Identification of Free Span on Underwater Pipeline using Side Scan Sonar and Dual-head Scanning Profiler

Danar G Pratomo1, Khomsin2, and P L Harlambang3
1,2,3 Department of Geomatics Engineering, Faculty of CIVPLAN, Institut Teknologi Sepuluh Nopember, Surabaya, 60111, Indonesia

Email: guruh@geodesy.its.ac.id

Abstract. Indonesia is a country that has an important role in the oil and gas industry. Considering this important role, it is necessary to conduct an inspection and safety inspection to support the sustainability of the oil and gas industry in Indonesia. In this study the method used is the processing of side scan sonar (SSS) and dual-head scanning profiler (DHSP) data obtained from PT. Pageo Utama. Side scan sonar data is used as a visual representation of the pipeline while dual-head scanning profiler data is used to obtain the topography of the sea and surrounding pipes to identify the dimensions of the free span. The result of this study shows 47 free spans from a 6.8 km underwater pipeline. Free span with the longest dimension is FS-43, with length of 42.109 m and height of 0.44 m, which is located at KP 6.045. Free Span with the highest dimension is FS-45, with height of 1.22 m and length of 20.329 m, which is located at KP 6.465.

1. Introduction
Indonesia is a country that has an important role in the oil and gas industry. Indonesia ranks 24th in the World and 3rd in the Asia Pacific as a world oil producer [1]. Considering this important role, it is necessary to conduct an inspection and safety inspection to support the sustainability of the oil and gas industry in Indonesia. According to the regulation on Republic of Indonesia, for every installation and equipment used in the oil and gas industry, inspection and safety inspection must be carried out, including pipe inspection [2]. There are several pipe inspections that must be carried out to maintain the durability of the pipes, one of which is the inspection of free span pipes located under the sea. Free span is a condition where the pipe does not have a support foundation so that the condition of the pipe is hanging free [3]. The condition of the free hanging pipe is common in pipes that are under the sea. This can occur due to several factors, namely seabed unevenness, changes of seabed topology (such as scouring), artificial support / rock beams, and strudel scours [4]. The working principle of the side scan sonar is to utilize acoustic waves so that they are able to differentiate the size of the particles forming the surface of the sea floor, such as rocks, mud, sand, gravel, or other types of aquatic bases [5]. However, the true side scan sonar cannot know the depth of a waters. Whereas dual-head scanning profiler has a working principle similar to multibeam echosounder (MBES), which utilizes acoustic waves to obtain depth data and underwater topography in the form of point cloud containing depth points. In this study, free span identification will be carried out using two methods, namely side scan sonar data and dual-head scanning profiler data and making inspection maps using both data.

2. Methodology
2.1. Data
The data in this research is using data from PT. Pageo Utama. Data acquisition uses several tools, namely:
1. Side scan sonar data. The survey was conducted using an EdgeTech 4200 side scan sonar instrument that is operated at frequencies of 100kHz and 400 kHz to obtain high resolution images with large coverage.
2. Data dual-head scanning profiler. The survey was carried out using a SeaKing Profiling Sonar dual-head scanning profiler instrument with a frequency of 1.1MHz.
3. Tidal data. Tidal observations were carried out for 96 hours at intervals every 1 hour. Tidal data is used to correct the depth of the results of the dual-head scanning profiler data acquisition.
4. Sound velocity data. Sound velocity calculation using the Valeport mini SVP instrument. Sound velocity data is needed to correct the speed of sound wave propagation in the dual-head scanning profiler data to get the actual depth.

2.2. Equipment
The equipment used in this research consisted of some software namely SonarWiz 5.0 owned by PT Pageo Utama, Qinsy 8.0 owned by PT. Main Pageo, and AutoCAD Civil 3D 2016. SonarWiz software is used as side scan sonar data processor. Qinsy software is used to process raw data of tidal, sound velocity, and dual-head scanning profiler data. The AutoCAD software is used for calculating free span dimensions and making inspection maps.

