Monopile Wind Turbine Foundations

More than 20 years of experience from Renewable Energy projects from all over the world enables us to provide our clients with state of the art engineering solutions for their monopile wind turbine foundations.

LICengineering A/S covers all disciplines for design and supervision of foundations for offshore wind farm projects as our solutions cover planning, analysis, design, installation schemes and site supervision.

Monopile Design and Analysis

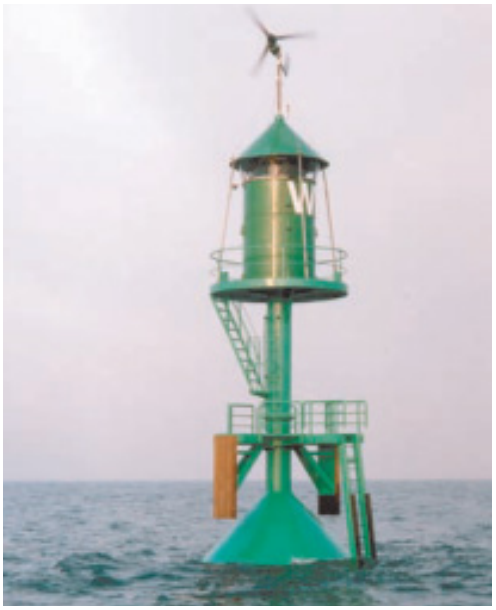
Mono-pile foundations for large offshore wind turbines are attractive and cost effective solutions. They are, however, very dynamical swaying back and forth in their eigenmodes, which means that special vibrational analyses are warranted to cover the situations with strong dynamical amplifications. This particular behavior means that both wind and wave loads interact hereby amplifying the response. LICengineering A/S has developed methods for calculating the joint response and applying these refined methods causes the foundation and tower design to be weight optimized.

Flange Design

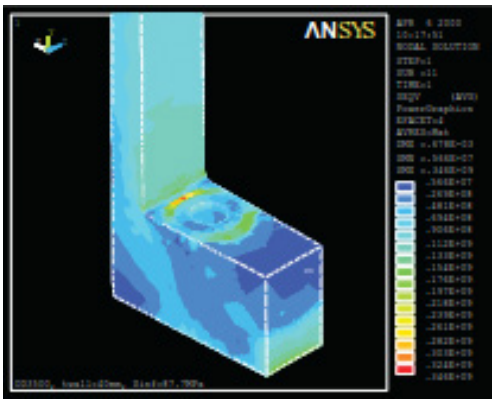
Being fatigue – rather than extreme load dominated structures, detailed analysis of the flange connections for 2MW class offshore wind turbines offers the possibility of fatigue life optimization. For flange design we use the finite element program ANSYS®. The picture to the right includes the effect of bolt pre-stressing together with a correct modeling of the contact boundary between the two flanges (only one shown)

Scour Design/Soil Mechanics

Offshore wind farms will typically be placed on shallow reefs or offshore dunes. This keeps the foundation costs down and protects the wind farm from the ship traffic. Reefs or dunes, however, tend to shift position. This means that special scour protections capable of following the changing seabed must be installed. LICengineering A/S has in the last decade developed protection schemes for the offshore industry in environments with changing sea-bottoms



Boat landing and ice cone for a navigational light in the Great Belt



Flange design using ANSYS®

Ship impact and scour protection, East Bridge, Great Belt

Drivability of Monopiles

A substantial part of the cost of a mono-pile foundation is the steel price. It is therefore highly beneficial for the projects to optimize the steel structure. This shall be done both for ultimate forces and for fatigue life. 2MW class mono-piles may be vibrated down the first distance. The last meters, however, they will normally have to be driven in order to obtain the necessary penetration. The most economical procedure will be to drive the pile with the flange for the turbine tower welded on. However, this opens up for risks such as deformation of, or exces-sive fatigue damage to, the flange during driving resulting in extensive repair work before the wind turbine tower can be installed.

