

Underwater Circular Curve Implementation for Offshore Pipe-line Installation

Case Study: South Pars Phase 12 Pipeline Snake-lay
Operation (5378)

By:
Kamyar Shojaee
Kito Enterprises Company, UAE



What is Offshore Pipe-Laying?

A three minutes [movie](#)

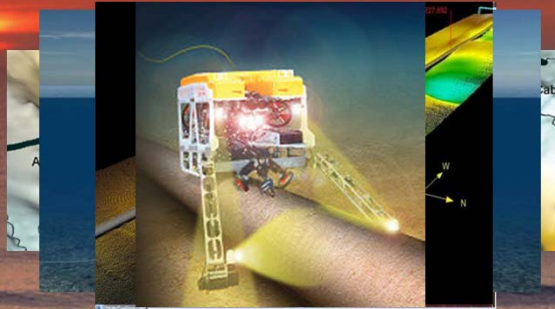
6/3/2011

Kito Enterprises

2

What Surveyors do in this industry?

- Pre-Engineering Survey
- Pre-Lay Survey
- Positioning services on Lay-barge during lay
- Post Survey
- As-Built Survey



6/3/2011

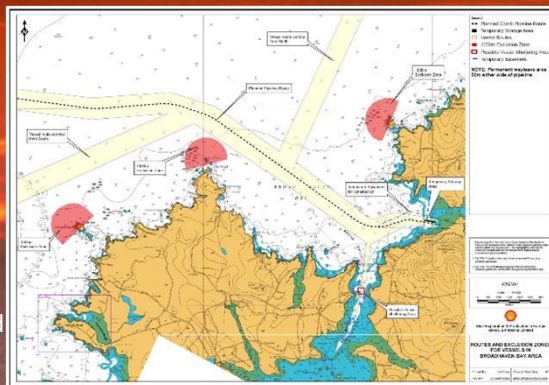
Kito Enterprises

3

Pipe-line Routes

Routes are designed based on:

- Topography of the seabed
- Seabed Hazards and debris
- Seabed layers and Soil characteristics
- Type of materials which is going to be transferred by pipeline

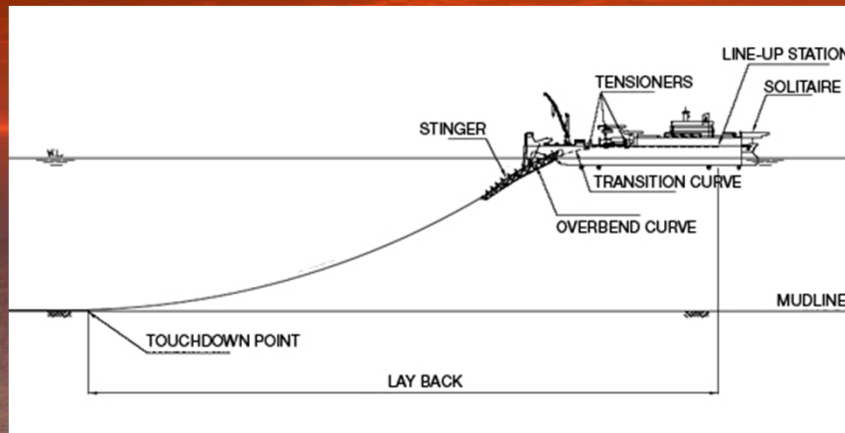


6/3/2011

Kito Enterprises

4

Definitions



6/3/2011

Kito Enterprises

5

What Surveyors Provide on Lay Barge

The screenshot shows a software interface with a map and a data table. The data table is as follows:

| Interpretation | Time | Range | Point/Quality |
|------------------------|---------|-------|--------------------|
| Latitude Pos (NMEA) | 712.000 | 1 Hz | 137.47 03076 0.00 |
| Longitude Pos (NMEA) | 712.000 | 1 Hz | 1201.14 471 E 0.00 |
| Height Pos (NMEA) | 712.000 | 1 Hz | 0.00 0.00 |
| Height Node GPS | 712.000 | N/A | 0.00 0.00 |
| Latitude Pos (NMEA 2) | 712.000 | 1 Hz | 137.47 03076 0.00 |
| Longitude Pos (NMEA 2) | 712.000 | 1 Hz | 1201.14 471 E 0.00 |
| Height Pos (NMEA 2) | 712.000 | N/A | 0.00 0.00 |
| Height Node GPS | 712.000 | N/A | 0.00 0.00 |
| CM Date | | 1 Hz | 2008.00 1.00 |

Below the table, there is a pink box with the following text:

Date: 11/4/2009
 Time: 14:37:12
 Steered Point: Stinger Hinge
 K 645602.66
 N 3029404.33
 East: 227.127 - 91.981743 N
 East: 52.228 - 2776849 E
 CM Gyro: 203.0
 ANT Gyro: 0.0
 CM SDO: 0.0
 ANT SDO: 0.0
 Sounding: 403.25 0
 SWAY: 189 203.0

