EXPERIMENTAL STUDY OF PIPELINE SCOURING ON SEABED AND IN-TRENCH CONDITIONS UNDER REGULAR WAVE MOTION

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ABSTRACT

Submarine pipeline is one of the media for the distribution of oil and gas from offshore platform to onshore which is considered more efficient. However, the use of pipeline still has any problem about its positioning that can be affected by the environment condition. The pattern of water flow will change when there is a structure that blocks flow. That can cause scouring at the bottom of the pipeline resulting in a freespan pipeline condition. If the pipeline design was not correctly calculated, it then will be experienced the structural failure for a short time. In the paper, the characteristic of pipeline scouring on sandbed and in-trench condition is investigated into the time scale of local scour in changing the regular wave condition in the the flume tank. The test model used are a PVC pipe with 1.5 inch in diameter and the median grain size diameter is \( d_{50} \) by 0.55 mm. The placement of the pipe on the basis varied in conditions laid on the bed \( (e/D = 0) \) and in-trench condition in changing the ratio of embedment to diameter \( (e/D = -0.05, e/D = -0.075 \) and \( e/D = -0.10) \). Moreover, the water depth was also varied to 40 cm and 50 cm. The largest depth and width of scouring occurs in pipe conditions \( (e / D = 0) \) with a water depth of 40 cm and a wave height of 15 cm, namely, scouring depth \( (S) = 0.989 \) cm and scouring width \( (w) = 8.314 \) cm. The scour depth maximum was reached within 25 minutes.
Experimental Study of Pipeline Scouring on Seabed and In-Trench Conditions under Regular Wave Motion

Key words: Experimental modelling, Regular wave, Scouring, Submarine pipeline.

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1. INTRODUCTION

Submarine pipeline placed on seabed or in-trench condition with variation of the ratio of embedment to pipe diameter (e/D) are generally used to transport the different fluids, i.e. water, oil and gas. Pipeline scouring is one of important aspect should be considered in pipeline design related with the stability of the pipeline due to scour occurring around pipelines, they might be destroyed and gave disadvantageous both economically and environmentally. Local scouring around marine pipeline due to wave motion has been investigated by some researchers, e.g. [1, 2, 3, 4]. Interaction of turbulence with seabed become so complex when its disturb by structure and flow that bring a suspended sediment [5]. Scour near the pipe is an impact of this interaction [6]. The depth of scouring hole and the entire form of hole predicted precisely as laboratory experiment. Pipeline scouring on the seabed in which a pipeline placed on will cause free span. Free spanning in offshore pipelines mainly occurs as a consequence of uneven seabed and local scouring due to flow turbulence and instability. Free span can occur when the contact between pipe and the bottom part of sea disappear and distance on seabed [3]. [7, 8, 9, 10] have shown that the bottom shear stress due to wave motions significantly influenced the bed-load sediment transport, it is expected to be used for predicting the pipeline scouring. The wave overtopping could also cause the sediment transport movement [11].

In the present paper, the pipeline scouring experimental under regular wave motions was done to analyze pipeline scouring characteristics in varying its placed on the seabed and in-trench condition within the ratio of embedment to diameter (e/D = -0.05, e/D = -0.075 and e/D = -0.1) and also varied in water depth and wave properties. The maximum scouring depth (Sm), width of scouring (w) and the scouring propagation rate based on the variation of experimental conditions was evaluated and presented.

2. EXPERIMENTAL SET-UP AND CONDITIONS

Experimental study take place at the flume tank belong to Department of Ocean Engineering, Institut Teknologi Sepuluh Nopember (ITS). It has the dimension size with a length of 20 m, a width of 2.3 m and a height of 2.5 m. The wave generator has the plunger system that can generate the regular and irregular waves with the maximum wave height of 30 cm, the maximum water depth of 80 cm and the wave period can be varied from 0.5 s to 3.0 s.

The experimental set-up is showed for the side and top view on Figure 1 and Figure 2, respectively. The partition is placed on a long the flume tank to reduce its width to be 25 cm used to fit the pipe length. The water depth is varied into 40 cm and 50 cm. The wave probe is placed on before and after pipeline model position to measure the water elevation. The seabed formed using plywood with a length of 150 cm, a width of 25 cm and a height of 25 cm filled by sand with the median grain size diameter (d_{50}) of 0.55 mm. The front and back slope are made within 1:10 on the left and right part, which made of plywood. The pipeline scouring mechanism was observed and recorded by using a camera put at the side of flume tank.

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The experimental conditions were given in Table 1, which consists of 15 cases in varying the wave height (H), water depth (d) and the ratio of embedment to pipeline diameter (e/D). In which, $S_m$ is the maximum scour depth, $w$ is the scour width. The maximum orbital velocity ($U_m$) and the Keulegan-Carpenter number (KC) for regular wave are calculated by Eq. (1) and Eq.(2), as follow

$$U_m = \frac{\pi H \cosh(k(z+d))}{T_w \sinh (kd)}$$  \hspace{1cm} (1)

$$KC = \frac{U_m T}{D}$$  \hspace{1cm} (2)

where $z$ is vertical distance from average water surface to the bottom, ($z = -d$ in the bottom), $T$ is wave period and $D$ is the pipeline diameter.

