Time scales for scour and backfilling below pipelines and around vertical piles in nonlinear random waves

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Introduction

Scour is a type of erosion that occurs around structures on a sandy seabottom. It is defined as erosion of sediments caused by the presence of the structure. Scour may occur around a variety of marine structures but in thesis it is investigated below offshore pipelines and around vertical piles, which are fundaments to marine structures as platform legs and wind turbine columns.

When pipelines and vertical piles on sandy seabeds are exposed to currents and random waves, scour may occur. Scour occurs around slender piles and pipelines due to vortex shedding, and around large piles due to flow mechanisms occurring in relation with the diffraction of waves.

For a given flow climate, the scour will develop to a maximum depth where it remains constant. When the flow climate changes, the scour depth will also change and the initial hole may be backfilled or it may increase. In this thesis, backfilling is considered.

The assessment of the time scales for scour and backfilling is of interest in this thesis and it is essential in the design of marine pipelines and foundations of vertical piles and in scour protection work. The time scale is the time it takes before the scour depth reaches its final depth. The time scale of scour created due to the presence of waves is of special interest because during storms it may occur quickly and thereby be critical.

Objective

The goal of this thesis is to apply a stochastic method to predict the expected value of the time scale of scour and backfilling around pipelines and vertical piles in random waves. The waves are assumed to be stationary and narrow banded such that the statistical distributions Rayleigh and Forristall can be employed.

Method & Analysis

Already existing formulas for the time scale of scour and backfilling are expanded with a stochastic method, allowing input of random waves. The waves are distributed according to the Rayleigh and the Forristall distribution. When the Rayleigh distribution is applied, the waves are linear while the Forristall distribution includes the second-order effects sum-frequency and difference frequency for long-crested and short-crested waves.

It is assumed that the (1/10)th highest waves in the given seastate contributes to sour. To be able to predict the expected value of the time scale, example values of field parameters are chosen. The time scale is plotted with different seastate parameters and for 3 diameters. All calculations and plotting are performed in MATLAB.

Results

The degree of nonlinearity in the waves typically increases in more severe seastates and in shallow water. The crests will be higher and sharper than those expected from a summation of sinusoidal waves, resulting in faster development of scour and therefore a shorter time scale. This can be seen in Figure 1 and 2 where the second-order waves represented by Forristall shows the smaller time scale than the linear waves from the Rayleigh distribution.

The contribution from the second-order effects will vary depending on the water depth regime. In finite water depth the difference frequency effects, which causes a decrease in the wave crest, is more significant for long-crested waves, resulting in lower amplitudes compared to the short-crested. Therefore, short-crested waves gives the shortest time scale in the finite water depth regime. Figure 3 shows the ratio of the time scale for short-crested and long-crested waves, given for different values of U_r and S_1. An increase in U_r and S_1 indicates higher second-order effects, which causes higher short-crested waves and therefore shorter time scale, which appears as isocurves smaller than 1. However, in deep water, Forristall neglects the difference-frequency effects causing long-crested waves to have the highest amplitude, resulting in shorter time scale for long-crested waves. This can be seen in Figure 3 for low values of U_r where the isocurves takes values higher than 1.