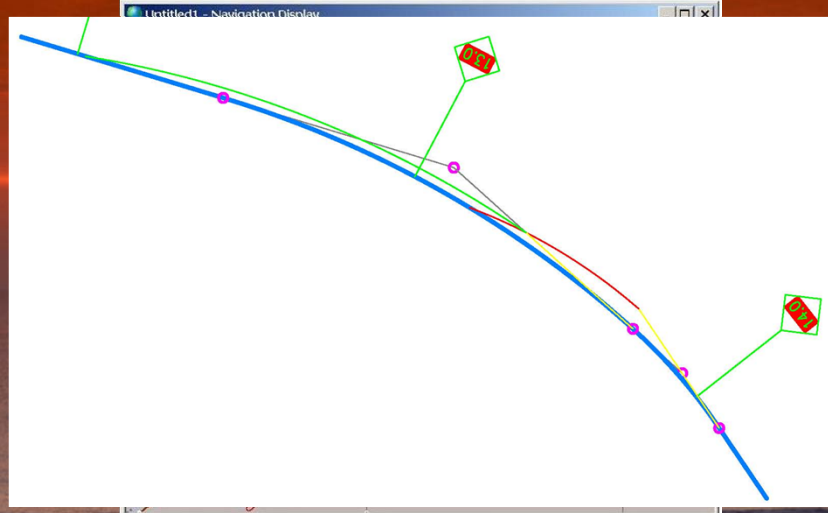
At the bottom of the interface, there is a status bar with the text: TO LE CHANGE 0.0792

6/3/2011

Kito Enterprises

6

Curve Implementation



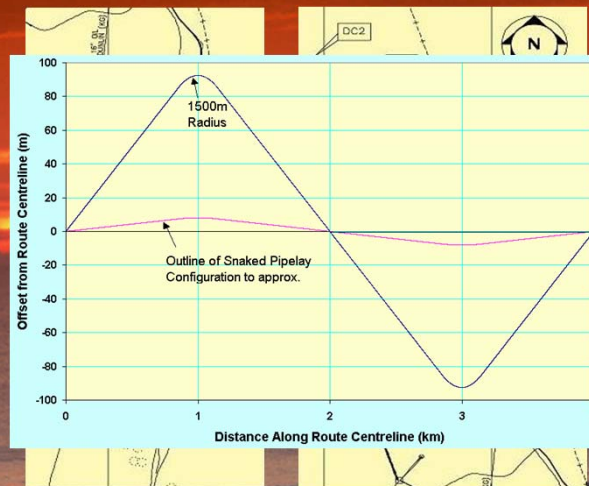
6/3/2011

Kito Enterprises

7

Snake-Lay

- High temperature material transfer
 - It may buckle the pipe longitudinally due to expansion
 - Wet buckle may happen during the commissioning

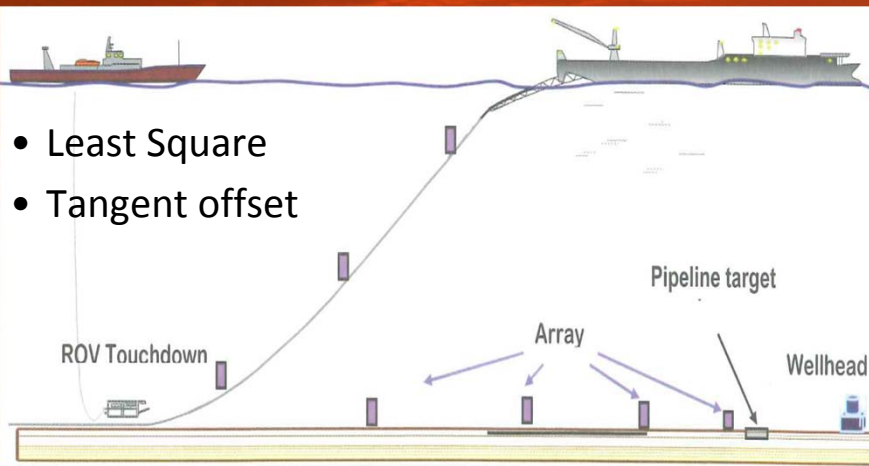


6/3/2011

Kito Enterprises

8

Online Curve Radius Monitoring



- Least Square
- Tangent offset

6/3/2011

Kito Enterprises

9

Least Square Method

Feasibility Study

$$A = \begin{bmatrix} 2x_1 & 2y_1 & -1 \\ 2x_2 & 2y_2 & -1 \\ \vdots & \vdots & \vdots \\ 2x_i & 2y_i & -1 \end{bmatrix}$$

