Offshore Support Structures with Suction Buckets: 
Parameter Fitting of a Simplified Foundation Model
Andreas Ehrmann, Nikolai Penner, Cristian G. Gebhardt, Raimund Rolfes 
Institute of Structural Analysis, Leibniz Universität Hannover 
Hannover, Germany

ABSTRACT
In this work the representation of an offshore support structure is fitted in terms of a simplified foundation model. Therefore, measurement data coming from the first jacket prototype of an offshore wind turbine with suction bucket foundation are taken as a reference for the adjustment of the proposed foundation model. The measurements are processed with an output-only technique, the Frequency Domain Decomposition. By assuming that uncertainties are located in the foundation modeling, the properties are varied to find a set of parameters that minimize the residual errors for the modal frequencies and modal shapes regarding the measurement data.

KEY WORDS: offshore support structure; suction buckets; simplified foundation model; parameter fitting

INTRODUCTION
The first wind turbine on a jacket substructure with suction bucket foundation has been installed in water depths of about 24 m at the offshore wind farm Borkum Riffgrund 1 located in the German North Sea in 2015. In contrast to oil and gas platforms and offshore substations with a huge dead load, a wind turbine, here a Siemens SWT-4.0-120, causes alternating compression and tension loads on the buckets. A research project on monitoring the Suction Bucket Jacket (SBJ) accompanies installation and operation to improve knowledge about the behavior of the foundation system. Therefore, the support structure has been equipped with a measurement system, mainly with strain gauges on the lower jacket legs above the bucket, the so defined clean section. The jacket installation started in August 2014, and finally in February 2015 tower and Rotor-Nacelle-Assembly (RNA) were mounted on top.

In the study measurement data from the completely installed offshore wind turbine (OWT) serve as a reference for fitting mass and stiffness parameters of a simplified model in terms of the suction bucket foundation. For data processing the output-only technique Frequency Domain Decomposition according to Brincker, Zhang, and Anderson (2000) is applied for both construction states, before and after the tower and RNA have been installed. A finite element model of the OWT is then built, where the simplified foundation model follows the approach of Doherty, Houlsby, and Deeks (2005). Here the bucket foundation system is considered as a reduced stiffness matrix. This approach is also adapted for a mass matrix. As a simplification it is assumed that large uncertainties are only located at the foundation and the finite element model is accurate, so the parameter studies concentrate on varying and fitting parameters from the simplified foundation model. Initially, the influence of single mass and stiffness parameters on residual errors of both, a limited number of modal frequencies and modal shapes, is investigated. Finally, all independent stiffness parameters are varied simultaneously according to a Latin Hypercube Sampling (LHS). Thus, the best accordance of modal parameters between the measurement results and those from the model are determined and the study finishes with a fitted configuration of the simplified foundation model.

The overall objective of this study is to improve the model of an OWT regarding the modal behavior of a real structure by locating uncertainties at the foundation. Within the research project on monitoring the Suction Bucket Jacket it contributes to bring this foundation system to market maturity for offshore wind turbines.

The remaining part of the paper is primarily organized in two main sections: After a brief introduction on the suction bucket technology MONITORING THE PROTOTYPE depicts the process of data evaluation and compares two construction states. After that, FINITE ELEMENT MODELING AND FITTING explains the model assumptions in detail and comprises parameter studies to find the minimal modal residuals. Finally, the results are discussed with emphasis on limitations of the work and concluding remarks are made.