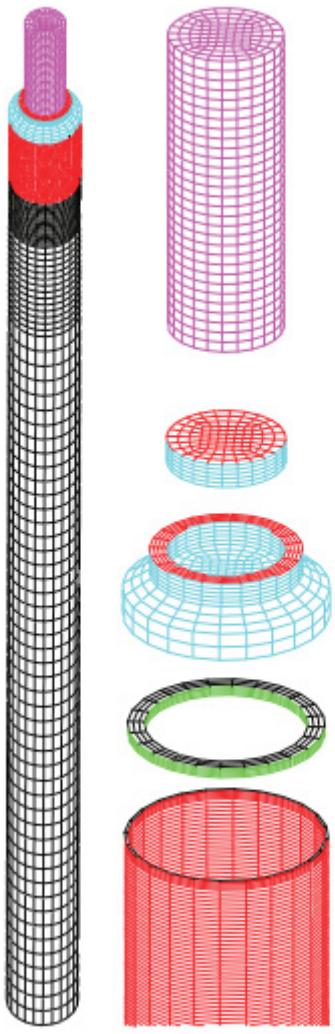
We have committed substantial resources to research the possible damages occurring during driving of large-diameter mono-piles with pre-fitted connection flanges. The research is made both with large scale field tests and with advanced numerical calculations. The objective is to define the flange which can sustain direct driving and to define safe procedures and equipment for driving to avoid deformations of pile and pre-fitted flange.

Driving of Ø1620 mm monopile at Horns Rev

Driving Analysis

We are conducting an extensive analysis scheme of numerical simulations of the driving process for piles with a pre-fitted flange. The effect of the impact loading on pile and flange are determined using the state-of-the-art Finite Element programs LS-DYNA3D™ and ANSYS®.

An exploded view of a Finite Element model of a pile, anvil and hammer is shown to the right. The two plotson the next page shows the analysis results of an extreme scenario where the pile wall may be too thin for the driving.



Finite Element model of a pile, anvil and hammer

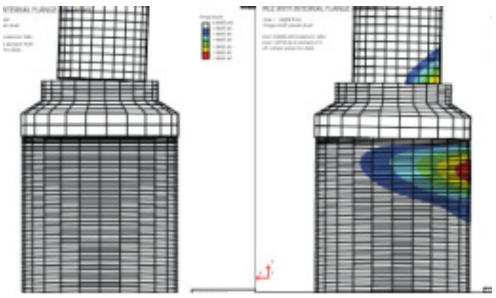
Ship Impact, Ice Forces, Boat Landing

For maintenance of offshore wind turbines vessels will have to be moored close to or at the monopile foundation. In environments with strong waves and currents this warrants relatively large vessels. These vessels may either accidentally hit the foundation or be pressed up against the boat landing by wave actions. Further, there may be vessels from the normal traffic which goes astray and hits the foundation.

Analysis of these scenarios leads to special designs of the boat landing, special maneuver constraints for the vessels and plans for navigational light(s) in the case of shipping channel(s). LICengineering A/S has executed several projects of this type for the Offshore Industry and Navigational Authorities.

Offshore Measurement of Hydrodynamic Forces

LICengineering A/S has, for the offshore industry, conducted a large number of tests both in the laboratory and in the ocean in order to determine hydrodynamic forces from waves and currents. Especially the dynamic response has been studied. The measurements have been the basis for the development of analytical methods and computer programs



Normal Scenario vs. extreme scenario

Project References - Monopile Foundations for Wind Turbines

- DAFENG H3 Offshore Wind Farm: Detailed Design for Monopiles
- Binhai #3 Offshore Wind Farm: Concept Study for Monopile
- Veja Mate Offshore Windfarm. Monopile and Transition Piece flange assessment for ultimate loading
- East Anglia Offshore Windfarms I & II: Work on monopiles to determine required Rochdale Envelope for project
- LEEDCO Offshore Windfarm: Technical assistance for detailed design. Secondary structures and ice cone; detailed design and analysis
- Triton Knoll Offshore Windfarm: FEED Study on monopiles/ transition piece connections and secondary steel design for monopiles
- Borssele Offshore Windfarm I & II: Monotower Design. Water depth approximately 30 m.
- Creyke Beck B: Foundation design concept study
- Horns Rev 3: Generation of 0^{th} iteration interface loads and super-elements from monopile foundations

Installation of DAFENG H3 Offshore Windfarm

Horns Rev Offshore Windfarm

For more information:

Hans Jørgen Riber, Head of Business Development

hjr@liceng.dk

+45 51 51 29 16

LIC ENGINEERING A/S

Hellerup Office
Ehlersvej 24
2900 Hellerup
Denmark
+ 45 39 62 16 42

Esbjerg Office
Kirkegade 25
6700 Esbjerg
Denmark
+ 45 75 18 16 88

Svendborg Office
Kulinggade 31E
5700 Svendborg
Denmark
+ 76 10 94 30

March 2020