2.3. Method
1. Side Scan Sonar Processing
The raw data is processed using SonarWiz software and then performed several corrections, namely slant range correction (SRC), time varying gain (TVG), and automatic gain control (AGC).
   a) Slant Range Correction (SRC)
   This correction aims to eliminate the water column in the middle of the image and correct the actual distance from the object that is near the nadir which is distorted by the presence of the water column [6].
   b) Time Varying Gain Correction (TVG)
   This correction aims to compensate for the difference in the sound level that returns between the nadir and the edges of the image, so that the resulting image has the same color hue between the area near the nadir and the edge of the image [7].
   c) Automatic Gain Control Correction (AGC)
   This correction aims to adjust the sound level on stone objects, mud, and seabed to get a clearer picture. This correction also aims to facilitate the interpretation of free span [8].
2. Tidal Processing
Tidal processing in this research uses the help of Qinsy software. To find out the value of the tidal constants from the research location, this study uses the least square method by calculating 5 constituents namely S₀, K₁, O₁, M₂, S₂, and N₂. From the values obtained from these constituents, it can be seen the value of MSL and the types of tides in the study area. The MSL value is obtained from the amplitude value of the constant S₀. The MSL value is needed as a reference for the vertical bathymetry data. To find out the type of tides, use the count formzahl with the formula in equation 1 [9]:
   \[ F = \frac{A_{K1} + A_{O1}}{A_{M2} + A_{S2}} \]  
   where F is the value of formzahl numbers, and \( A_{K1}, A_{O1}, A_{M2}, \) dan \( A_{S2} \) is the amplitude value of each tidal constant used
3. Sound Velocity Processing
Sound velocity data is processed using Qinsy software. Sound velocity data processing aims to correct the depth value error caused by the speed of acoustic wave velocity at each depth. The difference speed of acoustic wave velocity at each depth is caused by three factors, namely temperature, depth, and salinity. [10]
4. Dual-head Scanning Profiler Processing
Dual-head Scanning Profiler data is corrected by tidal data and sound velocity data with the help of Qinsy software. Then the data is used to identify the location of the top of pipe, right seabed, and left seabed from the underwater pipe. The results of the identification are the x, y, and z coordinates which are then plotted with AutoCAD Civil 3D 2016 software. From the results of the plotting coordinates, the dimensions (length and height) of the free span and calculation of the free span of the underwater pipeline are then made.

3. Result and Discussion
3.1. Side Scan Sonar
The side scan sonar data that has been corrected by SRC, TVG, and AGC can be used for underwater free span interpretation. The image can be seen in Figure 1.

![Figure 1. Side Scan Sonar Result](image1)

To identify the existence of free span, it can be seen by the presence of a white pipe shadow pattern that looks away from the black line, namely the underwater pipe. This can happen because there is a cavity between the pipe and the seabed which is known as the free span. In view, the comparison of the side scan sonar image display on pipes that experience free span, pipes that are not buried, and pipes that are partially buried on the seabed can be seen in Figure 2 below.

![Figure 2. SSS data Image display in (a) Free Span (b) Pipe above the Seabed (c) Pipe Burried on Seabed](image2)

3.2. Tidal
In this study, tide observations were made for 96 hours with observational time intervals that are every 1 hour. Figure 3. displays the tidal data at the research location.
From the tidal data at the study site, constituent calculations are carried out using the least square method. Table 1. shows the results of the constituent calculation using the least square method.

| No | Constituents | Amplitude Constituents |
|----|--------------|------------------------|
| 1  | $S_0$        | 1.499                  |
| 2  | $K_1$        | 0.194                  |
| 3  | $O_1$        | 0.167                  |
| 4  | $M_2$        | 0.516                  |
| 5  | $S_2$        | 0.445                  |
| 6  | $N_2$        | 0.139                  |

The results of the calculation of the constituent amplitude can be used to find out the mean sea level (MSL) value and Formhazl number. The mean sea level value can be known from the $S_0$ amplitude value that is 1.499. The mean sea level value is then used as a vertical datum in this study. That is because there is no importance for navigation safety or dock safety that requires (Lowest water level) LWL and (Highest water level) HWL values as vertical datums. The Formhazl number was 0.375, indicating that the area of the study had Mixed Semidiurnal tidal types.

