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# INFLUENCE OF WAVE LOAD VARIATIONS ON OFFSHORE WIND TURBINE STRUCTURES

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## ABSTRACT

**Nowadays, much attention is payed to the development of renewable energy resources. Wind energy plays a major role in this issue. That is why there is a growing interest for improving the design process of wind turbines at many aspects. This study compares two types of offshore wind turbines structures, the monopile and the jacket structure, in their dependency on wave load characteristics' variations. The examined wave characteristics are significant wave height and wave peak period. The jacket structure showed lower influence of increase of wave height to stresses in the cross section at the bottom of the structure compared to the monopile structure. The monopile structure showed slight dependency of stresses on increasing wave frequency, while the jacket structure showed nearly no dependency, due to its more complex geometry and higher stiffness.**

## NOMENCLATURE

| | | |
|---|---|---|
| *OWT* | = | Offshore wind turbine |
| *Ts* | = | Wave peak period (s) |
| *Hs* | = | Significant wave height (m) |
| *S* | = | Stress (MPa) |

## INTRODUCTION

Renewable energy resources are nowadays a growing industry, aiming to a gradual transition of energy production from fossil fuels to green energy. With respect to Kyoto protocol, many producers turn to renewable energy resources, which leads to a fact that more than 75% of new power capacity installations in EU in the year 2015 are renewable resources. The leading among the new renewable energy resources is wind energy [1]. In the

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last two decades, even more wind energy is harvested by moving offshore. That brings up a problem of more complicated and expensive installation, but wide available locations for wind farms and higher electricity output justify the decision to go offshore. In addition, the capacity of offshore wind turbines gradually grows, so nowadays the average OWTs' capacity is 4.8 MW [2]. Therefore, there is a growing interest in improving the design process of OWTs at many aspects, but the reduction of costs remains the main challenge.

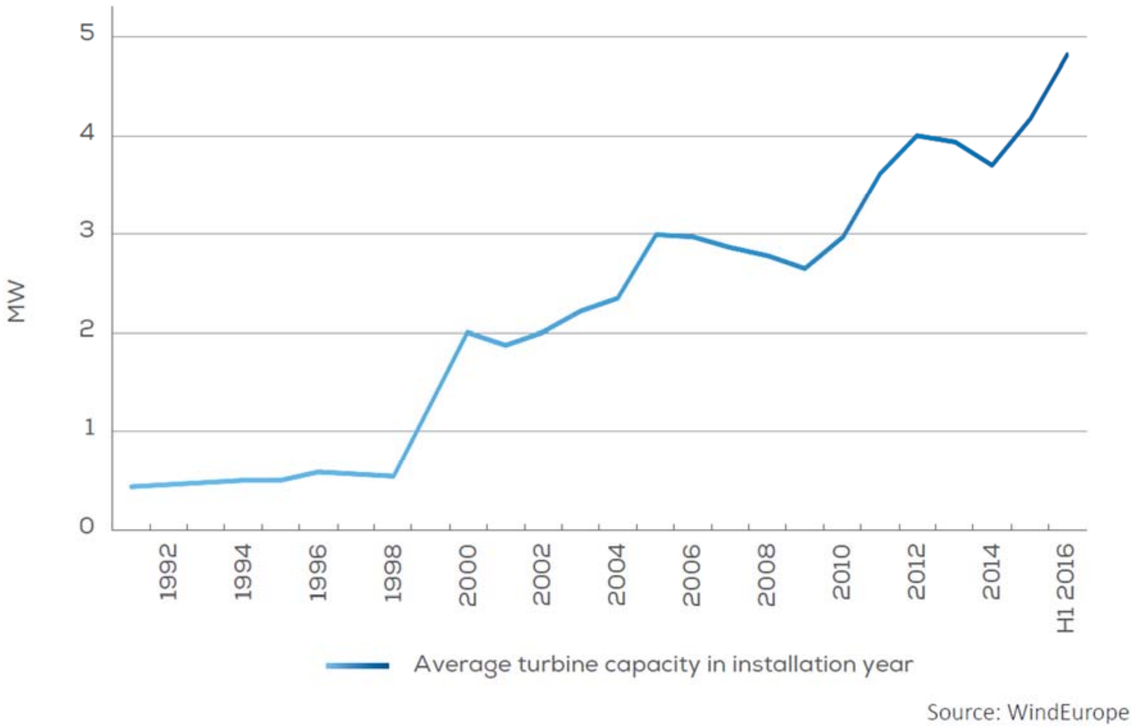


**Figure 1.** Average annual rated capacity of OWTs installed

The design of OWT support structures contains high number of stochastic variables that influence loads characteristics and structural responses. These variables cause many uncertainties, whose impact on a structural behavior is not obvious without a deeper investigation [3]. This study investigates the dependency of stresses in OWT structures on characteristics of wave loads.

