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Review and Opinion

About the doctoral dissertation of Olga Podrazka on

"Breaking sea wave impact loads on truss structures"

1. Preliminary remarks and work composition

The review was prepared on the basis of contract KB/153/2019 between the Institute of Hydro-Engineering, IBW PAN and myself.

The thesis presented for review consists of 122 pages including figures, tables, appendices and cited publications. The thesis is into 4 chapters, where chapter 1 contains the introduction, chapter 2 the theoretical background and literature review, chapter 3 the comparison or wave experimental data and observations in nature, chapter 4 the experiments in laboratory scale, chapter 5 the data analysis method and chapter 6 the results of the thesis. Chapter 7 and 8 contain the summary and conclusions and future work.

In the introduction the doctoral candidate discusses the background of her research work and discusses the current status of offshore wind energy development. Here, the different types of offshore wind turbine support structures are discussed. In addition, the importance of jacket-type substructures and the interaction of jacket-type substructures with waves are discussed. Finally, the thesis scope and objectives are defined in the introduction.

The second chapter discusses the theoretical background with a special emphasis on waves and the transformation of waves as well as the interaction of waves with structures and wave slamming forces on monopiles and jacket structure. This chapter includes the literature review.

The third chapter briefly discusses the four different general approaches to study wave interactions with coastal structures, namely analytical (theoretical) modelling, numerical modelling,field measurements, and, laboratory (physical) modelling including their advantages and disadvantages.

The fourth chapter describes the experiments in the lab where the experimental set-up, the range of tested wave conditions and the equipment to measure the wave forces are described. The

novelty here are the comparatively large scale of the structure which allows more detailed analyses of the local forces and the investigation of Truss-Structures, since most of the former model tests have been performed in small scales and with monopile layouts. The results of these former researches cannot be directly transferred to Truss Structures.

Chapters five and six describe the data analysis method and the results of the analyses. Special emphasis is laid on the wave characteristics and their changes, the total and the local slamming forces on the tested structure.

Chapters seven and eight summarize the work and draw conclusions for future extended research.

The main goal of the research is to better understand the processes related wave breaking near and at offshore structures and to quantify (estimate) the breaking wave forces on the jacket structure based on the model tests in comparison with existing formulations for monopiles. Here, it is the objective to propose an improved empirical formulation for jacket structures.

From the methodological point of view the candidate uses the results of large-scale model tests in combination with elaborated data analyses methods and existing empirical approaches.

2. Critical discussion of individual elements of the dissertation

2.1 Chapter 1 Introduction

The analysis of wave forces resulting on slender cylinders using theoretical approaches, physical laboratory experiment and/or numerical models is the subject of many research projects and research works at least since 1950 where Morison, et al. *(Morison, J. R., Johnson, J. W., & Schaaf, S. A. (1950, May 1). The Force Exerted by Surface Waves on Piles. Society of Petroleum Engineers. doi:10.2118/950149-G)* published one of the first complete theoretical approaches for the determination of wave forces on slender cylinders. After that many researchers including Goda, Sawaragi, Oumeraci, Hansen, Horikawa, and many others worked on the interaction of breaking waves with cylindrical structures. Nevertheless, many issues related to breaking waves loads on structures in general are still to be addressed especially when it comes to more complex constructions as Truss Structures or Jacket Structures in shallow water where depth-limited and wave-steepnes wave breaking play a role. The doctoral candidate addresses some of these open questions, namely:

- to better understand the breaking wave process in the vicinity of the offshore structures;
- to estimate the breaking wave forces acting on the jacket structure;
- to evaluate the applicability of empirical formulas used to calculate the slamming forces on monopiles to estimate those forces on jacket structures;
- to investigate the relationship between slamming wave forces acting on jacket structures and breaking wave characteristics;

Based on the work on the above-mentioned issues an improved empirical formula estimating the impact forces on jacket structures is proposed.

The open questions addressed in the research are clearly defined and of high importance. The methodological approach (large-scale hydraulic model in combination with state of the art measuring devices) is straight forward and sound but as an approach nothing new.

2.2 Chapter 2 "Theoretical background and literature review"

Water waves and transformation of waves in shallow water

In this section the physical processes leading to wave breaking and the resulting water surface form are described briefly based on existing studies. In addition, the special characteristics of breaking waves are defined. In my opinion a very short paragraph on the state of the technical knowledge on wave breaking and the respective parameterization of wave characteristics.

