

Re-designing the GBM Vibro-drill for post-installation retrieval

With increasing diameters of offshore monopile foundations, impact hammers require more energy per blow in order to drive them into the seabed. This does not only increase the fatigue loading on the monopile, but it also increases underwater noise that affects marine life. The increase in installation costs due to additional material on the monopile, noise mitigation and longer installation times drives contractors to look for alternative installation methods.

GBM's Vibro-drill strives to install monopile foundations through a combination of jetting, liquefaction and fluidization to reduce the soil resistance to such low levels that the monopile will penetrate the soil under its own weight and thereby significantly reducing underwater noise. Although the working principles are still being tested, the Vibro-drill design needs to be improved for commercial application. The design must include the three operational functionalities stated above, but to make the Vibro-drill re-usable for consequential monopile installations, additionally retrieval and structural rigidity are required.

For this thesis, the Vibro-drill is re-designed to include these functionalities. Starting from a process description, all load cases and additional design requirements were found. Based on a first global load case, a first selection was made for the connection mechanism. Subsequently, a Multi-Criteria Analysis was performed yielding two suitable concepts: the Vibro-Boxer and the Vibro-Polyp.

The Vibro-Boxer relies on three extending arms that connect with a specially designed pile shoe using twelve hydraulic grippers. To feed the system with hydraulic fluid, water and air, an umbilical connects the installation vessel with the central hub of the Vibro-drill. At the end of each arm, eccentric weights are used to vibrate the pile tip.

The Vibro-Polyp has a similar lay-out except for the arms and connection mechanism. Nine hinged arms form three sets of folding parallelograms to expand or contract the Vibro-drill. The connection is made through a set of pins on each arm that slide into holes in the pile shoe.

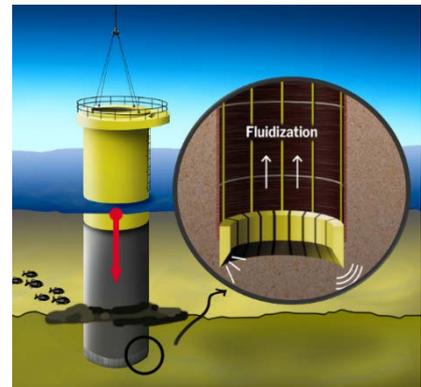


Figure 1. Working principle of the GBM Vibro-drill

Due to unknown soil properties and effectiveness of jetting, liquefaction and fluidization, the loads on the structure cannot be determined deterministically. Therefore, a Monte Carlo simulation is used to perform the structural analysis based on a best guesstimate for the distribution of these unknown parameters. Based on this approach, a tool is created that aims at performing the structural analysis while iteratively improving the design. As test results will become available after finalizing this thesis, input for the unknown parameters can be updated to improve the results of the structural analysis. Subsequently, based on this progressive insight, the design of the Vibro-drill can be optimized further. Note here that for the structural analysis, the system is assumed to be quasi-static which is a gross simplification of reality. Although this imposes limitations to the reliability of the results, this assumption is allowable for the preliminary re-design phase considered in this thesis. The structural analysis described here has been applied to both suitable concepts. For each concept, the external loads were identified and the internal loads were calculated. A series of structural checks in the Monte Carlo simulation provided a probability of failure. For both concepts the probability of failure was initially too high and therefore improvements to the structural components were made.

Based on the design criteria, the two optimized design concepts were compared. Due to the smaller frontal area of the Vibro-Polyp its soil resistance on the tip of the monopile and the Vibro-drill is the smallest and therefore requires the least eccentric force. Nevertheless, the structural analysis shows that its hinged arms are fatigue sensitive yielding a higher probability of failure. Therefore, despite its larger frontal area, the Vibro-Boxer has a higher reliability and is the most suitable concept for the Vibro-drill.

Finally, a more detailed design of the Vibro-Boxer concept is delivered that complies with all design requirements. For this design, recommendations are given on how to update the design based on the dynamic analysis and future test results.