## METHODOLOGY

Two types of reference OWT structures are studied and compared: the monopile and the jacket structure. Regarding the supporting structures of OWTs in general, monopile is the most commonly employed structure in shallow and medium water depths (0-30m), due to relatively easy installation and simple design. For higher water depths (20-50m), jacket support structures are employed due to higher stiffness, as well as smaller surface facing the wave movement compared to monopiles [4]. Both structures are modelled in finite element analysis tool, developed at the Institute for Steel Construction of Leibniz University of Hanover, namely Poseidon, specialized for wave-induced loads. Poseidon has an integrated tool for simulation of wave loads, by means of either irregular sea states, or single design waves [5]. Irregular sea states are generated as a superposition of a number of regular waves in order to achieve a very realistic model. However, it is not obvious how every single waveform from the sea state contribute to the caused stress. In order to perceive how sensitive are the structures to different wave characteristics (wave heights, frequencies), sea state is separated into single design waves, and each of them is applied to the structure. The stress results are recorded by the set of sensors positioned on the corresponding spots on the structures with the corresponding angles, and compared. Finally, it is stated which of the observed structural types is more sensitive to specific wave characteristics.

## RESULTS

The obtained results show that both of the reference structures stand higher stresses with the increase of wave height, as expected. It is demonstrated that both of dependencies are nearly linear, as the simulations are carried out in the domain of linear deformations without extreme loads. However, the dependency line for monopile is steeper, which shows that monopiles are more sensitive to wave heights compared to jacket structures, due to their geometry.

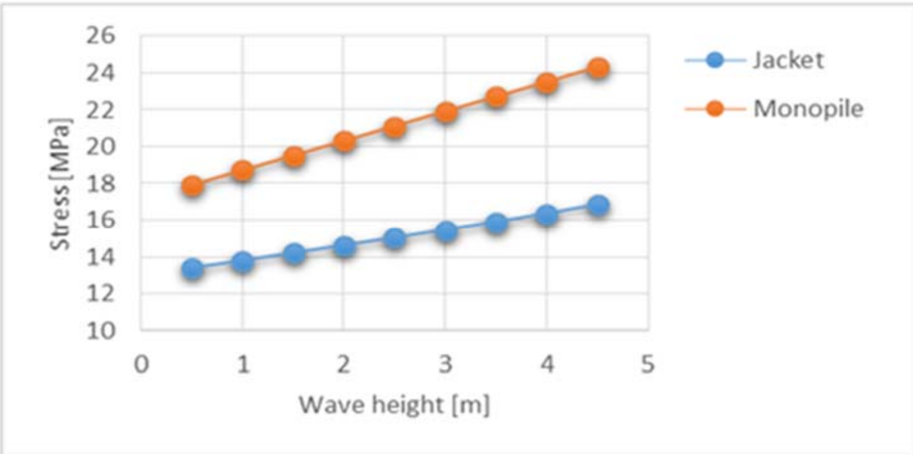


**Figure 2.** Significant wave height - stress dependency for monopile and jacket structure

Regarding different wave frequencies, the monopile structure shows slight increase of stresses with increase of wave frequency. The gradient of stress increase gets higher as the wave frequency approaches the first eigenfrequency of the structure. The jacket structures shows nearly no dependency on examined wave frequency change.

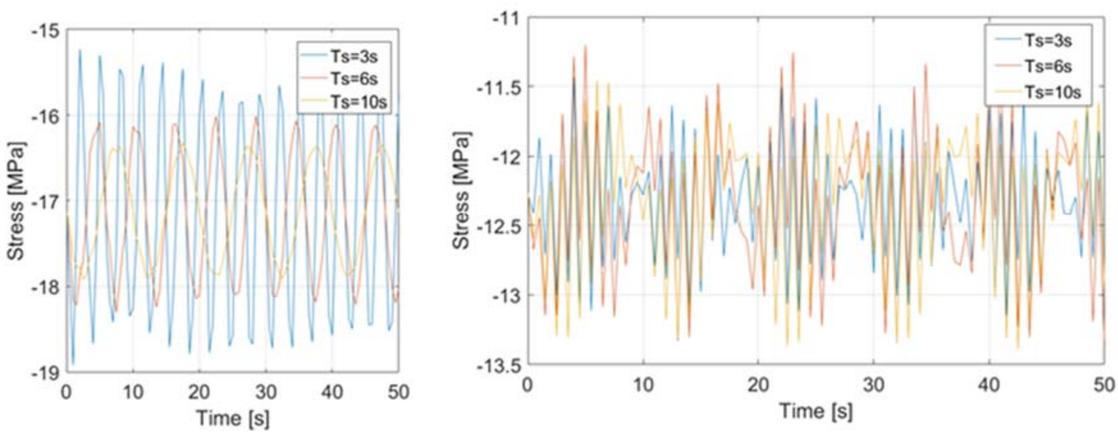


**Figure 3.** Stress results for monopile (left) and jacket structure (right) for different wave frequencies

## CONCLUSIONS

The obtained results show that the jacket structure is in general less sensitive to the change of wave load parameters compared to the monopile structure. Due to its complex geometry and higher stiffness, the jacket structure shows low linear sensitivity to the increase of wave height and nearly no sensitivity to change of wave period, while monopile shows steeper linear sensitivity to wave heights and sensitivity to decrease of wave periods. This research is focused on one, most frequent wind speed. For a complete overview, other wind speeds as well as the extreme load cases must be taken into consideration.

## ACKNOWLEDGEMENTS

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