Interactions between water waves and offshore structures

This paragraph is divided into the non-breaking, the breaking and the slamming wave forces. The paragraph shows a very brief overview on the known and widely applied approaches. The sub-paragraph on slamming forces on jacket structures is a little bit more elaborated and the main approaches and application regions are named. They are used and applied in Chapter 4 of the thesis.

Offshore wind turbines support structures

This paragraph give a brief introduction on the support structures for offshore wind turbines.

All in all Chapter 2 gives the reader a brief introduction into the problem without too much repeating of well-known approaches and technologies. The literature review could to my feeling be more inclusive.

2.3 Chapter 3 "Comparison of wave experimental data and observations in nature"

The goal of this short Chapter is to give a brief introduction to different approaches used for studies of wave processes and wave-structure interactions. The Chapter is short and by no means comprehensive. It basically names the approaches analytical, numerical and laboratory modelling and field measurements and gives the basic advantages and disadvantages – as already mentioned by no means comprehensive. From my point of view, it would have been nice to draw a conclusion from this Chapter for the methodology applied in this thesis.

2.4 Chapter 4 "Experiment in laboratory scale"

This chapter describes the experimental set-up and the experiments performed for the thesis. "The objective of the research was to investigate the slamming forces from plunging breaking waves acting on truss structures in shallow water regions and to improve methods to calculate these forces through large-scale model tests (Arntsen, Obhrai, and Gudmestad, 2013). The experiment was conducted in 2013 on the large wave flume at Coastal Research Center in Hannover, a Joint Central Institution of the Leibniz Universität Hannover and the Technical University of Braunschweig. It was one of the first attempts to study breaking wave forces on jacket structures on a large scale." The text describes the facilities in Hannover and the layout of the test set-up and the measurements performed. The analyses of the forces are based on recordings of the total and local forces. In addition, impulse hammer tests have been performed. The text and the methodology are straight forward.

The candidate explains that most of the tests have been performed with regular waves and with irregular, JONSWAP-distributed waves, and that, in addition, some tests with focused waves were performed. For the thesis only the tests with regular waves were taken into consideration. The candidate does not explain or indicate, why only the tests with regular waves have been taken into consideration.

2.5 Chapter 5 "Data analysis methodology"

This chapter describes the analyses methods used for the analyses of the waves – basically in the time domain. In addition to standard time series parameters two half-periods T'' and T' are defined. The other important wave parameter is the breaking distance and the braking wave characteristics.

In addition, and much more extensive than the analyses methods for the waves, the analyses methods for the reaction of the structure (the forces) have been introduced. Namely, the Frequency Response Function Method (paragraph 5.2.1), the Empirical Mode Decomposition Method (paragraph 5.2.2), the slamming coefficient (paragraph 5.2.3) and the slamming force characteristics (paragraph 5.2.4). The paragraph containing the "Frequency Response Function Method" is not easy to understand – at least for me – since it is based on a paper that I haven't read. In addition, not all parameters have been defined and explained. The other chapters are well written and good to understand.

The chapter ends with a very brief paragraph describing the error analysis.

In this chapter it became obvious to me that going through the thesis, I was a little bit confused about the parameters H_o (wave height in deep water / offshore wave height) and H_0 (individual wave height). For me they are used in a not usual way and at least on page 13 the terms have been used in a different way.

2.6 Chapter 6 "Results"

This is the main chapter of the thesis. It comprises roughly 50% of the written text. It starts with a wave-wise overview over the 40 cases taken into consideration.

Waves

The wave profile changes along the wave flume do not show any not expected behavior. As result, wave height changes in combination with the wave steepness have been takes as indicator for wave breaking. The description of the wave conditions show that all selected cases show breaking directly at the structure with an almost vertical wave front.

A formulation for the relation between the surf similarity parameter and the breaker distance has been proposed and assessed. One basic parameter is the coefficient A_d which is significant but not discussed in the thesis.

A formulation proposed by Goda for the breaker depth index was used to estimate the breaker height index instead based on a bias assessment. In addition, several other relationships have been analyzed based on the model tests. The goal is to estimate the breaking wave conditions based on the initial wave conditions.

