Effects of marine growth and damage on the modal parameters of a monopile test structure

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Introduction:

The accurate modelling of the supporting structures of wind energy converters is considered a challenging tasks since a variety of effects influence the dynamics behaviour of such structures.

The importance of these models are due to the fact that these play an important role in a wide range of applications such as Structural Health Monitoring, Fatigue Analysis and Damage detection.

Thus, the effect of marine growth, added mass and damage on the dynamics of supporting structures were tested using a scaled monopile model, as shown in Fig. 1.

Scaling was performed using the scaling laws of Froude and Cauchy, which are best suited for offshore structures. The structure was derived by scaling down, with a scaling of 1:30, the offshore wind turbine monopile defined in [1].

Multiple sensors, shown in Fig. 2., were used to measure the dynamic response of the monopile structure. Marine growth was applied using a synthetic sheet, shown in Fig. 3. which corresponds to the surface roughness and density of marine growth. Finally, damage was applied via three symmetric saw cuts of varying depth, also shown in Fig. 3.

Tests and Calculations:

The structure was tested a wave basin “Wellen- und Strömungsbecken Marienwerder” under following test conditions:

- Depth of water was 1,00 m.
- Waves were generated using the JONSWAP spectrum.
- Each test comprises of generating 500 waves .
- Various wave heights and wave periods were used.
- Multiple damage and marine growth levels were used.

Furthermore, free vibration tests were conducted in which the top of the structure is displaced and released.

The recorded response for each test is analyzed using a “Datadriven Stochastic Subspace Identification (SSI)” as well as a “Frequency Domain Decomposition (FDD)”. Multiple model orders were used to achieve a stability path, as explained in [2] to obtain mode shapes, frequencies and an estimation of modal damping.

The mode shapes, frequencies and damping of the first three modes were obtained from each test. As an example, the first and second frequencies are shown in Fig. 4 and 5 respectively. Extensive results can be found in [3].

Findings:

- Damage severity has an observable effect on all modal frequencies, with the highest effect on the first frequency.
- Damages larger than 5mm puncture the monopile wall and lead to a significant change the second and third modal frequencies, due to water intrusion.
- Marine growth severity has no observable effect on the first modal frequency, but does affect the second and third frequencies significantly. This can be attributed to the fact that the second and third modes have higher displacements near the marine growth application point.
- Marine growth possesses a significant effect on modal damping. This could be related to the surface roughness of marine growth that allows energy to be dissipated.

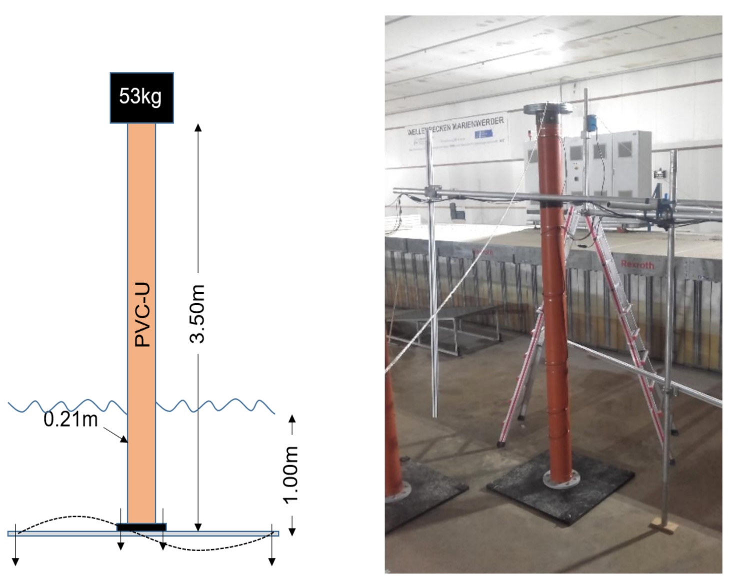

Fig. 1: Test structure and dimensions

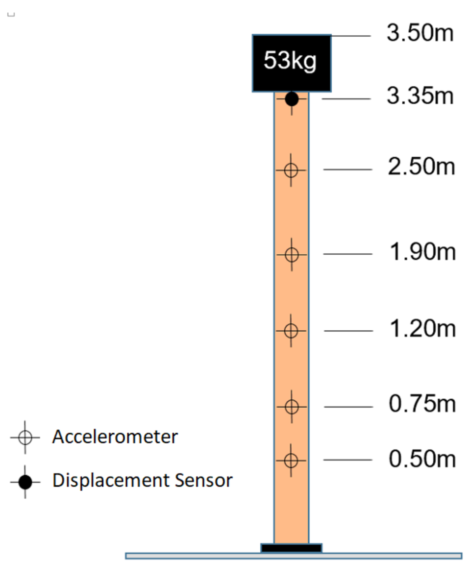

Fig. 2: Sensor Types and Locations

Fig. 3: Application of Marine Growth (Left) and Damage (Right)

Fig. 4: Identified first and second modal frequencies

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