sup>)  
 y<sub>n</sub> = Distance between neutral axis and the extreme fibre of pipe. = (Outer diameter/ 2) = DO/2 = (323. 9 x 10<sup>-3</sup>)/2 = 0.16195m  
 In order to find ( $\sigma$ ), Equate the Engineer's Bending Stress equation in following way.

=

$\sigma$  =

$\sigma$  =

Therefore, Maximum stress in overbend region = 251. 922 MPa or MN/m<sup>2</sup>.

### Comparison with Orcaflex result in Overbend Region:

Fig: 2 - Theoretical and Orcaflex Bending stress in overbend region

### 2. 2. Cable Catenary Analysis in Sagbend Region:

The various analysis of the sagbend region of the S-lay pipeline is carried out using Cable Catenary Theory. The key equations related with the cable catenary theory are as follows, 1)  $a * y^2$  2)  $y = 3$  (Rc) = Where, T = Tension at any general point (x, y) along length catenary = 200 KNH = Horizontal reaction force at touchdown point (N)  
 X = Horizontal distance of catenary from touchdown point (m)  
 Y = Vertical height of catenary from the seabed at

a point x (m)  $W_a$  = Submerged weight per unit length of catenary (N/m)  $R_c$  = Radius of curvature (m). Sea level  $T_{top}$  Point of Inflection  $T_{touchdown}$  point  $x_s$   $y_s$   $H$   $F$  Fig: 4 - Cable Catenary model of sagbend region.

### 2. 2. 1. Horizontal force at touchdown point:

The simple cable catenary equation is modified into the following form, a \*  $y$   $H = T - (W_a * y) = 200 \text{ KN} - (0.944 \text{ KN/m} * 36\text{m}) = 200 * 10^3 - (0.944 * 10^3 * 36) = 166.016 * 10^3 \text{ N} = 166.016 \text{ KN}$   $H = 166 \text{ KN}$ .

### 2. 2. 2. Deflection Profile:

The values of X coordinates are given in the Orcaflex software data. The value of Y coordinates for the corresponding X values are calculated by substituting the X coordinate values in the following simple cable catenary equation.  $y =$  The values of horizontal coordinate are considered up to 150 (m). Orcaflex X Coordinate (m) Theoretical Y Coordinate (m) 00251.780507. 1567516.24010029. 21012546. 32615067. 940 Table: 2- Deflection profile Theoretical x, y coordinates. Fig: 5 - Deflection profile in Sagbend region.

### 2. 2. 3. Superimposed Deflection Profile in sagbend region:

X Coordinate (m) Orcaflex Y Coordinate (m) Theoretical Y Coordinate (m) 000250.61.780503.57.156758.816.24010017.229.21012529.046. 32615041.867.94017550.094.50020052.1126.520 Table: 3- Theoretical and Orcaflex (x, y) coordinates. Fig: 6 - Superimposed deflection profile in sagbend region.



### 2. 2. 4. Radius of curvature:

Differentiating the simple catenary equation on both sides,  $y = [ \sinh ( )$

$(Rc) =$

$=$

$\cosh^2(ax) - \sinh^2(ax) = 1$  (Trigonometric equation)  $1 + \sinh^2(ax) = \cosh^2$

$(ax)$  Therefore  $(Rc)$  becomes,  $(Rc) = (Rc) =$

### 2. 2. 5. Bending Stress Profile:

In order to obtain the bending stress values the following formula is used,

$\sigma =$

The value of bending stress is obtained from substituting the value of X from Orcaflex software in the radius of curvature equation and bending stress equation. The calculated values are tabulated below, Horizontal Distance

X(m) Radius of curvature(m) Bending Stress ( $\sigma$ )(MPa) 10176. 434192.

70720178. 148190. 85330181. 032187. 81240185. 120183. 66550190.

467178. 50960197. 141172. 46570205. 230165. 66880214. 837158.

26090226. 086150. 385100239. 125142. 185110254. 120133. 795120271.

269125. 337130290. 790116. 923140312. 940108. 647145325. 086104.

617 Table: 4 - Calculated Theoretical values of Bending stress. Fig: 7 -

Theoretical bending stress profile in sagbend region.

### 2. 2. 6. Superimposed bending stress profile:

Horizontal Distance X(m) Orcaflex Bending Stress(MPa) Theoretical

Bending Stress (MPa) 1013192. 7072055190. 85330105187. 81240133183.

66550144178. 50960150172. 46570150165. 66880148158. 2690144150.

385100140142. 185110133133. 795120118125. 33713093116.

92314040108. 6471450104. 617  
Table: 5 - Shows the values of Theoretical and Orcaflex Bending Stress values. Fig: 8 - Theoretical bending stress profile in sagbend region.