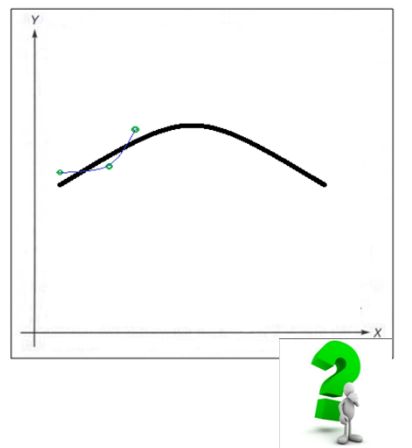
$$X = \begin{bmatrix} X_0 \\ Y_0 \\ f \end{bmatrix} \quad L = \begin{bmatrix} x_1^2 + y_1^2 \\ x_2^2 + y_2^2 \\ \vdots \\ x_i^2 + y_i^2 \end{bmatrix}$$

$$R = \sqrt{X_0^2 + Y_0^2 - f}$$

The observation equation and solution is as below:

$$AX = L + V$$

$$X = (A^T A)^{-1} A^T L$$



6/3/2011

Kito Enterprises

10

Least Square Method

Comparison of two survey

Comparison of two sets of as-built survey with least square method

| ROV fixes - First Try | | | ROV fixes - Second Try | | |
|-----------------------|------------|-------|------------------------|------------|-------|
| Eastings | Northing | Bias | Eastings | Northing | Bias |
| 638860.95 | 2951054.29 | -0.19 | 638860.95 | 2951054.29 | -0.19 |
| 638858.81 | 2951046.17 | -0.99 | 638859.81 | 2951046.17 | 0.00 |
| 638858.89 | 2951036.25 | -0.08 | 638858.89 | 2951036.25 | -0.08 |
| 638857.30 | 2951025.33 | 0.11 | 638857.30 | 2951025.33 | 0.11 |
| 638854.95 | 2951016.42 | -0.99 | 638855.95 | 2951016.42 | 0.00 |
| 638854.83 | 2951006.61 | 0.29 | 638854.83 | 2951006.61 | 0.29 |
| 638853.15 | 2950996.63 | 0.10 | 638855.15 | 2950996.63 | 0.16 |
| 638851.92 | 2950986.73 | 0.42 | 638852.92 | 2950986.73 | 1.41 |
| 638849.88 | 2950975.95 | 0.10 | 638849.88 | 2950974.95 | 0.21 |
| 638848.17 | 2950966.08 | 0.07 | 638849.17 | 2950967.08 | 0.95 |
| 638847.58 | 2950957.12 | 1.13 | 638848.58 | 2950958.12 | 2.01 |
| 638844.17 | 2950947.31 | -0.47 | 638843.17 | 2950947.31 | -1.46 |
| 638842.82 | 2950937.38 | 0.07 | 638842.82 | 2950937.38 | 0.07 |
| 638840.92 | 2950927.56 | 0.12 | 638840.92 | 2950927.56 | 0.12 |
| 638838.48 | 2950917.58 | -0.30 | 638838.48 | 2950917.58 | -0.30 |
| 638836.67 | 2950907.93 | -0.04 | 638836.67 | 2950907.93 | -0.04 |
| 638834.41 | 2950898.00 | -0.14 | 638834.41 | 2950898.00 | -0.14 |
| 638832.64 | 2950888.27 | 0.29 | 638832.64 | 2950888.27 | 0.51 |
| 638829.98 | 2950878.47 | -0.10 | 638829.98 | 2950878.47 | -0.10 |
| 638827.58 | 2950868.68 | -0.16 | 638827.58 | 2950868.68 | -0.16 |
| 638827.55 | 2950867.90 | 0.03 | 638827.55 | 2950867.90 | 0.03 |

| Least Squar Result - First Try | | | Least Squar Result - Second Try | | |
|--------------------------------|----------|----------|---------------------------------|----------|----------|
| Center of Curve | | Radius | Center of Curve | | Radius |
| E | 637672.8 | 1192.913 | E | 637912.2 | 950.9521 |
| N | 2951169 | | N | 2951129 | |

| Deviation | | |
|-----------|----------|----------|
| Center | | Radius |
| E | 302.034 | |
| N | -55.4549 | -306.754 |

| Deviation | | |
|-----------|----------|----------|
| Center | | Radius |
| E | 541.4124 | |
| N | -95.2832 | -548.715 |

