DAMPING OF WATER WAVES BY AN AIR BUBBLE BARRIER

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1. Introduction

Air bubble barriers (also called pneumatic breakwaters), as devices used for calming water waves and protecting engineering objects and infrastructure, or vulnerable coast, have many potential advantages, such as an ease and speed of installation, and their environment-friendly character. However, despite their attractive features, air bubble barriers have not found applications as permanent engineering structures, which is mainly due to high economic costs required for their running (the necessity of supplying a large quantity of air). It seems, though, that these devises can be effectively used in all cases when an action is required at short notice; for instance, to contain oil or other contaminant spills on the sea surface, to protect from waves a ship or a drilling platform in case of emergency, or to calm waves at a harbor entrance during heavy storms.

Although the idea of using air bubble curtains to dissipate water waves energy is about one hundred years old (Evans, 1955), still relatively little is known about the physics of the phenomena involved, and only very few, and erratic, attempts have been made to treat the problem analytically (Taylor, 1955). Most of the research effort so far has been spent on experimental work (Evans 1955, Bulson 1968, Liang 2006) and in situ observations of breakwater prototypes, and on this basis some approximate analytic formulae have been derived for engineers. There are practically no general-purpose tools yet to treat the problem by other means, analytically or numerically, in order to enable an accurate assessment of a planned pneumatic construction at its design stage. Very recently, the research on pneumatic breakwaters has been undertaken at the Institute of Hydro-Engineering in Gdansk, Poland, and it involves experimental, analytical and numerical work. This paper presents preliminary results of work on the development of a numerical model for the surface wave propagation through an air bubble barrier. Schematically, the problem under investigation is sketched in Figure 1.

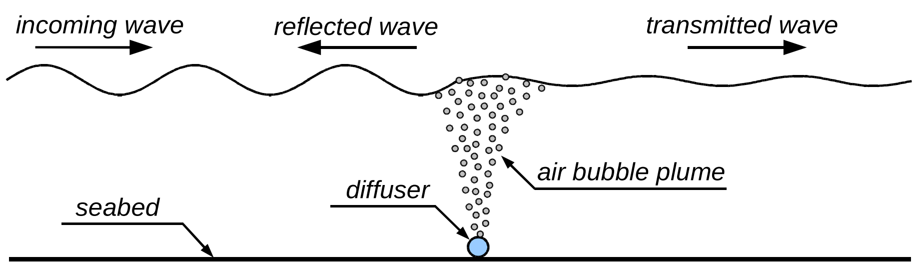

Figure 1. Wave propagation through an air bubble barrier.

2. SPH simulations

The problem is solved numerically by applying the smoothed particle hydrodynamics (SPH) method, which belongs to the class of meshless discrete approaches. In the SPH method (Monaghan 1992) both water and air are treated as inviscid and weakly compressible fluids, for

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which the pressure is related to density by constitutive equations. The latter assumption (in contrast to the common water incompressibility approximation) enables use of an efficient explicit time-stepping scheme (of the predictor-corrector type) for integration of the continuity and momentum equations describing the motion of the two fluids. In order to increase the accuracy of approximation of field functions and their gradients, a so-called corrected version of the SPH method is employed. In this version, standard interpolation functions (kernel smoothing functions in the SPH terminology) are modified in a way analogous to the moving least-square (MLS) approach known from other meshless methods (Belytschko et al. 1998). As we deal with a two-phase flow problem in which the two fluids, water and air, have significantly different densities, a special care is needed to ensure stability of the numerical scheme. For this purpose, some solutions proposed by Colagrossi and Landrini (2003) have been applied.

The SPH model has been used to simulate numerically a plane problem of free-surface waves propagating over the horizontal bed, as shown in Figure 1. For an incident wave of prescribed characteristics, the parameters of a wave reflected by the air barrier, and those of a wave transmitted through the barrier, are calculated. The simulations focus on the evaluation of the energy of the reflected and transmitted waves, expressed by means of the standard wave reflection and transmission coefficients. The main objective is to assess the wave energy dissipation efficiency of an air bubble barrier as a function of the incoming wave characteristics and the air discharge rate.

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