Dynamic Soil-Pile Interaction for large diameter monopile foundations

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ABSTRACT

Monopile foundations have been used in a large extent to support offshore wind turbines (OWT), being considered as a reliable and cost effective design solution. The accurate estimation of their dynamic response characteristics is essential, since the design of support structures for OWTs has been so far driven by their dynamic performance. The excitation frequencies are imposed by the rotation of the rotor, hence they are lumped close to the rotation frequency of the rotor (1P) and the lower blade multiples (2P, 3P). The prevailing design concepts originate from an 'avoidance of resonance' rule and are usually reported in double terms of the stiffness of the OWT and the foundation, i.e. soft –soft, soft – stiff, and stiff – stiff design approaches. In the first case the eigenfrequency of the system is reduced to excessively low values, where the cost reduction is considerable but wave fatigue may be problematic. In the third case except from the cost increase, the wind induced fatigue is an additional issue to be dealt with. The second concept is the one prevailing in current design practice and it actually sets the natural frequency of vibration of the OWT inside the narrow margin left between two restrictive frequency areas.

Moreover the design of monopile foundations when subjected to combined lateral and moment loading (the latter arising from the eccentricity of the applied wind pressure) usually dictates a large diameter steel pile with small slenderness ratio. Hence, aim of the study is to analyse the dynamic interaction of the soil and a single pile embedded in it by accounting for the geometric and stiffness properties of the pile. In doing so, a semi – analytical approach is adopted based on the fundamental solution of horizontal pile vibration by Novak and Nogami (1977). The dynamic impedance functions of the monopile foundation are obtained for varying soil conditions and it is shown that the first eigenfrequency of the soil layer controls the reduction of the stiffness and the increase of the radiation damping induced by the vibration of the monopile. Higher eigenfrequencies of the soil layer do not affect the soil – pile interaction. The decrease of the eigefrequency of the OWT depends on the aforementioned variation of the dynamic stiffness and the slenderness ratio of the monopile.

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