The summary: "All the parameters analyzed in this section vary from wave to wave, even under the same initial conditions. …" shows that the tests have a kind of randomness. This randomness is explained basically by the nature of the wave breaking process and some random features related to the model tests.

Total slamming forces

Maximum total slamming forces are observed for waves breaking at or slightly behind the structure. The total slamming forces show a high variability (factor 3 in the example given in fig. 6.16) over the individual tests.

The characteristics of the total slamming forces are discussed based on a number of scatter plots for all cases and for averages. Some of the analyzed characteristics are obvious, others are hard to see / determine in the scatter plots. It might have been better to somehow indicate the findings in the plots with lines, etc. Another suggestion would be to not show the non-relevant measurement (WG) out of the plots.

The dependency of the $C_s\lambda$ coefficient on the crest front steepness and (to a certain extent) of the breaking wave celerity is clearly shown (fig. 6.28) and the further use of the combined values as one parameter is clearly outlined.

Finally, the measured total slamming forces and the proposed calculation method are compared to available approaches (Goda and Wienke & Oumeraci). It is clearly shown that the two existing approaches overestimate the total slamming forces and that the derived method is in good agreement with the measured forces.

The discussion-paragraph is sound and summarizes the analyses and the results and also shows possible extensions as e.g. irregular waves, other wave directions, etc..

Local slamming forces

Maximum local slamming forces are in similarity to the maximum total slamming forces observed for waves breaking at or slightly behind the structure. The local slamming forces are depending on the surf similarity parameter with maximum force values around $\zeta = 0.525$. Rising time and duration are in an expected range.

The characteristics of the local slamming forces are discussed again on a number of scatter plots, basically for all cases at the different location “upper bracings” and “lower bracings”. The two results for the “upper bracings” look quite similar, which is also the case for the two results for the “lower bracings”. Here, no average value comparison which was very helpful for the total slamming forces has been performed. The assessment is sound.

I miss a little bit the discussion of the so called “outlier”. For me it is not obvious, why this value is taken as an outlier.

The analyses related to the local slamming coefficient Cs shows that the Cs – value is depending on the crest front steepness. A sound approximation method for the upper bound is given.

Finally, the measured local slamming forces and the proposed calculation method are compared to available approaches (Goda and Wienke & Oumeraci). It is clearly shown that the two existing approaches do not represent the measured local total slamming forces at all and that the derived method is in quite good agreement at the upper bound of the measured local slamming forces.

The discussion-paragraph is sound and summarizes the analyses and the results and also shows possible extensions as e.g., irregular waves, other wave directions, etc. In addition, it was pointed out that the estimation of local slamming loads still have significant uncertainties and show a broad bandwidth. It is recommended to include this bandwidth in the safety design.

2.7 Chapter 7 “Summary and conclusions Results” and Chapter 8 “Future work”

These chapter are based on the previous chapters and give a good summary of the work and the results and conclusions as well as recommendations for future research.

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3. Summary

Mrs Olga Podrazka has provided a very good dissertation, which covers important aspects related to the analyses and assessment of breaking wave induced loads on jacket structures. The approaches and methods are sound. The objective of the work of Mrs Podrazka was

- to better understand the breaking wave process in the vicinity of the offshore structures;
- to estimate the breaking wave forces acting on the jacket structure;
- to evaluate the applicability of empirical formulas used to calculate the slamming forces on monopiles to estimate those forces on jacket structures;
- to investigate the relationship between slamming wave forces acting on jacket structures and breaking wave characteristics;

In addition, she wanted to find a suitable methodology to extract relevant data (total and local slamming forces) from high-quality experimental measurements.

The work is a clear step forward for all of the named objectives.

The text is well-formulated and quite easy to read and can be clearly understood. I found only a few grammatical errors and typos.

The illustrations, figures and graphs are clear and help to understand the text. For some of the figures not all values, points and lines are explained in the figure caption or in the text – at least I haven't found them. In addition, the figure captions are not always self-explaining as e.g. in fig. 6.33.

The scientific value of the work is high. With his thesis Mrs Olga Podrazka has clearly proofed her ability to carry out independent scientific research.

I conclude that the doctoral dissertation of Olga Podrazka," Breaking sea wave impact loads on truss structures" meets all the requirements of a doctoral dissertation. I recommend that the PhD-Committee should accept the dissertation and continue the promotion process.

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