Data-based Conceptual Design of Offshore Jackets Using a Self-developed Database

Han Qian \textsuperscript{a)}, Emmanouil Panagiotou \textsuperscript{b)}, Steffen Marx \textsuperscript{a)}, Eirini Ntoutsi \textsuperscript{c)}

\textsuperscript{a)} Institute of Concrete Structures, Technische Universität Dresden, Dresden, Germany
\textsuperscript{b)} Department of Mathematics & Computer Science, Freie Universität Berlin, Germany
\textsuperscript{c)} Faculty for Informatik, Universität der Bundeswehr München, Munich, Germany

\textbf{ABSTRACT}

With increasing power classes of offshore wind turbines, more and more influence factors in different life phases of jacket substructures should be considered to improve the feasibility, economic efficiency and approvability in the jacket design process. The conventional design methods of jacket substructures for offshore wind turbines are complex and expensive. In this case, more efficient design methods should be raised and investigated. The current work in this paper contributes to the development of a database of windfarms with jacket substructures, in order to consider sufficient influence factors during the life process of the structure into the structural design. The correlations between pairs of design parameters (feature pairs) in the database are investigated. According to the results of statistical analyses, a data-based method to simplify the conceptual design of offshore jacket substructures is developed, which is intended to provide a preliminary jacket topology to the further design phases.

\textbf{KEY WORDS:} Jacket substructure; life process; database; influence factors; data-based method; conceptual design.

\textbf{INTRODUCTION}

In comparison with building structures, the substructures of offshore wind turbines are unfunctional structures whose main task is to transfer loads (Van Der Tempel, 2006). The structural design of offshore substructures is generally based on explicit theoretical and practical calculation methods as well as on the engineer's intuition (Li et al., 2021), which is the ability to make statements about a structure based on individual experience and unconscious perception. Regarding the first part, the calculation methods for offshore substructures have been developed over the past decades. The conventional methods are based on three design phases, i.e. conceptual design, iterative design and detailed design with the structural assessments in ultimate limit states (ULS), fatigue limit states (FLS) and accidental limit states (ALS) for specific design load cases (BSH, 2007; Van Der Tempel, 2006; Veritas, 2014). With these calculation methods, a number of researchers have investigated the structural behaviors of offshore substructures in specific load cases (Chew et al., 2016; Chen et al., 2016; Damiani et al., 2016). With higher requirements to the rated power of offshore wind turbines, the development of offshore megastructures is already ongoing. In this case, boundary conditions from manufacturing to installation of the offshore substructure or special requirements from maintenance also have large impacts on feasibility, economic efficiency and approvability of offshore windfarm projects. Therefore, it is necessary to consider essential partial aspects in the life cycle into the substructure design, which are based significantly on implicit knowledge or experiences of engineers that cannot be completely described mathematically.

Offshore jackets are substructures that are defined as a welded truss-like lattice framework and usually have three or four legs and anchors set on the seafloor, which make it safer to anchor a wind turbine tower foot (Veritas, 2014). Compared to other offshore substructures, jackets are more competitive in offshore wind industry when considering higher rated power of wind turbines and deeper waters in the construction sites. Its global estimate between 2021 and 2025 is of at least 1,083 jacketed turbines, including Europe, making it the second most popular ground-based foundation type after monopile (Offshore magazine, 2020). According to the existing projects and studies of offshore wind turbines, jacket substructures can be a more sensible alternative for the 5-MW wind turbines widely used in offshore windfarm and the wind turbines with higher power classes installed in medium water depths, since it has lighter weight and distributes the external loads to multiple anchor points on the seabed (Häfele, 2019). Compared to the advantages of jacket substructure, it also has greater complexity in structural design due to its diverse topology options regarding leg numbers and shapes, combinations of diagonal and horizontal bracing members as well as the tube cross-sections, etc. Because of its structural diversity, more specific constraints and higher design costs limit the developments of jacket substructures in past years. Therefore, innovative design methodologies need to be investigated to improve design efficiency and reduce costs. In this context, a database of offshore jacket substructures in consideration of sufficient influence factors plays an important role in simplifying the integrated design process of jacket substructures. The data in the database can directly or indirectly reflect the basis and commonalities of these well-designed jackets as well as implicit design experiences of engineers. In this work, the procedure for creating the