

SCOUR ONSET IN PIPELINES UNDER WAVES AND CURRENT: NEW MODEL APPLICATION

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The hydrodynamics and sediment transport around underwater pipelines are dynamics of concern for companies, like those involved in the oil&gas sector, in the offshore renewable energy market, as well as water utilities. Such dynamics have significant impacts on the working of underwater pipelines - such as sediment erosion/deposition around the pipe, freespan generation, pipeline deflection - and entail an important interaction among water, sediment and pipeline.

Since the 80's a large amount of literature has been produced on this topic mainly concerning the evaluation of the equilibrium scour depth and the time scale of the process in waves (e.g., Sumer and Fredsøe, 1990), currents (e.g., Bijker and Leeuwestein, 1984) and their combination (e.g., Cheng et al., 2014).

The evaluation of the conditions leading to the scour onset was also a topic of great interest. However, most of the research activities dealt only with either waves (Klomp et al., 1995; Sumer et al., 2001) or current conditions (Mao, 1986; Chiew, 1990; Sumer et al., 1991). As also reported in Fredsøe (2016) the only study on scour onset under pipelines in combined waves and currents refers to Zang et al. (2010).

AIM OF THE STUDY

The aim of the present work is to update an existing tool (*PIPESOIL*) first developed by Drago et al. (2007). Such tool is mainly used to evaluate the interaction between a pipeline and the soil in terms of freespan generation/evolution that can lead to the fatigue damage under specific environmental conditions (waves and current). It is based on semi-empirical relationships and accounts for the main phenomena:

- tunneling and scour onset;
- pipe self-lowering;
- free span formation/development;
- backfilling of the scour hole;
- unsupported pipeline sagging;
- pipeline self-burial;
- upstream backfilling and leeside erosion.

The updated tool requires equations and methods that can deal with the combined action of waves and current. Regarding the evaluation of the equilibrium scour depth, the time scale of the scour process and the definition of the shear stress, Zhang et al. (2017)'s method was applied because it is applicable universally to current-only, wave-only, and combined wave-and-current conditions.

About the scour onset, first the performance of Zang et al. (2010)'s method is checked; than a new method, based on experimental data, is proposed.

REANALYSIS OF EXISTING METHODS

Zang et al. (2010)'s method consists in a modification of the equation obtained in Zang et al. (2009), obtained from the results of a numerical model and valid for current only conditions. According to this method, the critical embedment (e_{crit}) associated to the onset of scour conditions is related to wave (U_w) and current (U_c) velocities by means of the following equation:

$$\frac{U_{crit}^2}{gD^{(1-n)(s-1)}} = \frac{2 \cos\left(\left(0.5 - \frac{e_{crit}}{D}\right)/0.5\right)}{\lambda_A \Delta C_{p0}} \quad (1)$$

where the critical velocity is computed as:

$$U_{crit} = \sqrt{(U_c + U_w)^2 / \beta}, \quad (2)$$

$\beta(\alpha) = -2.6208\alpha^2 + 2.7417\alpha + 0.8396$ is obtained from data fitting and $\alpha = U_c/(U_c/U_w)$. See Zang et al. (2010) for further details.

To evaluate the performance of this method, the experimental wave and current data of Sumer et al. (2001) are used as a benchmark. This method is found to work properly in current-only tests, but when wave intensity increases, it leads to unreliable results (see the results for wave-only tests in Figure 1). A new unique and more effective method is hence developed that accounts for the combined action of waves and current.

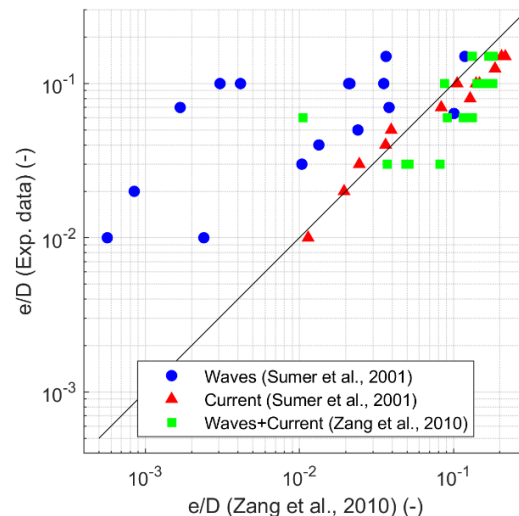


Figure 1 - Application of Zang et al. (2010)'s method to waves, current and wave-plus-current experimental data.