3.3. *Sound Velocity*

Sound Velocity data retrieval is used to correct dual-head scanning profile data by using the Valeport mini SVP tool of PT. Main Pageo. Acoustic wave propagation data is used as depth correction obtained by dual-head scanning profiler. Figure 4. displays a graph of acoustic wave velocity based on depth.
3.4. **Dual-head Scanning Profiler**

From x, y, z coordinate data from top of pipe, right seabed, and left seabed using Qinsy software before, then plotting with the help of AutoCAD software. The plot can be seen in Figure 5

![Figure 5. Sound Velocity Result](image)

In the plotting image, the yellow line is the underwater pipe that is inspected, the red line is the left seabed, and the green line is the right seabed. The data is then used to calculate the dimensions (length and height) of the free span and map of the results of the inspection. Free Span table can be seen in Table 2

| ID   | KP of Free Span | Dimension | ID   | KP of Free Span | Dimension |
|------|-----------------|-----------|------|-----------------|-----------|
|      |                 | Long (m)  |      |                 | Long (m)  |
|      |                 | Height (m)|      |                 | Height (m)|
| FS1  | 0.06            | 11.976    | FS25 | 2.313           | 14.838    |
|      |                 | 0.343     |      |                 | 0.484     |
| FS2  | 0.1             | 10.741    | FS26 | 3.694           | 12.74     |
|      |                 | 0.197     |      |                 | 0.177     |
ID | KP of Free Span | Dimension | ID | KP of Free Span | Dimension |
--- | --- | --- | --- | --- | --- |
| FS3 | 0.144 | 18.665 | 0.27 | FS27 | 3.913 | 11.812 | 0.175 |
| FS4 | 0.209 | 24.424 | 0.555 | FS28 | 4.185 | 9 | 0.08 |
| FS5 | 0.439 | 15.082 | 0.23 | FS29 | 4.231 | 24.856 | 0.146 |
| FS6 | 0.512 | 3.148 | 0.091 | FS30 | 4.389 | 18.443 | 0.193 |
| FS7 | 0.554 | 4.596 | 0.109 | FS31 | 4.48 | 9.017 | 0.2 |
| FS8 | 0.609 | 20.619 | 0.133 | FS32 | 4.573 | 19.821 | 0.16 |
| FS9 | 0.671 | 3.148 | 0.091 | FS33 | 4.913 | 20.329 | 0.373 |
| FS10 | 0.81 | 16.525 | 0.285 | FS34 | 5.002 | 13.637 | 0.455 |
| FS11 | 0.934 | 11.469 | 0.121 | FS35 | 5.038 | 20.67 | 0.784 |
| FS12 | 1.006 | 7.148 | 0.096 | FS36 | 5.213 | 17.65 | 0.24 |
| FS13 | 1.046 | 16.327 | 0.24 | FS37 | 5.345 | 22 | 0.175 |
| FS14 | 1.113 | 9.56 | 0.077 | FS38 | 5.389 | 12.82 | 0.373 |
| FS15 | 1.233 | 6.884 | 0.136 | FS39 | 5.424 | 20.366 | 0.373 |
| FS16 | 1.255 | 6.23 | 0.108 | FS40 | 5.535 | 20 | 0.408 |
| FS17 | 1.35 | 15.672 | 0.39 | FS41 | 5.572 | 29.69 | 1.192 |
| FS18 | 1.412 | 14.362 | 0.166 | FS42 | 5.907 | 12.393 | 0.341 |
| FS19 | 1.646 | 22.98 | 0.484 | FS43 | 6.045 | 42.109 | 0.44 |
| FS20 | 1.693 | 16.589 | 0.64 | FS44 | 6.142 | 16.37 | 0.144 |
| FS21 | 1.741 | 10.29 | 0.37 | FS45 | 6.465 | 20.329 | 1.22 |
| FS22 | 1.761 | 13.53 | 0.142 | FS46 | 6.502 | 28.938 | 1.094 |
| FS23 | 1.804 | 13.57 | 0.4 | FS47 | 6.636 | 7.52 | 0.112 |
| FS24 | 2.001 | 16.68 | 0.372 |

4. Conclusion
Based on the results and analysis carried out in this study, found a number of 47 free span points spread over 6.8 km of pipes. The first free span position is KP 0.06 to KP 0.072 and the last free span is KP 6.636 to KP 6.643. The longest dimension of free span is on the FS-43 with a length of 42.109 m and a height of 0.44 m at KP 6.045 and the highest free span is on the FS-45 with a height of 1.22 m and a length of 20.329 at KP 6.465.

5. References
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