TU Delft

Offshore & Dredging Engineering

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Design of a new type of impact hammer with the focus on the drive system of the ram

The number of wind farms that are commissioned, being installed, or prepared is still increasing due to a growing demand for green energy. To benefit from the higher wind velocities, which can be found at sea, and to prevent the visual pollution of the horizon, wind farms are being built offshore and installed in an ever increasing water depth. The technological development of energy generation allows the capacity of wind turbine generators to grow. Consequently the environmental loading increases, which demands the foundation structure to be stronger and hence to be larger. One of the most used foundation structures is the monopile. It is relatively cheap, simple to produce and simple to install. Usually the diameter of the monopile changes over its length. The bottom part has an increased diameter, not to just provide the required bearing capacity, but moreover to withstand the high bending moments introduced by the environmental loading and the weight of the turbine generator. The diameter at the connection with the tower of the turbine generator is in most cases a bit smaller.

Nowadays monopiles with a bottom diameter of 7.2 m and a top diameter of 6.3 m are being installed by Seaway Heavy Lifting (SHL). The impact hammers, which are used to drive these large monopiles, use a ram weight to drive the pile to its final penetration depth. This ram weight is located in the center of the hammer and is lifted by a hydraulic system. The diameter of the ram at the tip is about 1.2 m. In order to transfer the impact energy to the pile, which has a much larger diameter, an anvil is used. Due to the deflection of the anvil, energy is dissipated, which reduces the energy transferred from the hammer to the pile. The increasing diameter of the monopiles requires the anvil to become larger, which results in an increase of the energy loss. To compensate for the losses the capacity of the impact hammer is increased. As a consequence the stresses in the anvil will become an issue for the structural integrity and the fatigue life of the anvil. Furthermore the noise levels, caused by the impact driving of the piles, show an increase as a function of the monopile diameter and the impact energy. The noise levels are becoming more and more important due to environmental regulations to protect the sea life.

Based on these trends, SHL wants to investigate a concept for a new hammer, specifically aimed for these large diameter monopiles. The design is based on a revolved ram weight that hits an anvil ring, which is directly placed on top of the pile. The direct impact will reduce the energy losses between the hammer and the pile, so that the pile can be driven more effectively.
The impact force, which causes the stresses in the pile and the noise emission, is most affected by the contact stiffness between the hammer and the pile. Therefore the focus of this thesis is placed on the design of a hydraulic drive system which is able to adjust the contact stiffness.
A Matlab model of the hydraulic drive system is made, for which the impact energy can be changed by adjusting the impact velocity. The model includes a system which can vary the stiffness of the ram assembly.
To take into account the behaviour of the soil and the pile during impact, a pile-soil model is included. The pile is modelled by a system of lumped masses, whereas springs and dampers are added to model the soil behaviour. The impact force is calculated based on the contact stiffness and the relative displacement between the ram and the pile top.

An extensive analysis is performed of the effect of contact stiffness reduction and the associated pile set per blow. The analysis showed that the pile set per blow is reduced in case the contact stiffness is reduced. Furthermore the maximum impact force is reduced and the impact duration is increased. As a consequence the stress and the high frequency noise levels are reduced, which will contribute to the noise mitigation measurements.
The reduced pile penetration can be compensated by either an increase in the number of blows or by increasing the impact energy. However to achieve the same pile penetration for a reduced contact stiffness and a lower peak value of the impact force, the energy needs to be increased significantly. Therefore more energy is required for the proposed hydraulic drive system, although the stress and high frequency noise levels can be reduced.

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