6/3/2011

Kito Enterprises

11

Tangent Offset

Circular Curve Layout by Tangent Offset

(TD) and tangent offset (TO) can be calculated as below:

$$TD = c \cos \delta$$

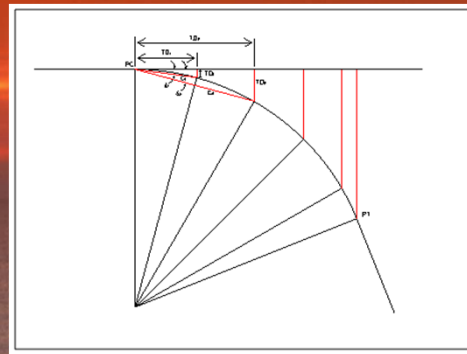
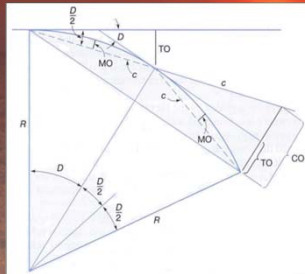
$$TO = c \sin \delta$$

Where δ angle ($D/2$ in figure) or deflection angle can be calculated by:

$$\delta = \frac{L}{2R}$$

And chord (c) formula is:

$$c = 2R \sin \delta$$



6/3/2011

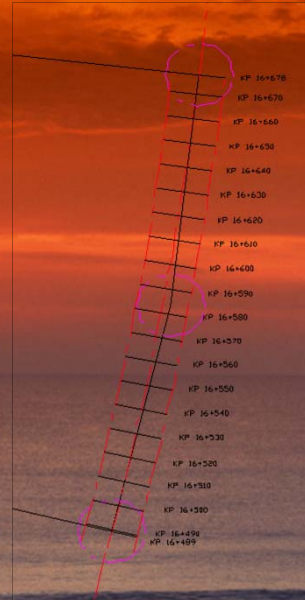
Kito Enterprises

12

Tangent Offset

Circular Curve Stationing and Staking

- Staking in the underwater operation is not going to be a real wooden or metal stakes which are stubbed on the sea bottom.
- The virtual staking will be done in online survey software and the positioning of the stakes will be fixed by "Go Go" method using DGPS and USBL.



6/3/2011

Kito Enterprises

13

Tangent Offset

Implementation in Operational mode

- **The curves will be staked** by KPs and the related parameters will be calculated
- **ROV fixes will be taken** in pre-designed stakes as the laying is going on.
- ROV fixes (Easting and Northing) will be entered into the related **calculation sheets** and the real tangent offset and biases will be calculated
- **The biases will be transmitted** on line via radio signals to the pipe-layer barge for DP operators' action.
- The next additional **movement of the barge** will be done based on the survey data to either port side or starboard side.
- The **actual radius of the curve** will be calculated as it is being expanded by more pulls based on tangent offsets. It helps to control the curve to stay in the corridor and given tolerances.

6/3/2011

Kito Enterprises

14

Tangent Offset Results

| Stake | IP | Staking Interval | Central Angle Increment | Deflection | | Chord | | Tangent | | ROY Inc. | | Analysis | | Verify (Should Match to Tol) | | Radius | |
|-----------------------------|----------|-----------------------------|-------------------------|----------------------------|----------------------|-----------------------|-----------|----------------------|--------------------|----------|----------|-------------------------|-----------|------------------------------|------|--------|-------------|
| | | | | Incremental Deflection (°) | Deflection Angle (°) | Incremental Chord (m) | Chord (m) | Tangent Distance (m) | Tangent Offset (m) | Bearing | Northing | Observed Tangent Offset | Error (m) | STED (%) | Pass | STED | Radius Base |
| Curve Summary Result | | | | | | | | | | | | | | | | | |
| Curve No. | Radius | Centre | | | | | | | | | | | | | | | |
| 1 | 1243.031 | 637623.594 E, 2951172.399 N | | | | | | | | | | | | | | | |
| 2 | 1308.170 | 639482.536 E, 2948034.657 N | | | | | | | | | | | | | | | |
| 3 | 1549.602 | 636289.238 E, 2946671.455 N | | | | | | | | | | | | | | | |
| 4 | 1312.937 | 639179.627 E, 2943153.238 N | | | | | | | | | | | | | | | |
| 5 | 1474.933 | 633015.246 E, 2944443.838 N | | | | | | | | | | | | | | | |
| 6 | 1284.163 | 633217.092 E, 2941276.737 N | | | | | | | | | | | | | | | |
| 7 | 1385.203 | 633111.248 E, 2940141.265 N | | | | | | | | | | | | | | | |

6/3/2011

Kito Enterprises

15


Conclusion

- LS method Does work for the curves which has implemented in order to find the radius of the curve
- TO is the best option to monitor the radius of curve during implementation of curve
- Once the pipeline was laid on the pre-designed route an As-Built survey could be done and the radius can be calculated by LS method

6/3/2011

Kito Enterprises

16



Thanks for your attention.

Any Question?

6/3/2011

Kito Enterprises

17