### 2. 3. Pipe - Wall Thickness using Buoyancy Principle:

Buoyancy force = Weight of the displaced fluid. = (Weight of the steel pipe in air - weight of the steel pipe in water). Therefore, Weight of the steel pipe in air = Buoyancy force + weight of steel pipe in water. Buoyancy force = Density of sea water ( $\rho_{\text{sea water}}$ ) \* volume of water (V) \* g =  $1030 * \pi * (D_o / 2)^2 * 9.81$  where,  $D_o = 0.3239\text{m}$ , the above equation becomes,  
Buoyancy force =  $832.565 \text{ N/m}$   
Weight of steel pipe in water ( $W_a$ ) =  $944 \text{ N/m}$   
Weight of steel pipe in air =  $832.565 + 944 = 1776.565 \text{ N/m}$   
Therefore, Weight of pipe in air =  $\rho_{\text{steel}} * V_{\text{per unit length}} * g$   
 $1776.565 = 7.8 * 10^3 * \pi * [(D_o / 2)^2 - (D_i / 2)^2] * 9.81$   
Substituting  $D_o = 0.3239\text{m}$  in above equation,  
 $D_i^2 = 0.07548$   
Therefore,  $D_i = 274.5 \text{ mm}$   
Thickness of the steel pipe =  
Where,  $D_o = 323.9 \text{ mm}$   
 $D_i = 274.5 \text{ mm}$

=

Thickness of steel pipe =  $24.7 \text{ mm}$

### 3. Critical Evaluation of Results:

Critical Evaluation of following three aspects are carried out in this report, a) Bending stress in the overbend region, b) Deflection profile in the pipeline sagbend region c) Bending stress variation in the sagbend region.

### **3. 1. Bending stress in the overbend region:**

The bending stress curve in the overbend region and sagbend region is shown in the graph below. The bending stress value of orcaflex is minimum at 145m while the theoretical value is minimum at 150m. From 150m to 200m, both orcaflex and theoretical bending stress value is similar with little variations. The similarity is due to the case that the Riser is analysed as a beam which is fixed at ends, whereas same initial position of touchdown point for both cases. Fig: 9 - Superimposed bending stress profile in both overbend and sagbend region. The Orcaflex software result shows the stress at point of inflection is zero. But, in the theoretical result the stress at point of inflection is not zero. This may be due to the following reasons. Some of the parameters such as frictional losses, direction of wind, direction of wave current may not be considered while calculating the theoretical bending stress.

### **3. 2. Bending Stress Variation in Sagbend Region:**

The sagbend region in the above mentioned graph is the area before 145m. Theoretical bending stress values of the sagbend region is obtained from the cable catenary theory. The variation between Orcaflex and theoretical result may be due to following reasons. a) In orcaflex software various types of factors are considered according to the method being used. The factors such as, buoyancy, weight, axial elasticity, friction and current drag are considered during calculation. b) In both Orcaflex and theoretical calculation the contact with soil is ignored. c) In both calculations the Buoyancy factor change with depth is assumed as constant. d) In theoretical calculation, large number of factors such as effect of axial stretch, bending stiffness, friction, <https://assignbuster.com/processing-and-pipelines-coursework-engineering-essay/>

soil reaction, static lateral displacement due to wind, current are not taken into account. e) In theoretical calculation, the riser is assumed as simple and inextensible cable. f) In both calculations if catenary method is used in the software, the effect of bending and torsional stiffness of the pipe can be neglected. g) In theoretical result, the bending stress would be high in sagbend region at touchdown point (RC will be maximum), while in Orcaflex result the bending stress will be minimum at the same point.

### **3. 3. Deflection Profile in the Pipeline Sagbend Region:**

The superimposed deflection profile in pipeline sagbend region is shown in the graph below, Fig: 10 - Superimposed deflection profile in Sagbend region. The Orcaflex values are within the limit of 50m water depth. But, the theoretical value shows variation from the limit. This variation is due to not considering the factors such as direction of wind and wave currents, drag force, top angle, hydrodynamic parameters during the theoretical calculation. There will be change in the tension along the catenary length whenever the horizontal distance from the touchdown point increases. This change in tension is not considered in theoretical calculation.

### **4. Conclusion:**

The results of Orcaflex software and analytical calculations are compared in detail. It is proved that the orcaflex software calculation is the detailed and the best method when compared to the analytical method of calculation. As it considers all the important factors, Orcaflex software is indeed can produce the accurate result than the cable catenary method. Even though the cable catenary method of calculation is less expensive when compared

to the Orcaflex software, but it will lead to the large variation in the final result.

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