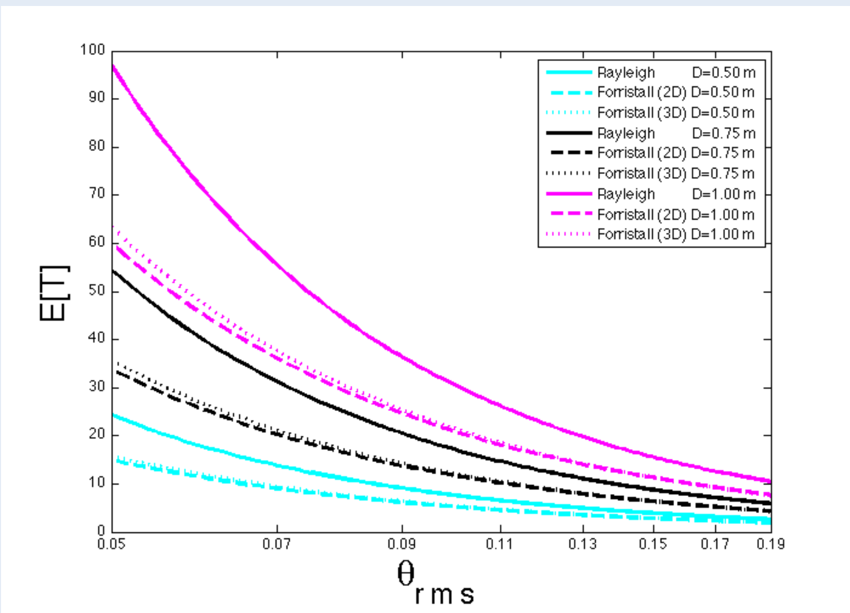

Figure 1: The time scale of scour below pipelines in linear and nonlinear waves for D=0.5 m, D=0.75 m and D=1m.

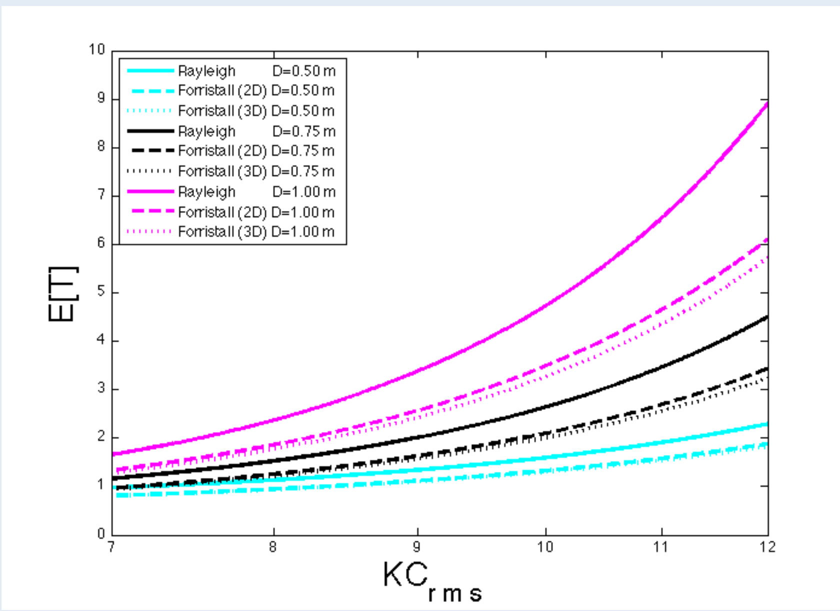

Figure 2: The time scale of scour around vertical piles in linear and nonlinear waves for D=0.5 m, D=0.75 m and D=1 m.

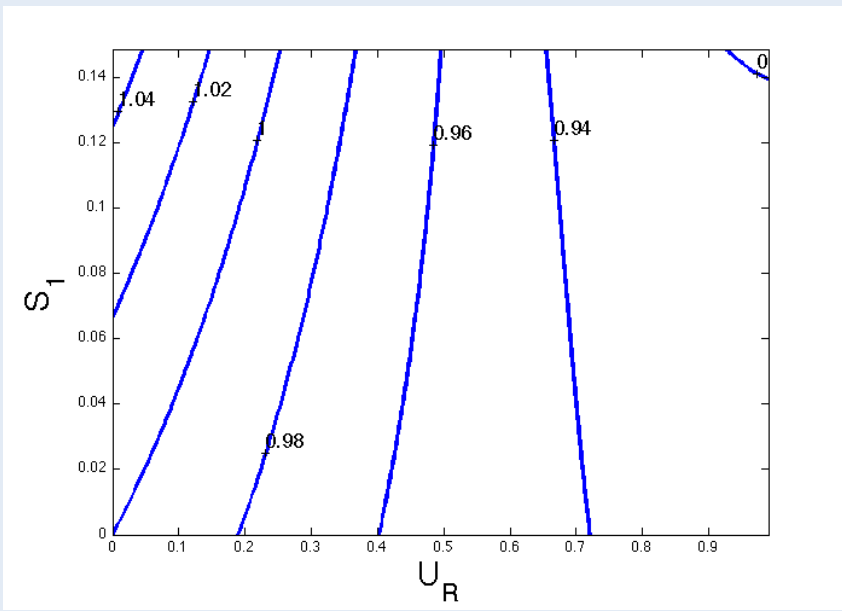

Figure 3: Ratio of the time scale of scour below piles for short-crested and long-crested waves for given numbers of U_r and S_1.