NEW METHOD

The new method consists in a modification of the equation for currents given in Sumer et al. (2001), where the coefficients a and b are introduced.

$$\frac{U_{crit}^2}{gD(1-n)(s-1)} = a(KC, \theta) \exp\left(9\left(\frac{e_{cr}}{D}\right)^b(KC, \theta)\right) \quad (3)$$

$$a(KC, \theta) = 0.025(1 - \exp(-14KC^{0.25}\theta^{0.7})) \quad (4)$$

$$b(KC, \theta) = 0.5 + \exp(-2.9KC^{0.25}\theta^{0.7}) \quad (5)$$

and the critical velocity is related to the sum of the velocities through Eq. 2, with a new polynomial expression for β , obtained from the data fitting:

$$\beta = 6\alpha^3 - 16\alpha^2 + 10\alpha + 1 \quad (6)$$

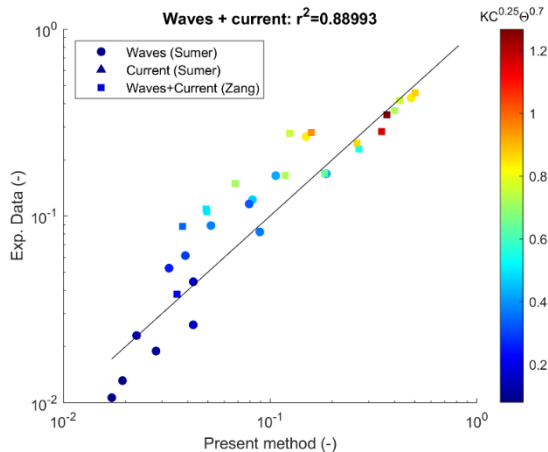


Figure 2 - Application to the new method to waves, current and wave plus current experimental data.

The application of this new method to the experimental data of Sumer et al. (2001) and Zang (2010) is reported in Figure 2 and a good value of the determination coefficient is obtained ($r^2=0.890$).

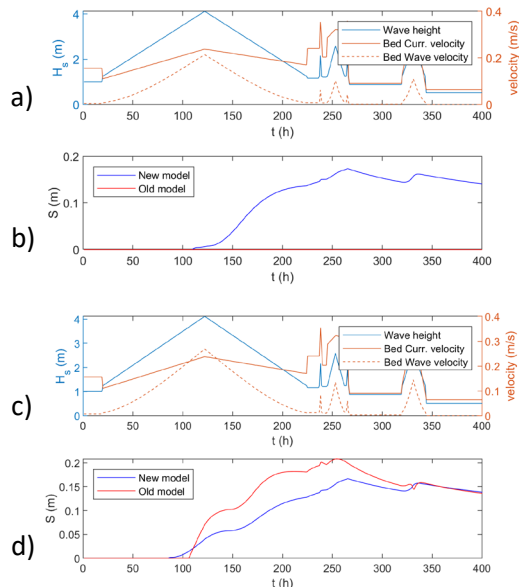


Figure 3 - Environmental conditions (panels a and c) and results of the two models for $h=45m$ (panel b) and $h=40m$ (panel d) in terms of freespans depth (S).

APPLICATION TO FIELD ENVIRONMENT

The new version of the *PIPESOIL* tool is compared in terms of freespan length to the old one using field information (Figure 3). Here, the two results refer to two different water depths ($h=45m$ and $h=40m$). In the old model, a small decrease in water depth induces an increase in wave velocity and, if this velocity becomes larger than current velocity, a different onset condition is applied, thus leading to very different results although the environmental conditions are rather similar. On the contrary, the new method provides a more uniform approach and small environmental variations do not substantially affect the results. The reliability of the results has thus increased.

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