Numerical and Experimental Modeling of Scour at Foundation Structures for Offshore Wind Turbines

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ABSTRACT

Regarding offshore foundation structures, there is presently a lack of knowledge of scour progression for complex structures like Tripod or Gravity Base foundations for offshore wind turbines. Typically, scour is investigated in physical model tests. As an extension, parts of the investigations could be carried out using numerical methods, which however requires that all relevant processes leading to scour are captured well by the model. The general possibility for conducting such numerical simulations is presented here, given by the examples of flow, shear stress and scour calculations for Tripod and Gravity Base foundations and a circular cylinder. The numerical investigations were carried out within the framework of OpenFOAM software code, which was extended by an appropriate scour model.

KEY WORDS: Scour; Offshore Wind; Physical Modeling; CFD; Numerical Modeling; OpenFOAM.

INTRODUCTION

When a structure is placed into the marine environment, it is exposed to fluid flow processes of the surrounding water. Regarding foundations for offshore wind turbines (OWT) or other offshore structures, in most cases scouring phenomena occur around the foundations, owing to the presence of the structure itself and hence affecting changes in the natural flow regime at the sea bed around the foundation, which may subsequently lead to increased sediment mobility. In the marine environment, scour is typically induced by combined loads due to waves and tidal currents. Depending on the structural type and given environmental conditions, in-situ measured scour depths around OWTs of several meters could be observed developed even within short periods, Rudolph et al. (2004), Whitehouse et al. (2008).

As a step to further develop the share of renewable energies on the German electricity supply, numerous offshore wind farms are intended to be constructed at the German coasts within the coming years. Detailed knowledge on scour development and its final effects on the stability and usability of the structures is therefore all the more important today. The starting signal for this development was given by the construction of the first German offshore test site alpha ventus in the North Sea, located 45km off the coast of the Borkum Island. Turbines were founded on Tripod and Jacket foundations here. Further wind farms in the North Sea area are currently in a planning stage or under construction, while turbines are founded on different structural types, e.g. Monopiles, Tripod, Jacket or Gravity Base foundations.

Due to the complexity of these various foundation types, significant knowledge gaps in scour initiation and progression and its probable effects on the stability and usability of the structures are partly given, leading to lacking practical design guidelines. Therefore, such complex structures are generally constructed on a secure-based, but therefore partly cost-ineffective strategy. A large part of the overall costs for offshore wind turbines is given by the foundation, Schaumann et al. (2004), for which reason the choice of the foundation type, an accepted scour depth and a probable scour protection system have an overall high significance.

In recent decades, numerous studies were carried out on scour at offshore structures, from which some empirical approaches on scour evolution were identified, however with main focus on cylindrical structures; for a compilation, see e.g. the works of Hoffmanns & Verheij (1997), Sumer & Fredsoe (2002) or Zinke et al. (2011). Based on this, current design guidelines and the respective literature give estimating values for scour depth calculations mainly for single pile foundations, ranging from typical values of 1.3 to 2.5 for the relative scour depth S/D, Sumer & Fredsoe (2002), GL (2005). Complex OWT foundation structures, which are geometrically different from those simple pile foundations, are not captured at all in current design guidelines. Due to the absence of alternatives, the particular rules are however partly utilized even for complex structural types today.

A problem of its application for more complex foundations is however given by the fact that design scour depths might either lead to values that are far from reality, or might not completely capture the actual, local scour development, as it is the case for scouring effects underneath structural elements, e.g. found at Tripod structures.

The main, goal of current research activities on OWT scour development, also within the context of the investigations presented here, therefore is to gain deeper knowledge of scour evolution at complex OWT types in order to improve scour prediction and reduce uncertainties in the dimensioning, which might allow more efficient foundation constructions, also going along with appropriate scour protection if necessary.

Typically, investigations on offshore structures are carried out in terms...