![Figure 1 Side View of Experimental Set Up](image1)

![Figure 2 Top View of Experiment Set Up](image2)

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<th>Table 1 Experimental Conditions</th>
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3. TESTING AND DATA RECORD
The calibration of water level generated by regular wave was done on the wave probe 1. It is used to know the relation between electrode change of submerged wave probe with voltage change recorded on recorder. The initial record of the wave probe position is considered to be a zero point. It then record three drops for every 5 minutes and it then returned to the point 0. It is then continued by raising 3 times and recorded for every 5 minutes and then returning to the starting point. The calibration will be adjusted to the results of the wave recordings during the test process to get the actual wave height.

Scouring observation and data record was done for every 5 minutes until reach the scour depth maximum. Scouring propagation rate can be showed by camera recording result. The experiment result was evaluated to show the influence of each experimental condition to the scour depth maximum, the scour width maximum and the scour propagation rate.

4. RESULTS AND DISCUSSION
4.1. Effect of Wave Height on Scour Depth and Width

![Figure 3 Corelation between the non-dimensional wave height \(H/gT^2\) and the non-dimensional maximum scour depth \((S_m/D)\)](image)

![Figure 4 Corelation between the non-dimensional wave height \(H/gT^2\) and the non-dimensional maximum scour width \((W_m/D)\)](image)
Figure 3 and Figure 4 show the effect of wave height on the scour depth and width, respectively. It showed the correlation between the non-dimensional wave height \((H/gT^2)\) with the non-dimensional scour depth \((S_m/D)\) and width \((w_m/D)\). The higher the value of \(H/gT^2\) showed the greater the scour depth \((S/D)\) and width \((w_m/D)\). The highest scour depth and width occur when the ratio of embedment to pipeline diameter \((e/D) = 0\). The decreasing of the value \(e/D\) gave the decreasing of the scour depth and width, respectively, and when the value of \(e/D = -0.1\) the pipeline scour does not occur.

4.2. Effect of Keulegan-Carpenter Number (KC) and \((e/D)\) on \(S_m/D\) and \(W_m/D\)

Effect of Keulegan-Carpenter Number (KC) and the ratio of embedment to pipeline diameter \((e/D)\) on the non-dimensional maximum scour depth \((S_m/D)\) and width \((W_m/D)\) are given in Figure 5 and Figure 6, respectively. It can be seen that the higher value of KC followed by the increasing of \(S_m/D\) and \(W_m/D\) as well as an increase the value of \(e/D\) until \(e/D = 0\) cause the increasing of the value \(S_m/D\) and \(W_m/D\). The highest the scour depth and width occurred on \(e/D = 0\) and \(KC = 4.37\) based on the experimental results.

**Figure 5** Effect of KC and \(e/D\) on the non-dimensional maximum scour depth \((S_m/D)\)

**Figure 6** Effect of KC and \(e/D\) on the non-dimensional maximum scour width \((W_m/D)\)

4.3. Comparison with Previous Experiments

The present experimental result was compared and evaluated with the previous studies conducted by [4] and [12]. The experimental results show that an increase the maximum scour
depth causes the increase in the value of KC as well as it is shown by the experimental results from [4] and [12]. However, in the present experiment results with in-trench conditions e/D = -0.1 there is little difference where scour depth is smaller than other previous studies. This is caused by differencing in the condition of placing the pipeline where [4] there is a gap between the seabed with the pipe, while in [12], the condition of the pipe on seabed (e / D = 0).

Figure 7 Comparison of the present experiment results and the previous experiments (Yasa (2011)[4], and Xu et al. (2010)[11])

### 4.4. Pipeline Scour Propagation Rate

Scouring propagation rate is the process of scouring in a certain time. As shown in Figure 8 that the largest scouring propagation rate occurred in conditions where H = 15 cm, d = 40 cm, and e / D = 0 based on data recording was done with interval 5 minutes for 60 minutes. The maximum scour depth (Sm) was reached at t = 20-25 minutes, for e/D = 0, e/D = -0.05 and e/D = -0.075, while for e/D = -0.1 the maximum scour depth (Sm) was reached at t = 10-12 minutes. Figure 9 showed the scour profile which depict the spatial and temporal variations of scour depth for e/D=0, H=15 cm and d=40 cm.

Figure 8 The scouring process until it reaches equilibrium at the pipe condition (e / D = 0) and in-trench conditions (e / D = -0.05, e / D = -0.075, e / D = -0.1)
Figure 9 Temporal scour profiles around the pipeline for e/D = 0, H = 15 cm, d = 40 cm

5. CONCLUSIONS

The experimental of pipeline scouring induced by regular wave have been conducted. It can be concluded that the higher the value of H/gT^2 showed the greater the scour depth (S/D) and width (w_m/D). The highest scour depth and width occur when the ratio of embedment to pipeline diameter (e/D) = 0. The decreasing of the value e/D gave the decreasing of the scour depth and width, respectively, and when the value of e/D = -0.1 the pipeline scour does not occur. Beside that the higher value of KC followed by the increasing of Sm/D and Wm/D as well as an increase the value of e/D until e/D =0 cause the increasing of the value Sm/D and Wm/D. The highest the scour depth and width occurred on e/D = 0 and KC = 4.37 based on the experimental results. As well as shown by the experimental results from [4] and [12]. However, in the present experiment results with in-trench conditions e/D = -0.1 there is little difference where scour depth is smaller than other previous studies.

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