Composite modelling of wind waves in designing of port hydraulic structures

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ABSTRACT

The method of two-way communication between different wave models (so-called composite modelling of waves) is researched in this paper. Two methods of composite modelling are considered: model nesting and modelling model. Coastal engineering projects that were performed in NRU MGSU (National Research Moscow State University of Civil Engineering) are described in terms of composite modelling of wind waves. Actual tasks emerging in practice are considered and analyzed; interpretation of numerical modelling results in terms of their further practical application is given. Presented numerical models were verified and put into designing practice.

KEY WORDS: Wind waves; numerical modelling; physical modelling; composite modelling; Vostok Bay; Wrangel Bay.

INTRODUCTION

The main methods for determining characteristics of wave processes, that are important for hydraulic engineering, are physical and numerical modelling of these processes in interaction with structures. Physical modelling has a longer history than numerical modelling. Recently, both methods have been developing and complementing each other. They are also complemented by field measurements and theoretical, computational methods (Kantarzhi and Kuznetsov, 2014).

Composite (hybrid) modelling is a combined use of physical and numerical models. Ideas for using hybrid modelling in hydraulics and hydraulic engineering appeared at early stage in development of numerical modelling methods (Sherenkov, 1978; Berkhoff, 1972; Berkhoff, 1976), but then they lost popularity. At that time, significant efforts were directed to development of numerical simulation technologies that are successfully applied today (Kantarzhi, Mordvinivsev, and Gogin, 2019). Currently, the technology of composite modelling is an increasingly popular hydraulic research method; accumulation and analysis of experience is taking place (Hadla, Anshakov, and Kantarzhi, 2020; Kantarji, 2020).

It is known that problems of sediment dynamics under action of waves and currents are the most difficult for modelling. Therefore, many papers are devoted to relevant studies of composite modelling, such as papers of Sierra, Gironella, Alsina, Oliveira, Caceres, Mosso, and Mestres (2009); Lynett and Liu (2004); Gerritsen and Sutherland (2011).

Historically hydraulic studies were based on downscale hydraulic (physical) simulations, respecting dynamic similarity. Then, hydraulic modelling was increasingly replaced by numerical modelling, which relies on mathematical description of turbulent processes and boundary conditions. Physical modelling and numerical modelling have advantages and disadvantages. It is also necessary to appreciate the role of theoretical research (desk study) and field measurements.

Terms “composite modelling” and “hybrid modelling” were discussed for some time. However, nowadays, composite modelling is more often used as naming of integrated and balanced combination of hydraulic and numerical modelling (Sutherland and Barfuss, 2011).

In composite modelling, research methods are so closely related that they are applied integrally, depending on problems being solved. In the paper of Sutherland and Barfuss (2011) a SWOT analysis of physical and numerical models is given. Both numerical and physical modelling are evolving. Numerical modelling is still based on physical modelling in its development. Composite modelling techniques can improve results of physical and numerical simulations by taking advantages of each of them.

It is difficult to quantify pros and cons of numerical and physical modelling. Judgments about what are merits of a particular type of model, or what kind of modelling is the best and more applicable, are usually qualitative (Fortes, Lemos, Neves, Reis, Santos, Pinheiro, and Sousa, 2008).

Balanced use of numerical and physical modelling of wind waves, in consideration of conditions of real studying objects, is presented in this paper. Some important ideas of composite modelling are considered, using and summarizing experience of performing similar works with participation of the authors. As examples, two objects performed in NRU MGSU are considered: a marine terminal in the Vostok Bay in the Sea of Japan as an example of model nesting technique, and a terminal in the Wrangel Bay in the Sea of Japan also as an example of model modelling technique. The article will be useful as an overview of application of composite modelling methods of wind waves in practice.