



## Simulation of Wave-Plus-Current Induced Scour Beneath Submarine Pipelines

Larsen, Bjarke Eltard; Fuhrman, David R.; Sumer, B. Mutlu

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# SIMULATION OF WAVE-PLUS-CURRENT INDUCED SCOUR BENEATH SUBMARINE PIPELINES

Bjarke Eltard Larsen, Technical University of Denmark, [bjelt@mek.dtu.dk](mailto:bjelt@mek.dtu.dk)  
 David R. Fuhrman, Technical University of Denmark, [drf@mek.dtu.dk](mailto:drf@mek.dtu.dk)  
 B. Mutlu Sumer, Technical University of Denmark, [bms@mek.dtu.dk](mailto:bms@mek.dtu.dk)

Scour beneath submarine pipelines has been the subject of much past research see eg. Sumer and Fredsøe (2002). To date most research, both numerical and experimental, has focused on scour induced by either pure waves or currents, while comparatively few studies have involved combined wave-plus-current environments. The present study, which is published in Larsen et al. (2016) focuses on the numerical simulation of wave-plus-current induced scour beneath submarine pipelines, based on a model solving Reynolds-averaged Navier-Stokes (RANS) equations, fully coupled with turbulence closure, bed and suspended load sediment transport descriptions, and a seabed morphological model. The model was utilized in simulating breaker bar development by Jacobsen et al. (2014) and has been used in simulating wave induced scour beneath pipelines by Fuhrman et al. (2014).

The model is utilized for the numerical study of combined wave-plus-current scour processes beneath pipelines. The results of 77 simulated wave-plus-current scour cases will be presented and analysed. The cases considered will consist of waves characterized by 10 different Keulegan-Carpenter numbers,  $KC=U_m T_w/D$  and up to eight different values of  $m=U_c/(U_c+U_m)$  which defines the relative strength of the current i.e.  $m=0$  corresponds to pure-wave conditions, with  $m=1$  corresponding to pure-current conditions. The resulting equilibrium scour depths are shown to be in accordance with existing experimentally-based expressions. In Figure 1 the time scale of the scour process is compared to the existing empirical formula from Fredsøe et al. (1992) for the time scale governing both the wave and current-induced scour,  $T^*=1/50 \theta_{cw}^{-5/3}$ . In Figure 1  $\theta_{cw}$  can be interpreted as the maximum Shields parameter of the combined wave-current flow. As can be seen the modelled time scales generally agree well for the pure wave and pure current cases whereas the time scales for combined waves and current are generally larger. The time scales are systematically reinvestigated and a new general expression for the time scale is proposed.

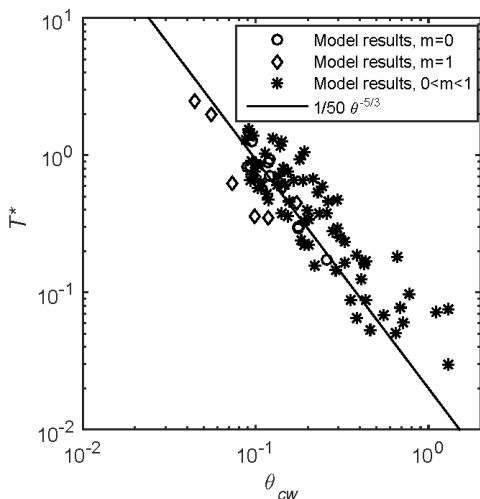


Figure 1 - Time scale of the scour development.

This expression is fully consistent with existing experimentally based relations at both pure-current and pure-wave limits, and is appropriate for engineering use. In Figure 2 the model results are compared to the new general expression which is of the form  $T^*=\Gamma(m) \theta_{cw}^{-5/3}$ , where  $\Gamma(m)$  is a relatively simple close form expression. The tight clustering, compared with Figure 1 around the full line in Figure 2, demonstrates that the generalized expression effectively unites the time scales for pure-current, pure-wave, as well as the combined wave-plus-current flows.

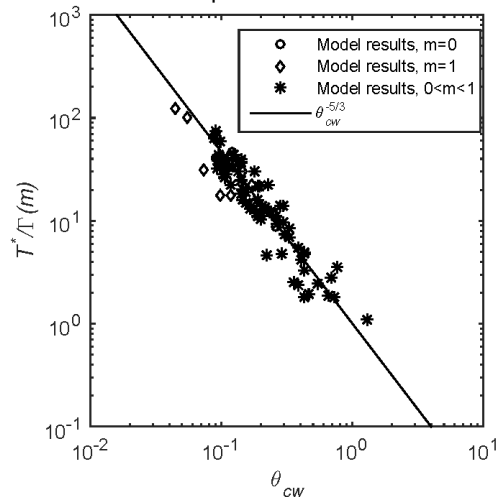


Figure 2 - Time scale of the scour development.

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